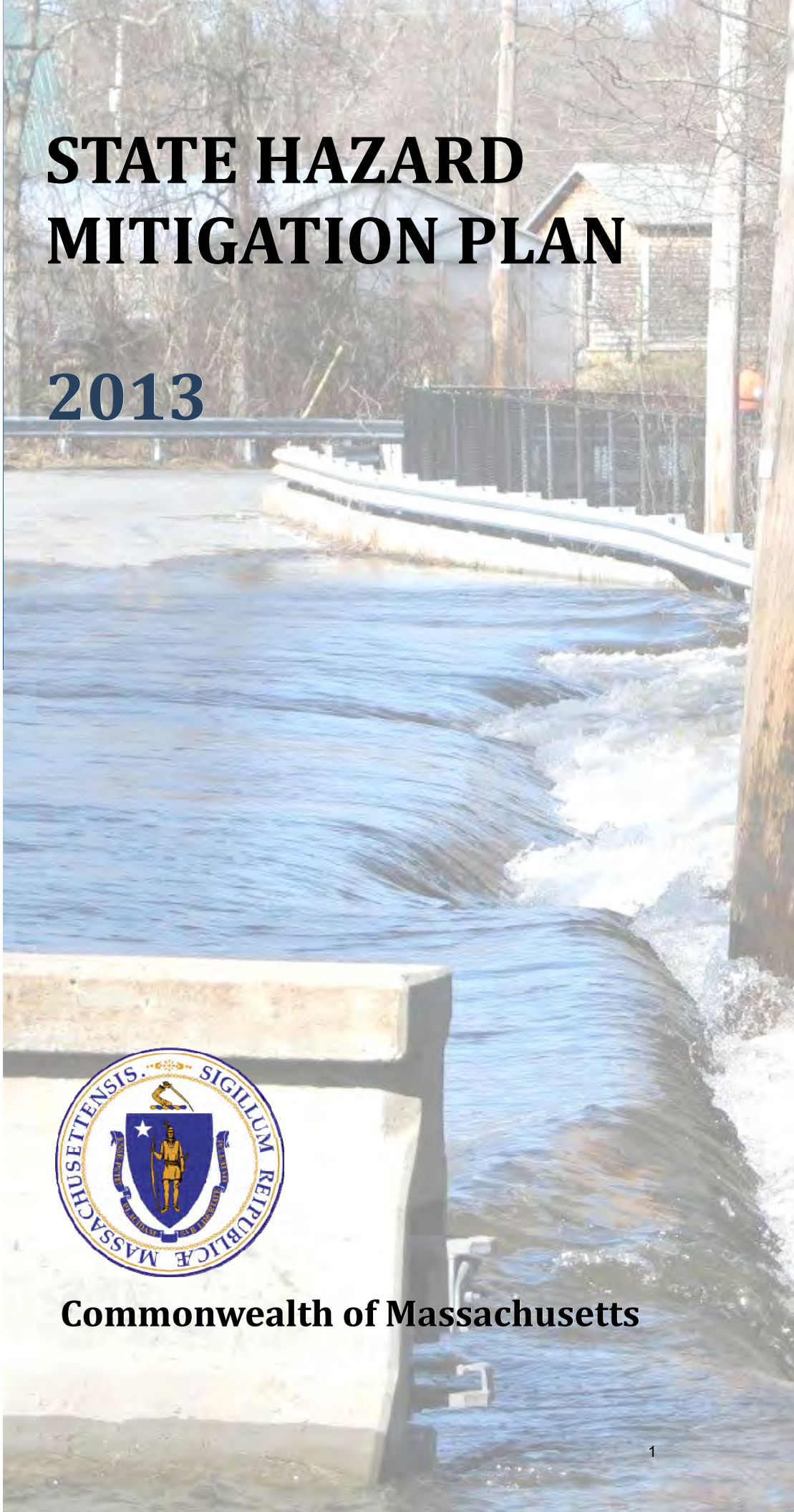
STATE HAZARD MITIGATION PLAN

2013



Commonwealth of Massachusetts

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STATE HAZARD MITIGATION PLAN

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APPENDICES

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October 11, 2013

Paul Ford, Acting Regional Administrator
FEMA Region I
99 High Street, 6th Floor
Boston, Massachusetts 02110-2132

Re: State Hazard Mitigation Plan Adoption

Dear Administrator Ford:

Please find enclosed for your review and approval the updated Commonwealth of Massachusetts State Hazard Mitigation Plan. Through this letter, we, the Director of the Massachusetts Emergency Management Agency (MEMA) and the Commissioner of the Massachusetts Department of Conservation and Recreation (DCR), hereby adopt this plan on behalf of the Commonwealth of Massachusetts. The plan is the result of a collaborative process involving our two agencies, a State Hazard Mitigation Interagency Committee, regional planning agencies, local government officials, and others.

The updated plan is consistent with the mission of our state hazard mitigation program: **Through partnerships, reduce the statewide loss of life, property, economy, infrastructure, and cultural resources from disasters through development of a comprehensive hazard mitigation program which involves planning, awareness, coordination, project development and implementation.** The updated plan identifies natural and manmade hazards to which the Commonwealth is vulnerable, profiles the range of natural hazards affecting the Commonwealth, assesses the Commonwealth's risk and vulnerability to natural and manmade hazards, examines existing hazard mitigation capabilities, develops statewide mitigation goals and strategies, and establishes a framework for implementing those goals and strategies as well as for monitoring, evaluating, and updating this plan.

We believe that the Commonwealth of Massachusetts State Hazard Mitigation Plan, as updated, is in full compliance with the planning requirements of the Disaster Mitigation Act of 2000 and the Final Rule (44 CFR Parts 201 and 206), thus keeping the Commonwealth of Massachusetts qualified to receive funding under all FEMA disaster assistance and hazard mitigation programs. Please accept our assurances that Massachusetts will comply with all applicable federal statutes and regulations in effect with respect to the periods in which it receives grant funding, and will amend its plan whenever necessary to reflect changes in state and federal laws and statutes, as required in 44 CFR 13.11 (c) and (d).

As primary implementing agencies, MEMA and DCR will work diligently with our State Hazard Mitigation Interagency Committee and all our hazard mitigation partners to implement the State Hazard Mitigation Strategy contained in the plan, thereby reducing the Commonwealth's vulnerability to natural and man-made hazards.

We would like to thank your staff for their valuable guidance and assistance in the preparation of this plan.

Sincerely yours,

Kurt N. Schwartz, Director
Massachusetts Emergency Management Agency

for JM
John P. Murray, Commissioner
Department of Conservation and Recreation

PLAN PROMULGATION

October 11, 2013

In accordance with the planning requirements of the Disaster Mitigation Act of 2000 and the Final Rule (44 CFR Parts 201 and 206), we, as primary implementing agencies, promulgate and adopt the Commonwealth of Massachusetts State Hazard Mitigation Plan.

Kurt N. Schwartz, Director
Massachusetts Emergency Management Agency

for Jim
John P. Murray, Commissioner
Department of Conservation and Recreation

ACKNOWLEDGMENTS

The *Commonwealth of Massachusetts 2013 State Hazard Mitigation Plan* was compiled by the State Hazard Mitigation Team, which consists of staff from the Massachusetts Emergency Management Agency and the Massachusetts Department of Conservation and Recreation:

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- Dan Nietsche
- Kathryn Fatherly
- Sarah White
- Eric Carlson
- Alex Gill

Many federal, state, and local agencies participated in the plan development during the 2013 update cycle. Information, guidance, and assistance provided by these various agencies greatly enhanced this document. Those agencies participating in this update cycle are listed within Appendix H.

Special appreciation is also extended to all of those individuals who participated in this update by contributing valuable time and efforts (the extensive list is provided in Appendix H). Your dedication and feedback made this update more comprehensive and set the high-quality standards for the drafts and revisions.

EXECUTIVE SUMMARY

BACKGROUND

At the turn of the millennium, the United States saw significant changes in the way it prepares for and responds to disaster events. The Disaster Mitigation Act of 2000 (DMA 2000) refocused Federal Emergency Management Agency (FEMA) programs toward enhancing the resiliency of the nation's communities through programs to reduce the exposure of people and properties to the impacts of natural hazards. The DMA 2000 was the first legislation to require states to develop and regularly maintain hazard mitigation plans that specifically address not only the local hazards of concern, but also strategies and actions to help reduce the impact of those hazards on citizens. With further refinement in 2002, Congress established a set of rules providing guidance and criteria for the content to be contained in hazard mitigation plans. To remain eligible for federal mitigation and public assistance funds associated with presidentially declared disasters, a state must have a FEMA-approved hazard mitigation plan.

The Commonwealth of Massachusetts was a forerunner in efforts to protect citizens through hazard mitigation almost 30 years ago, when it joined the National Flood Insurance Program, and later when the Commonwealth developed its first state mitigation hazard mitigation plan in 1986. Following subsequent disaster declarations, the Commonwealth updated its state hazard mitigation plan in 1989, 1993, 1998, 2000, 2004, 2007, 2010, and 2013. Each plan identified natural hazards, assessed vulnerability to the most frequent hazards, examined existing capabilities, developed statewide mitigation goals and strategies, and established a framework for implementing those goals and strategies.

NATURAL AND NON-NATURAL HAZARD RISKS

History has demonstrated that the Commonwealth of Massachusetts is vulnerable to damage from several types of hazards – both natural and non-natural. As required by DMA 2000, this plan focuses on the natural hazards of concern, which were identified in the following categories: flooding, coastal hazards, atmospheric hazards, severe winter weather, and fire hazards. According to the comprehensive risk analysis completed for the 2013 update, the Commonwealth of Massachusetts is most vulnerable to flooding, severe storms, and winter events. This plan also analyzes other natural hazards: dam failure, drought, hurricane, ice jam, ice storm, coastal erosion, sea level rise, nor'easter, wildfire, earthquake, landslide, tornado, tsunami, and extreme temperature.

The 2013 update of the state hazard mitigation plan is integrated with the Commonwealth's first Threat Hazard Identification and Risk Assessment (THIRA), which was completed simultaneously. The THIRA serves as the primary body of information related to all hazards of concern in the Commonwealth, including natural and non-natural hazards. It is a primary source of information supporting the hazard mitigation plan. The THIRA document is referenced throughout this document, and is considered a companion document. Selected elements of the THIRA are included as an annex.

DISASTER DECLARATIONS

Massachusetts ranks 35th out of 50 states and nine territories for the number of FEMA disaster declarations. Massachusetts has had more than 48 major disaster declarations, including federal disaster declarations and state disaster declarations. Since 1991, more than $600 million in federal aid and state aid has been disbursed to help Massachusetts residents recover from natural disasters. From February 1, 2010 through December 31, 2012, the Commonwealth was declared for six federal disasters.

COORDINATION AND PLANNING

One of the strongest partnerships that grew out of this mitigation program was the daily, cooperative relationship between the Massachusetts Emergency Management Agency and the Department of

Conservation and Recreation. Staff members from these agencies make up the State Hazard Mitigation Team and lead the State Hazard Mitigation Interagency Committee, which are the foundation of the mitigation program in Massachusetts. Their dedication and expertise in analyzing risks to citizens and infrastructure in Massachusetts allow for a successful mitigation program. For the 2013 update, the State Hazard Mitigation Interagency Committee was expanded to include new partners who supported this effort.

PROJECT IMPLEMENTATION

With the National Flood Insurance Program and the state planning strategies serving as a mitigation program cornerstone, and with the establishment of federal mitigation grant programs in the mid-1990s, Massachusetts has been successful in leveraging federal funding for hundreds of hazard mitigation projects. In addition, following presidential disaster declarations, the state has the option to contribute half, or 12.5 percent of the 25-percent non-federal share, for federal infrastructure support funds. Since 1991, the state has contributed more than $27 million to match FEMA's funding following presidentially declared disasters.

GOALS

The Statewide Hazard Mitigation Strategy for Massachusetts was updated for the 2013 Hazard Mitigation Plan to more closely align with the expansion of the program and growth of planning partnerships. The mission statement for the updated plan is as follows:

- Through partnerships, reduce the statewide loss of life, property, economy, infrastructure, and cultural resources from disasters through development of a comprehensive hazard mitigation program that involves planning, awareness, coordination, project development, and implementation.

The hazard mitigation goals of the Commonwealth were also enhanced for the 2013 plan update:

- Evaluate and analyze vulnerability in order to guide and promote sound mitigation activities through integrated planning to support a comprehensive state mitigation program.
- Increase awareness of the benefits of hazard mitigation through outreach and education.
- Increase coordination and cooperation between state agencies in implementing sound hazard mitigation planning and sustainable development.
- Promote cost-effective hazard mitigation actions that protect and promote public health and safety from all hazards with a particular emphasis on reducing damage to repetitive and severe repetitive loss properties.
- Monitor, evaluate, and disseminate information on the effectiveness of hazard mitigation actions implemented by state, local, and private partnerships.

STRATEGIES AND ACTIONS

From February 1, 2010 through December 31, 2012, the Commonwealth made progress on many of the strategies and mitigation actions identified in the previous hazard mitigation plan update. At the same time, new strategies were identified for the 2013 update (see Table 17-1). Four actions saw the most significant progress since 2010:

- **Development of the THIRA**— The development of the THIRA was completed in January 2013. The THIRA serves as the cornerstone for identifying all hazards of concern throughout the Commonwealth. Its risk assessment provides information and insight into the hazards; and that information was incorporated into the risk assessments in the hazard profiles provided with this hazard mitigation plan.

- **Increased planning partner and stakeholder involvement**—Development of the THIRA significantly increased the number of partners and stakeholders involved in hazard planning efforts in Massachusetts. Data gathering to complete the THIRA included review of reports, studies, after-action reports, and plans, as well as workshops and one-on-one interviews. The collected information supported other areas of the mitigation planning process, while significantly increasing local jurisdiction planning partner involvement. It is estimated that at least 50 individuals from various levels of governments—federal, state, and local—and private industry were involved in development of the THIRA. Many of these participants continued their involvement as the hazard mitigation plan was completed.
- **Development of elements for the Commonwealth's hazard mitigation plan to qualify as an enhanced plan**—The 2013 update incorporates planning elements necessary for the Commonwealth to gain enhanced plan status for the hazard mitigation plan, rather than standard plan status. Enhanced status can increase the amount of funds received by the Commonwealth after a disaster from 15 percent to 20 percent, greatly expanding the ability to fund projects across the state. One element of enhanced plan status is a streamlined process to conduct loss avoidance studies. Such studies determine the return on investment for projects, particularly projects designed to mitigate damage from natural hazards. An example of the benefits that such studies can demonstrate is the Commonwealth's work with FEMA to evaluate avoided losses on the FEMA-funded Ell Pond Flood Mitigation Project in the City of Melrose. A loss avoidance study of that project was conducted for the Massachusetts Emergency Management Agency in September 2010. Using FEMA's hazard modeling tool and benefit-cost analysis, the study demonstrated that 246 percent of the project cost was recovered, based on losses avoided since the project was completed in 2008 (FEMA, 2010). It is anticipated that similar studies can demonstrate similar results, further enhancing the significance of the Commonwealth's endeavor to maintain such efforts.
- **Increased program outreach and technical assistance regarding available hazard mitigation project grant program funding –** Since 2010 the Mitigation Unit at MEMA has added multiple positions to their staff. This expansion in staffing resources has provided the ability to increase direct technical assistance to communities and organizations throughout the Commonwealth. For example, in 2012 two Hazard Mitigation Grant Coordinators were hired to assist with FEMA Hazard Mitigation Assistance grant programs. With this expansion, the SHMT has increased their outreach efforts by approximately 50% over the level of effort since 2010.

SECTION 1. INTRODUCTION AND ASSURANCES

1.1 PURPOSE

The purpose of this State Hazard Mitigation Plan (SHMP) is to help the Commonwealth of Massachusetts and its residents understand when, where, why, and how natural hazards occur; minimize their impacts; and reduce the cost of recovery and rebuilding. This plan also outlines specific actions that should be taken by the federal, state, and local governments as well as the general public in order to manage the risks of natural hazards and reduce future costs of rebuilding. The SHMP is designed to be a reference for a variety of users having specific interests in some aspect of its detailed contents.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(7), which states the following:

Assurances. The Plan must include assurances that the State will comply with all applicable Federal statutes and regulations in effect with respect to the periods for which it receives grant funding, in compliance with 44 CFR 13.11(c) of this chapter. The State will amend its plan whenever necessary to reflect changes in State or Federal statutes and regulations as required in 44 CFR 13.11(d) of this chapter.

This document is an update of the 2010 Massachusetts State Hazard Mitigation Plan, in compliance with the Disaster Mitigation Act of 2000, or DMA 2000, (Public Law 106-390), and implementing regulations found in the Code of Federal Regulations (CFR) at 44 CFR Parts 201 and 206. Massachusetts had received Federal Emergency Management Agency (FEMA) Region I approval of its State Hazard Mitigation Plan in 1998, 2000, 2004, 2007, and 2010 in compliance with the requirements at that time of 44 CFR 206.405, specifically Subpart M, Hazard Mitigation Planning, of the Robert T. Stafford Disaster Relief and Emergency Assistance Act.

The 2013 edition of the Massachusetts State Hazard Mitigation Plan is written to meet the requirements for a state plan under 44 CFR 201, published by FEMA. It also meets the requirements of plan review guidance developed by FEMA in 2008 for updating state plans. With the standard hazard mitigation plan, Massachusetts qualifies for receipt of hazard mitigation funds according to the following formula:

- 15 percent for amounts not more than $2 billion
- 10 percent for amounts more than $2 billion and not more than $10 billion
- 7.5 percent for amounts more than $10 billion and not more than $35 billion.

The principal value of having a FEMA-approved state hazard mitigation plan lies in Massachusetts' potential for catastrophic events. In light of recent disaster events in the New England region, approval of a state hazard mitigation plan is in the best interest of everyone living in the Commonwealth, as the funds received after a disaster event can increase from 15 percent of grant funds available to 20 percent.

In addition, meeting the requirements of the regulations noted above keeps the Commonwealth of Massachusetts qualified to obtain all disaster assistance, including hazard mitigation grants available through the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Public Law 93-288, as amended).

This update incorporates the hazard mitigation lessons learned following recent disasters to be better prepared for future events. It meets DMA 2000 state mitigation planning requirements. This plan also accomplishes the following:

- Expands the Commonwealth's statewide risk assessment through integration of the Threat Hazard Identification and Risk Assessment (THIRA), which includes information on all hazards having the potential to impact the Commonwealth
- Documents the statewide strategy for regional and local hazard mitigation planning mandated under the DMA 2000
- Gives an overview of the state's current capabilities, areas of improvement, and strategies to improve hazard mitigation throughout the state
- Provides an overview of more than a decade of successful hazard mitigation projects funded through the Hazard Mitigation Grant Program, the Flood Mitigation Assistance Program, and the Pre-Disaster Mitigation Program.

1.2 AUTHORITY AND SCOPE

Prior to 2000, Section 409 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) (Public Law 93-288, as amended) was the impetus for the involvement of state and local governments in evaluating and mitigating natural hazards as a condition of receiving federal disaster assistance. A requirement of the Stafford Act's Section 409 was the development of a state hazard mitigation plan.

Under Section 409 of the Stafford Act, a state was required to update its state hazard mitigation plan following every presidential disaster declaration. Massachusetts updated and received FEMA approval of its state plan following presidential disaster declarations in 1986, 1987, 1989, 1993, and 1998. In addition, Massachusetts' State Hazard Mitigation Plan was reviewed and approved by FEMA Region I in 2000, 2004, 2007, and 2010.

The DMA 2000, with its Interim Final Rules, 44 CFR Part 201 and 206 (Hazard Mitigation Planning and Hazard Mitigation Grant Program), eliminated the state mitigation update requirement following each presidential disaster declaration. Currently, states must complete and receive FEMA approval of updated state mitigation plans every three years. These regulations also provide specific requirements for the content of a state hazard mitigation plan.

In response to Hurricane Sandy, which caused extensive human suffering and damage to public and private property, Congress passed the Sandy Recovery Improvement Act of 2013 (Public Law 113-2). The law authorizes several significant changes to the way FEMA may deliver disaster assistance under a variety of programs.

The 2013 SHMP update addresses all Stafford Act and the DMA 2000 elements required to achieve enhanced status. Achieving enhanced status means that states are able to successfully implement federal grant programs and that they have built successful mitigation programs. Receiving enhanced status provides states additional Hazard Mitigation Grant Program (HMGP) funds when a major disaster is declared.

The 2013 SHMP provides a framework that links pre- and post-disaster mitigation planning and measures with both public and private interests. The intent is to ensure an integrated and comprehensive approach to disaster loss reduction. This approach supports state administration of HMGP and non-disaster programs such as the Pre-Disaster Mitigation grant program (PDM) and the Flood Mitigation Assistance program (FMA). The SHMP represents a clear state commitment to mitigation activities, comprehensive state mitigation planning, and improved state program management.

1.3 ADOPTION BY THE STATE

This SHMP has been reviewed and endorsed by the State Hazard Mitigation Interagency Committee (SHMIC). This is a standing committee of state and federal agencies and private organizations involved in hazard mitigation (discussed in greater detail in Section 2). After review and approval of this plan by the SHMIC, the two primary state agencies responsible for preparing and implementing the hazard mitigation plan in Massachusetts—the Massachusetts Emergency Management Agency (MEMA) and the Department of Conservation and Recreation (DCR)—reviewed and adopted this plan.

The letter of adoption and assurance demonstrates the State's commitment to fulfilling the mitigation mission, legitimizes the plan, and authorizes the responsible agencies identified in the plan to execute their responsibilities. This letter is signed by the Director of MEMA and the Commissioner of DCR, is presented in the front of this plan.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(7)(d), and 44 CFR §201.5(c)(1), which states the following:

Review and Updates. The Plan "must be reviewed and revised to reflect changes in development, progress in statewide mitigation efforts, and changes in priorities and resubmitted for approval to the appropriate Regional Administrator every three years."

1.4 ASSURANCES

The Commonwealth of Massachusetts will comply with all applicable federal statutes and regulations in effect with respect to the periods in which it receives grant funding, in compliance with 44 CFR 13.11(c). The Massachusetts SHMP will be amended according to the process described in Section 18, whenever necessary to reflect changes in state or federal statutes as required in 44 CFR 13.11(d).

1.5 PLAN ORGANIZATION AND UPDATE INFORMATION

The 2013 SHMP is a comprehensive update of the 2010 plan. It has been reformatted for ease of use and to incorporate new information and data necessary to meet the enhanced plan status. All information previously contained in the 2010 plan has been incorporated in this plan and updated with the most current data available. Enhanced and standard plan elements have been integrated throughout the document to meet federal requirements. The newly updated plan illustrates the following:

- The Commonwealth has developed a comprehensive mitigation program.
- The Commonwealth effectively uses available mitigation funding.
- The Commonwealth is capable of managing all funding, including that which results from achieving enhanced status.

The plan is coordinated through appropriate state, local and regional agencies, as well as non-governmental interest groups. This 2013 Plan, and its future updates, will provide guidance in merging the planning efforts of all state agencies, local governments, the private sector, and non-profit organizations into one viable, comprehensive, and statewide mitigation program.

1.6 REVISIONS TO THE 2013 SHMP

The 2013 plan incorporates information for events, disasters, studies, and planning efforts occurring since the end capture date of the 2010 plan (February 1, 2010) through December 31, 2012. While Hurricane Sandy is referenced in various portions of the plan, damage assessment, and recovery efforts are still ongoing, so any information contained within the 2013 plan is preliminary in nature and will need to be updated with more accurate data for the 2016 update. The following are the main updates incorporated in this plan:

- New additions—There are several new additions to the 2013 SHMP. New elements, indicated as such throughout the document, support the Commonwealth seeking enhanced hazard mitigation plan status. They also include sections that can be used by local jurisdictions to support development of their own hazard mitigation plans and grant applications. The 2013 plan strives to be more robust in this nature, providing additional information and data. This document also incorporates information contained in the Threat Hazard Identification and Risk Assessment, which is the foundation for identification of all the hazards of concern throughout the Commonwealth.
- Maps, charts, and visual effects—Throughout the plan, maps, charts, and graphs were updated with current information. Each altered item was dated for ease in reference to make certain the most current information has been used. Sources used to create illustrations are referenced either within the body of the content, or beneath the illustration. In a few instances, data for specific illustrations contained in previous plan editions could not be re-created. In such cases, the date of the illustration is referenced.

1.6.1 Section Outline

The plan has been reorganized into a section format to enhance its usability and ease of reference. This format also allows for the addition of new sections, including supporting data for the enhanced plan requirements. The new plan organization is presented below; Section 2 presents a more detailed assessment of the planning process:

- **Section 1, Introduction and Assurances—**Updated with current information and reaffirmation of assurances on the part of the Commonwealth as required by 44 CFR 201.4 and 44 CFR 201.5.
- **Section 2, Planning Process—**Describes how the plan was reviewed and revised for the 2013 update; includes the agencies and individuals involved and the manner of their involvement. This section provides a link between state and local mitigation programs as well as the efforts to coordinate mitigation information between all levels of government. The SHMIC believes that an all-inclusive mitigation planning approach results in a better understanding of the risks and vulnerabilities the Commonwealth faces. This section was updated in general with current information.
- **Section 3, Coordination with Local Plans—**Description of the coordination of this plan with local planning initiatives. This section also provides a link between state and local mitigation programs, as well as efforts to coordinate mitigation information between all levels of government. This portion of the plan has been greatly enhanced to include analysis at the state, county, and city/town levels (depending upon the information captured), including information from plans developed by regional planning commissions as appropriate. This section of the plan describes support provided to local jurisdictions during the 2010-2012 update cycle. It describes how local plans were reviewed and approved with relevant information incorporated into the 2013 SHMP. It also discusses how local mitigation projects are reviewed, prioritized, and recommended for funding. Socio-economic profiles of the state's 14 counties are included. Population figures and median household incomes for each county were updated, using 2010 U.S. Census Data (unless otherwise indicated). Where more current data were available, it is indicated as such. Hazard tables and loss estimates were updated to reflect revisions made in the hazard profiles and determination of at-risk state facilities and economic impact, when available.
- **Section 4, State Profile—**Description of the state, including its geographic makeup, structure of government, and demographic data, updated with current 2010 data unless otherwise indicated.

- **Sections 5, Risk Assessment Introduction and Overview—**Description of the process followed for conducting both the Threat Hazard Identification and Risk Assessment (THIRA) and the natural hazards risk assessment; comparison of risk determined by the state's analysis to that determined by local jurisdictions; and identification of hazards of concern and ranking by the state and by local jurisdictions. The categorizing of similar hazards was modified slightly from the 2010 plan in order to more appropriately align the natural hazards of concern.
- **Sections 6 through 16, Hazard Profiles—**Hazard-specific information. All hazard profiles were reorganized during this update and are presented in a new layout. The profiles include the geographic areas of impact, loss estimations, and vulnerability assessments of people, property, and the economy. Risk assessments include both quantitative and qualitative assessments as appropriate to the hazards of concern and the ability to determine specific areas of impact and loss estimates. Additional information concerning specific hazard profiles is further discussed below.
- **Section 17, Mitigation Strategy—**Description of the goals, strategies, and mission statement for the SHMP (new to 2013). During this update, goals were reviewed and updated as discussed in detail in this section. Tables identifying the status of mitigation actions identified in the mitigation strategy were updated. New strategies were developed to enhance the state's resilience to disasters (new strategies are referenced as "New"). This section includes a loss avoidance study**,** as required by 44 CFR 201.5(b)(2)(iv), which is new to this edition. The loss avoidance study details the process to be used in future plan editions to determine the level of success of completed mitigation projects. This study goes beyond FEMA-funded projects and includes initiatives underway that have the potential to have a high impact on mitigation initiatives statewide.
- **Section 18, Plan Maintenance—**Description of the 2013 implementation process, how the 2010 process worked during the 2010-2012 period, and revisions made to the process for the current plan life cycle. The 2010 maintenance section was reviewed as a starting point for the current plan update. This section outlines how the current SHMP plan will be maintained once approved by FEMA.
- **Annexes:**
  - **Annex 1**, Threat Hazard Identification and Risk Assessment Components.
  - **Annex 2**, Massachusetts Administrative Plan for federally funded hazard mitigation grant programs.
- **Appendices**:
  - **Appendix A, Methodology**—This is a new section to the SHMP that provides a description of the analysis methodology used in the various sections of the plan. It provides greater detail than previous plan editions and provides an accounting for local jurisdictions to re-create a similar analysis.
  - **Appendix B , Best Available Science**—This is another new section, which provides a list of resources available for hazard information.
  - **Appendix C, Best Practices** —This is a new section that includes mitigation projects completed in Massachusetts. The intent to this section is to bring awareness of the types of mitigation projects completed and the types of difficulties that local jurisdictions and the State had in gathering all required data to complete grant applications. It is hoped that this section will provide a source for jurisdictions to gather information, as well as examples of projects that surrounding communities have completed.

- **Appendix D, State Agency Survey**—The State Agency Survey is a new effort on the part of the State Hazard Mitigation Team (SHMT) and SHMIC to further enhance state agency involvement and information gathering. This appendix contains survey and its results.
- **Appendix E, Local Plan Survey**—The Local Jurisdiction Survey is a new effort on the part of the SHMT and SHMIC to further enhance technical support to local jurisdictions and assist the state in capturing relevant information during local plan development. This appendix contains the newly developed survey.
- **Appendix F, Synopses of Local Plan Data**—This is a new section summarizing some of the reviewed local plans. Data presented are taken from the local plans and may include hazard data, risk assessment and loss information, the type of analysis performed, critical facility information, and unique strategies or capabilities. In some instances, Repetitive Flood Claim and Severe Repetitive Loss property information is provided.
- **Appendix G, STAPLEE Results—**This appendix presents the mitigation strategy update process using the STAPLEE criteria (social, technical, administrative, political, legal, environmental, and economic), as detailed in Section 17.
- **Appendix H, Participating Team Members—**This appendix lists team members associated with development of the plan.
- **Appendix I, National Flood Insurance Program Claims—**This appendix lists National Flood Insurance Program (NFIP) cities and claims filed throughout Massachusetts.
- **Appendix J, Ice Jam Table—**This appendix lists ice jams that have occurred in Massachusetts.
- **Appendix K, Glossary—**This appendix lists unique terminology associated with the plan, as well as acronyms used.
- **Appendix L, Bibliography—**This appendix lists sources referenced throughout the SHMP. It can be used as a source of information for local jurisdictions developing plans of their own.

1.6.2 Risk Assessment Hazard Profiles (Sections 6 –16)

The groupings of similar hazards were modified from the 2010 plan in order to more appropriately align hazards of concern. The current grouping is as summarized in Table 1-1. Data from previous plans are incorporated into the 2013 plan update, with new data added and previous data updated with the most current information. The profiles describe the hazards of concern, the risk assessment, and vulnerability based on those hazards. This plan includes all of the natural hazards profiled in the 2010 edition of the SHMP. The risk profiles include information on at-risk facilities owned or leased by state agencies. The profiles also contain programmatic information and resources as appropriate, such as the NFIP, Community Rating System (CRS), and Severe Repetitive Loss data (for the flood hazard profile). Information concerning non-natural or human-caused hazards is contained in Annex 1 (THIRA Profiles).

TABLE 1-1.
NATURAL HAZARD GROUPINGS IN 2010 AND 2013 HAZARD MITIGATION PLANS

	2010 Natural Hazard Grouping Titles						
2013 Hazard Groupings	Flood Related Hazards (Rain, Snow Melt, Dam Failure, Ice Jams)	Coastal Related Hazards (Storms, Erosion, Sea Level Rise, Sediments)	Other Natural Hazards (Fire, Drought, Extreme Temp)	Atmospheric Related and Winter Related Hazards (Snow, Ice Storms, Blizzard)	Atmospheric Related and Winter Related Hazards (Hurricane/ Tropical Storm, Nor'easter)	Atmospheric Related and Winter Related Hazards (Thunderstorm, Drought, Extreme Temperature, Winds, Tornadoes)	Geologic Hazards (Earthquake Landslide Tsunami)
Category: Flood-Related Hazards							
Inland or Riverine Flooding	X						
Dam Failure	X						
Ice Jams	X						
Category: Coastal-Related Hazards							
Decreased Sediment		X					
Coastal Erosion & Shoreline Change		X					
Sea Level Rise		X					
Category: Atmospheric-Related Hazards							
Hurricanes					X		
Nor'easter					X		
Tropical Storm					X		
Category: Severe Weather Hazards							
Thunderstorms						X	
Drought						X	
Extreme Temperatures						X	
Tornadoes						X	
High Winds						X	
Category: Severe Winter Weather Hazards							
Snow and Blizzards				X			
Ice Storms				X			
Category: Geologic Hazards							
Tsunami							X
Earthquake							X
Landslide							X
Category: Fire Hazards							
Major Urban Fires			X				
Wildfire			X				

Risk Assessment and Hazard Areas

Geospatial data sets for hazard areas in combination with geo-coded facility information was used to refine the projected loss information for state facilities. Some data sets used during this plan update have been enhanced dramatically as further described below. Data sets used for each hazard and the analysis methods used to estimate loss are detailed in Appendix A.

State Facilities Data—Leased and Owned

Working with the Massachusetts Division of Capital Asset Management, data sets were gathered listing all state-owned or leased facilities (total of 6,854 facilities). Previous plan editions estimated over 6,000

facilities. Of the data received, all locations were geocoded using the ArcGIS Online North America Streets 10.0 online geocoding service. Upon initial inspection of the MEMA Capital Asset Management Information System spreadsheet of owned facilities, 6,422 facilities were included. Of these, 5,398 were matched via geocoding to the street, rooftop, or street name geocoding level.

Out of the initial set of facilities, 916 facilities contained no address and 108 facilities would not match via coding with the address provided. After the initial geocoding of the owned facilities data, these 1,024 facilities were sent back to the Division of Capital Asset Management and Maintenance (DCAMM) for review and to obtain additional information that would allow them to be located. Of the 1,024 facilities sent back for updating, 935 were able to be successfully located with the inclusion of additional data. This allowed for 6,333 facilities to be included in the overall analysis of state-owned facilities, which is 98.6 percent of the 6,422 state-owned facilities that were provided. All 432 state-leased facilities were successfully geocoded, for a 100-percent return. The data set used to run the 2013 state-owned and -leased facility risk analysis included information on a total of 6,765 facilities.

These data were used along with FEMA's Hazus risk-modeling program to determine potential dollar losses. It was also used in an exposure analysis of hazards for which Hazus cannot be used. This information provides a more accurate risk assessment for the 2013 SHMP. Appendix A provides additional information concerning the process used to manipulate data into a usable format and to incorporate it into a comprehensive data management system/Hazus format.

Hazard Profiles

The 2013 SHMP focuses on the same natural hazards of concern as the 2010 plan. All profiles were updated to match a new format that includes information on at-risk state facilities, either through GIS exposure analysis or through Hazus analysis. All profiles were updated with current information, including all significant hazard events that occurred between early 2010 and December 2012. The following is a summary of hazard profile updates:

- **Section 6, Coastal Erosion Hazard Profile—**It includes sediment loss and sea level rise (sea level rise is also addressed in the flood profile). New maps are presented, and all data have been updated with the best available science accessible at the time of this update.
- **Section 7, Dam Failure Hazard Profile—**Limited data are available concerning inundation areas caused by dam failure, as this is considered confidential information and protected data by dam owners. The profile was updated with new dam maps and includes the best available science.
- **Section 8, Earthquake Hazard Profile—**This section was rewritten and enhanced using best available science. The profile includes information on the hazard as it relates to both the Commonwealth and its jurisdictions. Hazus modeling was used to determine risk and exposure at both the state and county levels. Once completed, the profile was reviewed by subject matter experts to validate and confirm the updates. The analysis used FEMA's new Shake Map catalog as appropriate. Analysis was also conducted using available National Earthquake Hazards Reduction Program (NEHRP) soils data to assess exposure.
- **Section 9, Fire Hazard Profile—**This profile includes both wildfires and major urban fires. State-owned and leased facilities with exposure to the urban interface/intermix zones were used to determine potential loss estimations. Major urban fire consists of a qualitative analysis, as prediction of future fire events in an urban area is not possible.
- **Section 10, Flood Hazard Profile—**This section was rewritten and enhanced to include more data such as NFIP, Repetitive and Severe Repetitive Loss properties, and CRS information, both generally and as they relate to the Commonwealth and its jurisdictions. In

previous plan editions, this information was contained in various portions of the plan. The SHMT felt that the data are better contained in one section, and referenced in other areas as needed. The best available Digital Flood Insurance Rate Map (DFIRM) databases (and, where not available, Quality-3 (Q3) data) were used to determine risk and exposure at the state and county levels. Information has been added on events occurring from February 1, 2010 through December 31, 2012. Any enhanced information on previous events was also incorporated. This section also includes information on ice jams, for which data have been updated with the most current information and maps, as well as to address sea level rise.

- **Section 11, Hurricane/Tropical Storm Hazard Profile—**Hazus analysis was conducted using historical events: Category 1—Gloria (1985); Category 2—Bob (1991); Category 3—1938 unnamed hurricane; and Tropical Storm—Irene. Data from the Sea, Lake and Overland Surges from Hurricanes (SLOSH) model were used, based on the most significant damage outputs per hurricane category. A wind-only loss analysis was conducted for state-owned and leased facilities; a combination wind and surge loss analysis was conducted for buildings across the state, summarized at the county level. The SLOSH model is a computerized numerical model developed by the National Weather Service (NWS) to estimate storm surge heights resulting from historical, hypothetical, or predicted hurricanes by taking into account the atmospheric pressure, size, forward speed, and track data. These parameters are used to create a model of the wind field, which drives the storm surge.
- **Section 12, Landslide Hazard Profile—**This section was reviewed and updated as appropriate. Little new data are available; however, the Commonwealth applied for and received two separate grants for landslide studies, which will greatly enhance this data set for future plan updates. These are discussed in greater detail in Section 5—Risk Assessment Overview, the landslide profile, and Section 17—Mitigation Strategy.
- **Section 13, Nor'easter Hazard Profile—**Hazus analysis was conducted for the 1978 Nor'easter. The SLOSH data set was used based on the "maximum of maximums" outputs per hurricane category. A wind-only loss analysis was conducted for state-owned and leased facilities; a combination wind and surge loss analysis was conducted for buildings across the state, summarized at the county level.
- **Section 14, Severe Weather Hazard Profile—**This profile was regrouped to incorporate drought, high winds, thunderstorms, tornado, and extreme temperatures. Maps were developed demonstrating areas of impact and statistical information as appropriate:
  - Drought hazard profile—This profile was updated with the most current information available. The risk assessment is based on a qualitative analysis, as modeling is not possible for this type of hazard.
  - High winds, thunderstorms, and tornados were combined in one profile. The profiles were updated to include most current events impacting the Commonwealth, as well as historical impacts, where available. The risk assessment is based on a qualitative analysis demonstrating areas of impact. The high winds profile addresses events that are below the wind speeds associated with other hazards, such as hurricanes.
  - Extreme Temperatures—This profile was updated with the most current information available. The risk assessment is based on a qualitative analysis, as modeling is not possible for this type of hazard.
- **Section 15, Severe Winter Storm Hazard Profile—**This profile was grouped to incorporate snow, blizzards, and ice storms. The profiles were updated with the most current information available, with maps demonstrating areas of impact. The analysis is based on a qualitative method, as GIS analysis is not possible to estimate losses, due to the inability to determine

geographic areas of impact. Also updated during this plan edition is the methodology transition from the Northeast Snowfall Impact Scale (NESIS) to the Regional Snowfall Index by the National Climatic Data Center (NCDC).

- **Section 16, Tsunami Hazard Profile—**This portion of the plan was updated to include the most current data available, and displayed in the new profile format.

The Hazus model provides some form of geospatial hazard zone information for four of the hazards: earthquake, flood, hurricane/tropical storm, and nor'easter. These are the hazards for which the state has an emphasis on preparedness and mitigation.

During the period that the SHMP was being updated, the Commonwealth was also in the process of developing a mandatory THIRA document, which included an extensive list of human-caused and technological hazards. Additional information concerning the THIRA document is contained in Section 5. Annex 1 presents non-confidential portions of the THIRA on the following hazards:

- Technological hazards—Blackouts, barge accidents, bridge failures, invasive species, public health hazards (e.g., epidemic, pandemic), train derailments, and truck accidents.
- Terrorist-related hazards—Biological/biological building, chemical/chemical building, improvised explosive devices (multiple types), radiological/radiological building, ramming, standoff (shoulder-fire) weapon, and toxic industrial chemicals.

1.6.3 Hazard Mitigation Grant Administrative Plan

Annex 2 to this plan is the most current and approved version of the Commonwealth's Administrative Plan and FEMA's notification of approval of it.

SECTION 2. THE PLANNING PROCESS

This section provides documentation of the planning process, including a chronological overview of the Commonwealth's hazard mitigation program since the late 1980s. It addresses the following:

- History and overview of statewide hazard mitigation planning process
- Coordination with state agencies
- Program integration

This section also reviews the progress and accomplishments of the Hazard Mitigation Program since 2010. Enhanced and standard plan elements are integrated throughout this section.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(1), which states the following:

Plan Content. To be effective the plan must include a description of the planning process used to develop the plan, including how it was prepared, who was involved in the process, and how other agencies participated.

2.1 PLANNING PROCESS HISTORY AND OVERVIEW

2.1.1 Timeline of Massachusetts Planning Efforts

Prior to the establishment of the federal Pre-Disaster Mitigation (PDM) grant program, the Commonwealth actively pursued available hazard mitigation planning funds through the Flood Mitigation Assistance (FMA) program and the Hazard Mitigation Grant Program (HMGP). With annual FMA planning funds since 1997 and HMGP planning funds, Massachusetts has funded several mitigation plans.

The following is a brief timeline of the mitigation planning efforts for the Commonwealth of Massachusetts.

- 1986—First state "409" plan is submitted to Federal Emergency Management Agency (FEMA) Region I for review and approval.
- 1989—Commonwealth submits an update report on the state plan to FEMA Region I for review and approval.
- 1991—First HMGP mitigation projects are funded through the Commonwealth.
- 1993—Commonwealth updates and submits an update of the state "409" plan and the HMGP administration to FEMA Region I for review and approval.
- 1998—Commonwealth updates and submits an update of the state "409" plan and the HMGP administration to FEMA Region I for review and approval.
- 2000—Commonwealth updates "409" plan to include additional information from the June 1998 floods and submits plan to FEMA Region I for review and approval.
- 2002—Commonwealth retains the services of a consultant to provide assistance with updating the

Massachusetts Holds New England's First Mitigation Planning Workshop

In August 1998, the Commonwealth developed and hosted New England's first hazard mitigation planning workshop with funding from FEMA Region I. Titled "Community-Based Hazard Mitigation Planning: Lowering the Risks and Costs of Disaster," this training clinic attracted over 100 planners and emergency managers from federal, state, and local governments as well as non-profit and private organizations. The meeting included distribution of a state-developed planning guide, created by the Flood Hazard Management Program of the Department of Conservation and Recreation: *Flood Hazard Mitigation Planning: A Community Guide 1997*.

statewide natural hazards risk assessment and GIS hazard maps project. This extensive risk analysis became the basis for the current risk assessment, which is continually being updated by the Commonwealth.

- 2003—State Hazard Mitigation Team (SHMT) develops a community guidebook, *Natural Hazard Mitigation Planning: A Community Guide*, to assist in developing local and regional plans. This was the first guidance for Massachusetts' communities with an all-hazards approach.
- 2004—Commonwealth completes first all-hazard mitigation plan and submits to FEMA Region I for review and approval.
- 2007—State Hazard Mitigation Plan (SHMP) update is developed in accordance with the requirements of 44 CFR Section 201.4. The SHMT leads the year-long update process and submits drafts for FEMA review. The 2007 plan was approved in October 2007.
- 2008—Commonwealth submits an amendment to the 2007 SHMP to include strategies for the new FEMA Severe Repetitive Loss grant program.
- 2010—Commonwealth again updates the 2007 edition for a 2010 plan. The SHMT holds a series of planning meetings to incorporate new hazards identified, information and data from local and regional mitigation plans, and an evaluation of the Commonwealth's mitigation goals and objectives. In addition to the planning workshops, members of the SHMT worked with Geographic Information Systems (GIS) staff at Massachusetts Emergency Management Agency (MEMA) to develop an updated hazard analysis to include any new or improved data available. Every section of the document was reviewed by the SHMT and updated as appropriate.
- 2013—Commonwealth hires a consultant to complete its first effort for an enhanced hazard mitigation plan and threat hazard identification and risk assessment (THIRA). Both plans are submitted to FEMA Region I for review and approval.

2.1.2 State Hazard Mitigation Team

The Commonwealth of Massachusetts has a unique interagency cooperation in the administration and management of its statewide Hazard Mitigation Program. This program is a joint effort between the Massachusetts Department of Conservation and Recreation (DCR) and MEMA. The SHMT is co-chaired by the State Hazard Mitigation Officer at DCR and the Disaster Recovery Manager at MEMA. The SHMT consists of the staff in DCR and MEMA working full-time on hazard mitigation programs, projects, and planning, such as the National Flood Insurance Program (NFIP) and FEMA Hazard Mitigation Assistance programs including HMGP, the FMA program, the PDM program. The SHMT meets monthly to coordinate team members' individual work assignments. The SHMT also coordinates the activities of the larger State Hazard Mitigation Interagency Committee, which is described below. SHMT members for the 2013 update are listed in Table 2-1.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(b), which states the following:

Planning Process. An effective planning process is essential in developing and maintaining a good plan. The mitigation planning process should include coordination with other State agencies, appropriate Federal agencies, interested groups, and be integrated to the extent possible with other ongoing State planning efforts as well as other FEMA mitigation programs and initiatives.

TABLE 2-1.
STATE HAZARD MITIGATION TEAM MEMBERS

Member Position	Agency
State Hazard Mitigation Officer/State NFIP Coordinator	DCR
Mitigation Grants Manager	MEMA
Hazard Mitigation Program Manager	MEMA
State Hazard Mitigation Planner	MEMA
Deputy Director Emergency Services	MEMA
Flood Hazard Mapping Coordinator	DCR
Hazard Mitigation Project Specialist	MEMA
Hazard Mitigation Grants Coordinator	MEMA
Hazard Mitigation Contract Specialist	MEMA
Environmental Engineer	DCR

2.1.3 State Hazard Mitigation Interagency Committee

Coordination with state and federal agencies and partnering with the private sector are priorities for the SHMT. Massachusetts has had an active State Hazard Mitigation Interagency Committee (SHMIC) since its creation in 1991, following two presidential disaster declarations: Hurricane Bob in August of that year and the Halloween Storm in October. This committee, which consists of state, federal, and private sector organizations, is responsible for reviewing and approving the SHMP, as well as other duties described later in this section.

State Hazard Mitigation Interagency Committee Members

Members of the SHMIC include representatives from the SHMT, THIRA project management, and representatives from the following government agencies and private organizations:

- State agencies:
  - Board of Building Regulation & Standards
  - Department of Agricultural Resources
  - Department of Conservation and Recreation
  - Department of Environmental Protection
  - Department of Fish and Game (several Divisions)
  - Department of Public Health
  - Department of Transportation
  - Division of Capital Asset Management and Maintenance (DCAMM)
  - Emergency Support Function Team Department of Public Safety
  - Executive Office of Energy and Environmental Affairs
  - Massachusetts Board of Library Commissioners
  - Massachusetts Emergency Management Agency (several Divisions)

  - Massachusetts Historical Commission
  - Massachusetts USDA
  - Office of Coastal Zone Management
- Federal agencies:
  - Federal Emergency Management Agency
  - National Oceanic and Atmospheric Administration (NOAA) (new in 2013)
  - Natural Resource Conservation Service
  - National Weather Service
  - U.S. Army Corps of Engineers, New England District
  - U.S. Geologic Survey
- Other agencies (includes planning partners and stakeholders, agencies to which presentations were made, or from which information was gathered):
  - American Red Cross
  - Boston Civil Engineers (new in 2013)
  - Civil Engineers Society (new in 2013)
  - Climate Change Adaptation Workshop (new in 2013)
  - Climate Change and Coastal Hazard Committee (new in 2013)
  - Franklin Regional Council of Governments
  - Massachusetts Association of Regional Planning Agencies
  - Massachusetts Fire Chiefs Association
  - Massachusetts Geological Survey
  - Massachusetts' River Alliance (new in 2013)
  - Metro Boston Homeland Security Region (new in 2013)
  - New England Disaster Recovery Exchange
  - Northeast States Emergency Consortium
  - Salvation Army
  - State Fusion Center (new in 2013)
  - State Homeland Security Advisory Council (new in 2013)
  - University of Massachusetts (various Departments)
  - Weston Observatory at Boston College
  - Woods Hole Oceanographic Institute

State Hazard Mitigation Interagency Committee Responsibilities

SHMIC responsibilities include the review and update of the SHMP as required by the Disaster Mitigation Act of 2000 and 44 CFR, Subpart M. These activities include the following:

- Review, update, and prioritize recommendations in the SHMP.

- Develop a comprehensive strategy for the development and implementation of the Commonwealth's mitigation program.
- Establish policies consistent with the statewide mitigation goals in the SHMP.
- Review submitted project applications for the HMGP and provide recommendations for funding. Provide recommendations as needed for the FMA program and the PDM program.
- Identify additional federal, state and local funding sources for mitigation projects.
- Act as subject matter experts for hazard mitigation projects from initiation to close-out.
- Meet a minimum of once a year during non-disaster years and meet on an as-needed basis following a presidential disaster declaration.

2.1.4 Threat Hazard Identification and Risk Assessment Committee

New to the 2013 update was the THIRA Committee, which met monthly from August 2012 through January 2013. The primary focus of this Committee was the development of the Commonwealth's first THIRA document, which addressed all hazards—natural, technological, and terrorist. The THIRA development began the development of the risk assessment, which is the basis of this 2013 update.

Updated FEMA guidelines require that each state administrative agency and urban area (designated under the Urban Areas Security Initiative) receiving FEMA Preparedness Grant funding complete and submit a THIRA. To meet this new requirement, a project management team was established to develop the THIRA. Project management team members included representatives from various state offices, who also were part of the hazard mitigation plan update process:

- Commonwealth Fusion Center
- Department of Agricultural Resources
- Department of Conservation and Recreation
- Department of Environmental Protection
- Department of Fire Services
- Department of Public Health
- Department of Transportation
- Executive Office of Energy and Environmental Affairs
- Executive Office of Public Safety and Security
- Massachusetts Emergency Management Agency (several Divisions)
- Massachusetts State Police
- Metro Boston Homeland Security Region
- Regional Homeland Security Councils
- State Homeland Security Advisory Council

In addition to the above, planning team agencies represented on the THIRA Committee include, but are not limited to the following:

- American Red Cross
- Boston Regional Intelligence Center
- Department of Public Health - Emergency Preparedness/Bioterrorism Committee

- Housing & Economic Development
- Massachusetts Animal Response Team
- Massachusetts Bay Transit Authority
- Massachusetts Bureau of Animal Health
- Massachusetts Commission for Deaf and Hard of Hearing
- Massachusetts Commonwealth Fusion Center
- Massachusetts Department of Conservation and Recreation
- Massachusetts Department of Environmental Protection (MassDEP)
- Massachusetts Department of Fire Services
- Massachusetts Department of Mental Health
- Massachusetts Department of Public Education
- Massachusetts Department of Public Health
- Massachusetts Department of Transportation
- Massachusetts Division of Energy Resources
- Massachusetts Emergency Management Agency
- Massachusetts Environmental Police
- Massachusetts Executive Office of Public Safety and Security
- Massachusetts Fire Services/ Hazardous Materials Response
- Massachusetts Information Technology Division
- Massachusetts Major City Police Chiefs Association Massachusetts State Police
- Massachusetts National Guard
- Massachusetts Office of Chief Medical Examiner
- Massachusetts Office of Disability
- Massachusetts Statewide Interoperability Executive Committee
- Massport
- New England Disaster Recovery Information X-Change
- Northeast Massachusetts Emergency Medical Services (EMS) Massachusetts Voluntary Organizations Active in Disaster
- Northeast Regional Homeland Security Council
- Office of Coastal Zone Management
- Southeastern Regional Homeland Security Council
- State 911 Transportation Security Agency
- U.S. Coast Guard
- Western Homeland Security Advisory Council

The THIRA process was integrated with the hazard mitigation planning process. For the THIRA development, information was collected from representatives of approximately 50 local, regional, state, federal, private, and non-governmental agencies. In many cases, this included multiple individuals from different parts of a single agency. The process also included review of existing plans and studies, past events, and extensive regional interdisciplinary meetings. These data directly supported development of the risk assessment elements of the THIRA and consequently the SHMP, as well as other planning components such as the capabilities assessment and strategy development.

To identify the threats and hazards of concern to be addressed in the THIRA, the Commonwealth reviewed the 2010 SHMP and Comprehensive Emergency Management Plan, and interacted with the State Fusion Center for relevant hazard information. As a result of the documents reviewed, the THIRA planning process began with a designated set of 21 natural hazards, six technological hazards, and 16 terrorism hazard scenarios (see Chapter 5).

The risk assessment portion of the THIRA identifies all hazards of concern with the potential to impact the Commonwealth. The THIRA document also serves as the basis of the SHMP's risk assessment. For the SHMP, the natural hazards were grouped together with like hazards (see Table 1.1 in Section 1).

Once the hazards were identified, a risk assessment and consequence analysis were completed for each hazard. The risk assessment weighed the hazards against the Commonwealth's capabilities. The THIRA focuses on the state-wide homeland security enterprise to implement the 31 core capabilities described in the National Preparedness Goal. It details those preparedness elements by narrowing the focus on the existing mitigation capabilities (see Section 17 of this plan). This assessment was a component of the risk analysis, which in turn was used to assess capabilities related to the threats and hazards of concern and subsequent steps of the THIRA process. This SHMP accepts the assessment and consequence analysis completed under the THIRA for non-natural hazards. Mitigation activities associated with the non-natural hazards (in the form of enhancements to build capability to mitigate risks) are detailed under the THIRA.

For the natural hazards of concern, the risk assessment in the THIRA focused on "scenario" events, elevated to a "maximum of maximums" (worst-case scenario) severity to ascertain the Commonwealth's level of risk. Building from that, the risk assessment for the SHMP was based on an additional process incorporating "probabilistic" and "deterministic" information (see Appendix A). In addition, the SHMP used a Comprehensive Data Management System update that incorporated data on state facilities from the Division of Capital Asset Management and Maintenance (DCAMM), as well as the general building stock provided for a Level 1 Hazus risk assessment. Descriptions of the risk assessments for each hazard are provided in individual hazard profiles (Sections 6 through 16) and Appendix A.

The THIRA process also used the System-wide Multi-hazard Risk Tool (SMRT) to quantitatively evaluate all-hazard risk for the Commonwealth. SMRT compares the risk of multiple types of hazard events across the Commonwealth. Hazard types evaluated using SMRT included human-initiated events, infrastructure failure, and natural hazards. SMRT allowed the Commonwealth to estimate the risk for each hazard and compare risk across hazards using common metrics. SMRT also assisted in identifying and prioritizing enhancements in security and readiness using risk-based decision-making and planning.

The THIRA document is classified *For Official Use Only*, therefore only portions of the document are presented in Annex 1 to this SHMP.

2.1.5 2010-2013 Mitigation Plan Update Schedule

The SHMT developed the timeline shown in Table 2-3 for the 2013 SHMP update. The SHMP update and THIRA were developed by many of the same staff and at about the same time, and information from the THIRA has been integrated into the SHMP where possible. The THIRA process is discussed in greater detail in Section 5.

TABLE 2-2.
2013 STATE HAZARD MITIGATION PLAN UPDATE SCHEDULE

Regulation/Policy	Massachusetts Planning Step	Timeline
THIRA		
FEMA Comprehensive Planning Guide (CPG) 201	Project Management Team (PMT) meetings	Weekly
	Identify threats and conduct hazard assessment and Hazard Assessment Identification	Aug 2012 – Nov 2012
	State and local capability assessment meetings	Oct 2012-Nov 2012
	State Homeland Security Advisory Council meeting to establish desired capability targets	December 2013
	Submit draft and final THIRA	January 2013
HMP Planning Process		
CFR 201.4(a)(1)-(b)	SHMIC meeting	Monthly
CFR 201.4(a)(1)-(b)	Review plan for update	Aug 2012 – June 2013
CFR 201.4(c)(7)(d)	FEMA Region I review period	July 2013 – Oct 2013
CFR 201.4(c)(7)(d)	FEMA Region I approval letter generated	Oct 2013
CFR 201.4(c)(5)(ii)-(iii)	Post final version to MEMA mitigation website and make copies available.	Oct 2013
HMP Risk Assessment and Information Update		
CFR 201.4(c)(2)(i)	Hazard identification and profiling	Aug 2012 – March 2013
CFR 201.4(c)(2)(ii)	Assessing vulnerability by jurisdiction and state facilities	Jan 2013 – April 2013
CFR 201.4(c)(2)(iii)	Estimating potential losses of jurisdiction and state facilities	Feb 2013 – April 2013
HMP Mitigation Strategy		
CFR 201.4(c)(3)(i)	Review Massachusetts' mitigation goal and determine if it remains adequate for reducing potential losses.	Jan 2013 – Feb 2013
CFR 201.4(c)(3)(ii)	Review and update existing mitigation measures and state capability	Jan 2013 – Feb 2013
CFR 201.4(c)(3)(iii)	Review, update, and evaluate current and new objectives and mitigation actions	Jan 2013 – March 2013
CFR 201.4(c)(3)(iii)	Update or add new objectives and mitigation actions	Jan 2009 – March 2013
HMP Local Mitigation Planning and Coordination		
CFR 201.4(c)(2)(i)-(iii)	Review and integrate identified hazards/risk analysis data from FEMA approved regional and local mitigation plans.	Dec 2012 – Apr 2013

2.1.6 Hazard Mitigation Planning Process 2010- 2013

The Commonwealth contracted with consulting firm Tetra Tech, Inc. for the 2013 SHMP update. At the same time, Tetra Tech worked with the Executive Office of Public Safety and Security and MEMA to develop the THIRA. The update process began with a review of the 2010 Plan Maintenance Section to determine areas on which this update would focus. FEMA's 2010 crosswalk and revisions recommended in that document were also incorporated into the update process.

As a result of the THIRA process, different elements of the plan update were initiated at different times. A kick-off meeting occurred in August 2012. In addition to telephone conferences, email exchanges and

one-on-one conversations, the SHMIC met several times during this update cycle. Large-group meetings occurred in June 2011, February 2012, August 2012, September 2012, January 2013, and February 2013. Survey deployment (discussed in Section 2.1.7 below) occurred in March 2013, hazard profile review in April 2013, plan review in May 2013, presentation of the plan for adoption in June 2013, and FEMA submission in July 2013.

Since completion of the 2010 edition of the SHMP, the SHMT and various SHMIC members completed regular reviews of the plan. These reviews began shortly after approval of the 2010 plan, and continued through adoption of the 2013 plan update. Reviews focused on different areas of the plan and included, among other areas, state and local jurisdiction strategies to determine progress and grant funding opportunities. Reviews also occurred with respect to hazards addressed in the plan as new data became available, or after a specific hazard event. Review also occurred as policies or programs were developed to determine the potential impacts from such activities, and to maintain current and consistent data to ensure that updated information was captured in this 2013 update.

A significant change for the 2013 update was the Commonwealth's choice to pursue enhanced plan status. It was determined that additional information would need to be included in the document to demonstrate the Commonwealth's efforts to integrate mitigation with other emergency management elements statewide and its "whole community" approach in these areas. Information was also incorporated so that the plan meets the standards of the Emergency Management Accreditation Program (EMAP).

The SHMT held a series of planning workshops and meetings to develop this 2013 update. A change from previous plan efforts was the formation of a project management team consisting of members of the SHMT and the Commonwealth of Massachusetts Homeland Security Division. Beginning in August 2012, the project management team (including both THIRA and SHMIC members) collected data to update hazard information for use in the risk profiles. This information was gathered from subject matter experts (including SHMIC subject matter experts), from local, state, and federal agencies, and from review of local and regional mitigation plans. Workshops were held throughout the Commonwealth to capture relevant information, which has been incorporated into both the THIRA and the SHMP update.

The project management team also met weekly from August 2012 through January 2013, when the initial draft of the THIRA document was completed. Upon completion of the THIRA, SHMIC members who were part of the THIRA project management team shifted focus solely to development of the 2013 SHMP update. After December 2012, the SHMT project management team continued weekly meetings, with the exception of a few weeks when the Commonwealth was responding to disaster events or unavailable due to previously scheduled exercises, such as the week-long FEMA training in March 2013.

The SHMIC met during a February 6, 2013 workshop to discuss the status of the 2013 process and to gain concurrence on plan sections. This day-long workshop included a status overview of the update process; a presentation of hazard maps; review and adoption of goals, objectives, and a new mission statement; review of existing mitigation actions and development of new actions; presentation of the state-agency survey; and review of grant applications and existing projects.

The committee met a final time on May 22, 2013, to discuss the plan, which had previously been presented for review and comment (the risk profiles April 11, 2013; the remainder of the plan May 10, 2013). All comments captured during the review process were discussed and incorporated as appropriate.

2013 State Hazard Mitigation Interagency Committee Review Process

For this plan update, the SHMT established a goal to facilitate a comprehensive SHMP review and update with increased collaboration of the SHMIC. Combined, these members formed the team who guided the plan's overall development and review. Review included all portions of the plan. The same members or agencies previously involved again participated in the process, but they were not assigned to specific subject-matter workgroups as was done for the 2010 update. Instead, the SHMIC members were more all-encompassing throughout the process. While each member was asked to review and provide input into the

entire plan, some members also served as subject matter experts for a specific hazard. In many instances, the area of expertise crossed over to secondary hazards. Each team member was asked to review and provide input on strategy development, including review of existing mitigation actions and goals and development of a mission statement (new for 2013). Members were also asked to provide information concerning the Commonwealth's capabilities for mitigating the impacts of the hazards of concern. Information gathered from all sources was incorporated as appropriate.

New reviewers added for this update included individuals focused on EMAP standards and elements, THIRA team/workgroup members, and increased DCAMM facilities personnel to assist with data to identify state facilities at risk. Specific areas of focus included, but were not limited to, the following:

- **Flood Related Hazards—**Review all information pertinent to flood related hazards, specifically riverine flooding, heavy rain, dam failure, and ice jams. Provide information with respect to the Severe Repetitive Loss and Repetitive Flood Claim programs, the Community Rating System program, and the current status of FEMA's Risk MAP (Risk Mapping, Assessment and Planning) project throughout the Commonwealth.
- **Coastal Related Hazards—**Review all information pertinent to coastal flood related hazards, specifically coastal storms, coastal erosion, and shoreline change.
- **Atmospheric and Winter Related Hazards—**Review all information pertinent to atmospheric and winter related hazards, specifically high winds, hurricanes, tornados, Nor'easters, severe thunderstorms, heavy snow, ice storms, and blizzards.
- **Geologic Hazards—**Review all information pertinent to geologic-related hazards, specifically earthquakes, landslides, major erosion, and tsunami.
- **Other Natural Hazards—**Review all information pertinent to other natural hazards, specifically wildfire, urban fires, drought, and extreme temperatures
- **EMAP Accreditation—**Review plan components to assess compliance with EMAP standards and make recommendations to enhance the plan to maintain EMAP accreditation.
- **THIRA—**Review all information pertinent to all hazards of concern, specifically the non-natural hazards (included in Annex 1 to this document): hazardous materials, nuclear events, transportation accidents, terrorism, and health related events. This also included a gap analysis of the 31 core capabilities.
- **Mitigation Strategy and State Capabilities—**Review and recommend revisions to the state capabilities assessment to provide information on state and local laws and regulations that impact the hazard mitigation strategy; review mitigation actions to identify overarching issues; review hazard profiles and secondary hazard effects to identify data limitations and gaps; and develop mitigation actions to address those gaps.
- **Goals and Mission Statement—**Review and revise the plan's goals to determine consistency with the goals in local jurisdiction plans and to determine the validity of the Commonwealth's overall mitigation strategy; develop a mission statement.
- **GIS Analysis—**Work with MEMA and Tetra Tech GIS staff to develop an updated hazard analysis that includes all new or enhanced data available. Every section of the 2013 updated SHMP was reviewed by the SHMT and the SHMIC and updated as appropriate.

Updated Information

2010 U.S. Census

All demographic information in this plan is from the 2010 U.S. Census and the Massachusetts Secretary of State. Data were also captured from the Massachusetts State Data Center at the University of

Massachusetts Donahue Institute. The *Massachusetts Economic Due Diligence Report* prepared by the University of Massachusetts (2013) was also used to capture population characteristics. American Community Survey reports were used in some instances. Sources are referenced whenever utilized.

2013 Map Revisions

The map revision process took place between January and April 2013. Tetra Tech worked with MEMA staff to revise data, run analyses, and develop the map products. The team developed a map template so that all maps for this plan are consistent with maps developed by MEMA for operational and other purposes. All maps were reviewed in detail and updated where new data were available.

Evaluation of Current Mitigation Measures

The Commonwealth of Massachusetts is unique in that it holds monthly meetings with SHMT members to review potential mitigation measures, grant opportunities, and project status to ensure continued compliance with grant requirements and reporting criteria, as well as to ensure continued use of existing funds through project tracking.

During the February 6, 2013 SHMIC meeting, existing mitigation measures were discussed to determine their level of effectiveness and to begin discussions on additional mitigation actions to be added during the 2013 plan update. The newly developed state-agency survey was initially deployed to members in attendance at this session and later was emailed to other state agencies. (See Section 2.1.7 for full detail).

One-on-one interviews by the State Hazard Mitigation Planner with various state agencies also occurred to expand existing mitigation measures. The Commonwealth has developed a strategy under which the State Hazard Mitigation Planner will expand these one-on-one efforts to further increase state agency involvement and increase mitigation activities.

The February planning workshop included a review of current mitigation measures and a review of the effectiveness of previously identified mitigation measures as they integrated with previously established goals. The workshop also discussed the enhancement of the strategies in local plans, noting that jurisdictions are beginning to understand the linkage between the risk assessments providing the information necessary to develop more robust strategies and projects.

Evaluation of Mitigation Goals, Strategies and Capabilities

The SHMT held the Evaluation of Mitigation Goals, Strategies, and Actions workshop on January 25, 2013. This planning workshop included an extensive review of current mitigation strategies and actions, including an analysis of the status and effectiveness of the actions. It was determined during the workshop that the goals as written required slight modification to more accurately embrace the goal of enhanced plan status. The goals also needed to better align with FEMA's "whole community" philosophy, while continuing to support local planning goals and efforts. Recommended revisions were presented to the SHMIC during its February 6 workshop, and after some minor edits, the 2013 goals were updated and approved. Section 17 contains the updated goals.

The February 6 meeting also included a brainstorming session to set forth potential strategies and actions for the 2016 plan update. A number of new actions were also identified for the 2013 plan update, many of which will support the Commonwealth seeking enhanced plan status. The February planning workshop also included a review of current mitigation measures and a review of the effectiveness of previously identified mitigation measures as they integrated with previously established goals. The workshop also discussed the enhancement of mitigation measures in local plans, noting that jurisdictions are beginning to understand the linkage between the risk assessments providing the information necessary to develop more robust strategies and actions.

During the SHMT's meeting of March 11, 2013, a potential new method for prioritizing future mitigation actions was discussed, given the SHMT's hope to enhance stakeholder involvement. It was felt that due to

each state department's own operating structure, use of FEMA's STAPLEE planning criteria (social, technical, administrative, political, legal, economic, environmental) may not necessarily work for prioritization of efforts as a greater number of mitigation actions are developed. Therefore, a new concept for prioritization was developed, as documented in Section 17 of this update. Based on the short timeframe involved since conceptualization of the new process, it was determined that for the 2013 plan update, STAPLEE would again be applied to all strategies and actions to ensure consistency and that the priorities are sound and justifiable. Once the 2013 SHMP has been approved, MEMA will work with FEMA Region I to refine the new concept to ensure that future plan updates remain in compliance with FEMA guidelines.

The SHMIC met again on May 22, 2013 to further discuss and review mitigation actions that had previously been developed and to gather additional information with respect to new mitigation actions. That information is incorporated in Section 17. The SHMIC also provided comments and input to all sections of the plan, which have been incorporated as appropriate.

2.1.7 2013 Enhancements

Increased Stakeholder Involvement

More than 50 agencies participated in the development of the Commonwealth's THIRA. Participants provided a variety of information for the THIRA's risk assessment, which is the base of the SHMP's risk assessment. In addition to the THIRA participants, other state agencies were included for the SHMP plan update, including DCR wildfire members, who will enhance the wildfire portions of the plan, and DCR Forest Division, who will provide input and information on critical areas, endangered species, and coastal-related hazards.

An important opportunity during this update was the inclusion of recovery and mitigation roles in the new Emergency Support Function Team, which is a multi-discipline team providing subject matter expertise for the state emergency operations center. The creation of the Emergency Support Function Team is part of a reorganization at MEMA beginning in May 2012. In accordance with the National Incident Management System, Massachusetts uses the Emergency Support Function structure to implement effective emergency management. This Team is the foundation of MEMA interagency partnerships for all phases of response, planning, preparedness, recovery, and mitigation. Representatives from most state agencies and departments and the private sector are on this team and are available to work together before, during, and after disaster events. An example of such an interagency partnership occurred during the 2010 spring flood when a special partnership was formed between Home Depot, the federal/state joint field office, and North Quincy High School to work on a mitigation project called The Dawg Haus. Information is available at http://www.boston.com/yourtown/news/quincy/2010/06/who_l.html.

The State Emergency Management Strategic Plan was completed during this plan update. In accordance with the new goals in this plan, the Emergency Management Strategic Plan includes comprehensive natural hazard mitigation program elements, is consistent with this plan, and supports the implementation and ongoing maintenance of this plan.

In November 2012, MEMA added a new functional-needs planner to ensure that considerations for persons with access and functional needs will be incorporated into all plans and procedures. While this new position joined late in the planning process for the 2013 update, the position will help enhance this element for future plan editions.

The Planner is currently engaged with the following high-level state emergency planning initiatives/projects:

- Writing MEMA's Access and Functional Needs Annex (a framework for coordination and support of access and functional needs functions across state agencies and supporting organizations during emergency situations or disasters).

- Developing a MEMA-based training, targeted to local emergency management directors, on planning guidance for access and functional needs populations. The progress of this project is periodically reviewed by MEMA's Access and Functional Needs Task Force for feedback.
- Developing an access and functional needs resource guide for Massachusetts local government and emergency management directors.
- Updating the Massachusetts Radiological Emergency Response Plan, and the Nuclear Power Station Public Informational Calendars to include considerations for access and functional needs populations, and to update any outdated terminology in the documents related to access and functional needs populations.
- Consulting with project stakeholders for the following projects: the Massachusetts Statewide Evacuation Coordination Project, the Massachusetts Mass Care Regional Shelter Project, the New England Regional Catastrophic Initiative Mass Care Project, and MEMA's Public Information Dissemination Strategic Plan.

SHMT members will work with the MEMA All-hazards Planning Section to ensure these efforts are integrated to the maximum extent possible with the SHMP. Current information with respect to vulnerable populations is addressed for each hazard, and within the Commonwealth's profile (Section 4). The addition of this new position and the information that will be generated will greatly enhance this effort.

The SHMT also developed new initiatives to increase involvement, including information gathering through deploying a survey to state agencies and planning partners (discussed below), more individual, one-on-one outreach, outreach during other planning initiatives, such as the update of the state strategic plan, development of climate change reports and plans, and increased collaboration of agencies and stakeholders. SHMIC and SHMT members also coordinated with other agencies and individuals as needed; supplied relevant information on new data, studies, and reports; and assisted with strategy review and development, as incorporated into this SHMP. In addition to the recommendations made during the information-gathering stage of the planning process, all members had the opportunity to review and comment on the entire draft SHMP update as an additional layer of editing and evaluation.

State Agency Survey

A new element introduced during the 2010-2013 update was the development of a state agency survey. In an effort to further enhance stakeholder involvement at the state level, the SHMT developed a pilot survey (Appendix D), which was deployed to the following state agencies:

- Board of Building Regulation & Standards
- Dam Maintenance
- DCR Bureau of Forest Fire Control
- DCR Division of Planning and Engineering
- DCR Office of Water Resources
- Department of Environmental Protection, Bureau of Resource Protection
- Division of Agricultural Development
- Division of Capital Asset Management, Office of Facilities Management
- Division of Fisheries & Wildlife
- Massachusetts Board of Library Commissioners
- Massachusetts Department of Transportation

- Massachusetts Division of Marine Fisheries
- Massachusetts Historical Commission
- Massachusetts Water Resource Authority
- MassDEP
- Northeast States Emergency Consortium
- Office of Coastal Zone Management
- University of Massachusetts
- Weston Observatory

Nine agencies responded to the survey; eight were existing members, one was not. The survey requires input from multiple divisions within an agency, so while the responses *by agency* were limited, the actual number of *participants and departments from various agencies involved* in completing the survey is much greater. The Survey Monkey web site used to conduct the survey allowed only 10 question. Results from the web site present only those 10 questions. A separate PDF version of the survey, which was provided to agencies as well via hard copy, contains the 15 questions that will be used for future plan updates. Survey results are provided in Appendix D.

There were several purposes to developing this survey, a primary of which was to capture information on existing mitigation efforts by agencies that are not part of the planning process and to determine if there are agencies who would like to become members of the SHMIC. Questions were also included to enhance the Commonwealth's risk assessment by gathering information about areas of concern by the state agencies. The survey asked about each agency's responsibility for emergency management as a whole, specifically mitigation planning related to services and potential funding opportunities for local communities (technical assistance); responsibilities within the state emergency operations center during activations; and responsibilities associated with recovery efforts after a disaster. The initial deployment of the survey, which occurred in February 2013, was limited so as to capture feedback on potential difficulties incurred in completing the survey, the length of time needed to complete the survey, and the range of responses received so as to ensure effectiveness of the information gathered. During future updates of the plan, this survey will be deployed to a much wider range of agencies, after recommendations for enhancements are incorporated. Information based on survey results is incorporated in specific areas of the plan as appropriate.

2.2 COORDINATION AMONG AGENCIES

The SHMIC was an active participant in the 2013 update of the SHMP. Since the previous update, there have been changes in membership to the committee, and several new agencies have elected to participate. Due to the size of the SHMIC, several forms of outreach were conducted to gain greater participation. For this update, much of the communication between members occurred via emails and telephone conference calls in addition to in-person meetings.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.5(b)(4)(ii), which states the following:

Demonstrate that the State is committed to a comprehensive mitigation program, which might include any of the following:

- A statewide program of hazard mitigation through the development of legislative initiatives, mitigation councils, formation of public/private partnerships, and/or other executive actions that promote hazard mitigation.

During the 2010-2013 update cycle, team members met regularly to provide information and updates to each section of the plan. Key partnerships and stakeholders are shown in Figure 2-1. The coordination

among agencies has significantly improved since development of the initial plan. Several agencies have hosted or submitted requests to host mitigation planning and project training workshops for state agency staff.

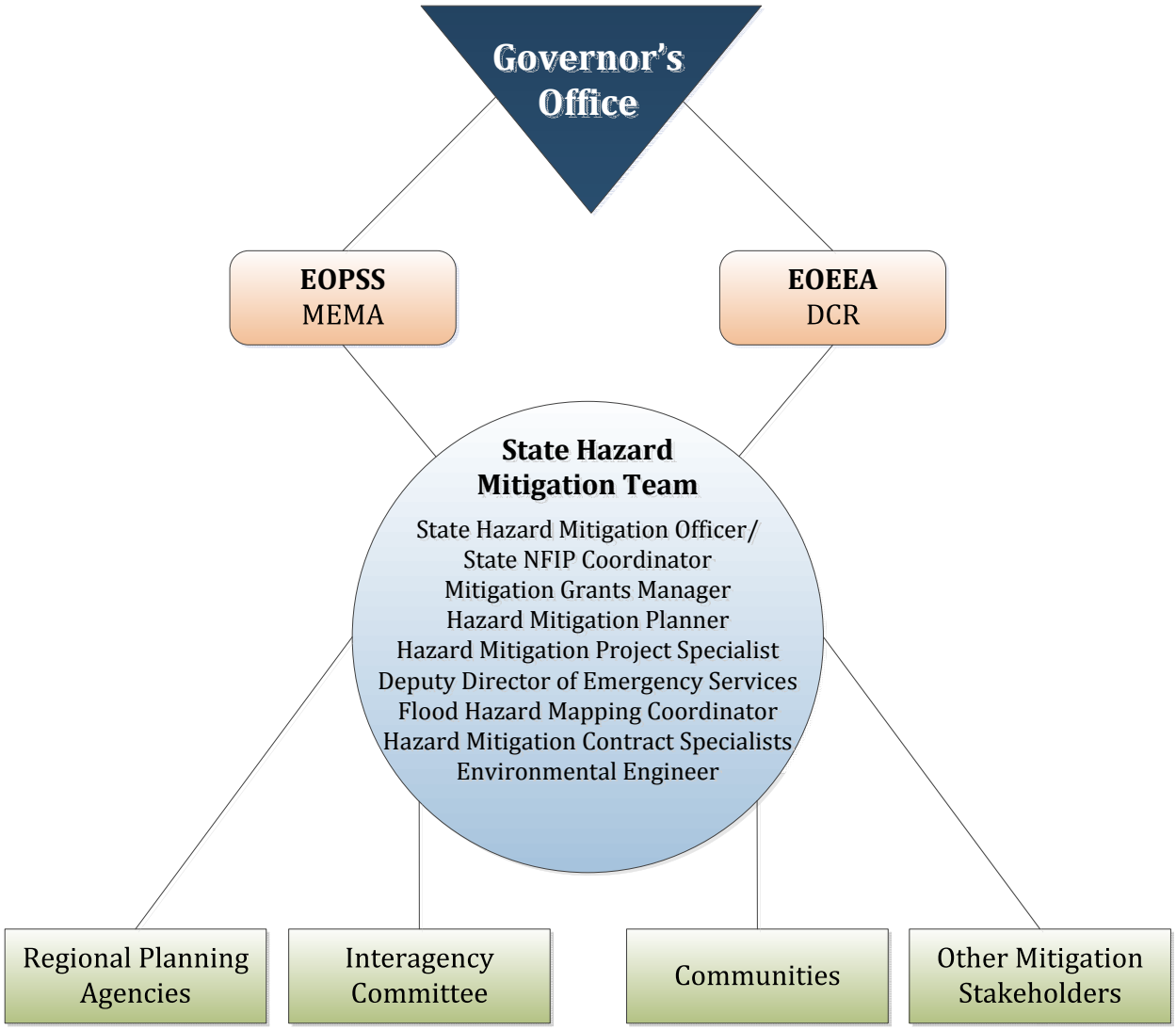


Figure 2-1. Partnerships and Stakeholders

During the time period February 1, 2010 through December 31, 2012, SHMT conducted several outreach efforts, including trainings and informational briefings related to planning and others specific to grants and projects. Section 3 presents detail on this outreach. The following are typical outreach efforts:

- Coastal Zone Management Workshop—Focus on coastal construction
- NOAA/U.S. Geological Survey Workshop—Focus on flood mapping
- Southeastern Massachusetts Building Officials Association Workshop—Focus on building codes and mapping
- Williamsburg Condominiums—Focus on insurance and mapping
- City of Fall River—Focus on base-flood elevations
- City of Cambridge—Focus on floodway requirements

- Town officials (various) and Lake Wyola Association—Focus on NFIP participation
- North Shore Task Force—Focus on use of flood insurance maps and studies
- Civil Engineers Society—Focus on mitigation planning and grant opportunities
- Climate Adaptation Workshop—Focus on mitigation planning and potential grant opportunities.

Coordination was also improved by other agencies posting and distributing mitigation opportunities and dates on their websites and newsletters. One of the questions posed in the survey administered for this update asked for information about agencies' services and technical assistance to local jurisdictions related to mitigation. Responses indicated that a wide variety of information and assistance is provided, including mapping, hazard information, studies, and reports. Additional information on the responses provided can be seen in Appendix E. This increased coordination has allowed the state to become even more resilient against natural hazards.

Interest groups at all levels of government were provided an opportunity to contribute information to this updated and to review the plan as written. The outreach period began in February 2013 with the presentation of the hazard profiles and risk maps, and continued through May 2013, with the entire plan being made available for review. Comments were solicited from several agencies during meetings and through email announcements. New to this year's review process was the development of a comment form, which more precisely tracked comments received. Once comments were received, the information was reviewed by the SHMT and incorporated as appropriate.

2.3 PROGRAM INTEGRATION

Program integration is a significant component in furthering the benefits gained of a hazard mitigation plan. The information contained in the plan can be used to support and impact policies, procedures, and programs at all levels of government. During the 2010-2013 update cycle, the Commonwealth took many steps to enhance resiliency to the hazards of concern through planning, programmatic development, funding opportunities, policies, establishing procedures, and enhancing program integration. The information provided below is a sample and not all-encompassing. Additional information concerning program integration is available in the capabilities assessment in Section 17.

2.3.1 Matching FEMA Assistance

Following presidential disaster declarations, the state may contribute half, or 12.5 percent, of the 25-percent local share of federal infrastructure support funds. Since 1991, the state has contributed more than $27 million to match FEMA's funding following declared presidential disasters.

2.3.2 Special Appropriations Following State Disasters

Although there is no separate state disaster relief fund in Massachusetts, the state legislature will enact special appropriations for communities sustaining damage following a natural disaster that is not large enough for a presidential disaster declaration. Since 1991, Massachusetts has issued 15 state disaster declarations and has provided more than $7 million in funding to aid communities affected by natural disasters.

2.3.3 State Revolving Fund

This statewide loan program through the Executive Office of Environmental Affairs assists communities in funding local stormwater management projects that help to minimize or eliminate flooding in poor drainage areas.

2.3.4 National Flood Insurance Program

The NFIP is a federal program, administered by FEMA, that makes flood insurance available in communities that agree to adopt floodplain management regulations that will reduce future flood damage. The program is intended to be a partnership between the federal government, states, and participating local jurisdictions. Congress created the NFIP in 1968 through the National Flood Insurance Act. The Act was passed to address the fact that homeowner's insurance does not cover flood damage, leaving much of the burden of flood recovery to general taxpayers through federal disaster relief programs. In general, flood insurance from private companies is either not available or extremely expensive. NFIP flood insurance is available anywhere (with limited exceptions, e.g., buildings entirely underground or entirely over water are not insurable) in a participating community, regardless of the flood zone. Federal law requires that flood insurance be purchased as a condition of federally insured financing used for the purchase of buildings in a special flood hazard area (SFHA), the area subject to inundation from the 1-percent-annual-chance flood (also known as the base flood or the 100-year flood).

Currently, 336 out of 351 Massachusetts communities participate in the NFIP. There are over 59,000 NFIP policies in place, with total insurance of $14 billion. Additional information on the NFIP program, including current status of the Commonwealth's maps and the data used for the 2013 plan update, is presented in Section 17 and in the flood hazard profile.

Flood Insurance Rate Maps

FEMA produces Flood Insurance Rate Maps (FIRMs) that show SFHAs to support the NFIP. The SFHA determines where flood insurance is required as a condition of a federally insured loan through the NFIP mandatory purchase requirement. The risk zones and flood elevations shown on the FIRMs within the SFHA are used to determine flood insurance rates. The SFHA also determines where NFIP floodplain management requirements must be enforced by communities that participate in the program. These include land use and building code standards. In addition to the NFIP, the FIRMs have taken on additional uses. They are used within FEMA's Individual and Public disaster assistance programs, FEMA's mitigation grant programs, and emergency management. In Massachusetts, the FIRMs identify areas where certain State Building Code and Wetlands Protection Act regulations are be enforced.

Communities and state agencies use FIRMs to meet NFIP participation requirements. In Massachusetts, the NFIP requirements are met through a series of state and local requirements. These include the State Building Code, the Wetlands Protection Act regulations, the Septic System regulations (Title V), and other locally adopted measures, most often a local floodplain zoning bylaw or ordinance. These regulations use FIRMs to determine specific requirements at a given location. Current effective FIRMs can often be viewed at local community offices. They are also available to view and purchase online at FEMA's Map Service Center website. These maps can be amended or revised to reflect existing topography or changes in flood characteristics. The Letter of Map Amendment (LOMA) process is often used to challenge a lender's determination that a building is in the floodplain.

Based on the April 30, 2013 NFIP Community Status List, the average age of effective FIRMs in Massachusetts is 10.42 years. This is significantly lower than the national average of about 25 years, which shows that the Commonwealth has been active in the new FEMA mapping initiatives.

Flood Map Modernization Program

FEMA is currently involved in an effort to modernize its inventory of FIRMs. FIRMs need to be updated for a number of reasons, including outdated base maps, development in watersheds, and advancements in flood modeling. Modernized FIRMs include an updated aerial photo base map. These maps are called Digital Flood Insurance Rate Maps (DFIRMs) because they are produced as a digital GIS-based product. The SHMT has partnered with FEMA and the DCR Flood Hazard Management Program to assist in the management and coordination of flood map modernization in Massachusetts.

Risk MAP Program

Risk Mapping, Assessment and Planning (Risk MAP) is a FEMA program that builds on the products of the Flood Map Modernization Program. FEMA began Risk MAP in 2009 with funding from the National Flood Insurance Fund and congressional appropriations for flood hazard mapping. Risk MAP integrates and aligns individual risk analysis programs into a more effective unified strategy:

> "[Risk MAP] provides communities with flood information and tools they can use to enhance their mitigation plans and take action to better protect their citizens. Through more precise flood mapping products, risk assessment tools, and planning and outreach support, Risk MAP strengthens local ability to make informed decisions about reducing risk." (FEMA, 2012).

Figure 2-2 presents the vision and goals of the program. Table 2-3 summarizes current Risk MAP status for counties in Massachusetts.

Source: FEMA, 2012

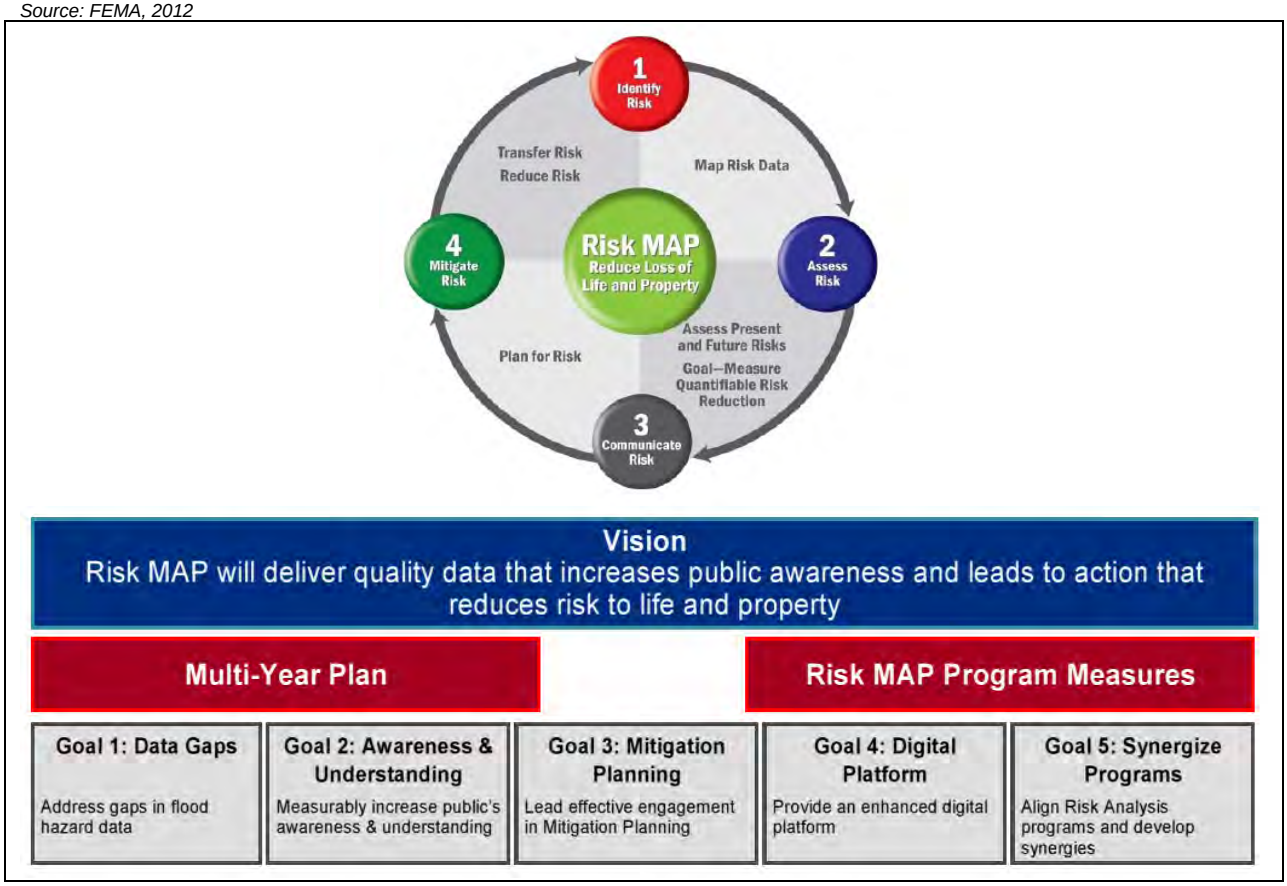


Figure 2-2. FEMA Risk MAP Program Vision and Goals

TABLE 2-3.
FEMA FIRM STATUS AND APPROXIMATE RISK MAP DELIVERABLE SCHEDULE

County	Current Status (December 31, 2012)	Estimated Schedule of Deliverables 2013	2014	Notes
Barnstable	Q3	Preliminary Maps	Effective Maps	All Barnstable County communities will get new maps. Coastal mapping update combined with first time countywide mapping.
Berkshire	Q3			
Bristol	DFIRM (July 7, 2009) *Preliminary DFIRM for Risk MAP update (12/2012) *Preliminary DFIRM for New Bedford/Fairhaven Levee: 10/2012		Effective Maps	The following communities are currently being updated: Rehoboth, Dighton, Swansea, Somerset, Seekonk, Fall River, Freetown, Berkley. Deliverable TBD The New Bedford/Fairhaven Levee has been certified. This affects the Towns of New Bedford and Fairhaven.
Dukes	DFIRM (July 6, 2010)	Preliminary Maps	Effective Maps	Entire new coastal study being performed which will impact all communities.
Essex	DFIRM (July 3, 2012)	Preliminary Maps	Effective Maps	New coastal mapping for all communities except Salisbury and Newburyport, which were already done in the 2012 mapping.
Franklin	Digital floodplain layer (1-percent flood event for Connecticut River only)			
Hampden	Revised Preliminary July 13, 2012 DFIRM	Effective Maps		
Hampshire	Q3			
Middlesex	DFIRM (June 4, 2010) *Preliminary DFIRM for Shawsheen Watershed (2011) * Preliminary DFIRM for Concord Watershed (2013)		Effective Maps	New hydraulic and hydrologic modeling and new mapping of the Concord River watershed, including the Sudbury, Assabet, and Concord Rivers. This affects the following communities: Lowell, Tewksbury, Chelmsford, Billerica, Westford, Carlisle, Bedford, Littleton, Acton, Boxborough, Concord, Lincoln, Stow, Maynard, Sudbury, Wayland, Hudson, Marlborough, Framingham, Natick, Ashland, Hopkinton, and Sherborn.
Nantucket	Preliminary DFIRM (July 26, 2012)		Effective Maps	Entire new coastal study.
Norfolk	DFIRM (July 17, 2012)	Preliminary Maps	Effective Maps	Update is only along the coast for the City of Quincy and the Town of Milton.
Plymouth	DFIRM (July 17, 2012) * Preliminary DFIRM Physical Map Revision (August 2012)	Preliminary Maps	Effective Maps	Physical Map Revision includes Towns of Marion, Mattapoisett, and Wareham. New coastal mapping for Scituate, Marshfield, Duxbury, Plymouth, and a small bit of Kingston.

TABLE 2-3.
FEMA FIRM STATUS AND APPROXIMATE RISK MAP DELIVERABLE SCHEDULE

County	Current Status (December 31, 2012)	Estimated Schedule of Deliverables 2013	2014	Notes
Suffolk	DFIRM (9/25/2009)	Preliminary Maps	Effective Maps	All new coastal modeling/mapping and that affects all 4 of the communities in Suffolk.
Worcester	DFIRM (July 4, 2011) and Q3 *Preliminary DFIRM (2013)		Effective Maps	New hydraulic and hydrologic modeling and new mapping of the Concord River watershed, including the Sudbury, Assabet, and Concord Rivers. This affects the following communities: Harvard, Bolton, Berlin, Boylston, Northborough, Southborough, Shrewsbury, Westborough, Grafton, Upton

Source: DCR (January 2013)

Risk MAP provides the data and tools that enable analysis and awareness of natural hazards. Communities can use Risk MAP data and tools to create or improve mitigation and disaster recovery plans, make informed decisions about land use and building codes, and communicate flood and other risks more effectively to citizens. This supports the nation's comprehensive emergency management framework for natural hazards and other threats. Risk MAP ultimately supports FEMA's priorities to strengthen the nation's resilience to disaster and supports FEMA's strategic priority to foster a community-oriented approach to emergency management nationally that strengthens local institutions, assets, and social networks to build sustainable and resilient communities. The implementation of Risk MAP occurs across six disciplines:

- Flood hazard mapping and engineering
- Levee strategy
- Coastal strategy
- Elevation Data
- Risk assessment
- Multi-hazard mitigation planning

Flood Hazard Mapping and Engineering

FEMA, through Risk MAP, continues to maintain the currency of the flood hazard data used in support of the NFIP. Leveraging successes from Flood Map Modernization, FEMA will continue to refresh more of the underlying engineering data depicted on the flood map. Flood Map Modernization focused on establishing a foundation for easier information depiction and distribution of the mapped flood hazard in digital format. As of November 2011, 92 percent of the nation's population has received a DFIRM. To ensure that Flood Map Modernization's investment is preserved and that synergies are realized, it is imperative to maintain the integrity and credibility of the underlying flood hazard data, and ensure that the information can be leveraged to improve mitigation activities beyond the minimum federal requirements for participation in the NFIP.

Risk MAP investments that are dedicated to flood hazard mapping will produce accurate flood hazard data, integrated watershed flood risk assessments, and more effective hazard mitigation plans. Risk

MAP's primary areas of focus include coastal flood hazard mapping, areas affected by levees, and significant riverine flood hazard data update needs.

The Risk MAP products suite was established to leverage the successes of Map Modernization and to further enhance the usability and value of flood hazard mapping by integrating that component with the risk assessment, mitigation planning, and risk communication processes into one seamless program. The Risk MAP products suite was augmented in 2012 to include coastal data-set products and data-set products related to dams. These new products will help communicate the flood risks associated with these high-risk, high-population impact hazards for coastal areas and rivers affected by the operation of dams.

Risk MAP products are being developed in collaboration with affected communities. FEMA's 10 regional offices throughout the United States manage the development and delivery of Risk MAP products. The first step in identifying needed Risk MAP products is to meet with representatives of state, local, and tribal entities. Such meetings are being held as Risk MAP projects are initiated. These initial discovery meetings typically cover the following topics:

- Flood risk changes over time.
- Identified watersheds FEMA will review in Risk MAP on the basis of risk, areas of significant development, and engineering and mapping needs, including:
  - State, local, and tribal inputs regarding Risk MAP project prioritization
  - Input for selected areas where updates to FEMA flood maps are ongoing within the watershed

Levee Strategy

As FEMA produced FIRMs for communities affected by levee systems, some stakeholders expressed concern about how flood risk was modeled on FIRMs when the levee is not certified and accredited. Members of both the U.S. House and U.S. Senate echoed this concern and asked the FEMA administrator to consider discontinuing the former levee analysis and mapping approach and to draw on current modeling techniques to more precisely reflect the level of flood hazard reduction that levee systems can provide, recognizing that uncertainty will remain. FEMA has proposed a cost-effective, repeatable, and flexible approach that:

- Complies with all statutory and regulatory requirements governing the NFIP, most notably 44 CFR § 65.10
- Leverages local input, knowledge, and data through proactive stakeholder engagement
- Aligns available resources for engineering analysis and mapping commensurate with the level of risk in the leveed area
- Considers the unique flooding and levee characteristics (solely from an engineering perspective) of each levee system.

FEMA coordinated with affected communities and other stakeholders in reviewing this new levee analysis and mapping approach for non-accredited levees. More information is available on FEMA's web site at: http://www.fema.gov/plan/prevent/fhm/lv_lamp.shtm.

Coastal Strategy

Throughout Flood Map Modernization, FEMA provided coastal communities with digital data in accordance with the program goals, but in almost all cases the underlying coastal flood hazard analyses were not updated. One notable exception is the post-Hurricane Katrina updates performed for Mississippi and Louisiana. The goals of the Risk MAP program extend beyond prior efforts, putting a greater focus on updating flood hazard data and engineering supporting NFIP maps and other Risk MAP products.

Given this change in focus and the limited updates performed throughout Flood Map Modernization, coastal communities will be provided with more comprehensive updates to their flood hazard data, similar to the updates following Hurricane Katrina. Additionally, affected coastal communities will be provided new Risk MAP products that increase communities' understanding of flood risk.

Throughout the Risk MAP Program, FEMA intends to update the nation's coastal Flood Insurance Studies and FIRMs and, where appropriate, establish new FIRMs in populated areas that previously had not been mapped. FEMA anticipates that it requires coastal funding through 2013 to initiate all updates. Upon initiation, coastal flood hazard and mapping updates can take three or more years of scoping, data collection, flood hazard analyses, and mapping, followed by regulatory appeal and compliance periods, during which the public has the opportunity to provide input and adopt the new maps into their local floodplain management ordinances. FEMA is identifying and prioritizing the study areas on the basis of mapping needs, flood risk, community and state cost-share, and cost efficiencies so that areas most in need are provided with updated maps as efficiently and expeditiously as possible.

Elevation Data

FEMA continues to invest in new ground elevation data as a key strategy for implementing Risk MAP. The acquisition of new elevation data has increased through coordination with the U.S. Geological Survey (USGS) and FEMA's cooperating technical partners. These strong partnerships help to increase the opportunities for the collection of new high-quality elevation data.

High-quality elevation data form the foundation for increasing the quality of the flood maps, aid in developing risk assessment data, and assist in developing actionable mitigation plans based on improved hazard data. The importance of the accuracy of elevation data for FEMA has been emphasized in two National Academies of Science reports. As a result, under the Risk MAP strategy, FEMA will obtain, and support partners' efforts to obtain, high-quality elevation data. FEMA will manage elevation data used for Risk MAP as part of its Engineering Library system that houses all supporting data used for Risk MAP.

FEMA will also continue to work with the USGS to integrate Risk MAP elevation data with other national elevation data resources to make the data more widely available and easier to use. FEMA and the USGS have memoranda of understanding in place to support this collaboration. In 2011, FEMA completed a project to reconcile the inventory of elevation data in the Engineering Library with the USGS elevation data holdings and transferred all existing elevation data from the FEMA Library to the USGS.

High-quality elevation data will increase the quality of the flood hazard maps, and the data will aid in developing risk assessment data, assist in developing actionable mitigation plans, and improve credibility, all of which help FEMA achieve its overall mission of reducing the impact of disasters. Furthermore, these data will result in a substantial increase in the public's awareness of risk—one of Risk MAP's operational goals—which in turn drives citizens to take actions toward mitigating risks. Finally, these data can be used for other purposes such as real-time flood inundation mapping to aid emergency response, water supply and quality modeling, and non-water related work such as roadway design, land use planning, communication and energy transmission line planning, and more. Because high-quality elevation data are useful in so many areas, FEMA is working with many interagency partners to maximize the use of all light detection and ranging (LIDAR) data. As a first step, FEMA is developing a policy to standardize LIDAR data collection specifications and data-sharing policies across the agency.

Risk Assessment

A risk assessment identifies hazards and their associated risks, including threats to public health and safety, the environment, property damage, and economic loss. The assessments combine the probabilities with the consequences in a way that quantifies risk. Quantifying the risk is a powerful way to communicate the threat, determine the key factors that cause it to be high, and ultimately perform trade-off analyses to determine the most effective way to reduce, avoid, or otherwise control it.

For NFIP purposes, the ability to compare flood risk across states and regions is critical. At the state and community levels, flood risk information helps community leaders with planning, evaluating costs and benefits associated with building codes, and achieving other preventive measures. An understanding of the flood risk is important to manage and mitigate risk for businesses and industries that may be located within or near the floodplain.

Through the integrated delivery of Risk MAP, one of the key data sets a given watershed will receive will be a flood risk assessment. FEMA uses the HAZUS tool for risk assessment and loss estimation. This assessment begins to quantify, in economic terms, the impact of a particular flood event. With this information available, local communities can begin to get a sense of the following:

- Economic losses to residential, commercial, and other assets within the community across a watershed
- Estimated damage to building stock
- Potential disruptions to the business community or tax base

To support Risk MAP and the development of risk assessments, FEMA is:

- Enhancing the Hazus model by developing storm surge methodology and adding a storm surge component of the hurricane module
- Leveraging NOAA's expertise in tsunami hazard identification to add a tsunami risk assessment to methodology to Hazus
- Updating the functionality and loss estimation accuracy for easier use by decision-makers and GIS users at the state, regional, and local levels so they incorporate risk assessment data into their emergency management and mitigation planning efforts

In addition, FEMA continues to provide training opportunities and communication materials on Hazus with the goals of educating new and existing Hazus users and gathering feedback on how to further improve the tool's ability to accurately assess risk and quantify losses from flood and other hazards.

Multi-Hazard Mitigation Planning

Hazard mitigation planning is the process used by state, tribal, and local governments to identify risks, assess vulnerabilities, and develop long-term strategies for protecting people, natural environment, and property from the effects of future natural hazard events. The process results in a mitigation plan that offers a strategy for breaking the cycle of disaster damage, reconstruction, and repeated damage; and a framework for developing feasible and cost-effective mitigation actions.

In September 2011, FEMA released new mitigation plan review tools and guidance that streamline the plan review process and reinforce the emphasis on mitigation strategies, specifically actions and implementation. To support Risk MAP in achieving the overarching mitigation planning strategy and vision, this project has achieved the following goals:

- Developed a refined, strategy-focused mitigation plan review process that meets the intent of the Stafford Act and 44 CFR Part 201 by leading communities to implement action to reduce risk.
- Developed the necessary tools to support the new mitigation plan review process, and to meet stakeholder needs and create efficiencies.

FEMA developed the new process in 2011 with feedback from internal and external stakeholders, including all FEMA headquarters and regional offices, state hazard mitigation officers, local government officials, the National Emergency Management Association, the Association of State Floodplain Managers, and the National Hazard Mitigation Association.

Community Rating System Program

The CRS is a voluntary program within the NFIP that encourages floodplain management activities that exceed minimum NFIP requirements. Flood insurance premiums are discounted to reflect the reduced flood risk resulting from community actions to meet the CRS goals of reducing flood losses, facilitating accurate insurance rating and promoting awareness of flood insurance.

For participating communities, flood insurance premium rates are discounted in increments of 5 percent. For example, a Class 1 community receives a 45-percent premium discount, and a Class 9 community receives a 5-percent discount. (Class 10 communities are those that do not participate in the CRS; they receive no discount.) The CRS classes are based on 18 activities in the following categories:

- Public information
- Mapping and regulations
- Flood damage reduction
- Flood preparedness.

CRS activities can help to save lives and reduce property damage. Communities participating in the CRS represent a significant portion of the nation's flood risk; over 66 percent of the NFIP's policy base is located in these communities. Communities receiving premium discounts through the CRS range from small to large and represent a broad mixture of flood risks, including both coastal and riverine flood risks. The Insurance Services Office administers the CRS program under FEMA contract.

As of October 1, 2012, there were 17 Massachusetts communities participating in the CRS program, as listed in Table 2-4. These communities represent 24.2 percent of the flood insurance policy base in the Commonwealth. The CRS classifications range from a Class 10 (no discount) to Class 8 (10-percent discount). Four participating communities have had CRS classifications rescinded and now receive no CRS discount. The total annual flood insurance premium discount for the Commonwealth as of October 1, 2012 was $1,499,113. This represents 2.17 percent of the total annual premium for the Commonwealth.

TABLE 2-4.
MASSACHUSETTS PARTICIPATING CRS COMMUNITIES

NFIP #	Community	CRS Entry Date	Current Effective Date	Current Class[a]	% Discount for SFHA	% Discount for non-SFHA	Status[b]
250286	Boston	10/1/1992	10/1/1997	10	0	0	R
250233	Braintree	10/1/1992	05/01/2008	9	5	5	C
250004	Chatham	10/1/1992	10/1/2008	8	10	5	C
250082	Gloucester	10/1/1992	10/1/1997	10	0	0	R
250008	Harwich	10/1/1995	11/1/2010	9	5	5	C
250085	Haverhill	10/1/1992	10/1/2008	9	5	5	C
250269	Hull	05/01/2008	05/01/2008	8	10	5	C
250273	Marshfield	10/1/1991	5/1/2007	8	10	5	C
250167	Northampton	5/1/2003	10/1/2010	10	0	0	R
250060	Norton	10/1/1991	10/1/2011	9	5	5	C
250010	Orleans	10/1/1993	10/1/2008	9	5	5	C
250278	Plymouth	10/1/1991	10/1/2008	9	5	5	C

TABLE 2-4.
MASSACHUSETTS PARTICIPATING CRS COMMUNITIES

255218	Provincetown	10/1/2011	10/1/2011	9	5	5	C
255219	Quincy	10/1/1993	10/1/2012	8	10	5	C
250282	Scituate	10/1/1991	5/01/2009	8	10	5	C
250218	Tewksbury	10/01/1993	10/01/2009	10	0	0	R
250349	Worcester	10/01/1995	10/012010	9	5	5	C

a. Communities rated as 10 are communities that previously participated in the CRS but are currently not in the program for various reasons.
b. Status: C = Current, R = Rescinded

2.3.5 Massachusetts Flood Hazard Management Program

The DCR Flood Hazard Management Program is the state coordinating office for the NFIP. Program staff work with FEMA and officials from NFIP-participating local communities (currently 336 of the Commonwealth's 351 communities) to implement the NFIP in Massachusetts. The Flood Hazard Management Program is a technical assistance program and has no regulatory authority, although staff does provide assistance to local communities in reviewing and developing required ordinances for NFIP compliance, as well as working with other state agencies to develop the Commonwealth's laws regulating the program (see Section 17 for detail on NFIP-related technical assistance provided). 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.

2.3.6 Executive Office of Energy and Environmental Affairs

The Massachusetts Executive Office of Energy and Environmental Affairs (EOEEA) is the agency responsible for analysis of statewide growth and its impacts. Representatives from the EOEEA sit on the SHMIC. This agency assists communities as needed with modifications to codes and regulations.

2.3.7 Office of Coastal Zone Management

The Office for Coastal Zone Management (CZM) balances the impacts of human activity with the protection of coastal and marine resources. CZM was established to work with other state agencies, federal agencies, local governments, academic institutions, nonprofit groups, and the general public to promote sound management of the Massachusetts coast. CZM is funded primarily through the Commonwealth, NOAA, and the U.S. EPA. The CZM program consists of enforceable program policies and management principles governing activities in the Massachusetts coastal zone. The coastal zone extends from the 3-mile limit of the state territorial sea to 100 feet beyond the first major land transportation route (a road, highway, rail line, etc.), as shown on Figure 2-3. It includes all of Barnstable County, Dukes County, and Nantucket County (Cape Cod, Martha's Vineyard, Nantucket, and Gosnold), tidal rivers and adjacent uplands, and anadromous fish runs in coastal towns. The coastal zone includes all islands, transitional and intertidal areas, coastal wetlands, and beaches within the Commonwealth.

Source: http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/cstzone.html

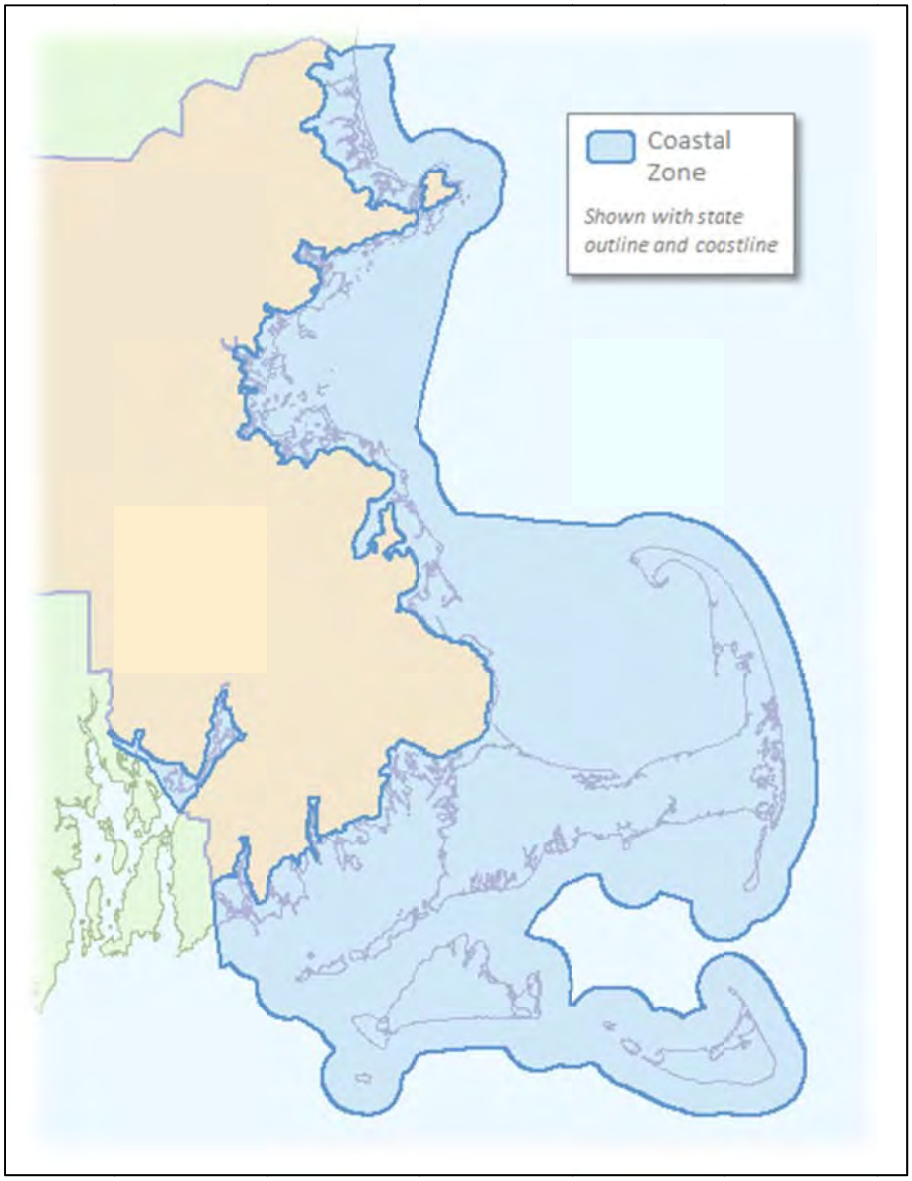


Figure 2-3. Massachusetts Coastal Zone

For planning and technical assistance coordination, the coastal communities are split among five Coastal Regions: North Shore, Boston Harbor, South Shore, South Coastal, and Cape Cod and Islands. Each area of the coast is impacted differently by each type of coastal hazard and has varying vulnerability. Additional information on the five Coastal Regions is incorporated in the coastal erosion hazard profile. Further information is at: www.mass.gov/czm/hazards/shoreline_change/shorelinechangeproject.htm.

The following are significant programs and recent projects related to CZM:

- To help coastal communities address challenges arising from storms, floods, sea level rise, and climate change, StormSmart Coasts provides a menu of options for successful coastal floodplain management. The website (http://www.mass.gov/czm/stormsmart/index.htm) includes regulatory tools, case studies, planning strategies, and other technical assistance materials. CZM's StormSmart Coasts program implements the Coastal Hazards Commission recommendation to establish a storm-resilient communities program to provide case studies

for effective coastal smart growth planning and implementation. This national model helps translate often overwhelming technical materials into user-friendly information for local planning efforts.

- In 2013, through collaboration with the USGS, CZM completed an update of the Massachusetts Shoreline Change Project, determining the amount of shoreline change from the mid-1800s through 2009. The USGS analyzed this latest shoreline with other shorelines at 50-meter intervals to compute long-term (approximately 150-year) and short-term (approximately 30-year) rates of shoreline change. Other shorelines added as part of this update include a 2000 shoreline derived by USGS that covers most of the ocean-facing coastline, as well as a 2001 shoreline for the South Shore that was delineated by Applied Coastal Research and Engineering. New shorelines and more than 26,000 transects with updated change rates, uncertainty values, and net distances of shoreline movement have been added to the Massachusetts Ocean Resources Information System Shoreline Change Browser.
- The CZM, in coordination with other stakeholders, updated the Massachusetts Ocean Management Plan and CZM Policy Guide, published in October 2011. The guidance includes the enforceable policies of the Ocean Plan, updates underlying legal authorities, and reinstates certain Federal Energy Regulatory Commission authorizations on the list of federal license or permit activities reviewed without prior approval. One of the primary established policies of the CZM, effective as of October 4, 2011, is to: "Preserve, protect, restore, and enhance the beneficial functions of storm damage prevention and flood control provided by natural coastal landforms, such as dunes, beaches, barrier beaches, coastal banks, land subject to coastal storm flowage, salt marshes, and land under the ocean" (CZM, 2011).
- The CZM provides an inventory of public seawalls and other structures (available at: http://www.mass.gov/czm/stormsmart/mitigation/infrastructure_reports.htm), prepared by the CZM in conjunction with DCR. This report includes the condition ratings and estimated repair or reconstruction costs for publically owned seawalls, revetments, groins, jetties and other structures. Resources such as this assist impacted communities in determining potential grant projects, providing excellent information on which to make decisions of whether to pursue a grant for such a project, and also providing information for incorporation into the actual grant application.

Additional information concerning the CZM is available in Section 17.

2.3.8 Massachusetts Smart Growth

As part of the Commonwealth's efforts to support smart growth, the Community Preservation Act (CPA) was enacted on September 14, 2000 (Chapter 267 of the Acts of 2000); it has since been amended five times for further enhancements. The CPA allows communities to create a local Community Preservation Fund to raise money through a surcharge of up to 3 percent of the real estate tax levy on real property for open space protection, historic preservation, and the provision of affordable housing. The act also creates a significant state matching fund, which serves as an incentive to communities to pass the CPA. These principles require communities to incorporate mitigation by protecting, among other things, critical areas and encourage development in areas outside hazard areas or to standards that reduce vulnerability to hazards. Further information on the CPA is available in Section 4.

2.3.9 MassDEP Wetlands Protection Act

Wetlands are protected from development by the state Wetlands Protection Act and, in some cases, by local wetlands protection bylaws. Freshwater wetlands support high biodiversity, including unique plant communities and many animal species that are dependent on wetlands for various life-cycle needs. Wetlands also capture heavy rains and prevent flooding downstream, absorb greenhouse gases from the

atmosphere, and store and purify groundwater. MassDEP provides support to mitigation efforts through permitting, regulatory, and funding opportunities. Wetland resource areas include both inland and coastal wetlands. Coastal wetlands include coastal beaches, dunes, barrier beaches, banks, and salt marshes. These are protected under the Massachusetts Wetlands Protection Act, in part for their ability to provide storm damage protection and flood control.

2.3.10 Massachusetts Department of Revenue

The Massachusetts Department of Revenue requires all communities to value all property each year. Every third year a complete recertification is required. Both a recertification and an interim-year adjustment (the two years in between the triennial recertification) include a detailed analysis of sales data as a basis for adjusting the property values. The goal is to keep the values as close as possible to 100 percent of market value and avoid an excessive swing in assessments in one year. This type of data can assist in the calculation of losses at both the local and state levels.

2.3.11 Low Impact Development

Development based on conventional zoning in Massachusetts often results in sprawl, with associated large impervious areas, loss of natural resources, increase in nonpoint source pollution, and alteration of hydrologic systems. Conventional developments often start with clearing and leveling of the entire parcel. The construction of wide, paved roads and large parking lots follows. These impervious areas eliminate vegetation (nature's natural pollution filters) and prevent water from infiltrating into the ground (which normally replenishes groundwater that supports nearby wetlands and streams). The result is the conveying of polluted runoff to water bodies. In order to deal with stormwater that runs off these sites, structural controls such as catch basins, pipes and detention ponds are used. Instead of "greenscapes," conventional landscaping of these developments brings additional concerns, including the introduction of non-native plants, use of herbicides, pesticides and fertilizers, and excessive water consumption.

In an effort to stimulate more robust low-impact development trends throughout the Commonwealth, DCR works with local jurisdictions to promote better land use trends. A recent example of this is the Pinehills, Plymouth Suburban project. When completed in 2014, the Pinehills development will comprise nearly 3,000 homes, 1.3 million square feet of commercial space, four golf courses, and significant areas of protected open space. The project was planned as an open-space mixed-used development, a special floating zone passed by Plymouth town meeting as an alternative to the standard subdivisions that dominate the region. The project is a multi-year collaboration between the town of Plymouth, state and local officials, and the developers. Pinehills serves as an example of compact design, reduction of impervious surfaces, water conservation, wastewater reuse, and historic preservation. The project partners are Wallace Associates LLC; New England Development of Newton; and managing partner Tony Green and The Green Company. In 2003, it won top honors from the National Association of Home Builders for Best Master-Planned Community in the Nation. In 2005 it was recognized for Best Smart Growth Community (EOEEA, 2013). Information on this and similar projects is available at: www.mass.gov/dcr/watersupply/ipswichriver/demo-projects.htm

2.3.12 DCR Bureau of Forest Fire Control and Forestry and the Nature Conservancy

The Massachusetts DCR Bureau of Forest Fire Control and Forestry works with local communities to address wildfire issues. For example, the Bureau joined forces with The Nature Conservancy to prevent wildfires from burning out of control through the Southeast Massachusetts Hazardous Fuels Mitigation and Ecosystem Restoration Project, which was developed with a $1.97 million stimulus grant to provide prescribed and mechanical fire treatments to 1,000 acres in the southeastern part of the Commonwealth, which contains highly flammable vegetation. The region is the second most volatile area in the country.

Additional information on the project is available at: http://www.mass.gov/recovery/see-the-impact/stimulus-stories/preventing-wildfires.html

2.3.13 Executive Office of Public Safety and Security—Board of Building Regulations and Standards

The Board of Building Regulations and Standards is an 11-member board that derives its authority to adopt regulations, administer provisions of the state building code, and operate various construction related programs from Massachusetts General Laws Chapter 143, Sections 93 through 100. Members of the Board were part of the SHMIC for the 2013 plan update, providing input to various elements of the plan. During 2010, DCR staff worked with the Board to develop the 8th Edition of the Massachusetts State Building Code. The updated ordinance more closely mirrors the I-Codes, and more accurately reflects Massachusetts permitting procedures. The 8th Edition also reflects the strict standards for development within coastal dunes. The 8th Edition of the Massachusetts State Building Code consists of both International Building Code and International Residential Code, with Massachusetts amendments to reflect stricter state standards that exceed the NFIP minimum requirements.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.5(b)(4)(iv), which states the following:

Demonstrate that the State is committed to a comprehensive mitigation program, which might include any of the following:

- To the extent allowed by State law, the State requires or encourages local governments to use a current version of a nationally applicable model building code or standard that addresses natural hazards as a basis for design and construction of State sponsored mitigation projects.

2.3.14 Coordinated Statewide Emergency Preparedness in Massachusetts Program

The Coordinated Statewide Emergency Preparedness in Massachusetts program (COSTEP-MA) promotes proactive steps to reduce losses from natural hazards, especially flooding or water damage following fires, through cooperative, team-building activities in communities and through educational activities within the cultural heritage and emergency management communities. COSTEP-MA has developed an annex to the Massachusetts Comprehensive Emergency Management Plan and promotes education and cooperation in communities to enhance the protection of cultural resources from natural disasters.

The preservation of historic and cultural resources must be carefully considered in order to protect the character of the region's city, town, and village centers. Many colonial era residences, mill structures, and village greens are already protected to some extent through the establishment of historic districts; however, additional consideration should be given to protecting such resources from potential natural hazards. Historic inventories and plans are essential in guiding historic preservation initiatives, and such plans should consider hazard mitigation. Effective preservation of these resources requires active stewardship and support of the overall community. COSTEP-MA works with communities in protecting these invaluable resources.

2.3.15 Massachusetts Emergency Management Agency

The Civil Defense Act of 1950 authorized the creation of the Massachusetts Civil Defense Agency (predecessor to MEMA) and the development of a statewide civil defense program. Massachusetts Executive Orders 144 and 242 amended and updated the Civil Defense Act of 1950 by creating the position of Secretary of Public Safety, coordinating emergency preparedness activities and promulgating a state Comprehensive Emergency Response Plan. Combined, these executive orders delineate the need for a comprehensive emergency management program administered by the Commonwealth, and authorized the creation of local organizations for emergency management in the political subdivisions of the Commonwealth. Emergency management is defined as the preparation for and the carrying out of all

emergency functions—to mitigate, prepare for, respond to, recover from, and prevent emergencies and disasters, including natural, human-caused, and technological hazards. The THIRA and SHMP's risk assessments indicate all hazards to which the Commonwealth and its jurisdictions are susceptible; completion of these risk assessments will contribute significant information to be used in all of FEMA's emergency management mission areas.

Alert and Warning

MEMA and many partner organizations and agencies, including the National Weather Service, FEMA, and the American Red Cross, use multiple methods to get information and alerts out to the public before and during emergencies. In addition to traditional media, Emergency Alert System, and weather radios, other new tools are being used. These include social media, smartphone apps, wireless emergency alerts on cellphones, websites, etc. The goal of these methods is an enhanced capacity to alert the public so that more people get the information and so that people hear messages from multiple methods to help them stay safe during emergencies.

National Weather Service StormReady Program

An estimated 90 percent of all federally declared disasters are weather-related, leading to around 500 deaths per year and nearly $14 billion in damage (NWS, 2013). Each year, Americans cope with an average of 100,000 thunderstorms, 10,000 of which are severe, 5,000 floods, 1,000 tornadoes, and an average of two land-falling deadly hurricanes. This is on top of winter storms, intense summer heat, high winds, wildfires, and other deadly weather impacts.

The National Weather Service created the StormReady program to help communities become more resilient to the impacts of these weather events. The StormReady Program helps arm America's communities with the communication and safety skills needed to save lives and property before and during extreme weather events. StormReady helps community leaders and emergency managers strengthen local safety programs. StormReady communities are better prepared to save lives from severe weather through advanced planning, education and awareness.

Currently, there are 16 StormReady sites in the Commonwealth of Massachusetts (see Figure 2-4): 11 communities (Agawam, Belmont, Boston, Braintree, Carver, Mansfield, Scituate, Shrewsbury, Southborough, Southwick, and Worcester), one commercial site (Six Flags), three universities (Boston College, Boston, and Harvard Universities), and one military site (Natick Soldier Systems Center).

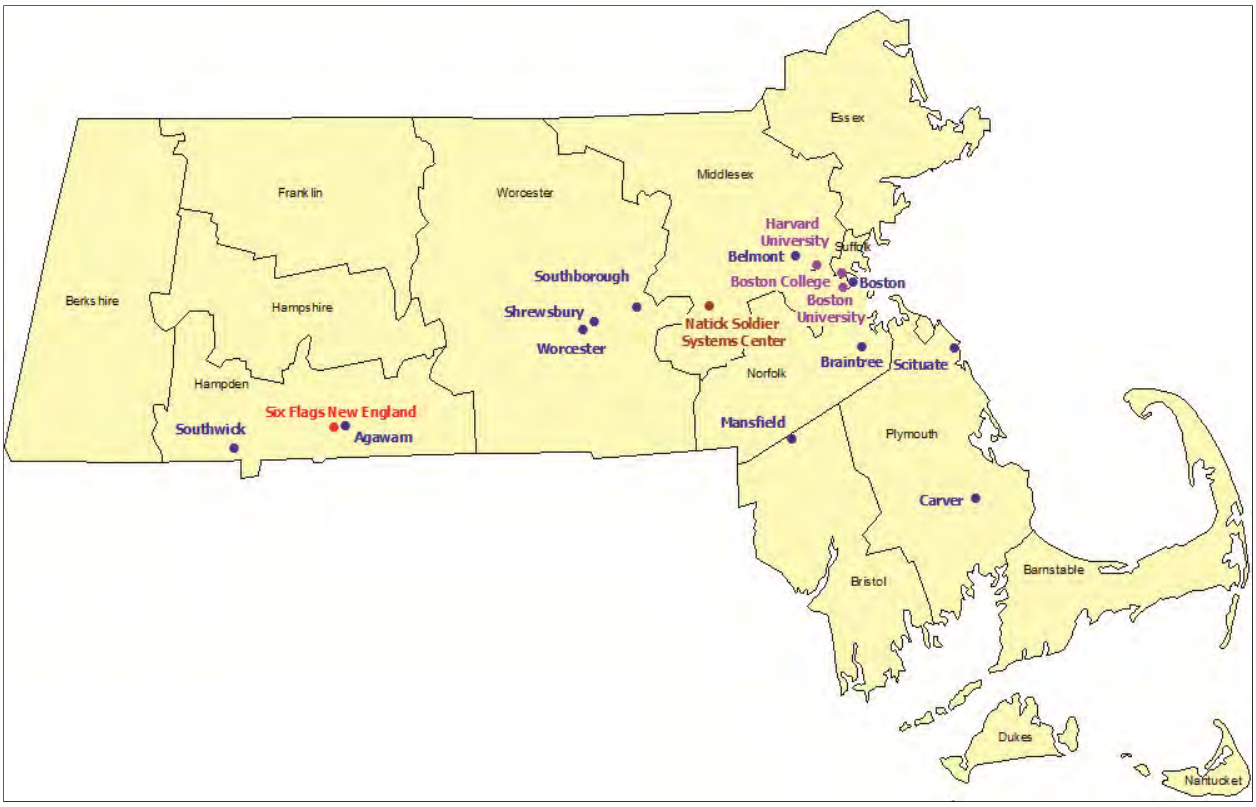


Figure 2-4. StormReady Sites in Massachusetts

Emergency Management Accreditation Program

Planning initiatives in Massachusetts are enhanced through the Commonwealth's participation in the Emergency Management Accreditation Program. EMAP is a voluntary assessment and accreditation process for government emergency management programs. It includes the following:

- A structure for identifying areas in need of improvement
- A methodology for strategic planning and justification for resources
- A catalyst for improved interoperability and professionalism
- Strengthened state, territorial, and local preparedness, including sharing of best practices.

EMAP uses national emergency management standards along with peer assessment teams to evaluate a program's activities—not just an agency, but a jurisdiction's entire program. The Commonwealth gained conditional EMAP accreditation on October 29, 2012.

2.3.16 Other Programs

The Commonwealth continues to make efforts to integrate mitigation to the greatest extent possible with other statewide planning and regulatory initiatives. For this plan update, the SHMT consulted with several ongoing planning initiatives in an attempt to integrate hazard mitigation beyond the programs described above. Additional initiatives, plans, programs and/or departments include:

- Partnerships with academic institutions to provide studies and supporting hazard information.
- Massachusetts Climate Protection Plan
- Massachusetts Drought Management Plan

- Coastal Hazards Commission Recommendations.

2.3.17 Groups, Commissions and Private Non-Profit Programs

Beyond the customary governmental departments and agencies, the SHMT has identified additional opportunities with which to integrate mitigation actions. Members of the SHMT participate in numerous programs across the Commonwealth related to hazard mitigation. The following list is a demonstration of those organizations, but is not a complete list:

- Association of State Floodplain Managers
- Climate Change Adaptation Advisory Committee
- Community Assistance Program-State Support Services Element National Policy Group
- Council of State Archivists Emergency Planning Committee
- International Emergency Management Working Group
- Massachusetts Coastal Hazards Commission
- Massachusetts Emergency Management Team
- Massachusetts Emergency Management Directors Advisor Committee
- Massachusetts GIS Advisory Council
- Massachusetts Public Private Workgroup
- Muddy River Technical Advisory Committee
- National Emergency Management Association
- Technical Advisory Committee for Coastal Construction and Environmental Issues
- Civil Engineers Society (new 2013 plan)
- Old Boston Statehouse (new 2013 plan)
- Massachusetts Water Resource (new 2013 plan)
- Coastal Zone Management Workgroup (new 2013 plan)
- Southeastern Massachusetts Building Officials Association (new 2013 plan)
- North Shore Task Force (new 2013 plan).

SECTION 3. COORDINATION OF LOCAL PLANNING

3.1 LOCAL FUNDING AND TECHNICAL ASSISTANCE

Since 1997, the Massachusetts State Hazard Mitigation Team (SHMT) has been providing grant funding for local mitigation plans, formerly flood mitigation plans, and technical assistance. The SHMT started working closely with Massachusetts' communities in 1997 on local flood mitigation plans in accordance with the Flood Mitigation Assistance (FMA) program. This program provides annual funding, through the NFIP, for communities to develop local flood mitigation plans. In 1997, the state also hired a full-time mitigation planner to work on the State Hazard Mitigation Plan and to provide technical assistance, with other SHMT members, to communities working on FMA plans.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(4)(i), which states the following:

Plan Content. To be effective the plan must include a section on the Coordination of Local Mitigation Planning that includes a description of the State process to support, through funding and technical assistance, the development of local mitigation plans.

Massachusetts is one of a few states in New England that have a position solely dedicated to hazard mitigation planning. This planning position, State Hazard Mitigation Planner, has been expanded to provide technical planning assistance to regional planning agencies and communities that are developing hazard mitigation plans. The planner also is responsible to coordinate the update of the SHMP to meet DMA 2000 requirements.

This technical planning assistance has involved meeting with local officials and local planning teams to provide overviews of the hazard mitigation planning process and mitigation plan requirements, and descriptions of potential hazard mitigation measures.

3.2 MULTI-JURISDICTIONAL AND LOCAL HAZARD MITIGATION PLANS

As part of the Commonwealth's strategy to meet DMA 2000 requirements for hazard mitigation plans, the SHMT has invested in regional planning agencies (RPAs). The RPAs develop multi-jurisdictional or regional hazard mitigation plans and annexes for participating communities. In addition to the funding provided through grants, communities may also develop mitigation plans without FEMA mitigation funds, including individual communities that have used HMGP funds for plans developed by contractors. The Commonwealth provided the opportunity for every community to participate through one of the RPAs by providing funding through various federal planning grants. Examples include the following planning efforts reported in the 2010 SHMP:

- In 2002:
  - Cape Cod Commission (CCC)
  - Franklin Regional Council of Governments (FRCOG)
  - Metropolitan Area Planning Council (MAPC)
  - Southeastern Region Planning & Economic Development District (SRPEDD)
- In 2003:
  - Berkshire Regional Planning Commission (BRPC)
  - Northern Middlesex Council of Governments (NMCOG)

  - Old Colony Planning Council (OCPC)
- In 2005:
  - Nantucket Planning & Economic Development Commission (NP&EDC)
  - Merrimack Valley Regional Planning Commission (MVPC)
  - Martha's Vineyard Commission (MVC)
  - Central Massachusetts Regional Planning Commission (CMRPC)
  - Pioneer Valley Planning Commission (PVPC)
  - Additional areas of the MAPC region
  - Two additional communities in the FRCOG
- In 2006:
  - Montachusett Regional Planning Council (MRPC)
  - Additional areas of the MAPC region
- In 2007:
  - All remaining communities in the MAPC region applied for planning grants.

The following additional planning efforts have been conducted since completion of the 2010 plan:

- In 2010:
  - MAPC (the Urban Core)
  - NMCOG
  - OCPC
- In 2011:
  - Town of Winchester
  - MVPC
  - BRPC
  - MRPC
  - University of Massachusetts Medical School
- In 2012:
  - PVPC (for multiple jurisdictions)
  - Town of Dartmouth
  - MVC
  - SRPEDD (for multiple jurisdictions)
  - BRPC.

To date, all communities in Massachusetts that have chosen to participate with an RPA have had an opportunity to begin or complete a multi-hazard mitigation plan.

3.2.1 Developing Local Mitigation Plans

At the end of the 2010 state planning cycle, there were about 130 communities in the process of completing a hazard mitigation plan. This category included conditionally approved plans and those under review. As of January 31, 2010, 58 communities in Massachusetts did not have a plan in place. Of those with no plan in place, 14 were not participants in the NFIP.

As of December 31, 2012, 39.3 percent of the Commonwealth had plans in place, 8.2 percent had conditional approval, 11 percent were approved by FEMA pending adoption, 6.5 percent were in review by MEMA, and 13 percent of the municipalities had expired plans. Figure 3-1 provides a breakdown of plans in place as of December 31, 2012.

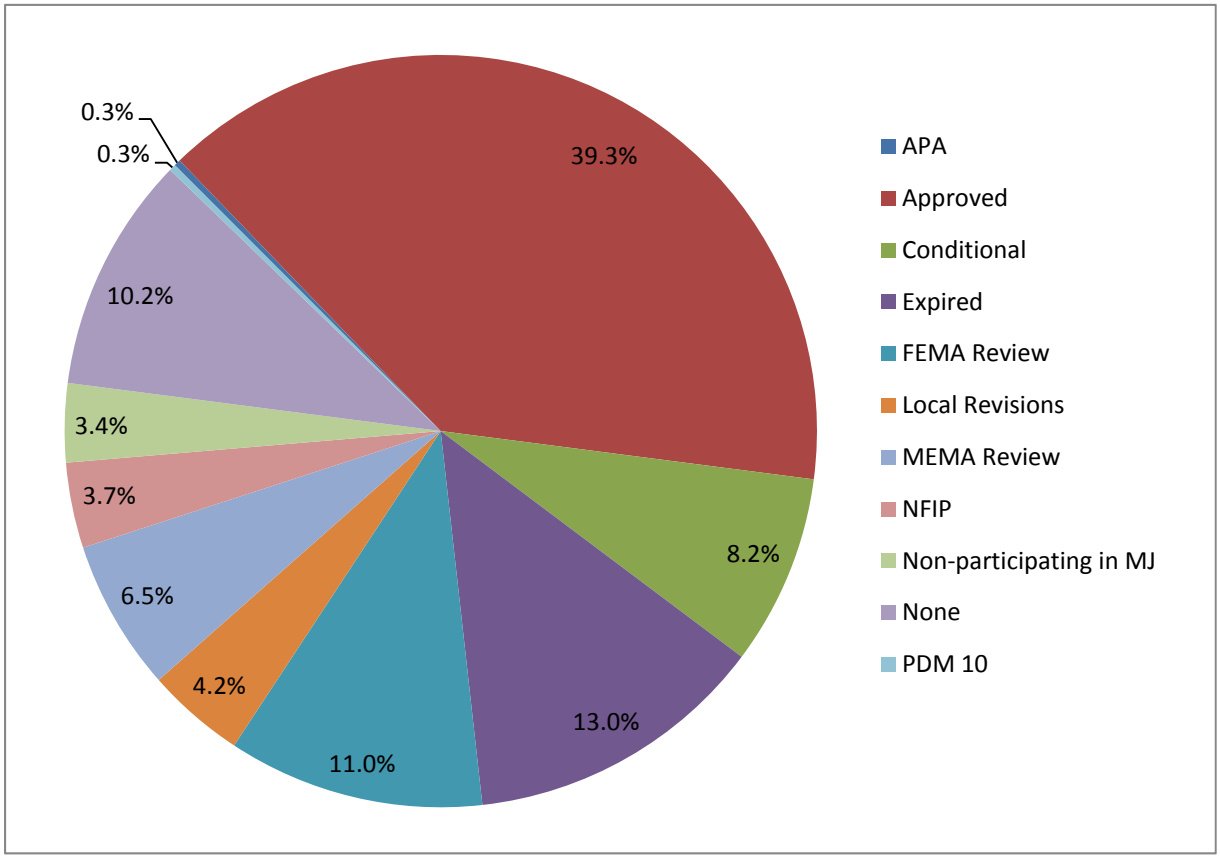


Figure 3-1. Mitigation Plan Counts by Community as of December 31, 2012

Historically, several of Massachusetts' universities and colleges have received FEMA Disaster-Resistant University planning grant funding and completed campus mitigation plans. Those funds are no longer available through the Unified HMA programs; however, many colleges have elected to pursue mitigation planning at the local and regional level as a part of the traditional Multi-hazard mitigation planning process involving the whole community. In addition to looking at their own vulnerabilities as institutions, the universities provide insight into the development of the Commonwealth's plan through subject matter expertise with respect to hazard information, strategy development, etc. Numerous subject-matter experts from public and private universities have participated in mitigation program implementation. Facilities and structures for institutions that are state-owned or operated are included in Division of Capital Asset Management and Maintenance data on which the risk assessment portion of this 2013 update is based.

The Commonwealth of Massachusetts also has two tribes within its boundary. One of those tribes, the Wampanoag Tribe of Gay Head, has a developed Tribal Hazard Mitigation Plan (direct with FEMA). The Mashpee Wampanoag Tribe does not have an approved plan.

3.2.2 Local Plan Updates

At the time of this plan's publication, several local mitigation plans have expired and have begun the update process. Fiscal Year 2010, 2011, and 2012 HMGP and PDM plan update grants have been awarded. At this time it is anticipated that the majority of plans expiring will be updated within a short period to ensure that continued mitigation efforts are in place and applicable for grant funding, as funding becomes available after plan completion and adoption. The SHMT is working to provide assistance to all communities and regions conducting a plan update.

3.2.3 Technical Assistance and Outreach

A noteworthy activity during the 2010-2013 update cycle is FEMA's mapping project throughout the Commonwealth. SHMT members have been deeply involved in this process, including attendance at discovery meetings and community meetings as maps are presented. As a result of map errors, the Commonwealth has had to devote resources to review maps and provide additional assistance to local communities. Due to involvement in FEMA's mapping project, the Commonwealth's general technical assistance on an ongoing basis has been less than what the Commonwealth would like to provide and has envisioned for future plan updates. Still, the state has increased its technical outreach compared to previous years.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.5(b)(4)(i), which states the following:

Demonstrate that the State is committed to a comprehensive mitigation program, which might include any of the following:

- A commitment to support local mitigation planning by providing workshops and training, State planning grants, or coordinated capability development of local officials, including Emergency Management and Floodplain Management certifications.

As is the case nationwide, most communities in Massachusetts do not have the staff capability to develop hazard mitigation plans without funding or technical assistance. In recognition of this reality, the SHMT developed a strategy consistent with the DMA 2000 to fund RPAs through the Pre-Disaster Mitigation (PDM) grant program and post-disaster funding available for hazard mitigation planning through HMGP. The RPAs have professional planners on staff with extensive knowledge of the communities in their regions. They provide a wide range of planning initiatives for local communities as discussed in greater detail in Section 4. The RPAs are customarily the entity that completes local and regional plans, so all plans—whether regional or single jurisdiction—are similar in layout and content.

Although most communities in the Commonwealth have joined forces with their RPAs for this planning effort, a number have decided to apply directly to FEMA through the state for funding to conduct their own planning process. A few jurisdictions have hired independent contractors to complete their plans. The SHMT works directly with those communities to assist them through the planning process. These plans are then to be integrated with any multi-jurisdictional or regional mitigation plan in place to remain consistent across the state.

General Technical Assistance to Local Communities

In support of enhancing planning initiatives statewide, MEMA and DCR staff provide varying types of technical assistance to the local communities:

- Site visits—one-on-one or planning teams
- Workshops
- Attendance at kick-off meetings
- Phone and conference calls
- Web-based meetings
- Emails
- Written correspondence
- Classroom settings
- Attendance at public meetings
- Samples and templates
- Publications, such as MEMA's info bulletins and newsletters, which are distributed regularly (examples are included in Appendix C).

Mitigation Planning Areas for Which Assistance Is Provided

The following are the areas of mitigation planning in which technical assistance has been provided (non-inclusive, but most common areas where assistance was provided):

- Community Rating System (CRS) and Insurance Services Office (ISO) support and interface
- Update versus new plan—Differences between the two and what is needed?
- Kick-off meetings—Detailed process involved
- Public meetings—What fulfills this requirement?
- Meeting with local planning teams to assist with issue resolution
- Mitigation strategy development
- Gaining public input and participation
- Risk analysis
- Capabilities assessment
- Data gathering, sources
- Hazus development
- GIS mapping
- Benefit-cost analysis development/training
- Planning team development—Who should be involved?
- NFIP requirements
- Repetitive Loss and Severe Repetitive Loss properties
- Funding sources
- Coordination with local planning mechanisms—What should be included?
- Review of plan drafts under development to handle any issues the jurisdiction experiences immediately rather than waiting until the plan is completed.

Samples/Documentation Provided to Jurisdiction at Onset of Planning Phase

At the beginning of a plan development or update, MEMA and DCR staff provide templates and information to assist each jurisdiction. Providing samples of previously approved annexes, plans, templates, etc. proved to be effective for many jurisdictions, especially those who were new to planning. Below are some of the examples provided:

- Plan review guide
- Planning guidance
- Risk analysis—samples of ways in which a risk can be analyzes
- STAPLEE worksheets
- Resolution for adoption
- NFIP guidelines/requirements
- Public meeting notice
- Newspaper ads announcing community meetings.

Training and Workshops

The following are examples of trainings and workshops provided:

- Benefit-cost analysis
- G318 mitigation planning training
- Risk analysis
- Hazus training (including sponsorship to EMI).

MEMA/DCR Staff Attendance at Non-State Workshops

MEMA and DCR staff attended numerous non-state-sponsored workshops, including the following:

- 2010, 2011, 2012—Association of State Floodplain Managers Conferences
- 2010, 2011, 2012—Benefit-Cost Analysis Training
- 2010—New England Mitigation Conference in Woodstock, Vermont
- 2011, 2012—Community Assistance Program; State Support Element Coordination Meeting.

Technical Assistance for Grants

During the PDM and HMGP application periods for disaster declarations DR-1895, DR-1959, DR-1994, DR-4028, and DR-4051, MEMA and DCR staff provided significant technical assistance to state agencies, local jurisdictions, and tribes for planning and project application. The staff provided any assistance requested by sub-applicants in order to complete a successful application. Estimates indicate that in excess of 200 individuals from various jurisdictions (cities, towns, planning commissions, and state agencies) received this type of training during the time period 2010-2012.

In July 2012, the MEMA Mitigation Unit expanded its staff to include two hazard mitigation grant coordinators. These coordinators have conducted over 25 formal grant briefings and informal technical assistance meetings with communities. The briefings consist of a two-hour presentation describing how mitigation is administered within Massachusetts.

In addition to the grant briefings, the coordinators have provided technical assistance in various settings. They hosted meetings in locations throughout the state for sub-applicants to discuss projects in development or ideas for projects within their communities. This "users-group" forum was very effective, as the discussions provided insight to attendees concerning different types of potential projects, as well as guidance and information on how to overcome any difficulties that may arise during project development.

The team has also visited sub-applicants at their locations, toured potential project locations to provide additional guidance on project eligibility, and assisted with developing benefit-cost analyses. Since July 2012, there have been over 30 such meetings, including communities such as Ludlow, New Braintree, Colrain, Winthrop, Shrewsbury, Framingham, Tolland, Essex, and Newbury.

In an effort to further enhance stakeholder involvement at the state and non-profit levels, the team has provided outreach specifically targeting state agencies, eligible non-profit organizations, and professional associations. Outreach has already been conducted for the Civil Engineers Society and is scheduled for the Climate Adaptation Workshop. There have also been project development meetings with fellow state agencies, including Mass DOT and DCR. The team has also worked to increase relationships with non-profit organizations such as Massachusetts Water Resource Authority and the Old Boston Statehouse.

Grant briefings and technical assistance meetings increase the visibility of mitigation programs throughout the Commonwealth and enhance sub-applicants' knowledge about program requirements. These enhancements will directly correlate to sub-applicants developing more complete and thorough applications. The improvements will also lead to more cost-effective projects that address and reduce vulnerability to hazards that the communities confront during a disaster event. This is especially important as the state gains enhanced plan status and increases the amount of funds available after a disaster incident.

As part of the Commonwealth's grant program technical assistance, a mitigation contract specialist conducts an initial site visit to review the state contract for every applicant and offer assistance with the following:

- Quarterly performance report
- Financial reporting
- Records retention
- OMB Circular A-133 _Single Audit
- Budget concerns
- Time extensions.

These efforts educate sub-applicants on reporting requirements and answer questions they have, further enhancing the Commonwealth's ability to effectively and efficiently manage the grants. Since December 2010, the Commonwealth's Mitigation Unit has conducted numerous site visits and final close-out inspections. The contract specialists also attend grant briefings and technical assistance meetings with HMGP coordinators providing guidance to potential sub-applicants on state contracting procedures and the reimbursement process. The combined efforts of the HMGP coordinators and contract specialists provides communities with an opportunity to ask for guidance on the entire process from application to final close-out. This increased participation helps sub-applicants better understand the process and have greater ease in navigating the reimbursement and close out.

Technical Assistance for National Flood Insurance Program: Community Assistance Visits and Community Assistance Contacts

As flooding is one of the primary hazards in Massachusetts and one of the hazards for which the greatest amount of mitigation, response, and recovery funds are expended nationwide, the Commonwealth specifically targets this hazard with for outreach and support to local communities. During the 2010-2012 time period, various types of technical assistance were provided to NFIP communities throughout the Commonwealth. This included Community Assistance Visits and Community Assistance Contacts, as well as assistance in the review or development of regulatory authority and ordinances. Each year, 14 Community Assistance Visits were conducted in person, as well as 10 telephone contacts to communities. In addition, 10 Community Assistance Contacts were made each year to various NFIP communities. These contacts provided information on implementing flood loss reduction measures and on floodplain management, as well as general information about the NFIP.

Develop/Review of Regulatory Authority

As a result of new maps being created by FEMA through the Risk MAP program, enhanced emphasis has been placed on review and assistance to local communities as they update or create ordinances to ensure continued NFIP compliance and to ensure that mitigation measures are instituted that are more effective than the minimum standards. This task is in coordination with the Risk MAP program. While regular reviews of ordinances are a natural process of the technical assistance delivered by DCR, this task is also reliant upon delivery of the new/updated FEMA maps.

The assistance provided to develop new ordinances includes three NFIP-participating communities that had no previous ordinance in place (Hardwick, Hawley, and North Brookfield); one community joining as a result of the outreach conducted (Warwick); and one intending to apply (Shutesbury). The number of ordinances reviewed and updated are as follows:

- 2010—Assisted in review and update of 67 floodplain ordinances
- 2011—Assisted in review and update of 57 floodplain ordinances
- 2012—Assisted in review and update of 105 floodplain ordinances.

Technical Assistance for State General Law Update

During 2010-2012, DCR staff worked with the Board of Building Regulations and Standards in developing the 8th Edition of the Massachusetts State Building Code. Once completed, the updated codes more closely mirrored the I-Codes and more accurately reflected Massachusetts' permitting procedures, including the stricter standards for development on coastal dunes. The 8th Edition of the Massachusetts State Building Code consists of both IBC and IRC, with Massachusetts amendments to reflect stricter state standards that exceed the NFIP minimum requirements.

As the State Building Code no longer places flood requirements in a single section of the code, references to the State Building Code required updating within the State Model Ordinance. During the 2010-2012 time period, the State Model Ordinance was updated to reflect changes in the 8th Edition of the State Building Code.

Community Information System

All data have been updated in the Community Information System and have remained current during the 2010-2012 time period to ensure continued compliance with the NFIP by the local communities.

Additional Outreach

During the 2010-2012 planning cycle, several additional outreach sessions were conducted for various interest groups—many of which are new for the 2013 update. These outreach sessions consisted of presentations, workshops, meeting attendance, and regional planning agency meetings. Participants included state agencies, local officials, engineers and surveyors, lenders, members of the insurance industry, and one international association—the International Erosion Control Association Conference held in Lowell, Massachusetts. The sessions and area of focus were as follows:

- Coastal Zone Management Workshop—focus on coastal construction
- NOAA/USGS Workshop—focus on flood mapping
- Southeastern Massachusetts Building Officials Association Workshop—focus on building codes and mapping
- Williamsburg Condominiums—focus on insurance and mapping
- City of Fall River—focus on base flood elevations
- City of Cambridge—focus on floodway requirements
- Town officials (various) and Lake Wyola Association—NFIP participation
- North Shore Task Force—focus on use of flood insurance maps and studies
- Risk MAP Discovery meetings throughout the Commonwealth
- NFIP workshops for local officials (multiple sessions and locations)
- NOAA Sea Level Rise Workshop—focus on flood mapping
- Hazard Mitigation for Cemeteries Workshop Presentation
- International Erosion Control Association Conference—focus on the use of flood maps
- Mass Maritime Workshop—focus on NFIP.

Based on the outreach, the Town of Warwick completed an application and joined the NFIP, effective May 14, 2012. Several other non-participating communities in Hampden County received information related to becoming an NFIP community in preparation of the release of FEMA's flood maps.

3.2.4 New Technical Assistance Currently Under Development

New information developed during this 2013 update includes a survey for use by local jurisdictions updating on their plans. The survey will provide them with information to stimulate ideas for the planning process. It also will provide information to MEMA to be incorporated into future plan updates.

MEMA Mitigation Planning and All Hazards Planning Units are working together to develop a new risk ranking concept that will standardize risk terminology across planning efforts. It is a new strategy for the 2013-2016 planning cycle. This will entail training by MEMA staff in a workshop-type session.

Another concept that MEMA is contemplating is the development of a hazard mitigation user's group that would meet quarterly and be led by the Commonwealth's Hazard Mitigation Planning Coordinator. The meetings would be an exchange for best-practice discussions among partners developing plans. The intent behind this user's group is to exchange information concerning areas of difficulty where planners have developed innovative ideas, or to gain information on how to address specific plan areas with which they are having difficulties.

The Commonwealth is also developing a number of new hazard-specific studies, such as a landslide study and a fluvial geomorphic assessment to identify areas prone to fluvial erosion. Once completed, this information will become available for future local and state level plan updates.

Additional information concerning technical assistance and programmatic support can be found in Sections 2 and 17.

3.2.5 Local Plan Review Process Standard Operating Procedure

Most local and multi-jurisdictional hazard mitigation plans in Massachusetts are submitted through an RPA. Plans are recorded in the MEMA Mitigation Plan Database on the date that they are received at MEMA. The review process is as follows:

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(4)(ii), which states the following:

Plan Content. To be effective the plan must include a section on the *Coordination of Local Mitigation Planning* that includes a description of the State process and timeframe by which the local plans will be reviewed, coordinated, and linked to the State Mitigation Plan.

- Step 1—Within a maximum of 45 days, if possible, a planner uses the Plan Review Guide to review plan submissions. The planner indicates the pages and records qualitative comments pertaining to 44 CFR 201.6 as well as to the mission of the SHMT and the SHMP.
- Step 2—If the plan meets all requirements—excluding 44 CFR 201.6 (c)(5), the planner forwards the plan and the Plan Review Guide to FEMA Region I for review:
  - The plans and Review Guide are emailed to FEMA Region I.
  - MEMA planner files a copy of the plan and a printout of the email sent to FEMA.
  - The submission is recorded in the MEMA Mitigation Plan Status Database.
- Step 3—After review of the submitted documents, if FEMA agrees that the plan meets the checklist, FEMA will send an "Approved Pending Adoption" letter to the RPA or community. (Skip to Step 7)
- Step 4—If the plan needs revision (FEMA does not agree that the plan meets the checklist), then the SHMT/mitigation planner provides comments and provides technical assistance to the RPA or community in order to ensure that the plan revisions are clear and executable by the RPA community.
- Step 5—The RPA or the community revises and resubmits a revised draft plan to the planner. The planner reviews the 2nd submission, confirms that it meets all the requirements, and fills out a checklist. Then the planner forwards the final draft plan and checklist to FEMA Region I for a second review.
- Step 6—FEMA Region I sends an Approved Pending Adoption letter to the RPA or the community with copies to the planner and state hazard mitigation officer. When the planner receives the Approved Pending Adoption letter, the following procedure is followed:
  - Record the conditional approval date in the MEMA Mitigation Database
  - File the letter in files for all communities listed on the letter
  - Copy the letter for the binder
  - Update the Mitigation Plan status map.

- Step 7—Upon receipt of the Approved Pending Adoption letter, the RPA or community is to formally adopt the mitigation plan by vote of its board, council, etc.
- Step 8—The RPA or community must forward the applicable documentation of local plan adoption to the planner. The planner then forwards the adoption documentation to FEMA by the following procedure:
  - The local plan adoptions are emailed to FEMA Region I.
  - MEMA planner files an official copy of plan adoption and a printout of the email sent to FEMA.
  - The submission date and date of local adoption are recorded in the MEMA Mitigation Plan Status Database.
- Step 9—FEMA reviews the adoption documentation and issues a Formal Letter of Approval to the RPA or community and sends a copy to the state hazard mitigation officer and mitigation planner.
- Step 10—Upon receipt of the Formal Approval Letter, the MEMA Planner:
  - Records the official date in the MEMA Mitigation Database and the five-year expiration date
  - Files the letter in files for all communities listed on the letter
  - Copies the letter for the binder
  - Updates the Mitigation Plan status map.
- Step 11—Three and a half years after the approval date, a letter is sent to remind the community of the upcoming plan expiration.

Provisions will be made under certain circumstances if the SHMT requires additional time to review local and regional plans. As local and multi-jurisdictional plans are approved, the hazard mitigation measures (and other elements) are entered into the Local/Regional Database, which is later incorporated into this section of the plan. For this update, measures were reviewed and analyzed by the SHMT to identify any trends and issues. Depending upon future funding, the Commonwealth will provide participating RPAs and communities with technical assistance as needed to implement cost-effective hazard mitigation measures.

3.2.6 Local Plan Integration

The SHMT reviews each multi-jurisdictional or local mitigation plan according to Stafford Act guidelines and applicable FEMA guidance and completes a checklist. During this review, the Commonwealth confirms that the plan is consistent with the SHMP. The State Hazard Mitigation Planning Coordinator, who is a member of the SHMT, manages this review and analysis. For this update, data from the multi-jurisdictional and local mitigation plans were compiled into an Excel workbook. That information is disbursed throughout the 2013 update, including (but not restricted to) goals, strategies, hazards of concern, loss estimation information (when available), hazard ranking and risk assessment data, and a more detailed written summation of various plans.

3.3 STATE AND LOCAL GOALS AND STRATEGIES

During the 2010-2012 timeframe, each local jurisdiction's plan was assessed for information in the plan and to verify data concerning risk as demonstrated in the Commonwealth's plan. Information captured during this review was integrated to demonstrate that the Commonwealth and all of the jurisdictions

therein are operating under a common goal to mitigate the impact of disasters. One way to demonstrate this is through the goals that each plan is required to develop. Review of local plans submitted during this update cycle (and plans that have expired but that constitute best available data) determined that the goals of the local plans and the goals of the SHMP closely match one another. However, as indicated in Section 17, the SHMT and SHMIC, during review of goals, determined that a modification of some goals was appropriate to align more closely with the intent of the Commonwealth and the local jurisdictions. The SHMT and SHMIC also developed a mission statement for the 2013 plan update. More information on the goals and mission statement are available in Section 2 and Section 17. Review of the local plans identified a close alignment with the Commonwealth's revised goals as indicated in Table 3-1.

TABLE 3-1.
2013 STATE GOALS AND LOCAL JURISDICTION COMPARISON

	Evaluate and analyze vulnerability in order to guide and promote sound mitigation activities through integrated planning to support a comprehensive state mitigation program.	Increase awareness of the benefits of hazard mitigation through outreach and education.	Increase coordination and cooperation between state agencies in implementing sound hazard mitigation planning and sustainable development.	Promote long-term cost-effective hazard mitigation actions that protect and promote public health and safety from all-hazards, now and under current and future conditions.	Monitor, evaluate, and disseminate information on the effectiveness of hazard mitigation actions implemented by state, local, and private partnerships.
Berkshire Regional Planning Commission	X	X	X	X	X
Cape Cod Commission	X	X	X	X	X
Central Massachusetts Regional Planning Commission	X	X	X	X	X
Franklin Regional Council of Governments	X	X		X	
Martha's Vineyard Commission	X	X			X
Merrimack Valley Planning Commission	X		X	X	
Metropolitan Area Planning Councils (MAPC plans combined)	X	X	X	X	X
Montachusett Regional Planning Commission	X	X		X	X
Nantucket Planning & Economic Development Commission	X	X		X	
Northern Middlesex Council of Governments	X	X	X	X	X
Old Colony Planning Council	X	X	X	X	X
Pioneer Valley Planning Commission	X	X	X	X	X
Southeastern Regional Planning and Economic Development District	X	X		X	X

Review of the local plans also indicated that while jurisdictions evaluated hazards in a similar manner and generally came to similar conclusions as those found of the SHMP, information with respect to dollar losses varied. There were also a few variations in additional hazards included in specific plans that relate to the local communities only, including a few non-natural hazards. One area of noted change from the previous plans to those reviewed during the 2010-2013 update cycle has been in the plan content.

Plans prepared during the initial DMA 2000 planning efforts were broad in nature. In more recent local plans, strategies, goals, objectives, and risk assessments have become more focused, providing more robust plans. During the initial plan cycle, local jurisdictions were unsure what the FEMA requirements were, and therefore were overly broad rather than succinct. Moreover, continued outreach to local jurisdictions by the SHMT to develop potential mitigation projects for grant funding after disaster events occur has proven very effective. The Commonwealth has been able to use most of the funds available, and in fact has projects on waiting lists for funding opportunities. These efforts demonstrate not only the continued expansion and robustness of the local plans, but also the Commonwealth's ability to manage grant programs and to use additional funds that may become available if enhanced status is granted.

Many local jurisdictions that have developed plans have realized the benefit of hazard mitigation planning beyond access to grant funds, finding that the plans help make the jurisdiction more resilient to hazards. Figure 3-2 shows categories in which local plans have addressed mitigation initiatives and strategies. These initiatives integrate into new programmatic efforts, develop or enhance new regulatory authority, and include structural and non-structural projects. Combined, they demonstrate the local jurisdictions' understanding of not only mitigation, but also FEMA's whole-community efforts supporting resilience through all mission areas: planning, preparedness, mitigation, response, and recovery.

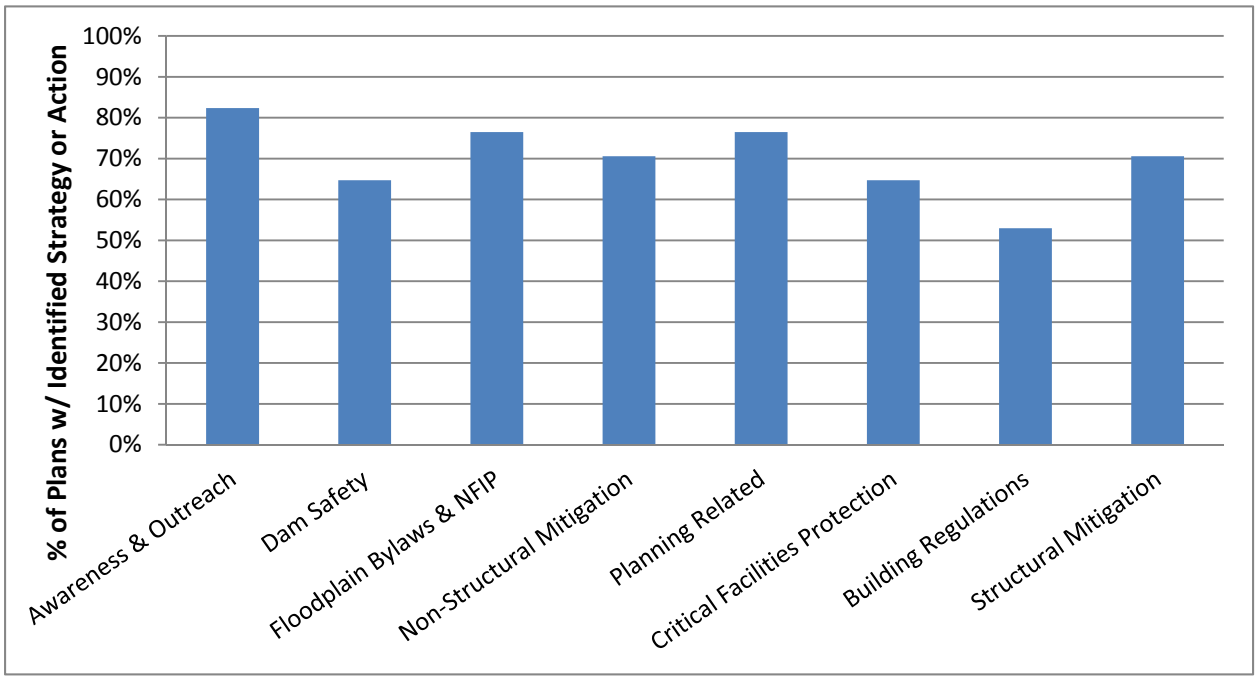


Figure 3-2. Strategies and Actions from Local Jurisdiction Plans

Table 3-2 depicts a snapshot of a few specific strategies from some of the local plans. These strategies are not verbatim from the plans, but are summarized for brevity. Many of these strategies also serve as a capability of the jurisdiction, and are redundant themes in plans by other jurisdictions. This table represents a new element in the 2013 plan.

TABLE 3-2.
EXAMPLE STRATEGIES FROM LOCAL PLANS

Mitigation Strategy	Grant Funded or Funding Eligible	Hazard[a]
Common in Multiple Plans		
All hazards tree mitigation	Multiple Grant, Funding Sources	IS, SWS, SW, N, H
Beaver dam flood prevention	Multiple Grant, Funding Sources	F, H, IS, SWS, SW, N
Mobile home elevation or tie down requirements	Multiple Grant, Funding Sources	F, H, IS, SWS, SW, N
Culvert upgrades; minor flood control projects; flood wall/berm construction	Multiple Grant, Funding Sources	F, H, IS, SWS, N, T
Data enhancements/gathering for GIS and hazard analysis for improved risk assessments	Multiple Grant, Funding Sources	MH
Bridge maintenance projects	Multiple Grant, Funding Sources	MH
Martha's Vineyard		
Establish flood control district by-laws	Not Eligible	F, H, T, I, D
Building and Zoning Advisory Committee	Not Eligible	MH
Surface water district site plan review and permitting from board for planning and restrictions	Not Eligible	F, H
In coordination with U.S. Army Corps of Engineers, work toward reconstruction of bridges	U.S. Army Corps of Engineers Funded	EQ, F, T, H, I, LS
Establish FireWise communities	Various Fire and PDM/HMGP Grants	WF
Central Massachusetts Regional Planning Commission		
Incorporate disaster mitigation actions into appropriate local and regional plans—master plans, land use, transportation, open space, and capital programming.	Not Eligible	MH
Install heavy duty snow fences to mitigate snow drifting and subsequent icy and dangerous roadway conditions on Dresser Hill Road, Carpenter Hill Road, Osgood Street, and Brookfield Road.	Multiple Grant, Funding Sources	IS, SWS, N
Integrate disaster mitigation concerns into transportation projects (e.g. drainage improvements, underground utilities)	Multiple Grant, Funding Sources	MH
Metropolitan Area Planning Council (from various MAPC plans)		
Acquire vacant flood prone lands: acquire priority open space parcels in floodplain areas to maintain flood storage and water infiltration capacity. These parcels may also be used for general conservation and recreation.		F, H, N, SWS, SW,
Public building assessments: Assess the earthquake vulnerability of all public buildings. Investigate options to make all public buildings earthquake-resistant.	Multiple Grant, Funding Sources	EQ
Since low-flow devices have not provided adequate mitigation for beaver-related flooding on Guelphwood Road, explore the feasibility of elevating the roadway.	Multiple Grant, Funding Sources	F, H, IS, N
Repair the Bay View seawall	Multiple Grant, Funding Sources	F, H, IS, SWS, N, T
Repair the eroded western coastal bank at Obear Park.	Multiple Grant, Funding Sources	F, H, N, SWS, SS
Berkshire Regional		
Residential elevations or retrofits	Multiple Grant, Funding Sources	F, H, N, SWS, SW
Flood mitigation via acquisitions or relocation of properties.	Multiple Grant, Funding Sources	F, H, N, SWS, SW

a. Hazards Addressed: EQ = Earthquake; F = Flood; T = Tsunami; SWS = Severe Winter Storm; WF = Wildfire; H = Hurricane; I = Ice Storm; D = Drought; LS = Landslide; CE = Coastal Erosion; SW = Severe Weather; N = Nor'easter; MH = Multi hazard

In addition to the strategies listed in the table, the following strategies are in four or more plans reviewed:

- Minimize and mitigate the impacts of flooding..
- Minimize and mitigate the impacts of any/all hazards
- Reduce the risk of dam failure.
- Increase the capacity of local governments to plan and mitigate natural hazards.
- Increase public awareness of natural hazard mitigation.
- Minimize the cost (financial impacts) of natural hazards.
- Hazard mitigation planning—continuity and updates.
- Implement programs to promote mitigation—apply for grants.
- Work with surrounding communities to ensure regional cooperation and solutions for hazards affecting multiple communities.
- Encourage future development in areas that are not prone to natural hazards.
- Educate the public about natural hazards and mitigation measures.
- Make efficient use of public funds for hazard mitigation.

3.4 PRIORITIZING LOCAL ASSISTANCE

3.4.1 Hazard Mitigation Project Eligibility and Prioritization

Massachusetts has had a FEMA-approved HMGP Administrative Plan since 1986, most recently updated in 2012, which details the process for prioritizing post-disaster mitigation funding of local mitigation projects. Massachusetts has also used similar criteria to prioritize local pre-disaster mitigation grants applications. Criteria for prioritizing local assistance for hazard mitigation grants are found in the State Grants Administrative Plan (see Annex 2). Eligible projects for pre-disaster and post-disaster hazard mitigation funding in Massachusetts must meet the following criteria:

- Must be in conformance with a FEMA-approved local and/or multi-jurisdictional all-hazards mitigation plan that meets DMA 2000 planning requirements (this guideline became effective Nov. 1, 2004).
- Must be in conformance with the Massachusetts SHMP developed under DMA 2000. Massachusetts places a priority on local mitigation projects that involve the following:

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(4)(iii), and §201.5(b)(2)(i)and (ii), which states the following:

To be effective the plan must include a section on the Coordination of Local Mitigation Planning that includes criteria for prioritizing communities and local jurisdictions that would receive planning and project grants under available funding programs, which should include:

- Consideration for communities with the highest risks.
- Repetitive loss properties.
- Most intense development pressures.

Further, that for non-planning grants, a principal criterion for prioritizing grants shall be the extent to which benefits are maximized according to a cost benefit review of proposed projects and their associated costs.

Requirement §201.5(b)(2)(i)and (ii): [The Enhanced Plan must demonstrate] the State's project implementation capability, identifying and demonstrating the ability to implement the plan, including:

- Established eligibility criteria for multi-hazard mitigation
- A system to determine the cost effectiveness of mitigation measures, consistent with OMB Circular A-94, Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs

  - Non-structural, or low-cost solutions (e.g., updating and enforcing local flood ordinances)
  - Retrofitting high-risk structures (e.g., elevating residences in coastal flood zones)
  - Acquisition of repetitive loss storm-damaged structures.
- Must be in compliance with all existing Massachusetts laws and regulations for construction, land alterations, and natural resource protection, such as the Massachusetts State Building Code, the Massachusetts Wetlands Protection Act and Regulations, the Massachusetts Wetlands Restriction Act, and the Massachusetts Coastal Zone Management Policies.
- Must be in compliance with municipal ordinances and zoning regulations.
- Must be in conformance with 44 CFR, Part 9, Floodplain Management and Protection of Wetlands, and 44 CFR, Part 10, Environmental Considerations.
- Must provide a solution to a problem independently, or provide a significant functional portion of a solution being addressed in a combined project. If the project constitutes a significant functional portion of a solution being addressed, the status of any associated dependent or supporting projects must be given. There must be reasonable assurance that the total mitigation project will be completed. The identification or analysis of a problem does not automatically qualify for eligibility.
- Must meet FEMA's cost-effective criteria such as the need to substantially reduce the risk of future damage, hardship, or losses resulting from a major disaster. Documentation will be required that demonstrates:
  - The problem is repetitive and/or poses a significant risk if left unsolved. Therefore, a brief history should be provided of previous occurrences of the problem at the project location, including dates and impact of each event, and/or an analysis of projected potential damage if the project is not completed must be given.
  - Sufficient information is provided to allow comparison of the cost of the project with the anticipated value of future direct damage reduction or negative impacts on the area.
  - The proposed project has been compared to alternatives, including non-structural approaches.
  - The proposal has been determined to be the most practical, effective, and environmentally sound alternative found after consideration of all available options.
  - The project contributes to the long-term solution of the problem it addresses. Therefore, an estimate of the effective life of the project and a listing of influence factors should be included.
  - Development of the project considers any long-range alterations to the area and the entities that it protects, and the project has future maintenance requirements that are financially feasible and can be modified, if necessary, without changing the impact on the area.

3.4.2 Hazard Mitigation Project Selection

Available federal funds for pre-disaster and post-disaster hazard mitigation assistance will most likely not be sufficient to support all eligible project applications. Recommendations for funding will be made to the regional FEMA office by the Director of MEMA and the Commissioner of DCR, under advisement by the SHMIC. FEMA will make the final selection of grants to be awarded. Mitigation measures proposed should not be intended to replace a facility that was damaged but should provide more protection to life

and property than what existed prior to the storm. Proposals will be evaluated and prioritized by the SHMIC and the SHMT according to the following criteria:

- The project application clearly describes the hazard/problem the proposed mitigation project is intended to address.
- If the hazard mitigation measure is not taken, it will have a detrimental impact on the applicant, such as potential loss of life, loss of essential services, damage to critical facilities/infrastructure, and/or economic hardship.
- The proposed project clearly describes the solution to the hazard/problem. This includes a detailed scope of work, budget, and alternative analysis. The proposed project appears to be the most practical, effective, and environmentally sound alternative.
- The application describes how the proposed project will provide long-term hazard mitigation benefits. The level of protection that will exist after the project is implemented is clearly defined.
- The project application clearly demonstrates that the project is cost-effective; anticipated benefits of the mitigation activity exceed the project costs. A well-defined benefit-cost analysis is provided with relevant supporting documentation.
- The application demonstrates the capability of the applicant to implement and complete the project in a timely manner. This includes all required environmental permitting, state and local.
- The application demonstrates the commitment of the applicant to get the project accomplished. This includes providing documentation of the availability of the non-federal cost match, and a description of relevant public/private partnerships.
- The application details how the proposed mitigation activity is consistent with SHMP, the FEMA-approved hazard mitigation plan for the local jurisdiction, and other plans (comprehensive land use plans, capital improvement plans, etc.)
- The proposed project is consistent with no-adverse-impact principles. Proposed mitigation activity is sustainable (with a priority on non-structural solutions), and provides environmental benefits.
- The proposed project is in a federally declared disaster area and/or mitigates the type of hazard that caused a declared event.

Upon completion of local and/or multi-jurisdictional plans, local hazard mitigation assistance will be based in part on the risk assessments, project recommendations, and benefit-cost analyses described in these plans. Massachusetts will use its Hazard Mitigation Grants Administrative Plan to guide, review, and prioritize local hazard mitigation assistance. Table 3-3 and Table 3-4 list the HMGP and other grant program applications received since 2010.

TABLE 3-3
HMGP GRANT APPLICATIONS RECEIVED 2010-2012

Grant #	Applicant Jurisdiction	Project Description/Title	RPA	County
1813	Beverly	Chubbs Brook	MAPC	Essex
1813	Chatham	Cotchinicut	CCC	Barnstable
1813	Chatham	Cow Yard	CCC	Barnstable
1813	Fitchburg	Columbia Ave/Dewey St	MRPC	Worcester
1813	Hudson	Brook Street	MAPC	Middlesex
1813	Marblehead	Mitigation Plan Update	MAPC	Essex
1813	MAPC	Urban Core Mitigation Plan Update	MAPC	
1813	Millis	Dover Road	MAPC	Norfolk
1813	Monson	Mechanic Street Water Main	PVPC	Hampden
1813	Northampton	Roberts Meadow Dam	PVPC	Hampshire
1813	Quincy	Spence Ave	MAPC	Norfolk
1813	Tewksbury	Pump Station Controls	NMCOG	Middlesex
1813	Westfield	Backflow valves	PVPC	Hampden
1813	Braintree	Staten Road	MAPC	Norfolk
1813	Georgetown	West Street/ Parker River	MVPC	Essex
1813	Hatfield	CT River Bank Stabilization	PVPC	Hampshire
1813	Medway	Bentwood Drainage	MAPC	Norfolk
1813	Milford	Godfrey Brook	MAPC	Norfolk
1813	Millis	Farm Street	MAPC	Norfolk
1813	Sterling	Control System	MRPC	Worcester
1813	Stockbridge	Interlaken Drainage	BRPC	Berkshire
1813	Wilbraham	Woodland Dell	PVPC	Hampden
1813	Massachusetts Board of Libraries	Mitigation for Memory	MAPC	Suffolk
1813	Northampton	River Road	PVPC	Hampshire
1895	Fitchburg	Shea Street Flood Hazard Mitigation	MRPC	Worcester
1895	Walpole	Norfolk Street Drainage Improvements	MAPC	Norfolk
1895	Plymouth	Federal Furnace Road Elevation Project/ Little West Pond Mitigation Project	OCPC	Plymouth
1895	Northampton	Channel Improvements at Roberts Meadow Brook	PVPC	Hampshire
1895	Coastal Zone Management Flood Maps	Flood Zone Identification and Delineation	MAPC	Suffolk
1895	Coastal Zone Management Homeowners	Educational Brochure for Property Owners	MAPC	Suffolk
1895	Quincy	Sagamore Creek Tide Gate	MAPC	Norfolk
1895	Winchester	All Hazard Mitigation Plan Update	MAPC	Middlesex
1895	UMASS Amherst-Geology	Improvements to Statewide Rockfall, Landslide, Stream Erosion, and Seismic Hazard Identification	PVPC	Hampshire
1895	Salem	Improvements to Canal Street Stormwater Infrastructure	MAPC	Essex

TABLE 3-3
HMGP GRANT APPLICATIONS RECEIVED 2010-2012

Grant #	Applicant Jurisdiction	Project Description/Title	RPA	County
1895	Tewksbury	South Street at Bridge Street Roadway Flood Proofing	NMCOG	Middlesex
1895	Cohasset	Jerusalem Road Culvert Improvements	MAPC	Norfolk
1895	Concord	Spencer Brook Culvert Replacement at Westford Road	MAPC	Middlesex
1895	Middleborough	Woloski Park Neighborhood Acquisition	SRPEDD	Plymouth
1895	Danvers	Route 62 Culvert Replacement	MAPC	Essex
1895	Arlington	Colonial Village Drainage Improvements and Fottler Ave Equalization Culvert	MAPC	Middlesex
1895	Wayland	Wayland Public Library Drainage Improvements	MAPC	Middlesex
1895	Georgetown	Culvert and Roadway upgrade at Central Street (Route 97) over Penn Brook	MVPC	Essex
1895	University of Massachusetts President's Office	University of Massachusetts Multi-Campus Hazard Mitigation Plan	PVPC	Hampshire
1895	Northampton	Improvements to Rover River Road Retaining Wall/ Floodwall	PVPC	Hampshire
1895	Westfield	William Riding Way Pump Station Improvements Project	PVPC	Hampden
1895	Wakefield	Non-Structural retro-fit of 1 residence on Greenwood Street	MAPC	Middlesex
1895	Merrimack Valley Planning Commission	Merrimack Valley Region Natural Hazards Pre-Disaster Mitigation Plan Update	MVPC	Essex
1895	Goshen	East Street Culvert Replacement	FRCOG	Hampshire
1895	Wilbraham	480 Main Street Detention Basin	PVPC	Hampden
1895	Holyoke	Gatehouse Flood Control Improvement Project	PVPC	Hampden
1895	Holyoke	Riverside Station Flood Control Improvement Project	PVPC	Hampden
1895	Tyngsborough	Tyngsboro Elementary School Driveway Culvert Improvements	NMCOG	Middlesex
1895	Hamilton	Bridge Street Culvert Upgrade	MAPC	Essex
1959	Greenfield	Green River Cemetery Landslide Mitigation	FRCOG	Franklin
1959	Milton	Unquity House	MAPC	Norfolk
1959	Lynnfield	Yorkshire Drive Drainage Improvements	MAPC	Essex
1959	Tewksbury	Shawsheen Street at Heath Brook Roadway Flood Proofing	NMCOG	Middlesex
1959	Georgetown	Culvert and Roadway Upgrade Parker River at Thurlow Street	MVPC	Essex
1959	Boxborough	HMGP 5% Initiative Emergency Shelter and Emergency Service Water Well Generators Grant	MAPC	Middlesex
1959	Pioneer Valley Planning Commission	Pioneer Valley multiple Local Hazard Mitigation Plan 2011	PVPC	Hampden
1959	Dartmouth	Town of Dartmouth Natural Multi-Hazard Mitigation Plan	SRPEDD	Bristol

TABLE 3-3
HMGP GRANT APPLICATIONS RECEIVED 2010-2012

Grant #	Applicant Jurisdiction	Project Description/Title	RPA	County
1959	Martha's Vineyard Commission	Pre-Disaster Mitigation Plans for Dukes County Towns	MVC	Dukes
1959	Whately	Mill River Bank Stabilization	FRCOG	Franklin
1959	Buckland	South Street Culvert Replacement	FRCOG	Franklin
1959	Montague	Millers Falls Road Soil Stabilization	FRCOG	Franklin
1959	Deerfield	Little Meadow Road Riverbank Stabilization	PVPC	Franklin
1994	Concord	Culvert Replacement at Fitchburg Turnpike	MAPC	Middlesex
1994	Concord	Culvert Replacement and Drainage Improvements at Lowell Road	MAPC	Middlesex
1994	Southborough	Cordaville Hall, Emergency Generator System	MAPC	Worcester
4028	Agawam	Agawam Town Hall Generator	PVPC	Hampden
4028	Chelmsford	Merrimack River Bank Stabilization and Sewer Protection at Wellman Road	NMCOG	Middlesex
1994	UMASS Amherst	Improvements to Statewide Seismic Risk ID and Est. of an Ops EQ Forecasting System	PVPC	Hampshire
1994	New Bedford	Natural Hazard Disaster Mitigation Plan Revision	SRPEDD	Bristol
1994	Savoy	Town of Savoy Hazard Mitigation Plan	BRPC	Berkshire
1994	Westford	Route 40 Culvert Improvement Project	NMCOG	Middlesex
4028	Gloucester	Poplar Street Flood Mitigation Project	MAPC	Essex
1994	Tewksbury	Culvert and Roadway Improvements at Pinnacle Street	NMCOG	Middlesex
1994	Cohasset	Flood-Proofing Sewer Manholes and Collection System in Floodplain	MAPC	Norfolk
4028	Tewksbury	Sewer Pumping Station Emergency Backup Generators	NMCOG	Middlesex
1994	Mattapoisett	Local Natural Hazards Mitigation Plan	SRPEDD	Plymouth
4028	Milford	Main Street Culvert Improvements at Godfrey Brook	MAPC	Worcester
4028	Saugus	Saugus River at Elm Street Flood Mitigation	MAPC	Essex
4028	Edgartown	Edgartown Dock Street Pump Station Upgrade	MVC	Dukes
1994	Marblehead Water and Sewer Commission	Pleasant Street Area Drainage Improvements	MAPC	Essex
1994	Wilbraham	Department of Public Works Facility Generator	PVPC	Hampden
4028	Easton	Town Hall Generator	OCPC	Bristol
1994	DCR Division of Water Supply Protection Quabbin Reservoir	Gate 8 Culvert Replacement	PVPC	Hampshire
1994	Williamstown	Spruces Mobile Home Park: Acquisition and Mitigation	BRPC	Berkshire
1994	Westport	All Hazard Mitigation Plan Update	SRPEDD	Bristol

TABLE 3-4
2010-2012 GRANT APPLICATIONS FOR FLOOD MITIGATION ASSISTANCE, LEGISLATIVE PRE-DISASTER MITIGATION, PRE-DISASTER MITIGATION COMPETITIVE, AND SEVERE REPETITIVE LOSS

Grant #	Applicant Jurisdiction	Project Description/Title	RPA	County
Flood Mitigation Assistance Grant Program				
2010	Scituate	2010 FMA Elevation Project	MAPC	Plymouth
Legislative Pre-Disaster Mitigation Grant Program				
2010	Lanesborough	Putnam Rd. Improvement	BRPC	Berkshire
2010	Winthrop	Point Shirley Flood Protection & Water Main Replacement Project	MAPC	Essex
Pre-Disaster Mitigation Competitive Grant Program				
2010	Braintree	Staten Road & Dickerman Lane Culverts Upgrade	MAPC	Suffolk
2010	Northern Middlesex Council of Governments	Pre-Disaster Mitigation Plan for the Northern Middlesex Region	NMCOG	Middlesex
2010	Salisbury	Town Creek Flooding Project	Essex	MVPC
2010	Old Colony Planning Council	OCPC Regional Multi-hazard Pre Disaster Mitigation Plan Update	OCPC	Plymouth
2011	Berkshire Regional Planning Commission	Multi-Jurisdictional Hazard Mitigation Plan	BRPC	Berkshire
2011	Pioneer Valley Planning Commission	Pioneer Valley multiple local multi-hazard mitigation plans	PVPC	Hampden
2011	Montachusett Regional Planning Commission	Montachusett Region Multi-hazard Mitigation Plan—Update	MRPC	Worcester
2011	University of Massachusetts Medical School	University of Massachusetts Medical School Multi-hazard Mitigation Planning 2011	CMRPC	Worcester
2012	Dartmouth	Natural Multi-Hazard Mitigation Plan	SRPEDD	Bristol
Severe Repetitive Loss Grant Program				
2012	Scituate	2012 Severe Repetitive Loss Elevation Project	MAPC	Plymouth

SECTION 4. STATE PROFILE

The Commonwealth of Massachusetts is one of six New England states that make up FEMA Region I. The name Massachusetts comes from Algonquian Indian words that mean the great mountain, an apparent reference to the tallest of the Blue Hills, a recreation area south of the Town of Milton. Massachusetts is one of the original 13 states (6th) of the Union (February 6, 1788). Its motto is *Ense Petit Placidam Sub Libertate Quietem*, which means "By the Sword We Seek Peace, But Peace Only Under Liberty." The state nickname is "the Bay State."

Massachusetts is the 14th most populated state in the nation. The state capital, Boston, is the most densely populated metropolitan area in the state. With a well-educated population, the state maintains a relatively high income level ($51,304 average per capita income—ranked 3rd in the nation) and a relatively diversified economy.

4.1 GOVERNMENT

4.1.1 Constitution

The Massachusetts constitution was ratified in 1780 during the Revolutionary War, nine years before the United States Constitution was adopted. It is the oldest written constitution still in use in the world. It specifies three branches of government: executive, legislative, and judicial.

4.1.2 Designation as Commonwealth

Massachusetts, like Pennsylvania, Virginia, and Kentucky, is called a "commonwealth," the term used in its constitution. When the constitution was ratified, commonwealth was a popular term for a body of people constituting a nation or state. The title was incorporated into the second draft of the state constitution, written by John Adams. This draft, under the heading "Frame of Government," states, "that the people...form themselves into a free, sovereign, and independent body politic, or state by the name of The Commonwealth of Massachusetts." The people had rejected the first draft of the constitution in 1778, which, along with all previous acts and resolves, used the name "State of Massachusetts Bay."

4.1.3 Organization of State Government

The State House in Boston is the primary seat of Massachusetts government. Six constitutional officers are elected for four years: The following are the officers as of January 2013:

- Governor: Deval Patrick
- Lieutenant Governor: Timothy P. Murray
- Secretary of the Commonwealth: William Francis Galvin
- Treasurer and Receiver General: Steven Grossman
- Attorney General: Martha Coakley
- Auditor: Suzanne Bump

The official name of the legislative body for Massachusetts is the General Court. It consists of a Senate, with 40 members elected every two years, and a House of Representatives, with 160 members elected every two years.

The Supreme Judicial Court consists of Chief Justice Margaret H. Marshall and five associate justices. The governor, with the advice and consent of an executive council, appoints all justices.

4.1.4 Counties

County government in Massachusetts, as in all of New England, is not a strong entity. The county level of government is not mentioned in the state constitution. It was established later by legislative action. The 14 counties, roughly from west to east, are Berkshire, Franklin, Hampshire, Hampden, Worcester, Middlesex, Essex, Suffolk, Norfolk, Bristol, Plymouth, Barnstable, Dukes, and Nantucket.

Massachusetts' counties were regional administrative districts before the Revolutionary War. Throughout Massachusetts' history the counties administered jails, health facilities, agricultural schools, registries of deeds and probate, county courthouses, county roads, and extension services.

For many years, there was criticism of county government as wasteful and inefficient. There were recommendations to abolish all county governments and transfer most of their functions to state agencies and their assets (land and buildings) to the Commonwealth. Counties as geographical and/or political regions have not been abolished or restructured, but their governments have been. Registers of deeds and probate, sheriffs, and district attorneys are still elected in county political districts, even where county government has been abolished. In counties that have not been abolished, county commissioners and treasurers are still elected.

Home rule legislation allows officials or voters in a county to establish a regional charter commission to study its government. The commission can submit one of three model charters for voter approval in that county at a statewide election or it can submit a special charter, which must first be approved by the state legislature. Cities and towns may choose a regional council of government charter, which is binding on cities or towns where a majority of voters approve it. The regional council of governments can provide services to cities and towns such as planning, public safety, engineering, water, and waste disposal. The participating communities pay assessments based on local property valuation. The legislature approved special charters to allow several counties to become regional councils of government.

4.1.5 Municipalities

There are 351 cities and towns in Massachusetts, each with its own governing body. Typically, elected mayors govern Massachusetts' cities and elected officials called selectmen govern the towns; however, there are exceptions. A board of selectmen is usually elected for a one-or-two-year term, and citizens participate in an annual town meeting. The open town meeting is the active legislature in a town. Some communities have a representative open town meeting, while others; have a true "open" town meeting. A current listing of state, county, and municipal government agencies and contacts may be found at the Commonwealth of Massachusetts website at www.mass.gov.

4.1.6 Planning Regions

Chapter 40B of the Massachusetts General Laws established 13 planning regions throughout the Commonwealth in 1963. These planning regions work in concert with partnering jurisdictions and organizations to complete planning tasks such as development of regional mitigation plans, transportation planning, economic growth studies, land use and energy planning, historic preservation, open space and natural resources, water and coastal resources, and mapping/GIS. These planning regions also support the Commonwealth's District Local Technical Assistance Program to pursue a variety of municipal shared-service initiatives and planning projects through a region-wide solicitation process. The regions are established as commissions or councils (collectively referred to as commissions in this SHMP), which are not federal, state or county agencies but regional advisory boards with representatives from each member

community. The commissions are composed of a member from each community represented. The 13 planning commissions represent jurisdictions as shown in Figure 4-1.

4.2 GEOGRAPHY

The following is a general overview of Massachusetts geography:

- Area: 8,257 square miles (land and water), 7,838 square miles (land only)—45th largest in the U.S.
- Largest body of water: Quabbin Reservoir (39 square miles)
- Longest river: Charles River (80 miles)
- Highest elevation: Mt. Greylock (3,491 feet)
- Lowest elevation: Atlantic Ocean (sea level)
- Number of state parks: 107
- Largest state park: October Mountain State Forest (15,710 acres)
- Number of national historical parks, seashores, and historic sites: 20
- Largest national area: Cape Cod National Seashore (43,500 acres)
- Municipal watershed lands: 245,000 acres
- Privately owned forest land: 3.2 million acres
- State forests and parks: 285,000 acres

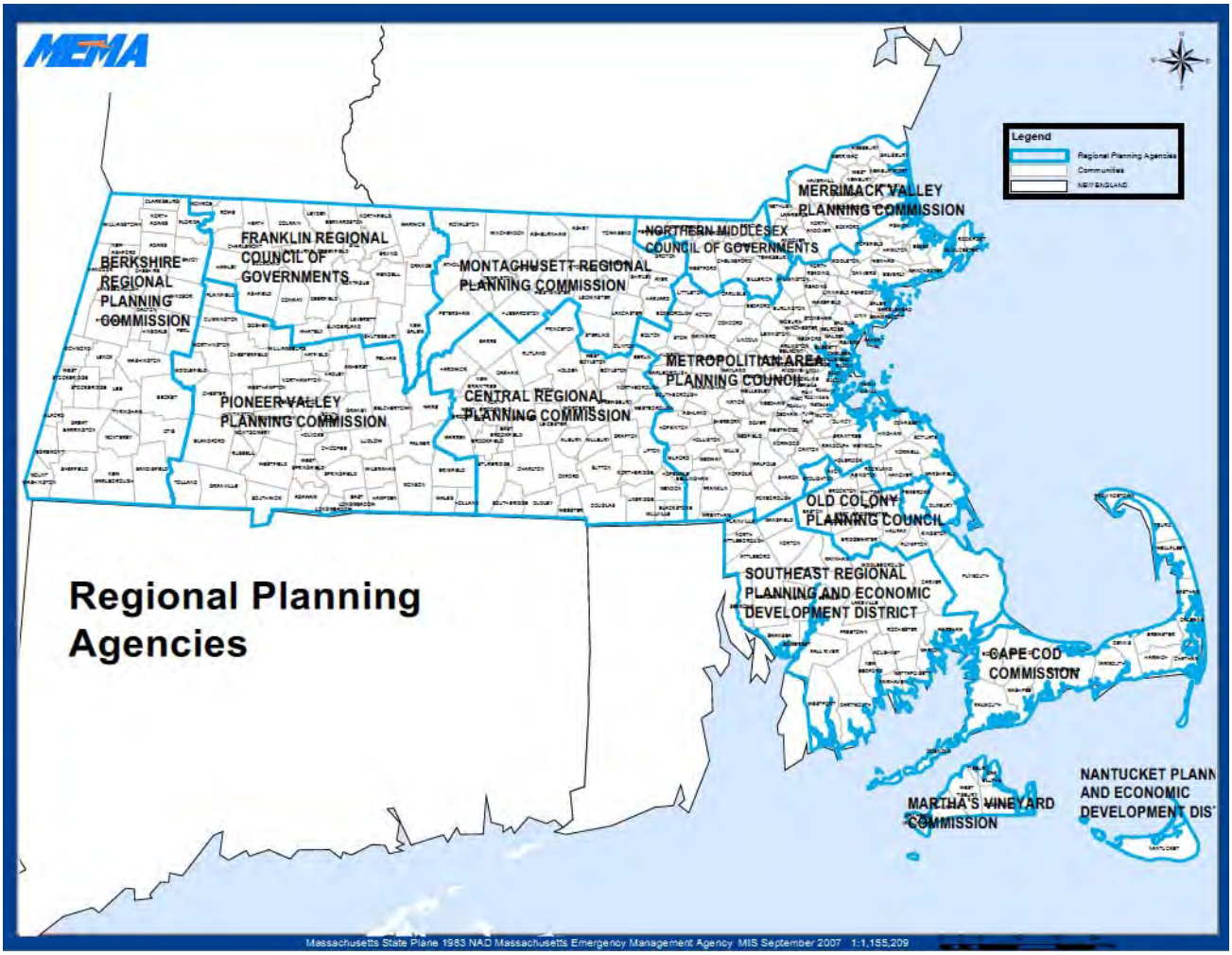


Figure 4-1. Massachusetts Regional Planning Agencies

4.2.1 Coastal Areas

Massachusetts features six coastal zones (North Shore, Boston Harbor/Massachusetts Bay, South Shore, Cape Cod and Islands, and South Coast), and varying inland regions. Each area has characteristics that affect its susceptibility to the hazards known to occur in the Commonwealth. Massachusetts' topography varies from rocky shores, sandy beaches, and salt marshes on the east coast, through rolling hills and fertile valleys, to wooded hills in the western part of the state.

4.2.2 Mountains

Substantial ranges in Massachusetts are the Berkshire Hills, Blue Hills, Holyoke Range, and Wapack. Mount Greylock in Berkshire County is the highest mountain in Massachusetts, at 3,491 feet. Other noteworthy mountains are Mount Williams in North Adams (2,951 feet); East Mountain in Hancock (2,660 feet); Mount Everett in Mt. Washington (2,602 feet); Spruce Hill in Adams (2,588 feet); Mount Frissel in Mt. Washington (2,453 feet); Potter Mountain in Lanesboro (2,391 feet); French Hill in Peru (2,214 feet); and Mount Wachusett in Princeton (2,006 feet).

4.2.3 Rivers

There are 4,230 miles of rivers in the Commonwealth of Massachusetts. The longest in-state river is the Charles, flowing 80 miles. The longest river in New England is the Connecticut, which flows from north to south for 67.5 miles in Massachusetts. Its tributaries are the Deerfield, Westfield, Chicopee, and Miller's rivers. Other major rivers in western Massachusetts are the Housatonic River, which flows south, and the Hoosic River, which flows north between the Hoosic and Taconic mountain ranges.

The Merrimack River, in the northeast, originates in New Hampshire and empties into the Atlantic Ocean. The Nashua and Concord rivers are major tributaries of the Merrimack. The Blackstone River flows south from the center of Massachusetts. The Mystic and Charles rivers flow into Boston Harbor, and the Taunton River enters Mount Hope Bay at Fall River.

4.2.4 Lakes

Massachusetts has more than 3,000 lakes and ponds. The largest of these are the Quabbin Reservoir (24,704 acres) and Wachusett Reservoir (4,160 acres), which are manmade. These two reservoirs provide metropolitan Boston with most of its public water supply.

The largest lakes of natural origin are Assawompsett Pond (2,656 acres) in Lakeville and Middleborough, drained by the Taunton River; North Watuppa Pond (1,805 acres) and South Watuppa Pond (1,551 acres) in Fall River and Westport, drained by the Quequechan River; Long Pond (1,361 acres) in Lakeville and Freetown, drained by the Taunton River; Lake Chargoggagogmanchaugagogchaubunagungamaug (1,188 acres)—usually called Lake Webster—in Webster, drained by the French River; Herring Pond (1,157 acres) in Edgartown on the island of Martha's Vineyard; Great Quittacas Pond (1,128 acres) in Lakeville, Rochester, and Middleborough, drained by the Taunton River; Lake Quinsigamond (1,051 acres) in Worcester, Shrewsbury, and Grafton drained by the Blackstone River; and Monponsett Pond (756 acres) in Halifax and Hanson, drained by the Taunton River.

4.2.5 Islands

Lying off Cape Cod are Martha's Vineyard, Nantucket, and the Elizabeth Islands:

- Martha's Vineyard, triangular in shape, is about 19 miles long and less than 10 miles wide. It contains the towns of Edgartown, Chilmark, Tisbury, West Tisbury, Aquinnah, and Oak Bluffs and is a popular summer resort.

- Nantucket, also roughly triangular, about 15 miles long and 3 to 4 miles wide, was once famed for its whaling industry. It too is now a popular summer resort.
- The Island of Tuckernuck is an island in the town of Nantucket, west of Nantucket Island and east of Muskeget. The island has an area of about 900 acres (1.4 square miles), and is privately owned by summer residents. The oldest home on the island was built in the mid-18th century. The island has no paved roads or public utilities.
- Muskeget Island is a low sandy island west of Tuckernuck Island and Nantucket, in the town of Nantucket. It has an area of 292 acres, and is primarily owned by the Town of Nantucket. Muskeget has a high elevation of 14 feet. Its northern shore is mostly sand dunes, and its southern shore is mainly marshes.
- The Elizabeth Islands are a group of about 22 small islands between Vineyard Sound and Buzzards Bay.

The Boston Harbor Island group includes the Four Brewsters, Bumpkin, Calf, Deer, Gallop's, George's, Grape, The Graves, Green, Hangman, Langley, Long, Lovell's, Moon, Nixes Mate, Peddock's, Raccoon, Ragged, Rainsford, Sara, Sheep, Slate, Spectacle, and Thompson's. Some islands have been made part of the mainland by the great amount of landfill that has gone on over the years. Governor's Island, where the first apple and pear trees in America were planted, is now a part of Boston's Logan International Airport. Most of the islands have been used for farming, resort-recreation areas, public facilities, or fortifications.

4.3 CLIMATE

The Commonwealth of Massachusetts, in general, has a humid continental climate with temperatures that average 68°F to 72°F in the summer and 28°F to 32°F in the winter. The mean annual precipitation ranges from 40 to 46 inches; one-third of this in snow. The growing season varies from area to area, with the period between the last killing frost in the spring and the first killing frost in the fall lasting approximately 160 days. The area is subject to a variety of severe weather events, which are further discussed in the risk assessment portion of this SHMP.

4.4 DEMOGRAPHIC CHARACTERISTICS

4.4.1 Current Population

Massachusetts is a relatively slow-growing, densely populated state. The 2010 population was 6,547,629, ranking 14th in the U.S. The state's population is concentrated in its eastern portion. According to current statistics, 99.6 percent of the state's population lives in a metropolitan area. As of July 1, 2011, population density was estimated to be 840.2 persons per square mile, compared to 88.1 for the United States as a whole. Among the 50 states, only Rhode Island and New Jersey have a greater population density (University of Massachusetts, 2013). The average household size is 2.50 persons, and the average family size is 3.10 persons.

The city of Boston is the largest city in New England, accounting for 9.5 percent of the Commonwealth's population. Boston is the hub of the Boston-Cambridge-Quincy Metropolitan Statistical Area, which includes the two southeastern New Hampshire counties and had a total population as of July 1, 2011 estimated at 4,591,112, or 34.8 percent of the total New England population. The three-county Boston-Quincy, MA metropolitan division is the largest component of that Metropolitan Statistical Area, with a total population as of July 1, 2011 estimated at 1,903,947 (University of Massachusetts, 2013).

The Commonwealth's 14 counties vary in size and population from Nantucket (44.97 square miles and population of 10,172) to Middlesex (817.82 square miles and population of 1,503,085) and Worcester

(1,510.77 square miles and population of 798,552). Table 4-1 lists county populations and areas. Table 4-2 lists the largest and smallest municipalities in Massachusetts. The largest municipality is the City of Boston, with a 2010 population of 617,594. More than half of Massachusetts' total population lives in the Greater Boston area. The smallest is the Town of Gosnold, with a 2010 population of 75.

TABLE 4-1.
COUNTY POPULATION AND AREA

County	Population (2010)	Total Area (sq. miles)
Barnstable	215,888	393.72
Berkshire	131,219	926.83
Bristol	548,285	553.10
Dukes	16,535	103.25
Essex	743,159	492.56
Franklin	71,372	699.32
Hampden	463,490	617.14
Hampshire	158,080	527.26
Middlesex	1,503,085	817.82
Nantucket	10,172	44.97
Norfolk	670,850	396.11
Plymouth	494,919	659.08
Suffolk	722,023	58.15
Worcester	798,552	1,510.77

Source: 2010 U.S. Census Data

TABLE 4-2.
LARGEST AND SMALLEST MUNICIPALITIES BY POPULATION

Municipality	County	2010 Population	Municipality	County	2010 Population
Largest			**Smallest**		
Boston	Suffolk	617,594	Alford	Berkshire	494
Worcester	Worcester	181,045	Tolland	Hampden	485
Springfield	Hampden	153,060	Rowe	Franklin	393
Lowell	Middlesex	106,519	Hawley	Franklin	337
Cambridge	Middlesex	105,162	Tyringham	Berkshire	327
New Bedford	Bristol	95,072	Aquinnah	Dukes	311
Brockton	Plymouth	93,810	New Ashford	Berkshire	228
Quincy	Norfolk	92,271	Mount Washington	Berkshire	167
Lynn	Essex	90,329	Monroe	Franklin	121
Fall River	Bristol	88,857	Gosnold	Dukes	75

Source: 2010 U.S. Census Data

4.4.2 Population Trends

Statewide Population Trends

Statewide population trends indicate a slow population growth, below the national average. According to Census Bureau revised estimates released in February 2011, the Massachusetts population growth since 2010 was estimated at 0.6 percent, ranking the Commonwealth 32nd in the U.S. By 2020, the Massachusetts population is anticipated to reach 6,767,732, only about 172,000 more (3 percent more) than the current population. Table 4-3 shows population changes between 1920 and 2010. The Commonwealth experienced a growth of 3.13 percent, or 198,532 people, between 2000 and 2010, and 15.1 percent, or 858,459 people, from 1970 to 2010. Population grew only 0.84 percent from 1970 to 1980, which was the slowest growing decade between 1920 and 2010. The fastest growing decade was between 1960 and 1970, with a 10.5 percent increase. Figure 4-2 compares Massachusetts annual growth since 1982 to the growth rates for all of New England and for the United States.

TABLE 4-3.
MASSACHUSETTS POPULATION CHANGES, 1920 - 2010

Year	Population	Change	% Difference
1920	3,852,356	N/A	N/A
1930	4,249,614	397,258	10.31
1940	4,316,721	67,107	1.58
1950	4,690,514	373,793	8.66
1960	5,148,578	458,064	9.77
1970	5,689,170	540,592	10.50
1980	5,737,037	47,867	0.84
1990	6,016,425	279,388	4.87
2000	6,349,097	332,672	5.53
2010	6,547,629	198,532	3.13

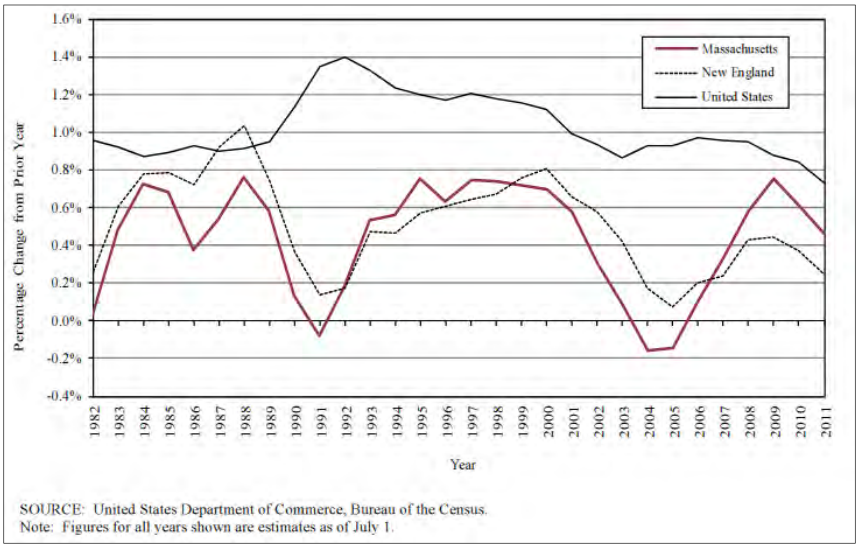


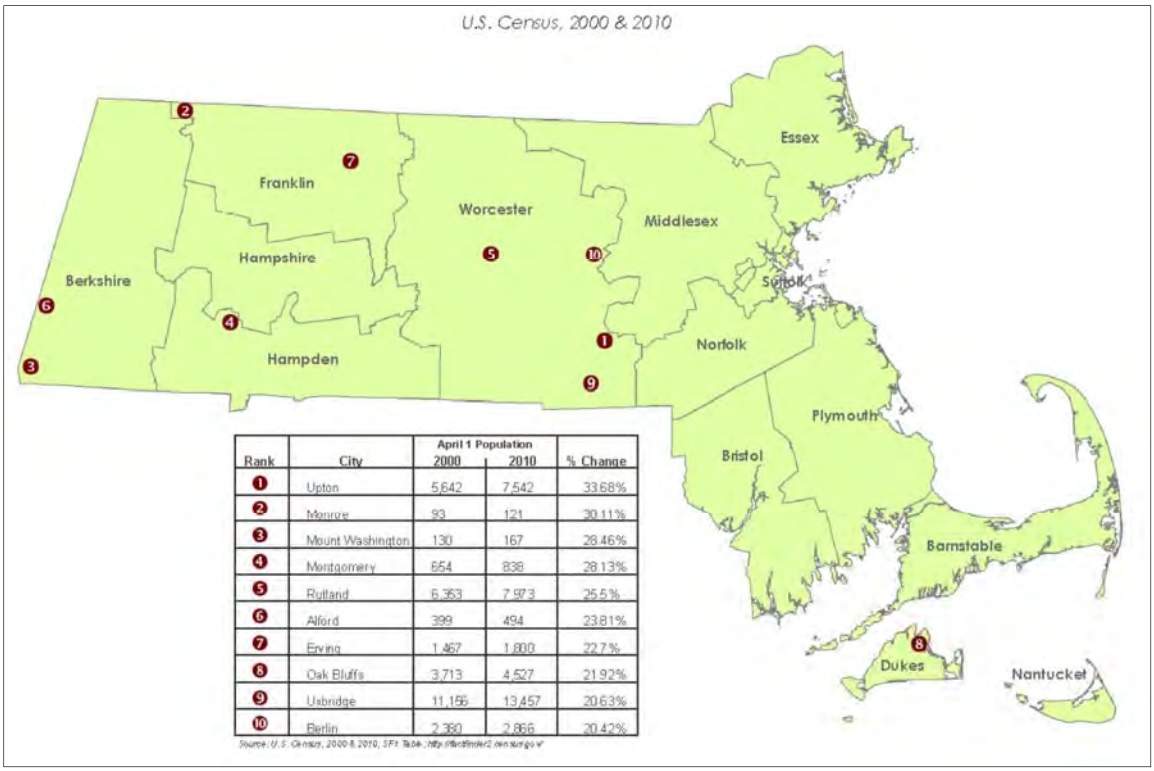
Figure 4-2. Annual Percentage Change in Population, 1982 - 2011

Population Trends by County

Table 4-4 summarizes growth projections by county. The highest growth was in Suffolk and Worcester counties. According to the U.S. Census data, four of the fastest growing cities are in Worcester County and three are in Berkshire County (see Figure 4-3).

TABLE 4-4.
POPULATION GROWTH PROJECTIONS BY COUNTY

	Population			Population Change		2020 Projection		Housing Units	
	2000	2009	2011	2009-2011	2000-2011	Population	Change from 2011	2009	2011
Barnstable	222,230	221,151	215,769	-5,382	-6,461	299,035	39%	155,686	161,001
Berkshire	134,953	129,288	130,458	1,170	-4,495	118,452	-9%	68,539	68,497
Bristol	534,678	547,433	548,922	1,489	14,244	576,868	5%	225,670	231,083
Dukes	14,987	15,974	16,766	792	1,779	21,822	30%	16,381	17,385
Essex	723,419	742,582	748,930	6,348	25,511	787,032	5%	299,508	307,559
Franklin	71,535	74,778	71,599	-3,179	64	73,806	3%	33,362	33,806
Hampden	456,228	471,081	463,783	-7,298	7,555	453,115	-2%	191,380	192,197
Hampshire	152,251	156,044	157,822	1,778	5,571	163,233	3%	61,949	62,766
Middlesex	1,465,396	1,505,006	1,518,171	13,165	52,775	1,469,494	-3%	598,481	614,036
Nantucket	9,520	11,322	10,142	-1,180	622	14,426	42%	10,657	11,776
Norfolk	650,308	666,303	675,436	9,133	25,128	652,440	-3%	266,793	271,502
Plymouth	472,822	498,344	497,579	-765	24,757	517,664	4%	194,237	201,419
Suffolk	689,807	753,580	730,932	-22,648	41,125	776,811	6%	305,127	317,327
Worcester	750,963	803,701	801,227	-2,474	50,264	843,534	5%	320,551	328,586
State Total	**6,349,097**	**6,596,587**	**6,587,536**	**-9,051**	**238,439**	**6,767,732**	**3%**	**2,748,321**	**2,818,940**



Rank	City	April 1 Population 2000	2010	% Change
1	Upton	5,642	7,542	33.68%
2	Monroe	93	121	30.11%
3	Mount Washington	130	167	28.46%
4	Montgomery	654	838	28.13%
5	Rutland	6,353	7,973	25.5%
6	Alford	399	494	23.81%
7	Erving	1,467	1,800	22.7%
8	Oak Bluffs	3,713	4,527	21.92%
9	Uxbridge	11,156	13,457	20.63%
10	Berlin	2,380	2,866	20.42%

Source: U.S. Census, 2000 & 2010, SF1 Table ; http://factfinder2.census.gov

Figure 4-3. Fastest Growing Cities by Population

4.4.3 Socioeconomic Status

This section provides information on characteristics of potentially at-risk populations in the Commonwealth. This information was captured from various sources, including the U.S. Census data, the University of Massachusetts 2013 Due Diligence Report, and the various plans reviewed (as indicated).

Poverty

Income influences the type of housing people live in, whether they can engage in mitigation actions to reduce the impacts of hazards, and how long it takes to recover from a disaster event. In addition, individuals in lower income brackets often live in hazard-prone areas because the cost of living may be lower. The ability to prepare for self-sustainment is often also influenced by the ability to maintain surplus supplies, which may not be feasible for families with limited income beyond a month-to-month capacity.

Table 4-5 summarizes poverty data by county. Income is based on factors including the individual, the economy, availability of jobs, and educational opportunity. Expenses can vary by location. Rural places are less expense but may offer fewer jobs; urban areas can be costly, even for renters.

TABLE 4-5.
AMERICAN COMMUNITY SURVEY 2009 – 2011 3-YEAR ESTIMATES FOR POVERTY, BY COUNTY

		Below Poverty Level	
	Total Population	Number	%
Barnstable	212,204	19,939	9.40%
Berkshire	125418	16,121	12.90%
Bristol	534,497	63,244	11.80%
Dukes*	16,217	1,649	10.20%
Essex	728,751	79,988	11.00%
Franklin	70,312	8,840	12.60%
Hampden	448,128	77,672	17.30%
Hampshire	135,184	17,274	12.80%
Middlesex	1,455,244	115,804	8.00%
Nantucket*	9,990	880	8.80%
Norfolk	653,134	40,407	6.20%
Plymouth	484,536	37,497	7.70%
Suffolk	684,311	148,692	21.70%
Worcester	772,817	81,125	10.50%

* These estimates are from the American Community Survey 2007-2011 5-year estimates; 3-year estimates are not available for these counties.

Education

Historically, education impacts salary levels. Availability of a skilled and well-educated population is an important resource for the Commonwealth. Only the District of Columbia had a higher percentage of adults with a bachelor's degree or higher in 2011, according to the Census Bureau's American Community Survey (ACS). The ACS also found that Massachusetts had a smaller portion of persons who had not completed high school, 10.8 percent, than the national average of 14.1. Massachusetts' black and Hispanic populations achieved college degrees at roughly half the rate of its white population but their rates were higher than the national averages. The most current Census data are shown in Figure 4-4 through Figure 4-6. Current education by county is presented in Table 4-6.

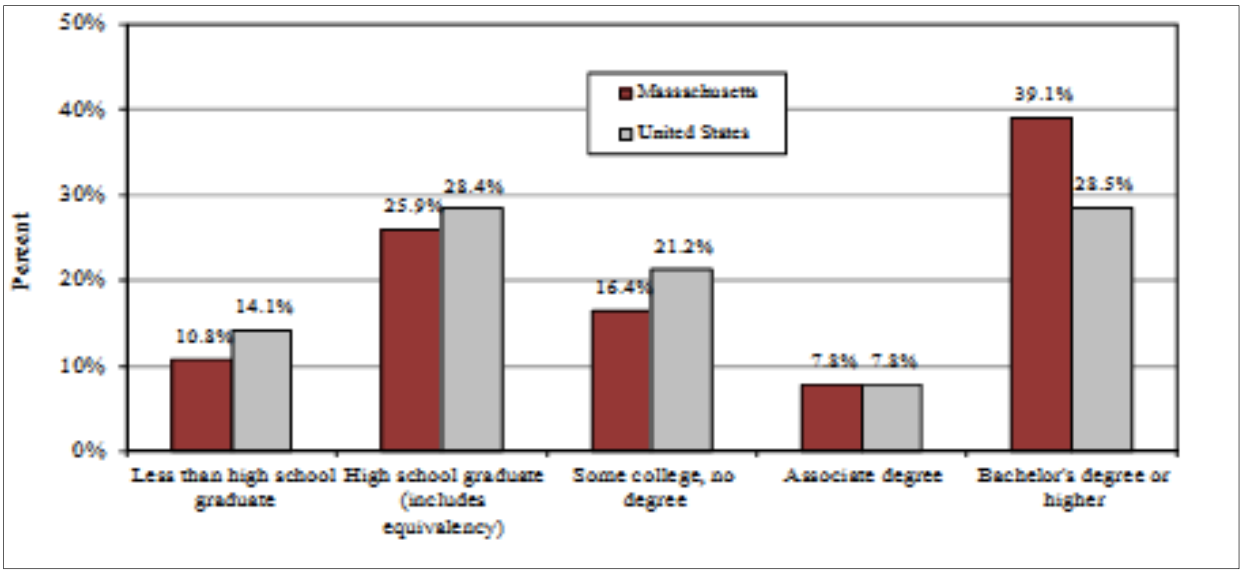


Figure 4-4. Educational Attainment of Population 25 and Older, 2011

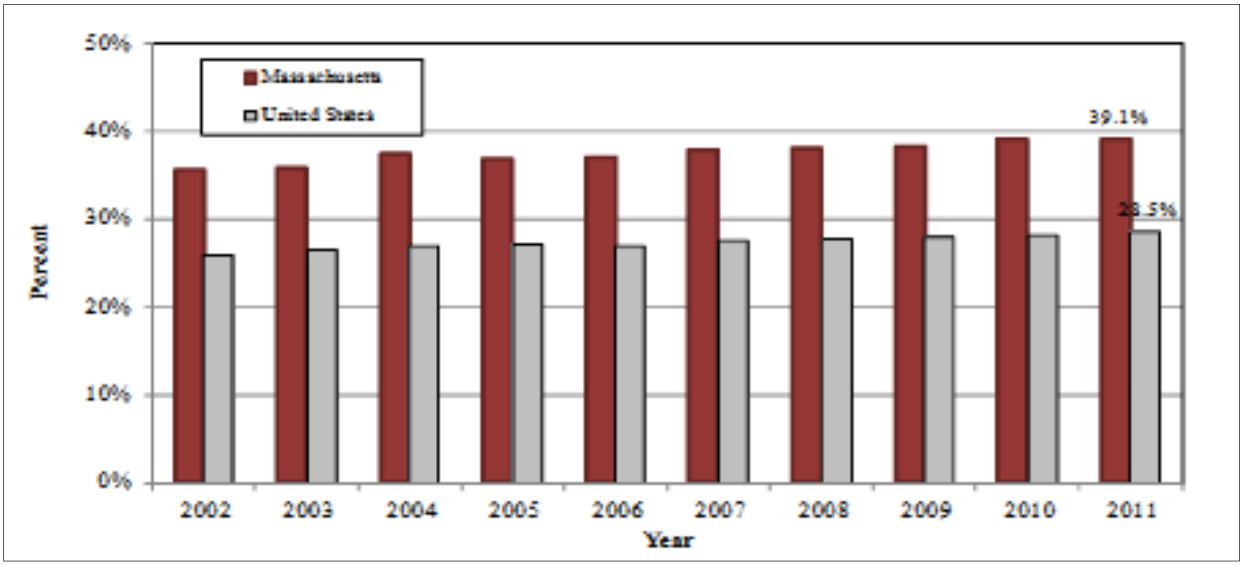


Figure 4-5. Percent of Population with a Bachelor's Degree or Higher, 2002 - 2011

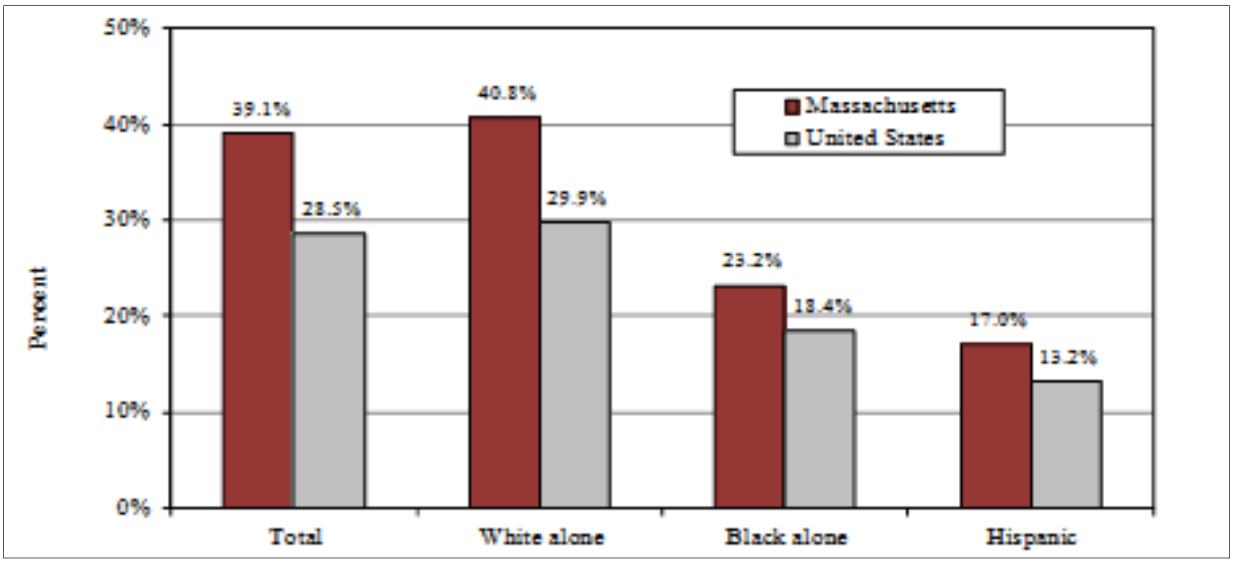


Figure 4-6. Percent of Population with a Bachelor's Degree or Higher, by Ethnic Origin, 2011

TABLE 4-6.
AMERICAN COMMUNITY SURVEY 2009 – 2011 3-YEAR ESTIMATES FOR EDUCATION, BY COUNTY

	Less than High School Graduate	High School Graduate/ GED	Some College/ Associate's Degree	Bachelor's Degree or higher
Barnstable	8,726	40,042	49,512	64,031
Berkshire	8,862	30,698	25,215	26,917
Bristol	67,048	110,704	96,512	93,907
Dukes *	844	2,631	3,254	5,031
Essex	54,875	132,632	130,024	183,040
Franklin	4,074	14,619	15,560	16,767
Hampden	49,895	94,282	83,754	72,264
Hampshire	6,887	24,194	24,530	40,212
Middlesex	81,045	225,257	204,251	516,702
Nantucket*	496	1,871	18,442	3,051
Norfolk	26,915	97,594	108,106	224,588
Plymouth	25,093	99,667	94,312	110,116
Suffolk	75,327	113,310	88,764	184,511
Worcester	56,527	146,961	143,419	178,293

* These estimates are from the American Community Survey 2007-2011 5-year estimates; 3-year estimates are not available for these counties

Ethnicity

History has demonstrated that certain population groups generally experience longer recoveries due to lower incomes, lower savings and insurance, and their use of relief organizations differently. Table 4-7 summarizes ethnicity in the state. In 2010, 97.4 percent of the population reported only one race. Hispanics (of any race) made up 9.6 percent of the state's population, African-Americans 6.6 percent, Asians 5.3 percent and Native Americans 0.03 percent. Distribution by county is presented in Table 4-8.

TABLE 4-7.
STATEWIDE ETHNICITY BY PERCENT AND POPULATION

	Percent of Total	Population
Hispanic	9.59%	627,654
African-American	6.63%	434,398
Asian	5.34%	349,768
Native Hawaiian and Pacific Islander	0.03%	2,223
Native American	0.29%	18,850
Other	4.66%	305,151
Caucasian	80.41%	5,265,236
Multiple	2.63%	172,003

TABLE 4-8.
AMERICAN COMMUNITY SURVEY 2009- 2011 3-YEAR ESTIMATES FOR ETHNICITY, BY COUNTY

	Total Population	Black or African American	American Indian/ Alaska Native	Asian	Native Hawaiian/ Pacific Islander	Other Race
Barnstable	212,204	4,599	N/A	2,195	N/A	2,076
Berkshire	125418	3,013	N/A	N/A	N/A	N/A
Bristol	534,497	18,432	N/A	10,271	N/A	13,997
Dukes*	16,217	679	260	118	N/A	156
Essex	728,751	24,199	1,197	23,514	N/A	69,339
Franklin	70,312	N/A	N/A	N/A	N/A	N/A
Hampden	448,128	38,646	N/A	9,094	N/A	40,531
Hampshire	135,184	2,600	N/A	6,120	N/A	N/A
Middlesex	1,455,244	65,080	1,809	135,914	N/A	36,246
Nantucket*	9,990	799	N/A	111	N/A	28
Norfolk	653,134	36,788	N/A	57,146	N/A	7,432
Plymouth	484,536	40,376	N/A	6,307	N/A	10,341
Suffolk	684,311	157,312	2,001	55,484	N/A	50,851
Worcester	772,817	29,592	1,361	31,822	N/A	20,767

* These estimates are from the American Community Survey 2007-2011 5-year estimates; 3-year estimates aren't available for these counties

Historically, 14.7 percent (957,414 persons) of the Commonwealth's population was not born in the United States. Approximately 50 percent identified with a single-ancestry group and 33 percent with the multi-ancestry group; 11.7 percent were not specified. According to the 2007-2011 American Community Survey, of the single-ancestry groups, the six leading groups were Irish (23.3 percent), Italian (14 percent), English (11.3 percent), French (8.2 percent), German (6.6 percent), and Polish (5.1 percent).

Language

Language differences can pose difficulties in understanding and implementing preparedness and mitigation actions, as well as accessing and using available disaster relief. Those who do not speak English as a primary language have a barrier preventing them from preparing for a disaster, responding to an event, or applying for assistance after a disaster. A knowledge of the languages spoken in a community allows emergency responders to prepare for communication difficulties by establishing resources to help address any issues that may arise. Table 4-9 provides an overview of language data by County.

TABLE 4-9.
AMERICAN COMMUNITY SURVEY 2009-11 (3-YEAR ESTIMATES)—CHARACTERISTICS OF PEOPLE BY LANGUAGE SPOKANE AT HOME, BY COUNTY

	Total Population (> 5 years old)	People who speak only English at home	% English Only Speakers	People who speak a language other than English at home	% Other Language Speakers
Barnstable County	207,285	189,823	91.6%	17,462	8.4%
Berkshire County	124,949	115,660	92.6%	9,289	7.4%
Bristol County	517,194	409,665	79.2%	107,529	20.8%
Essex County	700,716	534,930	76.3%	165,786	23.7%
Dukes County*	15,288	14,200	92.9%	1,088	7.1%
Franklin County	67,998	64,216	94.4%	3,782	5.6%
Hampden County	435,794	330,341	75.8%	105,453	24.2%
Hampshire County	151,858	136,446	89.9%	15,412	10.1%
Middlesex County	1,420,438	1,063,720	74.9%	356,718	25.1%
Nantucket County*	9,506	8,247	86.8%	1,259	13.2%
Norfolk County	633,902	517,637	81.7%	116,265	18.3%
Plymouth County	466,970	413,449	88.5%	53,521	11.5%
Suffolk County	683,227	429,076	62.8%	254,151	37.2%
Worcester County	751,856	619,107	82.3%	132,749	17.7%

* 2007-2011 American Community Survey 5-year Estimates, as 3-year ACS estimates are not available for these counties

Age Distribution

Individuals in the very young and elderly age groups are more vulnerable than other age groups to hazards of concern, with reduced ability to self-manage care. Additional care and resources are often required to meet the needs of these age groups. Preparedness and recovery activities may overlook senior citizens. Their age could lead them to have difficulty after a disaster, perhaps not qualify for loans, or become further disabled because of the disaster. Table 4-10 presents current age data by county. Projections through 2030 are shown on Table 4-11 and Figure 4-7. The 65-and-over and 85-and-over age groups are expected to grow in the coming decades.

TABLE 4-10.
AMERICAN COMMUNITY SURVEY 2009- 2011 3-YEAR ESTIMATES FOR AGE, BY COUNTY

	Total Population	Age		
		under 18 years	18-64 years	65 years and over
Barnstable	212,204	36,542	122,988	52,674
Berkshire	125418	24,831	77,143	23,444
Bristol	534,497	120,180	340,402	73,915
Dukes*	16,217	3,505	10,233	2,479
Essex	728,751	170,049	457,123	101,579
Franklin	70,312	13,684	46,064	10,564
Hampden	448,128	107,303	278,016	62,809
Hampshire	135,184	25,589	90,251	19,344
Middlesex	1,455,244	317,352	947,869	190,023
Nantucket*	9,990	2,058	6,777	1,155
Norfolk	653,134	150,432	409,010	93,692
Plymouth	484,536	117,514	300,948	66,074
Suffolk	684,311	125,976	485,963	72,372
Worcester	772,817	183,947	491,867	97,003

* These estimates are from the American Community Survey 2007-2011 5-year estimates; 3-year estimates aren't available for these counties

TABLE 4-11.
PROJECTED POPULATION BY AGE GROUP, 2000 - 2030

Projected Massachusetts Population by Age Group 2000-2030 (in thousands)

Year	0-4	5-17	18-24	25-44	45-64	65-84	85+	All Ages	Median Age
2000	397.3	1,102.8	579.3	1,989.8	1,419.8	743.5	116.7	6,349.1	36.5
2005	395.1	1,055.6	488.9	1,844.0	1,602.5	693.1	103.7	6,182.9	38.2
2010	400.7	1,083.1	670.2	1,769.7	1,817.1	750.6	158.0	6,649.4	38.8
2015	409.7	1,064.2	656.0	1,746.1	1,857.1	856.5	168.9	6,758.6	39.2
2020	422.3	1,070.9	617.5	1,775.8	1,809.3	987.8	172.0	6,855.5	39.5
2025	431.0	1,087.7	616.2	1,782.5	1,703.3	1,137.8	180.1	6,938.6	39.7
2030	430.6	1,115.0	610.7	1,783.9	1,608.7	1,251.2	211.9	7,012.0	40.2

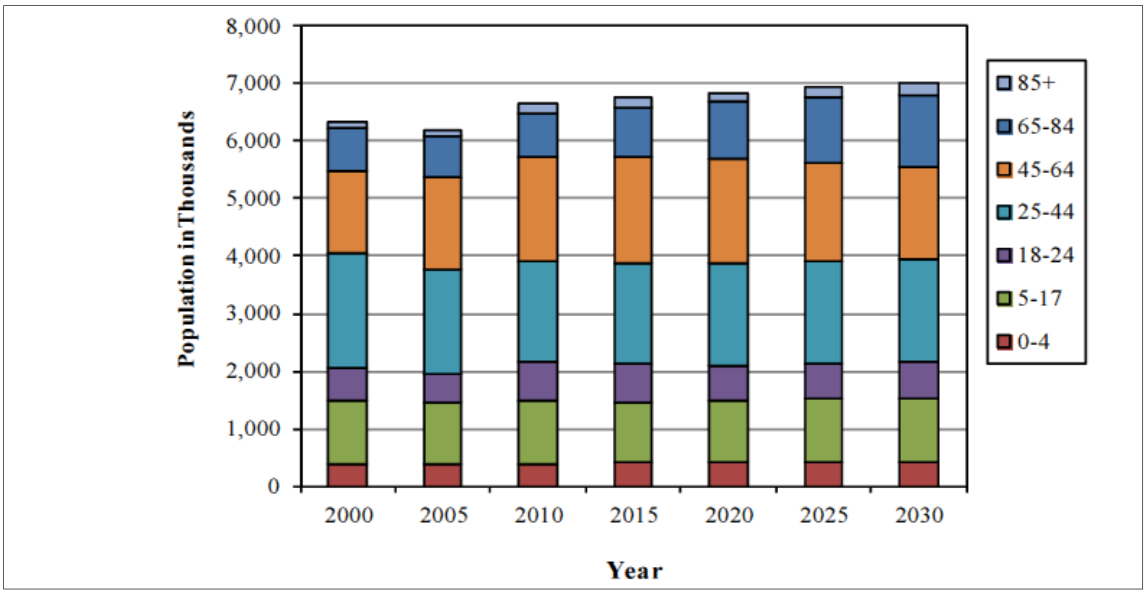


Figure 4-7. Projected Population by Age Group, 2000 – 2030

Disability Status

The 2010 U.S. Census estimates 54 million non-institutionalized Americans with disabilities in the U.S.—about one in five persons. People with disabilities are more likely than the general population to have difficulty responding to a hazard event, due to hearing, sight, mobility or mental impairments. Additionally, a significant percentage of working-age individuals with disabilities may not work, making it difficult for the disabled to prepare in advance of a disaster, or even receive information of a potential event occurring, depending on how the information is presented.

Efforts must be coordinated to meet the access and functional needs of individuals with disabilities. Determining the percentage of population with a disability will provide emergency management personnel and first responders the information necessary to plan by having individuals available to provide services necessary for those with access and functional needs. Emergency managers need to distinguish between *functional* and *medical* needs to allow them to plan for incidents that require evacuations and sheltering.

4.5 HOUSING

The older a home is, the greater the risk that natural disasters pose to it. Homes constructed after international building codes were adopted or after the first flood maps were established are more likely to withstand damage from hazards such as floods, high winds, snow loads, and earthquake because they were built to higher standards. Some jurisdictions are experiencing growth and development at a slightly faster rate than the state average; however, statewide there is no significant increase in development. New residential and commercial development has not experienced a significant amount of change at the statewide level. Statewide during 2011, only 7,725 build permits were issued. Table 4-12 summarizes basic housing data.

TABLE 4-12.
HOUSING DATA

	Number	Percent
Occupied housing units	2,443,580	100.0
Owner-occupied housing units	1,508,248	61.7
Renter-occupied housing units	935,332	38.3
Average household size of owner-occupied unit	2.74	(X)
Average household size of renter-occupied unit	2.13	(X)

Source: US Census Bureau, Census 2000 (Most recent as of 2013 writing).
http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk

4.6 LAND DEVELOPMENT

Figure 4-8 shows changes over the past 30 years of the area covered by major land use classifications in Massachusetts. The Executive Office of Environmental Affairs has been encouraging smart growth for more than a decade. The Office's smart growth efforts include providing information, incentives, and funding to help local leaders and residents make informed decisions about growth and development.

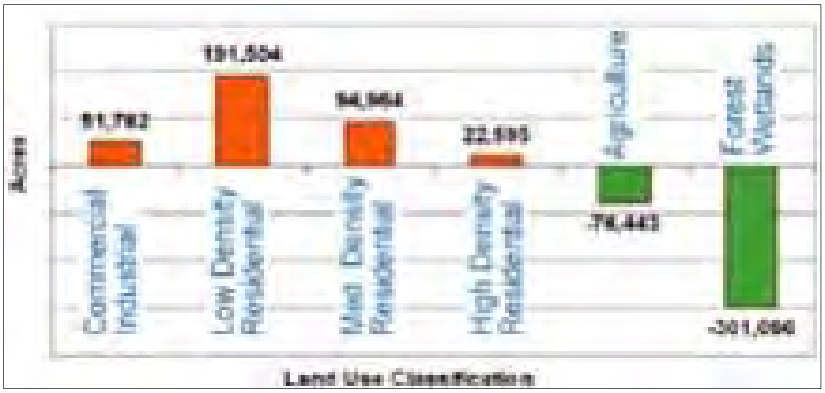


Figure 4-8. 30-Year Change in Land Use

The policies and programs of the Smart Growth and Urban Environments Team attempt to proactively address, through better development and redevelopment, the negative effects of sprawl, which consumes large amounts of open space and farmland, overburdens existing infrastructure, exacerbates tight municipal budgets, and damages natural resources and the environment. Over $3 million in funding has been provided to municipalities to implement smart growth.

The Community Preservation Act (CPA), signed into law in 2000 (Chapter 267 of the Acts of 2000) and subsequently amended five times, allows communities to create a local Community Preservation Fund to raise money through a surcharge of up to 3 percent of the real estate tax levy on real property for open space protection, historic preservation, and affordable housing. The act also creates a state matching fund, which serves as an incentive to communities to pass the CPA. These principles require communities to incorporate mitigation by protecting, among other things, critical areas and to encourage development in areas outside hazard areas, or standards that reduce vulnerability to hazards and protect public health, safety, and the environment.

4.7 TRANSPORTATION INFRASTRUCTURE

4.7.1 Statewide Authority

The Massachusetts Department of Transportation (Mass DOT) is responsible for maintaining the transportation infrastructure in the Commonwealth of Massachusetts. The Mass DOT Secretary appoints an administrator for each of Mass DOT's four divisions:

- **Highway Division—**The Highway Division includes the roadways, bridges, and tunnels of the former Massachusetts Highway Department and Massachusetts Turnpike Authority, as well as the Tobin Bridge. The Division also includes many bridges and parkways previously under the authority of the Department of Conservation and Recreation. The Highway Division is responsible for the design, construction, and maintenance of the Commonwealth's state highways and bridges. The Division is responsible for overseeing traffic safety and engineering activities including the Highway Operations Control Center to ensure safe road and travel conditions.
- **Rail and Transit Division—**This Division is responsible for all transit initiatives and oversees all regional transit authorities of the Commonwealth. The Mass DOT Board of Directors serves as the governing body of the Massachusetts Bay Transportation Authority. The Rail and Transit Division is responsible for maintaining buses, trolleys, and ferry terminals accounting for 1.2 million weekday trips servicing 175 cities and towns throughout the Commonwealth.
- **Aeronautics Division—**The Aeronautics Division has jurisdiction over the Commonwealth's public use airports, private use landing areas, and seaplane bases. It is responsible for airport development and improvements, aviation safety, aircraft accident investigation, navigational aids, and statewide aviation planning. The Division certifies airports and heliports, licenses airport managers, conducts annual airport inspections, and enforces safety and security regulations. It is responsible for 39 public use airports, which collectively contain approximately 49 miles of paved runways, 23 of which are 5,000 feet or longer. Based on 2008 airport rankings, Logan International Airport was the 20th-busiest airport in North America in terms of passenger volume, and 21st in terms of aircraft movement. In 2009, Logan served over 25.5 million passengers arriving and departing, with over 345,000 total flight operations. (Mass DOT Transportation Facts, 2009).
- **Registry of Motor Vehicles—**The Registry of Motor Vehicles Division is responsible for vehicle operator licensing and vehicle and aircraft registration, available online and at branch offices across the Commonwealth. The Registry oversees commercial and non-commercial vehicle inspection stations.

According to the American Public Transportation Association, every dollar invested in transportation produces $4 in economic return. The *Massachusetts Statewide Airport Economic Impact Study*, a recent analysis by the Mass DOT Aeronautics Division, estimates that the 39 airports of the Commonwealth, including Logan International Airport, generate $11.9 billion in total annual economic activity and $4.9 billion in total annual payroll from the 124,369 jobs that can be traced to the aviation industry. Likewise, commuter rail service to the South Coast is projected to create 3,800 new jobs and generate nearly $500 million in new statewide economic activity every year.

Mass DOT's single largest operating expense is for snow and ice removal.

4.7.2 Roadways and Traffic Counts

Automobiles are the most common mode of commuting in Massachusetts, as shown in Figure 4-9. Currently, there are 36,000 miles of roadways statewide, with drivers collectively travelling in excess of 54 billion miles annually, consuming approximately 4 billion gallons of gas annually. In Boston, the Central Artery/Tunnel project processes approximately 536,000 vehicles per weekday. This includes 323,000 vehicles entering on the expressways, and 213,000 from local ramps (including the Logan tunnels). The highest traffic volume location in the state is the I-93/I-95 Interchange in Woburn and Reading, processing in excess of 375,000 vehicles per weekday.

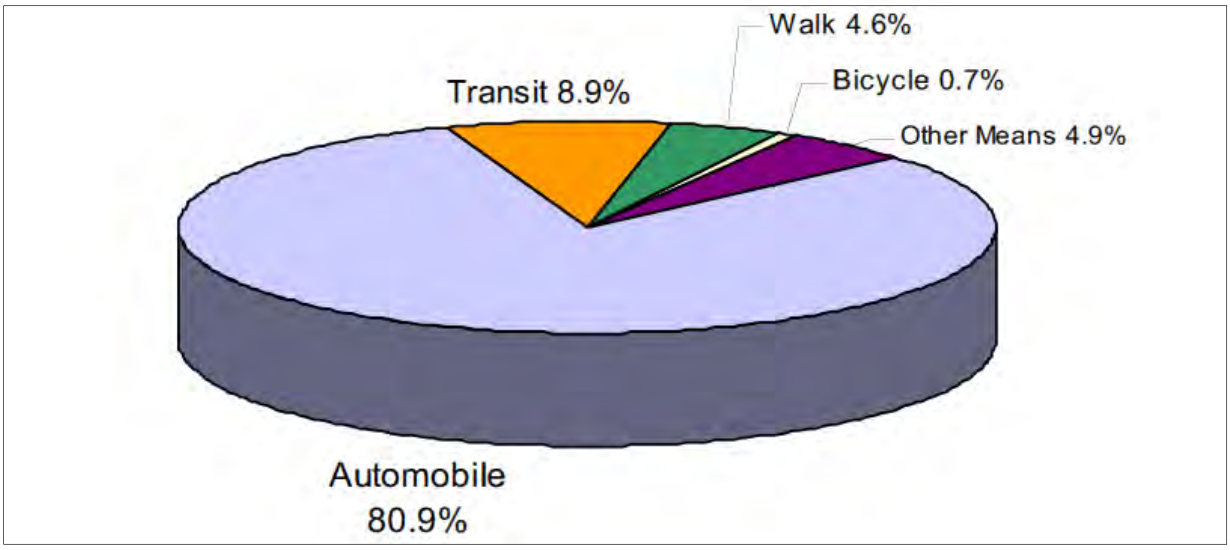


Figure 4-9. Massachusetts Commuting Modes, 2008

4.7.3 Bridges

Bridges are an integral part of the highway infrastructure system and need to be designed to provide safety for the traveling public. Bridge failures can result in the disruption of commerce and services, significant repair costs, and loss of human life. Bridge failure can also leave motorists stranded. If a bridge failures occur as a result of a disaster event, the impact can be significant, as a lack of ingress and egress to areas by citizens or by first responders can increase risks.

The Commonwealth has been proactive in maintaining the integrity of its bridges. According to the 2010 Annual Report prepared by Mass DOT, the "Governor's landmark eight-year, $3 billion Accelerated Bridge Program: has been responsible for repairing deficient and obsolete bridges across the Commonwealth. Since the Patrick-Murray Administration filed legislation approved by the Legislature creating the program in 2008, the number of structurally deficient bridges has dropped from 543 to 494, a decline of nearly 10 percent. Through early fall 2010, Mass DOT advertised more than 110 Accelerated Bridge Program construction projects with a combined construction budget value of nearly $700 million." Enhancements to the bridges include structural retrofits to sustain impact from hazard events such as earthquakes, as well as enhancements to improve resiliency from flooding. The Accelerated Bridge Program projects included the I-495 Bridge Bundle, which will replace six major bridges carrying northbound and southbound traffic on I-495.

Ownership of bridges varies from federal highway system bridges to locally owned or private bridges. The 2010 National Bridge Inventory identified 4,299 bridges in the Commonwealth, divided by bridge type as follows:

- Slab—595
- Stringer /Multi-Beam or Girder—2,870
- Girder & Floor Beam System—124
- Tee Beam—220
- Box Beam or Girders (Multiple)—215
- Box Beam or Girders (Single or Spread)—136
- Frame (Except Culverts)—123
- Orthotropic—0
- Truss-Deck—16.

The potential impacts on bridges from hazard incidents are described in the hazard profiles of this SHMP.

4.8 ECONOMY

4.8.1 Business Sectors

Economic vitality is a significant contributor to the Commonwealth's ability to rebound after a disaster event. A strong economy allows industries to pre-plan for events, such as through development of business continuity plans or continuity of operations plans, which have proven to be significant contributors in sustaining businesses impacted by disaster (Tierney, 1997). The Massachusetts economy is diversified among several sectors, the four largest being real estate and rental/leasing, professional and technical services, manufacturing, and health care and social assistance (see Figure 4-10 and Table 4-13). Combined, these sectors contributed 46 percent of the 2011 gross domestic product (GDP). Manufacturing replaced the finance and insurance sector during 2011 as the third largest sector.

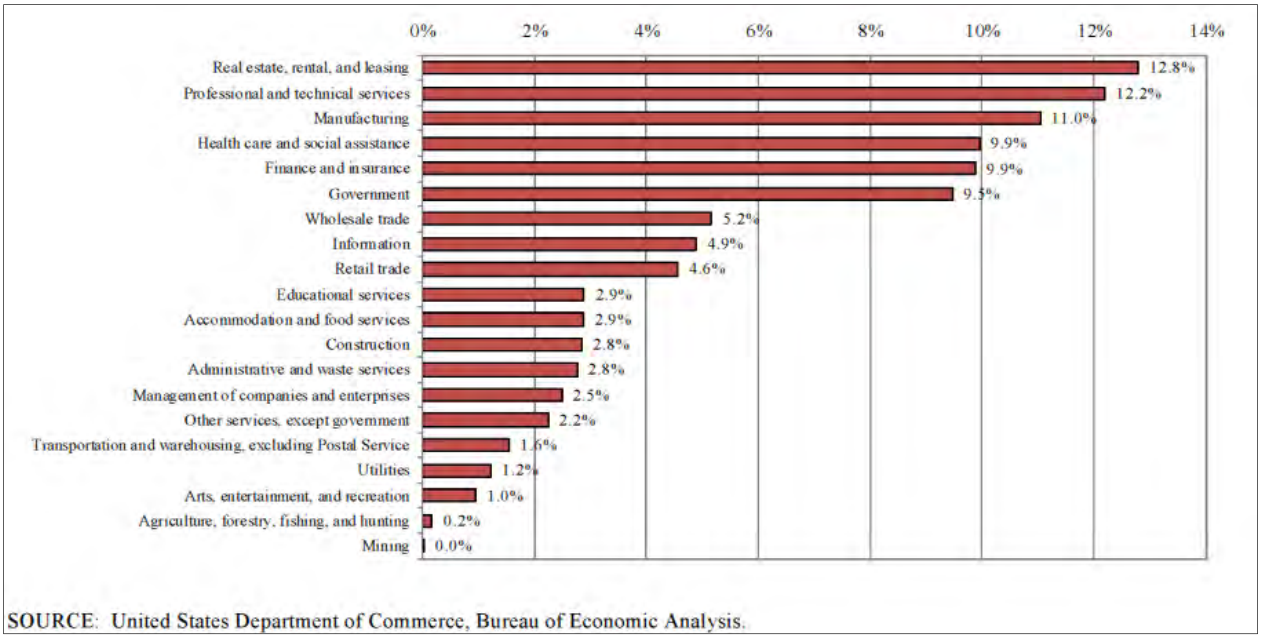


Figure 4-10. North American Industry Classification System (NAICS) Composition of Massachusetts Gross Domestic Product, 2011

TABLE 4-13. RANK OF INDUSTRY CONTRIBUTION TO MASSACHUSETTS GDP, 2002 – 2011

NAICS* Industry Sector	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total Gross Domestic Product by State										
Private industries										
Agriculture, forestry, fishing, and hunting	19	19	19	19	19	19	19	19	19	19
Mining	20	20	20	20	20	20	20	20	20	20
Utilities	17	17	17	17	17	17	17	17	17	17
Construction	9	9	9	10	10	10	10	10	10	12
Manufacturing	5	3	4	4	3	2	3	3	2	1
Wholesale trade	8	7	7	7	7	7	7	8	9	8
Retail trade	7	8	8	8	8	9	9	9	8	9
Transportation and warehousing, excluding Postal Service	16	16	16	16	16	16	16	16	16	16
Information	10	10	10	9	9	8	8	7	7	7
Finance and insurance	2	2	2	3	4	4	4	4	4	4
Real estate, rental, and leasing	1	1	1	1	1	1	1	1	1	2
Professional and technical services	3	4	3	2	2	3	2	2	3	3
Management of companies and enterprises	13	14	15	15	15	15	14	14	15	14
Administrative and waste services	15	13	13	11	11	11	11	11	11	10
Educational services	11	12	12	13	13	13	13	13	13	13
Health care and social assistance	6	6	6	6	5	5	5	5	5	5
Arts, entertainment, and recreation	18	18	18	18	18	18	18	18	18	18
Accommodation and food services	12	11	11	12	12	12	12	12	12	11
Other services, except government	14	15	14	14	14	14	15	15	14	15
Government	4	5	5	5	6	6	6	6	6	6

4.8.2 Trade Volume

Total trade volume (exports and imports) increased 7.0 percent, to $61 billion, from 2010 in 2011, returning to pre-recession levels. Canada, at $11.4 billion and 18.6 percent, was by far the Commonwealth's most valuable trading partner. The trade deficit, $5.7 billion, grew at a slower pace of 29.5 percent in 2011, versus 53.1 percent in 2010. Export and import data are as follows.

- Exports: Massachusetts ranked 15th in the United States in 2011 and first in New England with $27.7 billion in exports. This was a 5.5 percent increase from the previous year's export value from the Commonwealth, while national exports increased almost three times as much by 15.9 percent. Total exports from New England also grew by 4.2 percent. Canada was the Commonwealth's top export destination in 2011, with $3.7 billion.
- Imports: Imports grew to $33.4 billion in 2011 but at a slower pace, 8.8 percent, than in 2010. Canada was also the largest source for Massachusetts imports in 2011: $7.7 billion or 22.9 percent of the statewide total.

Figure 4-11, Figure 4-12 and Figure 4-13 summarize key trade data.

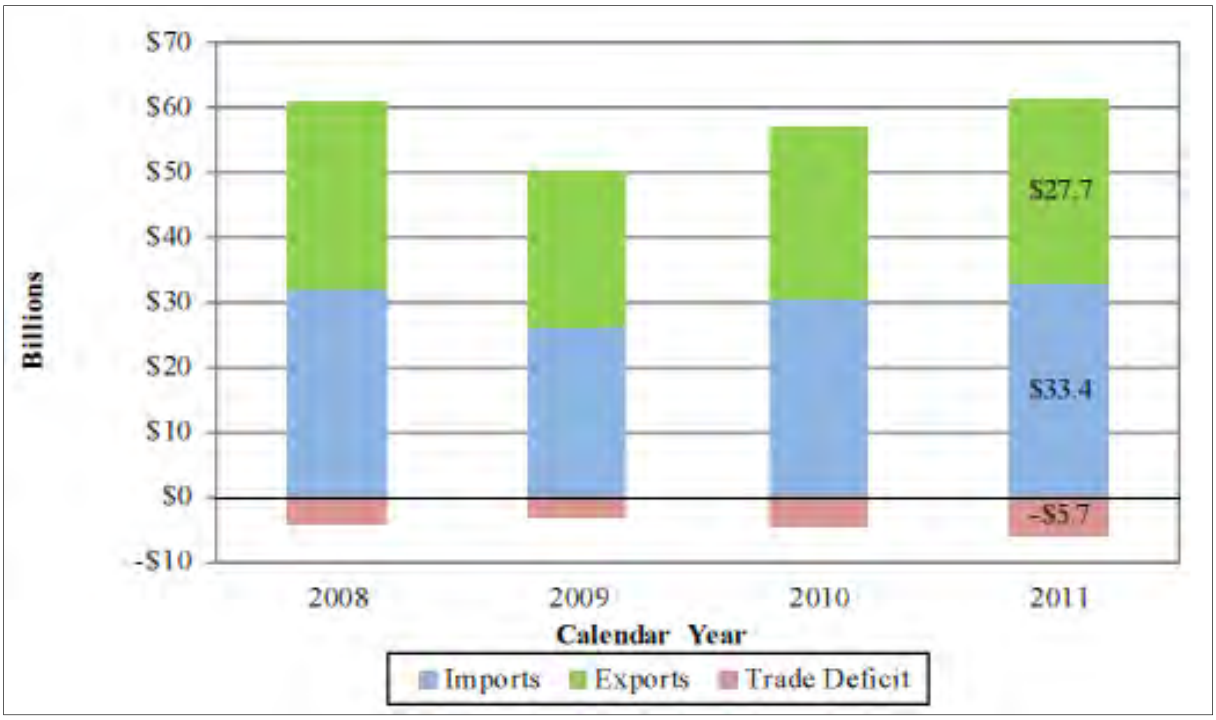


Figure 4-11. Massachusetts Imports, Exports and Trade Deficit

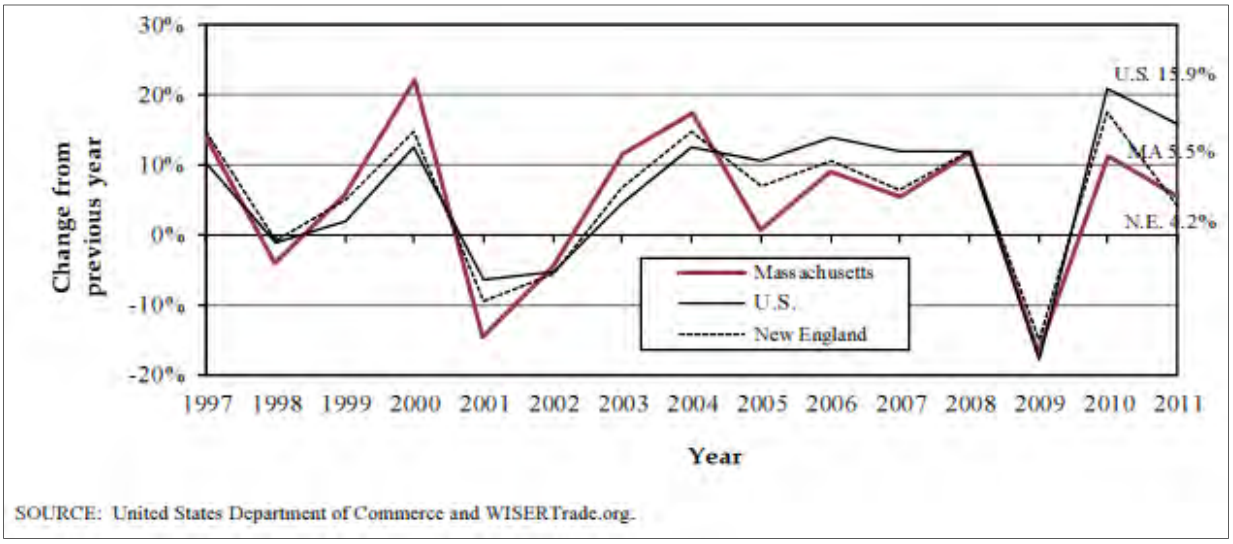


Figure 4-12. Export Growth for Massachusetts, U.S. and New England

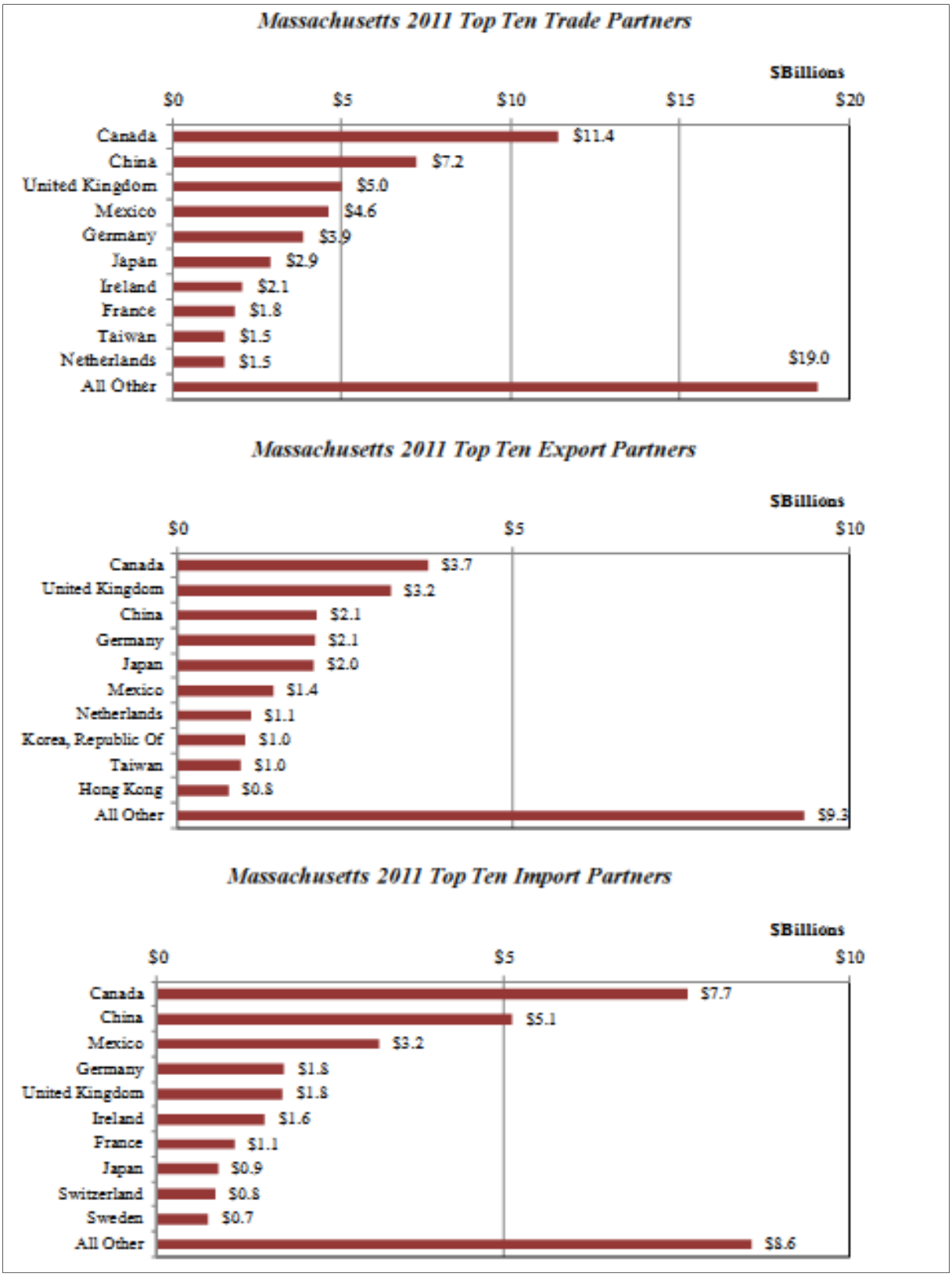


Figure 4-13. Top Ten Trade Partners by Trade Type

4.8.3 Agriculture

Agriculture information by county and for the entire state is provided in the following sections, based on 2007 reports from the U.S. Department of Agriculture Statistics Services. The reports are updated on a five-year cycle, but the 2012 reports were not yet available as of March 2013; they will be incorporated in the next plan update, as appropriate. Generalized data are presented in Table 4-14 through Table 4-16.

TABLE 4-14.
2011 TOP FIVE AGRICULTURE COMMODITIES

	Farm Receipts ($1,000s)	% of State Total	% of U.S. Total
1. Greenhouse/nursery	158,300	30.7	1.0
2. Cranberries	102,164	19.8	29.7
3. Dairy products	47,960	9.3	0.1
4. Aquaculture	21,900	4.2	1.6
5. Apples	20,569	4.0	0.9
All commodities	**515,598**		**0.1**

Source: http://www.ers.usda.gov/data-products/state-fact-sheets/state-data.aspx

TABLE 4-15.
2011 TOP FIVE AGRICULTURE EXPORTS

	Exports ($1 millions)	Rank Among States
1. Other products*	133.6	38
2. Fruits, fresh	39.3	13
3. Fruits, processed	25.1	13
4. Vegetables, processed	12.0	32
5. Vegetables, fresh	7.4	32
Total exports	**225.7**	**43**

Source: http://www.ers.usda.gov/data-products/state-fact-sheets/state-data.aspx
* Other products include live animals, other meats, animal parts, eggs, wine, beer, other beverages, coffee, cocoa, hops, nursery crops, pet food, inedible materials, and prepared foods.

TABLE 4-16.
2007 TOP 5 COUNTIES IN AGRICULTURAL SALES

	Total Receipts ($1,000s)	% of State
1. Middlesex County	81,708	16.7
2. Worcester County	80,550	16.4
3. Plymouth County	78,440	16.0
4. Franklin County	56,844	11.6
5. Bristol County	44,245	9.0
State Total	**489,820**	

Source: http://www.ers.usda.gov/data-products/state-fact-sheets/state-data.aspx

Statewide

In 2007, there were 7,691 farms in the Commonwealth, with a total land area of 517,879 acres. The average size of a farm was 67 acres. According to the 2007 Census of Agriculture, 3,688 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the Commonwealth was over $489.8 million, with total sales averaging $63,687. Crop sales, including nursery and greenhouse, accounted for over $364.4 million (74.4 percent) of total sales. Livestock, poultry and their products accounted for over $125.3 million (25.5 percent) of total sales. The lead agricultural products sold were nursery, greenhouse, floriculture and sod ($169.1 million); fruits, tree nuts and berries ($100.6 million); and vegetables, melons, potatoes, and sweet potatoes ($15.7 million) (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

Barnstable County

In 2007, there were 406 farms in Barnstable County, with a total land area of 5,233 acres. The average size of a farm was 13 acres. According to the 2007 Census of Agriculture, 217 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the County was over $17.6 million, with total sales averaging $43,475. Crop sales accounted for over $10.1 million (57.4 percent) of total sales. Livestock, poultry and their products accounted for over $7.5 million (42.5 percent) of total sales. The lead agricultural products sold were aquaculture ($7.3 million); fruits, tree nuts and berries ($5.4 million); and nursery, greenhouse, floriculture and sod ($3.8 million) (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

Berkshire County

Berkshire County has the third largest agricultural sector in the Commonwealth. In 2007, there were 522 farms in Berkshire County, with a total land area of 66,352 acres. The average size of a farm was 127 acres. According to the 2007 Census of Agriculture, 254 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the County was over $20.6 million, with total sales averaging $39,465. Crop sales accounted for $7.726 million (38 percent) of total sales. Livestock, poultry and their products accounted for $12.875 million (62 percent) of total sales. The lead agricultural products sold were milk and other dairy products from cows ($10.6 million); nursery, greenhouse, floriculture and sod ($2.6 million); and vegetables, melons, potatoes, and sweet potatoes ($2.1 million) (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

Bristol County

In 2007, there were 777 farms in Bristol County, with a total land area of 39,252 acres. The average size of a farm was 51 acres. According to the 2007 Census of Agriculture, 368 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the County was over $44.2 million, with total sales averaging $56,944. Crop sales accounted for $36.56 million (83 percent) of total sales. Livestock, poultry and their products accounted for $7.67 million (17 percent) of total sales. The lead agricultural products sold were nursery, greenhouse, floriculture and sod ($22.49 million); fruits, tree nuts and berries ($6.5 million); and vegetables, melons, potatoes, and sweet potatoes ($6.3 million) (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

Dukes County

In 2007, there were 81 farms in Dukes County, with a total land area of 7,916 acres. The average size of a farm was 98 acres. According to the 2007 Census of Agriculture, 37 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the County was over $3.3 million, with total sales averaging $41,193. Crop sales accounted for $2.261 million

(68 percent) of total sales. Livestock, poultry and their products accounted for $1.076 million (32 percent) of total sales. The lead agricultural products sold were nursery, greenhouse, floriculture and sod ($1.45 million); vegetables, melons, potatoes, and sweet potatoes ($714,000); and cattle and calves ($105,000) (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

Essex County

In 2007, there were 531 farms in Essex County, with a total land area of 27,834 acres. The average size of a farm was 52 acres. According to the 2007 Census of Agriculture, 240 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the County was over $25 million, with total sales averaging $47,122. Crop sales accounted for $18.9 million (76 percent) of total sales. Livestock, poultry and their products accounted for $6.03 million (24 percent) of total sales. The lead agricultural products sold were nursery, greenhouse, floriculture and sod ($11.5 million); fruits, tree nuts and berries ($2.05 million); and vegetables, melons, potatoes, and sweet potatoes ($3.9 million) (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

Franklin County

In 2007, there were 741 farms in Franklin County, with a total land area of 79,465 acres. The average size of a farm was 107 acres. According to the 2007 Census of Agriculture, 350 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the County was over $56.8 million, with total sales averaging $76,712. Crop sales accounted for $36.23 million (64 percent) of total sales. Livestock, poultry and their products accounted for over $20.614 million (36 percent) of total sales. The lead agricultural products sold were nursery, greenhouse, floriculture and sod ($16.25 million); milk and other dairy products from cows ($13.02 million); and vegetables, melons, potatoes, and sweet potatoes ($10.64 million) (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

Hampden County

In 2007, there were 508 farms in Hampden County, with a total land area of 36,841 acres. The average size of a farm was 73 acres. According to the 2007 Census of Agriculture, 226 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the County was $25.735 million, with total sales averaging $50,659. Crop sales accounted for $21.424 million (83 percent) of total sales. Livestock, poultry and their products accounted for $4.311 million (17 percent) of total sales. The lead agricultural products sold were nursery, greenhouse, floriculture and sod ($7.58 million); vegetables, melons, potatoes, and sweet potatoes ($7.34 million); and milk and other dairy products from cows ($2.7 million) (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

Hampshire County

In 2007, there were 711 farms in Hampshire County, with a total land area of 52,756 acres. The average size of a farm was 74 acres. According to the 2007 Census of Agriculture, 358 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the County was over $38.6 million, with total sales averaging $54,314. Crop sales accounted for over $28.5 million (74 percent) of total sales. Livestock, poultry and their products accounted for over $10.1 million (26 percent) of total sales. The lead agricultural products sold were vegetables, melons, potatoes, and sweet potatoes ($13.02 million); milk and other dairy products from cows ($6.25 million); and tobacco ($5.7 million) (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

Middlesex County

In 2007, there were 700 farms in Middlesex County, with a total land area of 33,893 acres. The average size of a farm was 48 acres. According to the 2007 Census of Agriculture, 341 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the County was over $81.7 million, with total sales averaging $116,726. Crop sales accounted for over $68.7 million (84 percent) of total sales. Livestock, poultry and their products accounted for over $12.9 million (16 percent) of total sales. The lead agricultural products sold were nursery, greenhouse, floriculture and sod ($56.7 million); other animals and other animal products ($6.7 million); and vegetables, melons, potatoes, and sweet potatoes ($6.2 million) (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

Nantucket County

In 2007, there were 14 farms in Nantucket County, with a total area of 615 acres. The average farm size was 44 acres. According to the 2007 Census of Agriculture, 12 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the County was over $2.8 million, with total sales averaging $206,131. Crop and livestock sales information was not provided. Information regarding lead agricultural products sold was not provided in the 2007 Census of Agriculture (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

Norfolk County

In 2007, there were 264 farms in Norfolk County, with a total land area of 11,654 acres. The average size of a farm was 44 acres. According to the 2007 Census of Agriculture, 126 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the County was over $13.9 million, with total sales averaging $52,926. Crop sales accounted for over $12.9 million (93 percent) of total sales. Livestock, poultry and their products accounted for over $987,000 (7 percent) of total sales. The lead agricultural products sold were nursery, greenhouse, floriculture and sod ($8.1 million); horses, ponies, mules, burros and donkeys ($420,000); and other crops and hay ($317,000) (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

Plymouth County

In 2007, there were 882 farms in Plymouth County, with a total land area of 49,612 acres. The average size of a farm was 56 acres. According to the 2007 Census of Agriculture, 464 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the County was over $78.4 million, with total sales averaging $88,935. Crop sales accounted for over $73.08 million (93 percent) of total sales. Livestock, poultry and their products accounted for over $5.3 million (7 percent) of total sales. The lead agricultural products sold were fruits, tree nuts and berries ($60.5 million); nursery, greenhouse, floriculture, and sod ($9.6 million); and aquaculture ($3.3 million) (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

Suffolk County

The 2007 Census of Agriculture Profiles was not provided for Suffolk County.

Worcester County

In 2007, there were 1,547 farms in Worcester County, with a total land area of 106,357 acres. The average size of a farm was 69 acres. According to the 2007 Census of Agriculture, 690 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the County was over $80.5 million, with total sales averaging $52,069. Crop sales accounted for over $44.7 million (55 percent) of total sales. Livestock, poultry and their products accounted for over

$35.8 million (45 percent) of total sales. The lead agricultural products sold were nursery, greenhouse, floriculture and sod ($23.3 million); fruits, tree nuts and berries ($10.4 million); and milk and other dairy products from cows ($9.2 million) (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

4.8.4 Local County Business Patterns

The County Business Pattern is an annual U.S. Census Bureau series that presents sub-national economic data by industry. It covers most of Massachusetts' economic activity.

Statewide

According to the 2010 County Business Patterns, Massachusetts had 169,790 business establishments. The retail trade industry had the highest number of establishments in the Commonwealth, making up 14.38 percent of all businesses. Following retail trade was professional, scientific, and technical services, making up 12.56 percent of all business. The third largest industry in 2010 was health care and social assistance, making up 10.66 percent of all businesses. Table 4-17 provides 2010 industry and employment information for the Commonwealth.

TABLE 4-17.
2010 ECONOMIC CENSUS FOR MASSACHUSETTS

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	16,437	$4,813,348	252,157
Administrative and support and waste management and remediation services	9,730	$7,431,235	191,267
Agriculture, forestry, fishing and hunting	356	$31,955	1,061
Arts, entertainment, and recreation	3,050	$1,738,271	51,323
Construction	16,844	$6,233,410	102,086
Educational services	2,669	$7,560,289	192,514
Finance and insurance	9,437	$20,673,481	197,247
Health care and social assistance	18,102	$26,344,109	564,011
Industries not classified	473	$13,900	630
Information	3,492	$8,363,745	96,450
Management of companies and enterprises	1,141	$9,227,956	84,941
Manufacturing	6,907	$13,898,053	226,698
Mining, quarrying, and oil and gas extraction	86	$82,834	1,039
Other services (except public administration)	16,947	$3,442,274	116,647
Professional, scientific, and technical services	21,334	$22,751,895	247,470
Real estate and rental and leasing	6,366	$2,357,982	41,659
Retail trade	24,412	$9,163,826	343,890
Transportation and warehousing	3,565	$2,947,799	75,037
Utilities	281	$1,318,818	12,861
Wholesale trade	8,161	$10,009,076	129,557

Source: U.S. Census, 2010
* = This number only includes paid employees

Barnstable County

Barnstable County had 8,214 business establishments in 2010. The retail trade industry had the highest number of establishments, making up 18.41 percent of all businesses. Following retail trade was accommodations and food services, making up 13.51 percent of all business. The third highest industry in 2010 was construction, making up 12.17 percent of all businesses. Table 4-18 provides 2010 industry and employment information for Barnstable County.

TABLE 4-18.
2010 ECONOMIC CENSUS FOR BARNSTABLE COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	1,110	$42,295	10,593
Administrative and support and waste management and remediation services	594	$17,551	2,534
Agriculture, forestry, fishing and hunting	37	$293	58
Arts, entertainment, and recreation	224	$10,792	1,688
Construction	1,000	$38,477	3,827
Educational services	96	$8,460	1,196
Finance and insurance	348	$35,103	2,321
Health care and social assistance	805	$147,886	15,519
Industries not classified	18	$148	33
Information	138	$16,051	1,451
Management of companies and enterprises	22	$8,013	532
Manufacturing	184	$24,541	2,065
Mining, quarrying, and oil and gas extraction	4	D	b
Other services (except public administration)	697	$24,405	3,822
Professional, scientific, and technical services	733	$57,391	4,624
Real estate and rental and leasing	333	$9,843	1,191
Retail trade	1,512	$83,407	14,131
Transportation and warehousing	144	$12,797	1,596
Utilities	9	$8,816	336
Wholesale trade	206	$13,415	1,260

Source: U.S. Census, 2010
* = This number only includes paid employees
b = 20-99 employees
D = Withheld to avoid disclosing data for individual companies; data are included in higher level totals

In 2007, the majority of jobs on Cape Cod were in two sectors tied to tourism: retail (18 percent) and accommodation and food services (15 percent). The average annual wage in the retail sector was $27,557, while average wage in accommodations and food service was $19,829. The 2007 County average wage was $37,691. Actual wages in both sectors may be marginally higher because employment data do not account for the many part-time or seasonal jobs in these industries. A significant portion of activity in

these industries is related to tourism and second homeowners, particularly on the Outer Cape, where the year-round population is very small.

The Cape Cod economy is made up of trade sectors and local service sectors. The dominant trade sector is tourism (tourists and second homeowners earn their money off-Cape but spend it on Cape Cod). Traditional industries such as fishing, shell-fishing, and cranberry cultivation are trade/export sectors. Based on previous research, Cape Cod has a number of emerging industries with the potential to diversify and expand the region's economy. These include marine research and technology, arts and culture, information and related technology, renewable energy and related technology, and education and knowledge creation.

Unemployment in Barnstable County is greatly influenced by the seasonality of the Cape's summer tourist season, with employers either eliminating or reducing staff during the fall, winter, and spring. The Lower/Outer Cape, in particular, experiences high unemployment during the off-season. Provincetown's unemployment rate is well above 20 percent for six months of the year. The average annual rate of unemployment for the Lower/Outer Cape from May 2008 through April 2009 was 7 to 10 percent, while the average for Provincetown was 10 percent. In the Barnstable Metropolitan Statistical Area, which includes all of Cape Cod, the unemployment rate was 4.8 percent in May 2008, with the state rate at 4.9 percent. The unemployment rate in the Metropolitan Statistical Area was 7.8 percent in May 2009.

Berkshire County

Much of Berkshire County is rural, but the economy is dominated by the health care and social assistance industries. The three largest employers in the Berkshires are Berkshire Health Systems, Pittsfield Public Schools, and General Dynamic Advanced Information Systems. Based on the American Community Survey of 2006-2008, the per capita personal income estimate for the County was $28,074. The labor force (16 years and older) was 73,188. The 2009 annual average unemployment for the region was 5,892 and was at a rate of 8.1 percent. The unemployment trend for the County shows a gradual trend of increased unemployment until 2004; in 2007 the number of unemployed individuals rose sharply.

Berkshire County had 4,029 business establishments in 2010. The retail trade industry had the highest number of establishments in the County, making up 17.65 percent of all businesses. Following retail trade was construction, making up 12.88 percent of all business. The third highest industry in 2010 was accommodation and food services, making up 12.56 percent of all businesses in Berkshire County. Table 4-19 provides 2010 industry and employment information for Berkshire County.

TABLE 4-19.
2010 ECONOMIC CENSUS FOR BERKSHIRE COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	506	$134,434	7,385
Administrative and support and waste management and remediation services	223	$61,437	1,554
Agriculture, forestry, fishing and hunting	10	$1,097	41
Arts, entertainment, and recreation	102	$40,155	1,628
Construction	519	$115,211	2,381
Educational services	58	$135,240	4,083
Finance and insurance	168	$124,946	2,249

TABLE 4-19.
2010 ECONOMIC CENSUS FOR BERKSHIRE COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Health care and social assistance	436	$463,485	11,291
Industries not classified	14	$332	b
Information	74	$48,582	978
Management of companies and enterprises	16	$83,611	779
Manufacturing	158	$273,718	4,911
Mining, quarrying, and oil and gas extraction	5	$3,509	81
Other services (except public administration)	359	$49,400	2,213
Professional, scientific, and technical services	361	$152,612	2,559
Real estate and rental and leasing	118	$23,831	742
Retail trade	711	$209,062	8,576
Transportation and warehousing	64	$21,032	779
Utilities	13	D	c
Wholesale trade	114	$55,556	1,217

Source: U.S. Census, 2010
* = This number only includes paid employees
b = 20-99 employees
c = 100-249 employees
D = Withheld to avoid disclosing data for individual companies; data are included in higher level totals

Bristol County

Bristol County had 12,804 business establishments in 2010. The retail trade industry had the highest number of establishments in the County, making up 17.46 percent of all businesses. Following retail trade was construction, making up 11.81 percent of all business. The third highest industry in 2010 was health care and social assistance, making up 10.9 percent of all businesses in Bristol County. Table 4-20 provides 2010 industry and employment information for Bristol County.

TABLE 4-20.
2010 ECONOMIC CENSUS FOR BRISTOL COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	1,234	$272,470	18,948
Administrative and support and waste management and remediation services	669	$226,263	7,484
Agriculture, forestry, fishing and hunting	117	$4,502	300
Arts, entertainment, and recreation	210	$65,489	3,406
Construction	1,512	$383,750	6,897

TABLE 4-20.
2010 ECONOMIC CENSUS FOR BRISTOL COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Educational services	151	$116,670	5,026
Finance and insurance	573	$275,992	5,721
Health care and social assistance	1,396	$1,561,840	39,023
Industries not classified	34	$798	36
Information	164	$168,956	3,194
Management of companies and enterprises	64	$544,180	5,193
Manufacturing	717	$1,524,341	27,739
Mining, quarrying, and oil and gas extraction	4	D	b
Other services (except public administration)	1,272	$177,724	7,527
Professional, scientific, and technical services	1,075	$295,852	6,025
Real estate and rental and leasing	425	$63,730	1,787
Retail trade	2,236	$812,974	33,108
Transportation and warehousing	347	$253,777	7,392
Utilities	25	$70,381	886
Wholesale trade	579	$862,762	13,026

Source: U.S. Census, 2010
* = This number only includes paid employees
b = 20-99 employees
D = Withheld to avoid disclosing data for individual companies; data are included in higher level totals

Dukes County

Dukes County had 1,007 business establishments in 2010. The construction industry had the highest number of establishments in the County, making up 19.27 percent of all businesses. Following construction was retail trade, making up 19.07 percent of all business. The third highest industry in 2010 was accommodation and food services, making up 12.61 percent of all businesses in Dukes County. Table 4-21 provides 2010 industry and employment information for Dukes County.

TABLE 4-21.
2010 ECONOMIC CENSUS FOR DUKES COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	127	$32,095	553
Administrative and support and waste management and remediation services	71	$16,605	259
Agriculture, forestry, fishing and hunting	1	D	a
Arts, entertainment, and recreation	39	$14,918	223
Construction	194	$35,215	657
Educational services	8	$1,123	31
Finance and insurance	29	D	e
Health care and social assistance	57	$37,144	703
Industries not classified	4	$131	2
Information	17	$5,504	126
Management of companies and enterprises	1	D	a
Manufacturing	18	$4,047	105
Mining, quarrying, and oil and gas extraction	72	$8,922	276
Other services (except public administration)	70	$13,098	232
Professional, scientific, and technical services	56	$6,283	138
Real estate and rental and leasing	192	$42,477	1,024
Retail trade	127	$32,095	553
Transportation and warehousing	29	$7,112	154
Utilities	3	D	b
Wholesale trade	19	$1,723	48

Source: U.S. Census, 2010
* = This number only includes paid employees
a = 0-19 employees
b = 20-99 employees
D = Withheld to avoid disclosing data for individual companies; data are included in higher level totals

Essex County

Essex County had 17,877 business establishments in 2010. The retail trade industry had the highest number of establishments in the County, making up 14.35 percent of all businesses. Following retail trade was professional, scientific, and technical services, making up 11.96 percent of all business. The third highest industry in 2010 was health care and social assistance, making up 11.45 percent of all businesses in Essex County. Table 4-22 provides 2010 industry and employment information for Essex County.

TABLE 4-22.
2010 ECONOMIC CENSUS FOR ESSEX COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	1,740	$413,217	24,023
Administrative and support and waste management and remediation services	1,026	$527,708	14,747
Agriculture, forestry, fishing and hunting	74	$11,403	253
Arts, entertainment, and recreation	370	$122,568	5,958
Construction	1,794	$556,012	9,203
Educational services	269	$276,428	8,972
Finance and insurance	910	$779,905	10,497
Health care and social assistance	2,047	$2,317,626	56,395
Industries not classified	45	$1,317	65
Information	314	$479,865	6,766
Management of companies and enterprises	98	$714,905	6,569
Manufacturing	877	$2,487,017	37,346
Mining, quarrying, and oil and gas extraction	4	$2,383	39
Other services (except public administration)	1,795	$281,555	11,145
Professional, scientific, and technical services	2,138	$968,907	13,429
Real estate and rental and leasing	578	$103,323	2,599
Retail trade	2,565	$997,371	37,026
Transportation and warehousing	334	$174,857	4,937
Utilities	27	D	f
Wholesale trade	872	$978,918	12,192

Source: U.S. Census, 2010
* = This number only includes paid employees
D = Withheld to avoid disclosing data for individual companies; data are included in higher level totals
f = 500-999 employees

Franklin County

Franklin County had 1,590 business establishments in 2010. The retail trade industry had the highest number of establishments in the County, making up 17.17 percent of all businesses. Following retail trade was other services (except public transportation), making up 11.89 percent of all business. The third highest industry in 2010 was health care and social assistance, making up 11.01 percent of all businesses in Franklin County. Table 4-23 provides 2010 industry and employment information for Franklin County.

TABLE 4-23.
2010 ECONOMIC CENSUS FOR FRANKLIN COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	158	$26,355	1,860
Administrative and support and waste management and remediation services	77	$13,064	528
Agriculture, forestry, fishing and hunting	6	$652	b
Arts, entertainment, and recreation	37	$8,784	572
Construction	168	$29,618	642
Educational services	33	$53,640	1,243
Finance and insurance	56	$24,979	564
Health care and social assistance	175	$119,688	3,319
Industries not classified	5	$134	a
Information	31	$21,530	474
Management of companies and enterprises	11	$40,470	500
Manufacturing	108	$168,870	3,882
Mining, quarrying, and oil and gas extraction	3	$1,857	b
Other services (except public administration)	189	$15,320	719
Professional, scientific, and technical services	120	$19,081	482
Real estate and rental and leasing	37	$2,797	143
Retail trade	273	$76,250	2,919
Transportation and warehousing	33	$13,815	454
Utilities	6	$13,674	138
Wholesale trade	64	$43,273	873

Source: U.S. Census, 2010
* = This number only includes paid employees
a = 0-19 employees
b = 20-99 employees

Hampden County

Hampden County had 9,709 business establishments in 2010. The retail trade industry had the highest number of establishments in the County, making up 16.23 percent of all businesses. Following retail trade was health care and social assistance, making up 11.84 percent of all business. The third highest industry in 2010 was other services (except public administration), making up 10.85 percent of all businesses in Hampden County. Table 4-24 provides 2010 industry and employment information for Hampden County.

TABLE 4-24.
2010 ECONOMIC CENSUS FOR HAMPDEN COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	932	$205,534	14,258
Administrative and support and waste management and remediation services	543	$188,117	6,316
Agriculture, forestry, fishing and hunting	13	$1,188	b
Arts, entertainment, and recreation	138	$53,107	3,510
Construction	895	$355,691	5,851
Educational services	142	$209,020	8,805
Finance and insurance	522	$734,459	10,114
Health care and social assistance	1,150	$1,468,126	37,004
Industries not classified	14	$236	a
Information	117	$136,896	2,835
Management of companies and enterprises	56	$200,098	2,701
Manufacturing	608	$1,023,434	20,243
Mining, quarrying, and oil and gas extraction	7	$2,718	b
Other services (except public administration)	1,053	$182,874	7,813
Professional, scientific, and technical services	866	$433,676	7,210
Real estate and rental and leasing	349	$64,421	1,993
Retail trade	1,576	$556,754	22,586
Transportation and warehousing	243	$183,587	4,877
Utilities	19	$116,808	1,223
Wholesale trade	466	$324,651	6,393

Source: U.S. Census, 2010
* = This number only includes paid employees
a = 0-19 employees
b = 20-99 employees

Hampshire County

Hampshire County had 3,541 business establishments in 2010. The retail trade industry had the highest number of establishments in the County, making up 15.42 percent of all businesses. Following retail trade was health care and social assistance, making up 12.34 percent of all business. The third highest industry in 2010 was other services (except public administration), making up 10.84 percent of all businesses in Hampshire County. Table 4-25 provides 2010 industry and employment information for Hampshire County.

TABLE 4-25.
2010 ECONOMIC CENSUS FOR HAMPSHIRE COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	369	$76,468	5,329
Administrative and support and waste management and remediation services	184	$37,003	1,313
Agriculture, forestry, fishing and hunting	15	$833	53
Arts, entertainment, and recreation	77	$10,900	560
Construction	383	$67,272	1,534
Educational services	99	$270,749	8,715
Finance and insurance	149	$75,253	1,445
Health care and social assistance	437	$468,893	17,184
Industries not classified	14	$183	15
Information	67	$53,677	1,011
Management of companies and enterprises	10	$6,308	177
Manufacturing	142	$172,258	3,408
Mining, quarrying, and oil and gas extraction	7	$1,688	b
Other services (except public administration)	384	$52,232	2,022
Professional, scientific, and technical services	358	$78,522	1,630
Real estate and rental and leasing	115	$13,756	464
Retail trade	546	$184,987	7,620
Transportation and warehousing	63	$22,787	837
Utilities	7	$10,157	c
Wholesale trade	115	$81,772	1,709

Source: U.S. Census, 2010
* = This number only includes paid employees
b = 20-99 employees
c = 100-249 employees

Middlesex County

Middlesex County had 42,001 business establishments in 2010. The professional, scientific, and technical services industry had the highest number of establishments in the County, making up 16.29 percent of all businesses. Following was retail trade, making up 12.29 percent of all business. The third highest industry in 2010 was health care and social assistance, making up 10.71 percent of all businesses in Middlesex County. Table 4-26 provides 2010 industry and employment information for Middlesex County.

TABLE 4-26.
2010 ECONOMIC CENSUS FOR MIDDLESEX COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	3,536	$1,056,359	54,684
Administrative and support and waste management and remediation services	2,456	$2,386,379	51,483
Agriculture, forestry, fishing and hunting	22	$2,530	70
Arts, entertainment, and recreation	694	$211,703	9,388
Construction	3,924	$1,733,556	27,274
Educational services	739	$3,485,394	72,824
Finance and insurance	2,092	$2,314,512	29,081
Health care and social assistance	4,497	$5,155,772	108,178
Industries not classified	131	$4,368	190
Information	1,216	$4,767,443	43,498
Management of companies and enterprises	392	$4,927,407	40,967
Manufacturing	1,685	$4,147,982	56,239
Mining, quarrying, and oil and gas extraction	13	$3,389	b
Other services (except public administration)	4,001	$910,828	28,755
Professional, scientific, and technical services	6,842	$12,023,009	117,900
Real estate and rental and leasing	1,537	$648,278	11,280
Retail trade	5,162	$2,250,156	79,241
Transportation and warehousing	730	$581,282	16,029
Utilities	47	$254,344	2,013
Wholesale trade	2,285	$4,008,575	42,395

Source: U.S. Census, 2010
* = This number only includes paid employees
b = 20-99 employees

Nantucket County

Nantucket County had 887 business establishments in 2010. The construction industry had the highest number of establishments in the County, making up 25.48 percent of all businesses. Following construction was retail trade, making up 13.08 percent of all business. The third highest industry in 2010 was accommodation and food services, making up 13.08 percent of all businesses in Nantucket County. Table 4-27 provides 2010 industry and employment information for Nantucket County.

TABLE 4-27.
2010 ECONOMIC CENSUS FOR NANTUCKET COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	116	$35,134	544
Administrative and support and waste management and remediation services	106	$30,349	367
Agriculture, forestry, fishing and hunting	1	D	a
Arts, entertainment, and recreation	25	$13,253	172
Construction	226	$29,516	550
Educational services	7	$2,545	b
Finance and insurance	15	$8,508	124
Health care and social assistance	31	D	e
Industries not classified	1	D	a
Information	13	$4,406	81
Management of companies and enterprises	2	D	a
Manufacturing	10	$1,255	27
Mining, quarrying, and oil and gas extraction	1	D	a
Other services (except public administration)	51	$7,778	167
Professional, scientific, and technical services	51	$10,040	154
Real estate and rental and leasing	54	$6,526	102
Retail trade	150	$34,718	751
Transportation and warehousing	16	$3,399	74
Utilities	1	D	a
Wholesale trade	10	$2,695	36

Source: U.S. Census, 2010
* = This number only includes paid employees
a = 0-19 employees
b = 20-99 employees
D = Withheld to avoid disclosing data for individual companies; data are included in higher level totals
e = 250-499 employees

Norfolk County

Norfolk County had 19,033 business establishments in 2010. The professional, scientific, and technical services industry had the highest number of establishments in the County, making up 13.63 percent of all businesses. Following was retail trade, making up 13.42 percent of all business. The third highest industry in 2010 was health care and social assistance, making up 11.14 percent of all businesses in Norfolk County. Table 4-28 provides 2010 industry and employment information for Norfolk County.

TABLE 4-28.
2010 ECONOMIC CENSUS FOR NORFOLK COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	1,510	$435,943	24,072
Administrative and support and waste management and remediation services	1,105	$725,197	18,212
Agriculture, forestry, fishing and hunting	8	$1,307	b
Arts, entertainment, and recreation	289	$269,140	5,727
Construction	1,980	$987,868	16,229
Educational services	290	$455,948	12,757
Finance and insurance	1,199	$2,068,011	25,184
Health care and social assistance	2,120	$2,196,735	58,977
Industries not classified	71	$3,200	114
Information	390	$814,165	11,863
Management of companies and enterprises	119	$625,715	6,513
Manufacturing	615	$1,207,986	19,658
Mining, quarrying, and oil and gas extraction	13	$10,616	160
Other services (except public administration)	1,876	$409,979	13,560
Professional, scientific, and technical services	2,595	$1,755,459	20,871
Real estate and rental and leasing	776	$377,900	6,445
Retail trade	2,554	$1,150,010	41,677
Transportation and warehousing	374	$301,937	6,692
Utilities	23	D	g
Wholesale trade	1,126	$1,317,474	17,852

Source: U.S. Census, 2010
* = This number only includes paid employees
b = 20-99 employees
D = Withheld to avoid disclosing data for individual companies; data are included in higher level totals
g = 1,000-2,499 employees

Plymouth County

Plymouth County had 11,786 business establishments in 2010. The retail trade industry had the highest number of establishments in the County, making up 16.17 percent of all businesses. Following retail trade was construction, making up 12.47 percent of all business. The third highest industry in 2010 was professional, scientific, and technical services, making up 10.68 percent of all businesses in Plymouth County. Table 4-29 provides 2010 industry and employment information for Plymouth County.

TABLE 4-29.
2010 ECONOMIC CENSUS FOR PLYMOUTH COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	1,022	$263,662	16,260
Administrative and support and waste management and remediation services	733	$446,140	9,926
Agriculture, forestry, fishing and hunting	17	$2,151	b
Arts, entertainment, and recreation	254	$75,496	3,233
Construction	1,470	$457,654	7,825
Educational services	151	$88,323	3,078
Finance and insurance	646	$428,400	6,376
Health care and social assistance	1,184	$1,156,930	28,064
Industries not classified	23	$286	36
Information	156	$129,133	2,320
Management of companies and enterprises	94	$429,355	4,071
Manufacturing	488	$502,858	10,108
Mining, quarrying, and oil and gas extraction	8	$7,759	126
Other services (except public administration)	1,127	$197,573	7,087
Professional, scientific, and technical services	1,259	$377,043	6,901
Real estate and rental and leasing	353	$55,949	1,352
Retail trade	1,906	$694,271	26,737
Transportation and warehousing	273	$156,461	4,231
Utilities	29	$150,047	1,446
Wholesale trade	593	$401,221	6,309

Source: U.S. Census, 2010
* = This number only includes paid employees
b = 20-99 employees

Suffolk County

Suffolk County had 19,525 business establishments in 2010. The professional, scientific, and technical services industry had the highest number of establishments in the County, making up 15.45 percent of all businesses. Following was retail trade, making up 12.32 percent of all business. The third highest industry in 2010 was accommodations and food services, making up 12.11 percent of all businesses in Suffolk County. Table 4-30 provides 2010 industry and employment information for Suffolk County.

TABLE 4-30.
2010 ECONOMIC CENSUS FOR SUFFOLK COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	2,364	$1,217,512	50,140
Administrative and support and waste management and remediation services	957	$1,354,295	34,891
Agriculture, forestry, fishing and hunting	7	$2,051	35
Arts, entertainment, and recreation	311	$702,720	10,707
Construction	837	$708,000	8,872
Educational services	348	$1,983,295	52,516
Finance and insurance	1,796	$12,660,951	87,124
Health care and social assistance	1,775	$7,967,937	129,045
Industries not classified	55	$1,461	63
Information	521	$1,331,836	16,557
Management of companies and enterprises	173	$1,443,162	14,566
Manufacturing	324	$529,421	9,688
Mining, quarrying, and oil and gas extraction	3	$1,483	b
Other services (except public administration)	2,318	$743,922	20,488
Professional, scientific, and technical services	3,017	$5,359,292	50,862
Real estate and rental and leasing	1,045	$837,863	10,792
Retail trade	2,405	$819,739	30,157
Transportation and warehousing	488	$819,823	16,952
Utilities	26	$167,508	1,574
Wholesale trade	755	$769,768	11,037

Source: U.S. Census, 2010
* = This number only includes paid employees
b = 20-99 employees

Worcester County

Worcester County had 17,625 business establishments in 2010. The retail trade industry had the highest number of establishments in the County, making up 14.88 percent of all businesses. Following retail trade was health care and social assistance, making up 11.28 percent of all business. The third highest industry in 2010 was construction, making up 11.02 percent of all businesses in Worcester County. Table 4-31 provides 2010 industry and employment information for Worcester County.

TABLE 4-31.
2010 ECONOMIC CENSUS FOR WORCESTER COUNTY

Industry	Number of Establishments	Annual Payroll ($1,000)	Number of Employees*
Accommodation and food services	1,713	$353,645	23,508
Administrative and support and waste management and remediation services	958	$377,315	11,326
Agriculture, forestry, fishing and hunting	28	$2,311	86
Arts, entertainment, and recreation	280	$86,586	4,551
Construction	1,942	$584,416	10,344
Educational services	276	$444,708	13,208
Finance and insurance	888	$970,364	15,741
Health care and social assistance	1,988	$2,708,757	58,069
Industries not classified	44	$718	b
Information	260	$302,450	4,933
Management of companies and enterprises	83	$176,487	2,360
Manufacturing	973	$1,747,841	31,279
Mining, quarrying, and oil and gas extraction	12	$8,823	134
Other services (except public administration)	1,751	$291,207	11,046
Professional, scientific, and technical services	1,829	$978,263	14,218
Real estate and rental and leasing	590	$109,175	2,631
Retail trade	2,622	$934,316	38,335
Transportation and warehousing	427	$342,412	10,033
Utilities	45	D	h
Wholesale trade	916	$767,405	12,615

Source: U.S. Census, 2010
* = This number only includes paid employees
b = 20-99 employees
D = Withheld to avoid disclosing data for individual companies; data are included in higher level totals
h = 2,500-4,999 employees

4.8.5 Employment

Employment by Industry

Like many industrial states, Massachusetts has seen a steady decline of its machinery manufacturing jobs base over the last several years, reflected in both the number of jobs and the share of total employment. Several service sectors have grown to take the place of manufacturing. These service sectors now account for over half of the total payroll employment, while financial activities, government, information, trade, transportation, and utilities have remained level, or in some instances, have declined share of economic growth. Between 2000 and 2010 (latest data available), several industries grew faster than the state average, while others fell significantly as shown in Table 4-32.

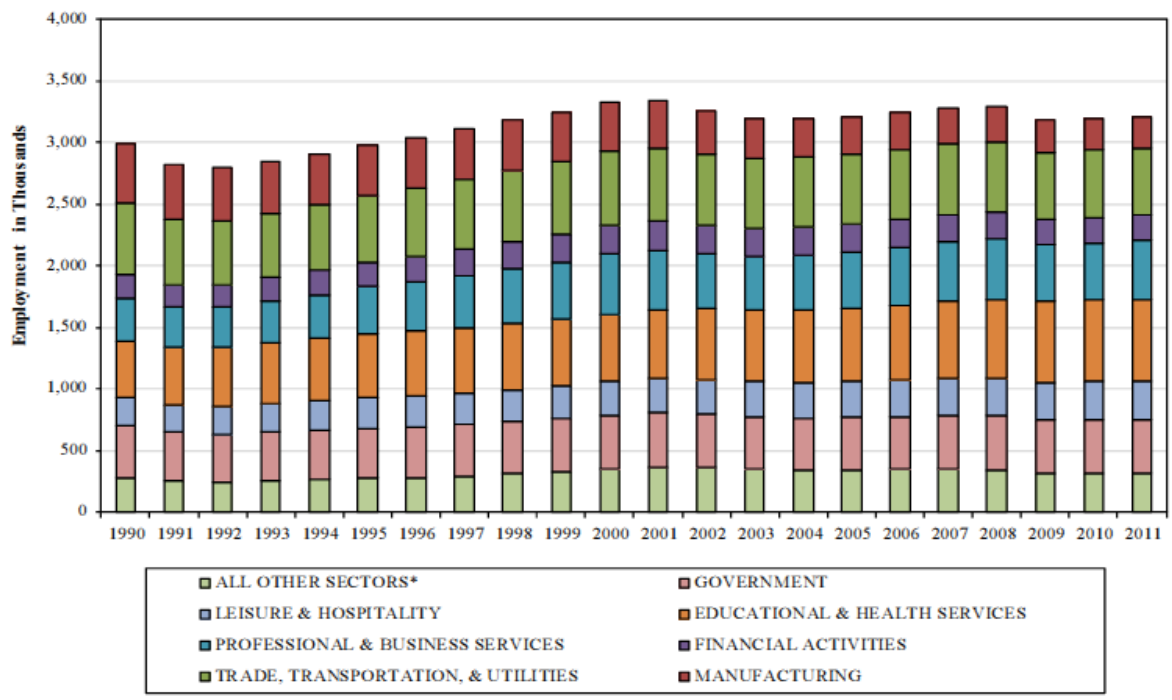
TABLE 4-32. INDUSTRY SUBSECTORS WITH SUBSTANTIAL GROWTH OR REDUCTION

NAICS* Industry Subsector	Percent change 2000-2010
Computer and electronic product manufacturing	371.5%
Information and data processing services	220.6%
Publishing industries, except Internet	73.2%
Computer systems design and related services	65.9%
Rental and leasing services and lessors of intangible assets	-10.4%
Fabricated metal product manufacturing	-12.1%
Insurance carriers and related activities	-15.6%
Machinery manufacturing	-18.7%

Note: Subsector represents at least a half percent of Massachusetts GDP in the latest year.
SOURCE: United States Department of Commerce, Bureau of Economic Analysis. Updated June 2012.
*North American Industry Classification System.

Rebounding from significant declines in 2002 and 2004, non-agricultural employment in Massachusetts increased 0.5 percent in 2005 and continued to increase annually through 2008. With continued growth in 2010 (0.3 percent) and in 2011 (0.6 percent), non-agricultural employment remains 3.9 percent below its all-time peak in 2001. Nationwide, 2011 non-agricultural employment was up 1.1 percent from 2010, but down 0.4 percent from 2001. The seasonally adjusted estimate for the Commonwealth is 142,000 below the 2001 peak.

Figure 4-14 through Figure 4-16 provide the annual average employment breakdown according to the Massachusetts Division of Unemployment Assistance for the time period 1990-2011.



SOURCE: MA Division of Unemployment Assistance.
*Includes Mining & Natural Resources, Construction, Information, and Other Services.

Figure 4-14. Annual Average Employment in Massachusetts by Super-Sector, 1990-2011

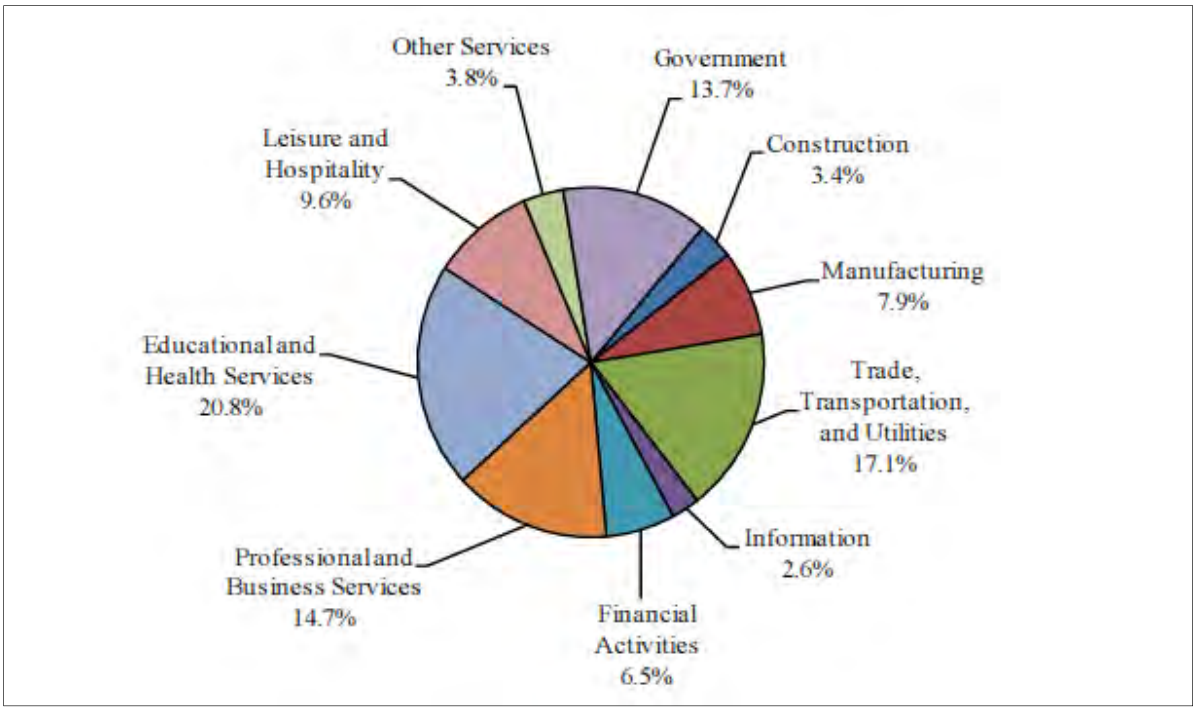


Figure 4-15. Massachusetts Non-Farm Payroll Employment by NAICS Super-Sector, 2010 - 2011

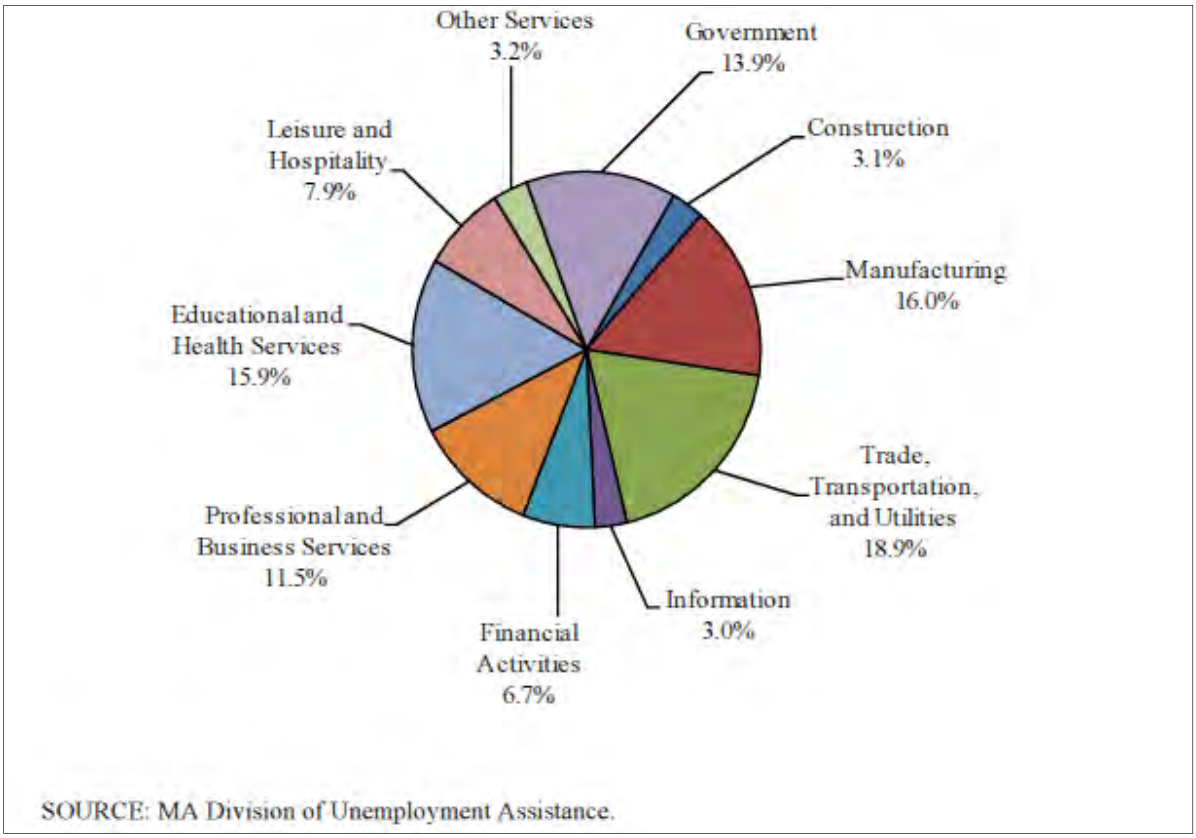


Figure 4-16. Massachusetts Non-Farm Payroll Employment by NAICS Super-Sector, 1990-1991

Largest Employers in Massachusetts

Table 4-33 lists the 25 largest private employers in Massachusetts based upon employment covered by the Unemployment Insurance system as of December 2012. Macy's replaced Partners Health Care from the March 2011 list. This list may not include some employers who do business in the state under multiple legal names or register each facility as a separate employer**.** Table 4-34 lists Fortune 500 companies headquartered in Massachusetts. Between 2011 and 2012, three companies gained in that ranking, seven fell, and one remained unchanged. Global Partners, located in Waltham, climbed 124 places on the list, the largest leap for a Massachusetts company.

TABLE 4-33. 25 LARGEST PRIVATE EMPLOYERS IN MASSACHUSETTS, DECEMBER 2011

Bank of America, NA	Massachusetts Institute of Technology
Baystate Medical Center, Inc.	Raytheon Company
Beth Israel Deaconess Medical Center	S & S Credit Company, Inc.
Boston Medical Center Corporation	Shaw's Supermarkets, Inc.
Boston University	Southcoast Hospitals Group, Inc.
Brigham & Women's Hospital, Inc.	State Street Bank & Trust Company
CVS Pharmacy, LLC	Target Corporation
Demoulas Super Markets, Inc.	The Children's Hospital Corporation
E.M.C. Corporation	UMass Memorial Medical Center
General Hospital Corporation	United Parcel Service, Inc.
Harvard University	Verizon New England, Inc.
Home Depot U.S.A., Inc.	Wal-Mart Associates, Inc.
Macy's Retail Holdings, Inc.	

SOURCE: Massachusetts Executive Office of Labor & Workforce Development, Division of Unemployment Assistance, Research Department 7-13-12.
NOTE: This alphabetic listing includes private employers reporting large numbers of jobs covered by the Massachusetts unemployment insurance program. The information is based on December 2011 employment for employers as registered for unemployment insurance. The list may not include those employers who do business in Massachusetts under multiple legal corporations and those who register each store, facility or franchisee as a separate employer.

TABLE 4-34. MASSACHUSETTS COMPANIES IN 2012 FORTUNE 500 LIST

Rank 2012	Rank 2011	Company	Industry	2011 revenues (millions)
84	82	Liberty Mutual Ins. Group (Boston)	Insurance: P & C (stock)	$34,671
114	108	Staples (Framingham)	Specialty Retailers: Other	$25,022
117	104	Raytheon (Waltham)	Aerospace and Defense	$24,857
121	101	Mass. Mutual Life Ins. (Springfield)	Insurance: Life, Health (mutual)	$24,226
125	119	TJX (Framingham)	Specialty Retailers: Apparel	$23,192
139	152	EMC (Hopkinton)	Computer Peripherals	$20,008
182	306	Global Partners (Waltham)	Wholesalers: Diversified	$14,836
225	227	Thermo Fisher Scientific (Waltham)	Scientific, Photo, Control Equipment	$11,780
262	253	State St. Corp. (Boston)	Commercial Banks	$10,207
335	305	Boston Scientific (Natick)	Medical Products & Equipment	$7,622
476	476	Biogen Idec (Weston)	Pharmaceuticals	$5,049

SOURCE: Fortune, May 21, 2012 issue.

Unemployment Rate

The unemployment rate in Massachusetts was consistently below the national average from mid-1995 through November 2005, with similar patterns of gradual improvement after the mid-2003 peak. The Massachusetts rate exceeded the U.S. rate for 17 months starting in December 2005, but only three of those differences exceeded 0.2 percent. Since April 2007, the state rate has been at or below the comparable (seasonally adjusted) U.S. rate. In October 2007, the Massachusetts rate was 4.4 percent, the lowest it had been since October 2001. By September 2012, the Massachusetts rate rose to 6.5 percent from 6.0 percent in June 2012. Figure 4-17 compares the unemployment rate in the state with those in New England and the U.S. Current employment data by county are presented in Table 4-35.

According to the 2013 Due Diligence Report completed by the University of Massachusetts, as of July 31, 2012, the Massachusetts Unemployment Trust Fund had a balance of $640 million. This balance is the sum of the private contributory account balance of $547 million and the government contributory account balance of $93 million. This compares to a March 2012 balance of $12.6 million, with a private contributory portion of –$81.6 million. The August 2012 Unemployment Insurance Trust Fund report indicated that the private contributory account balance was estimated to be $1.761 billion by the end of 2016 according to the Moody's-based outlook.

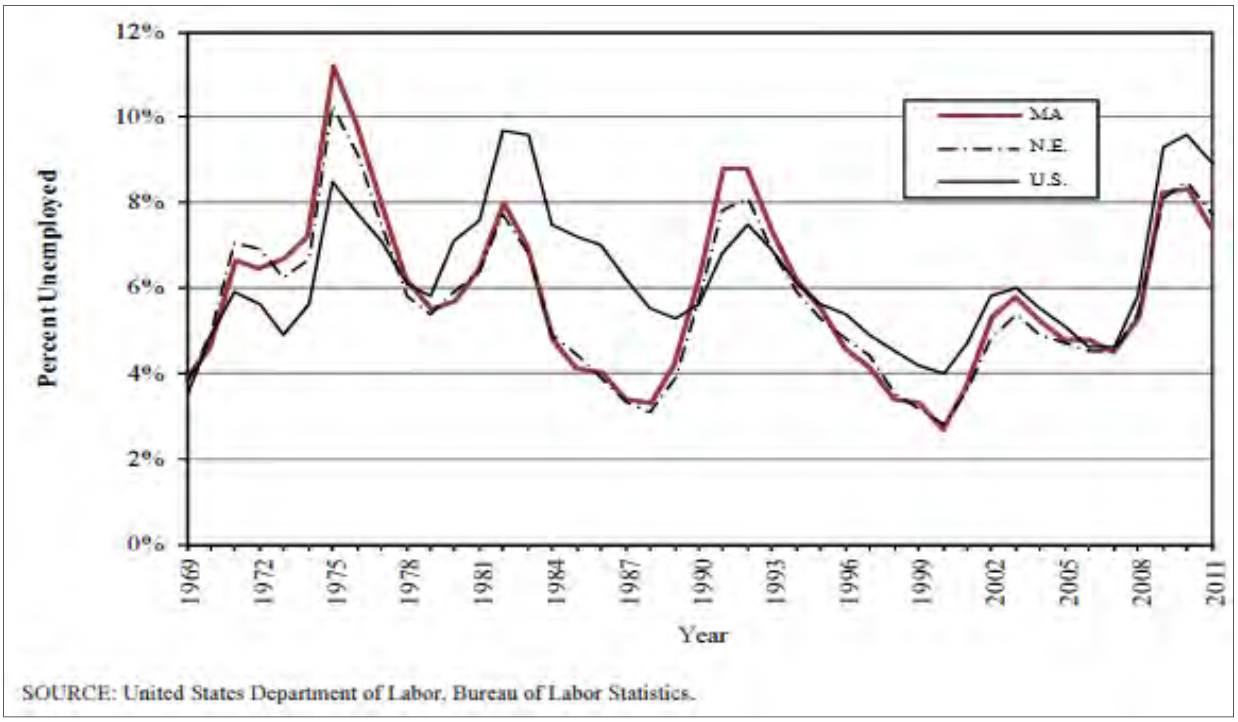


Figure 4-17. Annual Average Unemployment Rate, 1969 – 2011

TABLE 4-35.
AMERICAN COMMUNITY SURVEY 2009- 2011 3-YEAR ESTIMATES FOR EMPLOYMENT BY COUNTY

	Labor Force 16 years & over	Employed	Unemployed
Barnstable	108,807	99,604	9,203
Berkshire	68,149	61,299	6,850
Bristol	294,800	261,219	33,581
Dukes *	8,924	8,474	450
Essex	395,349	360,819	34,530
Franklin	40,881	37,359	3,522
Hampden	228,390	202,832	25,558
Hampshire	78,749	72,717	6,032
Middlesex	843,991	778,980	65,011
Nantucket*	6,186	6,011	175
Norfolk	367,870	337,244	30,626
Plymouth	267,590	239,785	27,805
Suffolk	404,221	357,502	46,719
Worcester	427,666	385,644	42,022

* These estimates are from the American Community Survey 2007-2011 5-year estimates; 3-year estimates aren't available for these counties

4.9 DISASTER INFORMATION

Between 1953 and 2012, FEMA Region I experienced more than 150 federal emergency and disaster declarations, 28 of which impacted Massachusetts. The Commonwealth received six disaster declarations from February 1, 2010 through December 31, 2012 that are included in this plan update:

- March 2010, Severe Storm and Flooding (FEMA Disaster Declaration DR-1895)
- March 2011, Severe Winter Storm and Snowstorm (DR-1959)
- June 2011, Severe Storms and Tornadoes (DR-1994)
- September 2011, Tropical Storm Irene (DR-4028)
- January 2012, Severe Storm and Snowstorm (DR-4051)
- December 2012, Hurricane Sandy (DR-4097).

The Commonwealth was also impacted during the 2013 update planning cycle by a significant snowstorm in January 2013 and by the Boston Marathon bombing event of April 2013. A breakdown of federal disaster declarations is provided in Table 4-36. Further detail on state and federal disaster declarations, along with summaries of distributed funds, is provided in Section 5 (Table 5-2).

TABLE 4-36.
HISTORY OF FEDERAL DISASTER DECLARATIONS, 1953 – 2012

Disaster No. [a]	Disaster Type	Date	Incident Period	Barnstable	Berkshire	Bristol	Dukes	Essex	Franklin	Hampden	Hampshire	Middlesex	Nantucket	Norfolk	Plymouth	Suffolk	Worcester	**Total by Disaster**
EM-3350	Hurricane Sandy	10/28/12	10/27/12 - 11/8/12	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3343	Severe Storm	11/01/11	10/29/11 - 10/30/11		X			X	X	X	X	X		X			X	**8**
EM-3330	Hurricane Irene	08/26/11	8/26/11 - 9/5/11	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3315	Hurricane Earl	09/02/10	9/1/10 - 9/4/10	X		X	X	X				X	X	X	X	X	X	**10**
EM-3312	Water Main Break	05/03/10	5/1/10 - 5/5/10					X				X		X		X		**4**
EM-3296	Severe Winter Storm	12/13/08	12/11/08 - 12/18/08		X	X		X	X	X	X	X				X	X	**9**
EM-3264	Severe Storms and Flooding	10/19/05	10/7/05 - 10/22/05			X												**1**
EM-3252	Hurricane Katrina Evacuation	09/13/05	8/29/05 - 10/1/05	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3201	Snow	02/17/05	1/22/05 - 1/23/05	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3191	Snow	01/15/04	12/6/03 - 12/7/03	X	X	X		X	X	X	X	X		X	X	X	X	**12**
EM-3175	Snowstorm	03/11/03	2/17/03 - 2/18/03	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3165	Snowstorm	03/28/01	3/5/01 - 3/7/01		X			X	X		X	X		X			X	**7**
EM-3153	Fire	12/06/99	12/3/99 - 12/13/99					X				X		X	X	X	X	**6**
EM-3119	Extreme Weather/ Flooding	10/23/96	10/20/96 - 10/25/96															**0**
EM-3103	Blizzards, High Winds and Record Snowfall	03/16/93	3/13/93 - 3/17/93	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3059	Blizzard and Snowstorm	02/07/78	02/07/78													X		**1**
FM-2116	Russell Fire	09/12/95	09/05/95															**0**
DR-4097	Hurricane Sandy	12/19/12	10/27/12 - 11/8/12	X		X	X						X		X	X		**6**

TABLE 4-36.
HISTORY OF FEDERAL DISASTER DECLARATIONS, 1953 – 2012

Disaster No. [a]	Disaster Type	Date	Incident Period	Barnstable	Berkshire	Bristol	Dukes	Essex	Franklin	Hampden	Hampshire	Middlesex	Nantucket	Norfolk	Plymouth	Suffolk	Worcester	**Total by Disaster**
DR-4051	Severe Storm And Snowstorm	01/06/12	10/29/11 - 10/30/11		X				X	X	X	X					X	**6**
DR-4028	Tropical Storm Irene	09/03/11	8/27/11 - 8/29/11	X	X	X	X		X	X	X			X	X			**9**
DR-1994	Severe Storms and Tornadoes	06/15/11	06/01/11							X							X	**2**
DR-1959	Severe Winter Storm and Snowstorm	03/07/11	1/11/11 - 1/12/11		X			X		X	X	X		X		X		**7**
DR-1895	Severe Storm and Flooding	03/29/10	3/12/10 - 4/26/10			X		X				X		X	X	X	X	**7**
DR-1813	Severe Winter Storm and Flooding	01/05/09	12/11/08 - 12/18/08		X			X	X	X	X	X					X	**7**
DR-1701	Severe Storms, Inland & Coastal Flooding	05/16/07	4/15/07 - 4/25/07	X	X		X	X	X	X	X				X			**8**
DR-1642	Severe Storms and Flooding	05/25/06	5/12/06 - 5/23/06					X				X				X		**3**
DR-1614	Severe Storms and Flooding	11/10/05	10/7/05 - 10/16/05		X	X			X	X	X	X		X	X		X	**9**
DR-1512	Flooding	04/21/04	4/1/04 - 4/30/04					X				X		X		X	X	**5**
DR-1364	Severe Storms & Flooding	04/10/01	3/5/01 - 4/16/01			X		X				X		X	X	X	X	**7**
DR-1224	Heavy Rain And Flooding	06/23/98	6/13/98 - 7/6/98			X		X				X		X	X	X	X	**7**
DR-1142	Severe Storm/ Flooding	10/25/96	10/20/96 - 10/25/96					X				X		X	X	X		**5**
DR-1090	Blizzard	01/24/96	1/7/96 - 1/13/96	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
DR-975	Winter Coastal Storm	12/21/92	12/11/92 - 12/13/92	X			X	X				X	X	X	X	X	X	**9**
DR-920	Severe Coastal Storm	11/04/91	10/30/91 - 11/2/91	X			X	X					X	X	X	X		**7**
DR-914	Hurricane Bob	08/26/91	08/19/91	X		X	X	X		X		X	X	X	X	X	X	**11**
DR-790	Severe Storms, Flooding	04/18/87	3/30/87 - 4/13/87		X			X	X	X	X	X		X			X	**8**
DR-751	Hurricane Gloria	10/28/85	09/27/85	X	X	X	X	X	X	X	X	X		X	X	X	X	**13**
DR-650	Urban Fire	12/03/81	12/03/81					X										**1**

TABLE 4-36.
HISTORY OF FEDERAL DISASTER DECLARATIONS, 1953 – 2012

Disaster No. [a]	Disaster Type	Date	Incident Period	Barnstable	Berkshire	Bristol	Dukes	Essex	Franklin	Hampden	Hampshire	Middlesex	Nantucket	Norfolk	Plymouth	Suffolk	Worcester	**Total by Disaster**
DR-546	Coastal Storms, Flood, Ice, Snow	02/10/78	2/6/78 - 2/8/78	X		X	X	X					X	X	X	X		**8**
DR-405	Fire (City of Chelsea)	10/16/73	10/16/73													X		**1**
DR-357	Toxic Algae in Coastal Waters	09/28/72	09/28/72	X		X	X	X					X	X	X	X		**8**
DR-325	Severe Storms, Flooding	03/06/72	03/06/72					X						X	X	X		**4**
DR-43	Hurricane/ Floods	08/20/55	08/20/55															**0**
DR-22	Hurricanes	09/02/54	09/02/54															**0**
DR-7	Tornado	06/11/53	06/11/53															**0**
			Total	**18**	**19**	**21**	**17**	**33**	**18**	**20**	**19**	**28**	**14**	**29**	**25**	**29**	**25**	
			Major Disaster Declaration	**10**	**9**	**11**	**10**	**20**	**8**	**11**	**9**	**15**	**7**	**17**	**16**	**17**	**13**	**28**

a. Disaster numbers are coded as follows: EM = Emergency Declaration; DR = Major Disaster Declaration; FM = Fire Management Assistance

Each county in the state has been impacted at least seven times. Essex received 33 federal declarations, 20 of them disaster declarations. Norfolk and Suffolk each sustained 29 state and federal declarations, and Middlesex sustained 28 declarations. Nantucket has the fewest disaster declarations. Figure 4-18 shows the frequency of declared disasters in Massachusetts by county.

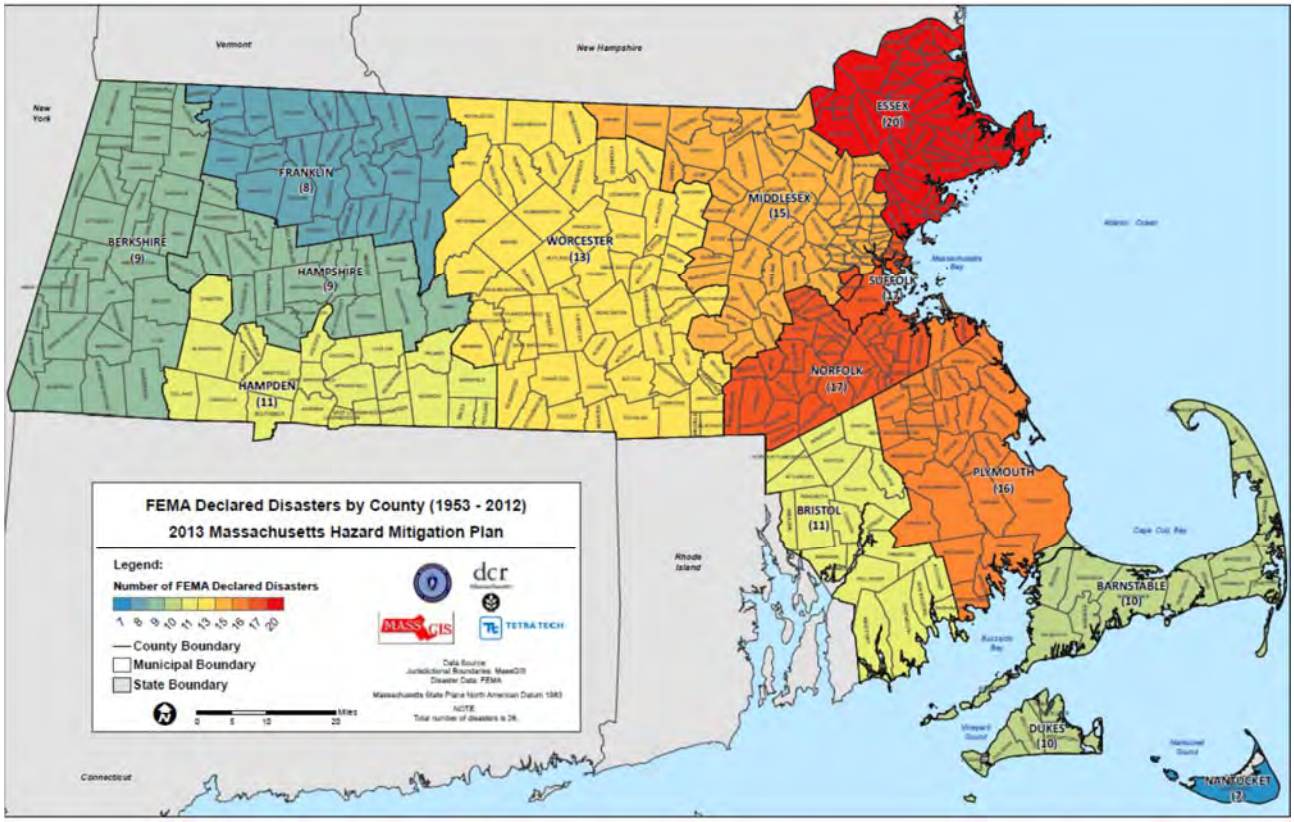


Figure 4-18. FEMA-Declared Disasters by County

CHAPTER 5. RISK ASSESSMENT OVERVIEW

5.1 THIRA PROCESS

The SHMP risk assessment process began with development of the Threat Hazard Identification and Risk Assessment (THIRA). The THIRA serves as the foundational risk assessment method for identifying hazards, assessing their risks, and analyzing their consequences for all preparedness and planning efforts in the Commonwealth. The THIRA process took into account hazards that had been documented in various plans, including the 2010 SHMP. Using this information, the Commonwealth can undertake additional risk assessment methodologies, such as the SHMP risk assessment process, to conduct more concentrated assessments of certain THIRA-identified hazards for a specific planning purpose (such as hazard mitigation planning). The THIRA serves as the risk assessment and consequence analysis process for non-natural hazards. The SHMP risk assessment process incorporated an additional, focused risk assessment for natural hazards (see Appendix A).

5.1.1 Process Guidelines

FEMA issued guidelines in 2012 that required all state administrative agencies and urban areas (designated under the Urban Areas Security Initiative) receiving FEMA Preparedness Grant funding to complete and submit a THIRA to the FEMA regional federal preparedness coordinator. The process followed for the 2012 THIRA development was established in *Comprehensive Preparedness Guide (CPG) 201*, which aligns with the planning requirements of 44 CFR 201.4 in several areas and is therefore a logical beginning for updating this plan. The basic plan development steps for the THIRA are illustrated in Figure 5-1.

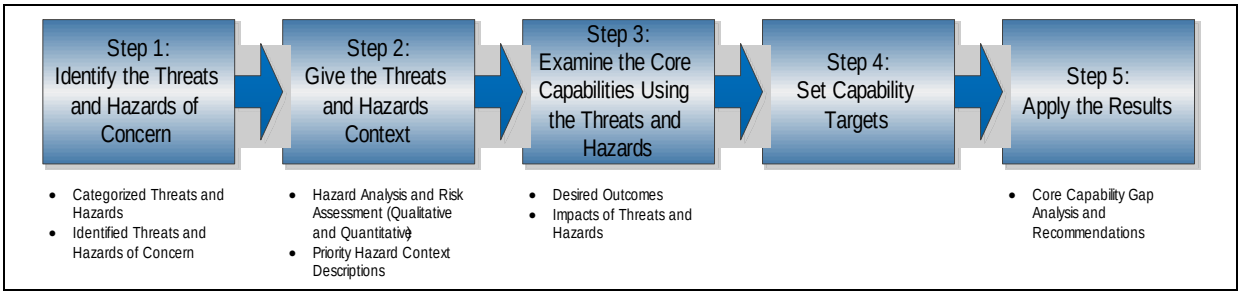


Figure 5-1. FEMA Risk Assessment Methodology

5.1.2 Identification of Hazards of Concern

To identify threats and hazards of concern for the THIRA, the SHMT reviewed the 2010 SHMP and Comprehensive Emergency Management Plan and interacted with the Commonwealth Fusion Center for hazard information. As a result of the document review and stakeholder comments, the THIRA planning process began with recognizing 21 natural hazards, six technological hazards, and 16 terrorism hazard scenarios. Of these, the following were determined to be relevant for the THIRA:

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(2)(i), which states the following:

To be effective the plan must include an overview of the type and location of all natural hazards that can affect the State, including information on previous occurrences of hazard events, as well as the probability of future hazard events, using maps where appropriate.

- Natural Hazards
  - Drought
  - Earthquake
  - Flood
  - Hurricane and Tropical Storm
  - Ice Jam
  - Ice Storm
  - Landslide
  - Pandemic (in THIRA)
  - Severe Nor'easter
  - Severe Winter Event
  - Thunderstorm
  - Tornado
  - Wind Storm
- Technological Events
  - Blackout
  - Bridge Failure
  - Commodity Shortage
  - Dam Failure
  - Nuclear Power Station Radiological Release
  - Transportation Accidents
- Terrorist Events
  - Active Shooter
  - Biological Weapon
  - Chemical Weapon
  - Cyber Attack – Data
  - Cyber Attack – Infrastructure
  - Explosive Device
  - Radiological Device

This list, developed during the kickoff meeting (see Section 2), represents the hazards of concern for the Commonwealth, including the natural hazards profiled in the 2013 SHMP update. The hazards of concern were verified during the review of local hazard mitigation plans as a part of the integration phase of this plan update. The SHMP accepts the assessment and consequence analysis completed under the THIRA for non-natural hazards. Mitigation actions associated with the non-natural hazards, in the form of enhancements to build capability to mitigate these hazards, are detailed under the THIRA, which is included in Annex 1.

5.2 NATURAL HAZARDS RISK ASSESSMENT

Building from the THIRA, the SHMP risk assessment adds further analysis for the natural hazards of concern, including a probabilistic and deterministic process as defined below and in Appendix A. This risk assessment provides a factual basis for the mitigation goals and actions proposed by the SHMP. Loss estimations based on historical losses can help to identify jurisdictions most vulnerable to impacts from hazards. Probabilistic and deterministic analysis assists in determining potential future losses, based on severity, extent, potential impact, and probability of occurrence. All this information assists at the state and local levels to form an overall strategy for the mitigation plan.

The hazard profile chapters of the plan examine the natural hazards that have the potential to impact the Commonwealth, identify counties and populations that are most vulnerable to each hazard, identify hazards of greatest concern based on the THIRA, and estimate potential losses from the hazards at the state and local levels. This statewide overview estimates potential losses by jurisdiction as well as for state facilities. The state risk assessment includes the following:

- An overview of the type and location of all natural hazards, including historical occurrences and probability of future occurrence
- An analysis of the vulnerability of state facilities to identified hazards
- An analysis of local jurisdictions' vulnerability to identified hazards
- An estimate of potential losses by jurisdiction and to state-owned facilities.
- An overview of the exposure of population, critical facilities, economy, etc. to each hazard.

The SHMT compiled data from multiple sources, including FEMA-approved regional and local hazard mitigation plans (current plans, as well as expired plans if they represent best available data); county level information from the U.S. Census; Indiana State University; various councils of

government and planning commissions; the University of Massachusetts; previous loss data; and other sources. Extensive GIS analysis and Hazus modeling was performed, integrating information from federal, state, and local sources. Each hazard profile contains updated maps, which were produced to illustrate areas at risk from natural hazards. Each hazard profile presents risks in addition to areas most vulnerable to the hazard. The following definitions apply for terms used in the risk assessment:

- Hazard—Natural (or human-caused) source or cause of harm or damage, demonstrated by actual (historical events) or potential (probabilistic) events.
- Risk—The potential for an unwanted outcome resulting from a hazard event, as determined by its likelihood and associated consequences and expressed, when possible, in dollar losses. Risk represents potential future losses, based on assessments of probability, severity, and vulnerability. In some instances, dollar losses are based on actual demonstrated impact, such as through the use of the Hazus model. In other cases, it is demonstrated through exposure analysis due to the inability to determine the extent to which a structure is impacted.
- Location—The area of potential or demonstrated impact within the region in which the analysis is being conducted. In some instances, the area of impact is within a geographically defined area, such as a floodplain. In other instances, such as for severe weather, there is no established geographic boundary associated with the hazard, as it can impact the entire Commonwealth.
- Probability—Probability is used as a synonym for likelihood, or the estimated potential for an incident to occur.
- Severity—The extent or magnitude upon which a hazard is ranked, demonstrated in various means, e.g., Richter Scale, Saffir-Simpson Hurricane Scale, Regional Snowfall Index, etc.
- Vulnerability—The degree or level of damage, e.g., building performance (functionality), damage, or the number of people injured.
- Consequence—The effect of a hazard occurrence. Consequence is demonstrated by impact on population, physical property (e.g., state facilities, local jurisdiction assets and general building stock, critical facilities), responders, operations, the environment, the economy, and public confidence in state governance. A consequence analysis meets the Emergency Management Accreditation Program standard for hazards identified in state plans.

5.3 HAZARD PROFILE REVIEW

A hazard is a phenomenon that has the potential to produce harm or other undesirable consequences to a person or thing. Hazard profiles in Sections 6 through 16 describe each natural hazard that affects the Commonwealth, the likely location of hazard impact, facilities at risk, the severity and extent of the impact, previous occurrences, and the probability of future hazard events. All hazard profiles were updated for the 2013 update with any available new information. Data from the 2010 plan were retained where it was appropriate and current. Further information on the hazard profile development process is provided in Section 1, Section 2, and Appendix A.

5.3.1 Information Sources

The 2013 hazard profiles are based on a wide range of information and data, including best available science and most current information on hazards, impacts, and the vulnerability of jurisdictions. The data collection for this plan was from February 1, 2010, through December 31, 2012.

State facilities data used in the risk assessment were provided by the Division of Capital Asset Management and Maintenance (DCAMM) (see Section 1 and Appendix A). The SHMT and SHMIC directed the revision of each hazard profile to include significant hazard events that occurred between

February 1, 2010, and December 31, 2012; added new hazard zone maps; and updated other information as necessary. Subject-matter experts from various disciplines provided relevant data, including updated studies and reports (e.g., coastal hazard data and updated earthquake and landslide data), and reviewed and updated the completed hazard profiles. This expert review ensured the accuracy and currency of information, validated the criteria used to assess vulnerability, and ensured conformity with federal requirements. Extensive GIS data from state, regional, and local sources were utilized. Data from various FEMA-approved local and multi-jurisdictional multi-hazard mitigation plans were incorporated with existing statewide data sets as applicable. The most up-to-date and accurate information available for this update was compiled from several federal sources. Appendix B lists many of the sources used. It is intended that Appendix B will be continually updated to maintain a list of resources available for local jurisdictions' use as they update their local plans. The following are key information sources used:

- Historical disaster records and documents, including, but not limited to, reports and spreadsheets maintained by MEMA as it relates to assistance made available following disasters
- Literature developed by state and national hazard experts containing best available science and most current knowledge of hazards
- Current hazard zone maps, including new Shake Maps, SLOSH models, and Q3 Flood Data
- Written and oral communication from state and national hazard experts
- State facilities inventory developed by DCAMM, with information provided by state agencies
- Federal Emergency Management Agency
- Hazard Research Laboratory, Department of Geography, University of South Carolina
- National Drought Mitigation Center, University of Nebraska-Lincoln
- National Oceanic and Atmospheric Administration (NOAA) and its agencies/programs (National Climatic Data Center and National Weather Service)
- U.S. Forest Service
- U.S. Department of Agriculture
- U.S. Geological Survey, U.S. Department of the Interior
- U.S. Army Corps of Engineers
- Office of the State Climatologist
- Other state offices, including Agriculture, Commerce/Economic Development, Health, Ecology, and Social and Health Services agencies.

5.3.2 Data Limitations

The following data limitations were identified and strategies developed to assist in future plan updates:

- Digital Flood Insurance Rate Maps are not available for all counties; however, the Commonwealth is currently working with FEMA to update maps and will continue throughout the 2013-2016 update cycle to be a technical partner in enhancing this project.
- The DCAMM facility database could not provide all of the necessary property attributes to determine potential dollar losses without making assumptions based, in part, on RS Means 2010 (see Appendix A). Enhancing these data is a continuing strategy for the 2013 plan.
- Hazard data for some hazards, such as landslides and wildland fires, were limited. The Commonwealth previously received a grant for a project to study landslide issues in the Commonwealth, as well as developing a statewide dataset for this hazard that will be

available to all local jurisdictions for use in future plan updates. This item is listed in the strategy portion of the plan as a 2013 new project.

- Limited information was available about state and local critical facilities. The Commonwealth is addressing this in a mitigation action presented in this plan (a new project for 2013) to enhance future state-level planning efforts and local planning efforts.

5.4 STATEWIDE HAZARD ASSESSMENT

To assess all natural hazards that have occurred or could occur in Massachusetts, a natural hazards risk matrix was developed. Information contained in this matrix was based on the THIRA, best available science, input from committee members, historical data concerning past hazard events, review of local plans, and input from various subject matter expertise. This process is similar to the process used for risk ranking by many local jurisdictions. Results are presented in Table 5-1. Similar information was displayed in the 2010 plan, but the table has been modified into a new format. This table also includes information with respect to the non-natural hazards as identified within the THIRA, which contains the full analysis for non-natural hazards. The assessment was based on the following categories and criteria:

- Frequency (for natural hazards only):
  - Very low: events that occur less often than once in 100 years (Less than 1% probability per year)
  - Low: events that occur from once in 50 years to once in 100 years (1% to 2% probability per year)
  - Medium: events that occur from once in 5 years to once in 50 years (2% to 20% probability per year)
  - High: events that occur more frequently than once in 5 years (Greater than 20% probability per year)
- Severity:
  - Minor: Limited and scattered property damage, limited damage to public infrastructure and essential services not interrupted, limited injuries or fatalities.
  - Serious: Scattered major property damage, some minor infrastructure damage, essential services are briefly interrupted, some injuries and/or fatalities.
  - Extensive: Widespread major property damage, major public infrastructure damage (up to several days for repairs), essential services are interrupted from several hours to several days, many injuries and/or fatalities.
  - Catastrophic: Property and public infrastructure destroyed, essential services stopped, numerous injuries and fatalities.

TABLE 5-1.
2013 HAZARD ASSESSMENT—HAZARDS OF GREATEST CONCERN

Hazard	Frequency[b]	Severity[a] Likely Level	Severity[a] Potential Worst-Case	Area of Impact	Area of Occurrence
Natural Hazards					
Flood (including Ice Jam)	High	Serious	Catastrophic	Regional	Statewide
Dam Failure	Very low	Extensive	Catastrophic	Local	Regional
Coastal Hazards	High	Serious	Extensive	Regional	Regional
Hurricane/ Tropical Storm	Medium	Serious	Catastrophic	Widespread	Statewide
Nor'easter	High	Minor	Extensive	Widespread	Statewide
Earthquake	Very low	Serious	Catastrophic	Regional	Statewide
Landslide	Low	Minor	Extensive	Local	Statewide
Snow & Blizzard (Severe Winter Weather)	High	Minor	Extensive	Widespread	Statewide
Ice Storm (Severe Winter Weather)	Medium	Minor	Extensive	Regional	Statewide
Wildland Fire	Medium	Minor	Extensive	Local	Regional
Major Urban Fires	Low	Minor	Serious	Isolated	Statewide
Thunderstorm (Severe Weather)	High	Minor	Extensive	Regional	Statewide
High Wind (Severe Weather)	High	Minor	Extensive	Regional	Statewide
Tornado (Severe Weather)	Medium	Serious	Extensive	Local	Statewide
Drought (Severe Weather)	Low	Minor	Serious	Widespread	Statewide
Extreme Temperature (Severe Weather)	Medium	Minor	Serious	Widespread	Statewide
Tsunami	Very low	Extensive	Catastrophic	Widespread	Regional
Non-Natural Hazards of Concern – Not profiled in SHMP but data are available in Annex 1					
Public Health Hazard (epidemic or pandemic)		Extensive	Catastrophic	Widespread	Widespread
Blackout		Minor	Extensive	Widespread	Widespread
Bridge Failure		Minor	Extensive	Local	Regional
Commodity Shortage		Serious	Extensive	Widespread	Widespread
Nuclear Power Station Radiological Release		Serious	Catastrophic	Widespread	Regional
Transportation Accident		Minor	Serious	Isolated	Statewide
Terrorist Related Risk - Not profiled in SHMP - Privileged data					
Active Shooter		Minor	Serious	Isolated	Statewide
Biological Weapon		Serious	Extensive	Local	Statewide
Chemical Weapon		Serious	Extensive	Local	Statewide
Cyber Attack - Data		Serious	Extensive	Widespread	Statewide
Cyber Attack – Infrastructure		Serious	Extensive	Widespread	Statewide
Explosive Device (improvised or vehicle-borne)		Serious	Catastrophic	Widespread	Statewide
Radiological Device		Extensive	Catastrophic	Local	Statewide

a. Two severity ratings were assigned for each hazard: A likely level used in the risk assessment, and a potential worst-case defined for consideration in developing the THIRA and mitigation goals and actions.
b. Frequency analysis is not included for non-natural hazards; the criteria are specific for natural hazard frequency and are not transferable. See Annex 1 for details on the non-hazards.

- Area of Impact (extent of impact on any locality for a particular event):

  - Isolated: a single whole or partial community impacted
  - Local: One community to several communities impacted
  - Regional: many communities to a county impacted
  - Widespread: multiple counties impacted
- Area of Occurrence (location and size of areas likely to experience this hazard in the future):
  - Isolated: Scattered areas around the Commonwealth can experience this hazard
  - Regional: Multiple communities and counties can experience this hazard
  - Statewide: The entire Commonwealth can experience this hazard

The completed risk assessment was reviewed and confirmed by the SHMIC during the February 6, 2013 meeting. Based on comparison of the 2010 and 2013 matrices, there were no changes in the perceived hazards of concern in the last three years. However, because of numerous enhancements in this risk assessment, there are minor differences between the Commonwealth's identified areas of impact and those identified in local plans (see Section 5.6.3). Information concerning areas of impact and notable variations in analysis are discussed in each hazard profile in this plan update.

5.4.1 Secondary Effects of Hazards

Some hazards can be a secondary effect of the occurrence of another hazard. For example, an earthquake can trigger fires, landslides, floods, ground liquefaction, or a tsunami; and an area experiencing drought is at greater risk of wildland fire. Table 5-2 shows connections among hazards, indicating that all hazards identified have at least one associated secondary risk.

5.5 STATEWIDE LOSS ESTIMATION APPROACH

5.5.1 State Facilities

The Commonwealth of Massachusetts owns and operates more than 6,000 properties and facilities. DCAMM provides state agencies with public-building design, construction, maintenance, and real estate services and manages an inventory of state property infrastructure and critical facilities. The vulnerability assessment in terms of type of facilities is outlined in detail in Section 5 and in Appendix A. There are more than 190 types of facilities in the DCAMM database that are included in this vulnerability assessment. The following list is just a short snapshot of some of the key critical facilities.

- Boat ramp
- Bridge
- Corrections
- Courthouse
- Dams/dam operations building
- Day care facility
- Docks/piers/marinas
- Electrical distribution/substation
- Fire station
- Fuel dispensing station
- Hospital / clinic
- Laboratory / research
- Library
- Marine & water transportation
- Military structure
- Miscellaneous
- Museum /monument
- Police station/barracks
- Pump house
- Residence/dormitory
- Salt/sand shed
- School
- Sewage treatment plant
- Telecommunications
- Water supply
- Office

TABLE 5-2.
SECONDARY HAZARD EFFECTS MATRIX

Primary Hazards	Structural Damage	Utility Outage	Chemical Release/ Spill	Commodity Shortages	Emergency Comm. Failure	Erosion	Structural Fire	Mold	Carbon Monoxide Poisoning	Disease	Flooding	Landslide	Dam Failure	Storm Surge	Tornado	Wildland fire	Hail	Tsunami
Coastal Erosion	X										X	X						
Coastal Flooding	X		X			X		X		X		X						
Inland Flooding	X	X	X			X		X		X		X	X					
Hurricane/ Tropical Storm	X	X	X	X	X	X		X	X	X	X	X	X	X	X			
Tornado/ Downburst	X	X	X					X										
Major Thunderstorm/ Lightning		X					X								X	X	X	
Earthquake	X	X	X	X	X		X		X	X	X	X	X					X
Winter Storms/Nor'easters	X	X		X		X	X		X		X			X				
Ice Storms	X	X		X	X		X		X									
Ice Jam	X										X		X					
Landslide	X					X												
Wildland fires	X						X											
Tsunami	X	X	X	X		X		X		X	X							
Major Urban Fire	X	X	X															
Drought				X												X		
Epidemic / Pandemic Disease				X														

The Commonwealth retained a consultant to perform the first statewide hazard analysis for state-owned property in 2002, using a previous version of this database. For the 2013 update, some of the DCAMM data were digitally enhanced with aerial photography. These data were then analyzed with FEMA's Hazus and ArcGIS software. This analysis used best available data as required by guidance. A more detailed description of the process is available in Appendix A. Some hazards, such as severe weather or severe winter storms, do not have a customary geographic boundary of impact, so statewide GIS layers were not available or were not compatible to this analysis; these are evaluated qualitatively.

Potential losses are shown in each hazard profile, as applicable. The DCAMM facility database was used to determine potential dollar losses. Where information was lacking, assumptions were made. All locations were geocoded using the ArcGIS Online North America Streets 10.0 online geocoding service. Upon initial inspection of the DCAMM Capital Asset Management Information System spreadsheet of facilities, 6,422 facilities were included; 5,398 facilities were matched via geocoding to the street, rooftop, or street name geocoding level. Out of the initial set of facilities, 916 facilities contained no address and 108 facilities would not match via coding with the address provided.

After the initial geocoding of the owned facilities data, these 1,024 facilities were sent back to DCAMM for review and to obtain additional information that would allow them to be located. Of the 1,024 facilities sent back for updating, 935 were able to be successfully located with the inclusion of additional data. This allowed for 6,333 state-owned facilities to be included in the overall analysis of state-owned

facilities, out of the 6,422 that were provided (98.6 percent). All 432 state-leased facilities were successfully geocoded, for a 100-percent return. The dataset utilized to run the 2013 state-owned and -leased facility risk analysis included information on a total of 6,765 facilities.

These data were used for a Hazus analysis to determine potential dollar losses or for an exposure analysis for hazards for which Hazus cannot be utilized. Additional information concerning the process utilized to manipulate the data into a useable format and to incorporate the information into a Hazus comprehensive data management system is contained in Appendix A.

5.5.2 Critical Facilities

All critical facilities, whether state or local, were used and obtained from MassGIS. Their data was more accurate in terms of location and more current than the default critical facility inventories in Hazus. The facility types used, in addition to those listed above, were police stations, fire stations, hospitals, emergency operation centers (state only) and schools (including pre-K through grade 12 and colleges).

5.5.3 Bridges

Included in the state impact is the potential for infrastructure failure, including bridges. Studies have shown that a bridge failure is most likely caused by an extreme event, the most prevalent type being flooding and scour. Table 5-3 lists the distribution of the Commonwealth's bridges by county.

TABLE 5-3.
BRIDGE COUNT BY COUNTY

	Number of Bridges				Area (square Miles)			
	All	Deficient[a]			All	Deficient[a]		
County	Bridges	SD	FO	Total	Bridges	SD	FO	Total
Barnstable	104	10	48	58	64,520	14,189	24,890	39,079
Berkshire	427	39	104	143	120,440	6,554	47,522	54,076
Bristol	384	51	138	189	339,293	113,296	107,948	221,244
Dukes	5	3	2	5	2,661	2,389	272	2,661
Essex	386	39	142	181	375,741	67,794	98,268	166,062
Franklin	289	56	60	116	120,528	35,708	26,781	62,489
Hampden	424	47	191	238	467,139	40,476	173,264	213,740
Hampshire	253	32	79	111	82,829	13,001	24,312	37,313
Middlesex	775	95	339	434	565,017	68,315	258,195	326,510
Nantucket	2	0	2	2	318	0	318	318
Norfolk	331	24	182	206	191,820	15,619	102,294	117,913
Plymouth	283	23	106	129	142,293	10,690	52,648	63,339
Suffolk	387	58	198	256	784,877	158,943	366,788	525,731
Worcester	986	114	390	504	488,107	47,576	214,614	262,190
Total	**5,038**	**593**	**1,981**	**2,574**	**3,745,746**	**594,711**	**1,498,114**	**2,092,825**

a. Deficiency codes: SD = Structurally Deficient/ FO = Functionally Obsolete
Source: http://www.fhwa.dot.gov/bridge/nbi/county09a.cfm#ma

Redundancy, the ability of a bridge system to sustain damage without collapse, has a significant role in the prevention of bridge failures. In a non-redundant bridge system, the failure of any one critical member may result in the collapse of all or a portion of the bridge system. In a redundant system, two or more components must fail before the bridge system collapses. There are three types of redundancy for bridges:

- *Internal Redundancy*—Internal redundancy relates to the fact that the failure of one element of a member will not result in the failure of other elements of the member. For example, riveted plate girders and multiple eye-bar truss members have internal redundancy. In a riveted plate girder, if a crack begins in one of the elements, it will not propagate directly into adjacent elements. Welded plate girders and rolled sections do not have internal redundancy.
- *Structural Redundancy*—Structural redundancy refers to the redundancy that exists as a result of continuity within the framing element. A statically indeterminate structure, such as a continuous beam, could be classified as being structurally redundant.
- *Load Path Redundancy*—Load path redundancy is related to the ability of the structure-carrying load following the loss of a single member. A bridge such as a two-girder superstructure is classified as non-redundant because it does not have any alternative load paths. The failure of a single girder in a two-girder bridge could result in failure of the entire bridge system. Another example is a single column pier.

Regularly scheduled inspections enable bridge owners to recognize the general condition of a bridge and help to detect any problems that could lead to a failure. Under the National Bridge Inspection Standards, bridges are to be inspected at regular intervals not to exceed 24 months. These schedules may vary if more rigorous requirements have been implemented at the state level.

Bridges rarely experience complete failure during non-extreme events, however when such failures do occur, the results can be catastrophic. Between 1854 and 2007, over 110 bridge failures have occurred in the United States (Cambridge, 2012). Failures occurring in Massachusetts include the following:

- Bussey Bridge, Boston, March 14, 1887—Iron Railroad Bridge collapsed due to poor construction. 30 people were killed with an additional 40 injured.
- Swing bridge in Boston-Charlestown, 1945—Ship impact with bridge while in half-open position resulted in partial collapse.
- Sullivan Square motorway bridge, Boston, 1952—Design error creating instability of scaffolding caused complete collapse.
- Tobin Bridge, September 10, 1973—An overloaded truck traveling northbound rammed into a support beam, knocking the southbound deck on the viaduct section onto the northbound deck, causing significant traffic issues. The collapse shut down the bridge for more than two months as workers repaired both decks of the collapsed viaduct section.
- High Bridge, May 28, 1999—Motorists bound for northern New England for the Memorial Day weekend experienced tire blowouts. The Massachusetts State Police shut down the bridge, and inspectors discovered that the upper deck had separated from the roadway by 8 inches because three of four rusted stringer beams supporting the upper deck had failed. (Source: http://www.bostonroads.com/crossings/zakim/)

5.5.4 Historic and Cultural Resources

The Commonwealth of Massachusetts has a rich cultural heritage and makes every effort possible to preserve that heritage. Cultural resources are an integral part of the Commonwealth's economic vitality, are essential to daily functions, and provide the continuity upon which society depends. Housed in libraries, museums, archives, city and town halls, public records repositories, museums, historical societies, cemeteries, places of worship, and historical properties, these resources represent irreplaceable

elements of the state culture. They exist in many forms: objects, records, manuscript collections, photographs, artistic works, artifacts, audio-visual collections, landscapes, and historic structures. Cultural assets serve as a reminder of the past and a driving force in present day society.

COSTEP-MA is working to protect the cultural heritage and to ensure that it is not ignored in the event of a local or regional disaster. Through its efforts in coordinating disaster mitigation, planning, preparedness, response, and recovery, COSTEP-MA has worked closely with cultural custodians, first responders, and emergency management professionals from all levels of government. Efforts to protect the Commonwealth's cultural heritage are carried out through coordinating community activities that promote cultural heritage, including educational opportunities, historic inventories, and plans essential to determining strategies for preservation. Cultural heritage resources are often valuable, vulnerable, rare, unique, and irreplaceable. They are essential to the functioning of society and to the recovery of municipalities following a disaster.

According to the COSTEP-MA website (www.mass.gov/mblc/constepma) many buildings, collections, and sites of historic and cultural significance are located in FEMA-designated flood zones. At least one quarter of Massachusetts communities have identified cultural resources that are located in flood zones.

In 2011, COSTEP-MA was awarded a hazard mitigation grant by FEMA and MEMA to conduct a three-year public awareness project on risk assessment and mitigation planning to cultural heritage collections and resources and essential government records in the Commonwealth. The project, called *Mitigation for Memory: Safeguarding Massachusetts Cultural History*, is designed to educate emergency management professionals, municipal planners and officials, regional planning agency directors, and cultural custodians. The project focuses on the importance of risk assessment and mitigation planning for cultural resources in hazard mitigation planning for the community. This grant-funded project brings together the representatives of these groups to identify the most efficient ways to integrate mitigation planning for cultural resources into the municipal plan. In addition, workshops will be conducted to train cultural heritage personnel in risk assessment and mitigation planning for their own institutions (on a micro level) as compared to the broader (macro level) of the municipal mitigation plan. The grant is being administered by the Massachusetts Board of Library Commissioners.

5.5.5 Economic Impact

This is a new element for the 2013 plan. Economic recovery after a disaster event is essential to a community's ability to rebound from the event. Resources for recovery following disasters are often limited, especially for small- and medium-sized businesses. Post-disaster business loans require a lengthy application process and often cause indebtedness to an extent greater than before the disaster occurred (Dalhamer and Tierney 1998; Runyan 2006). Given the challenges to post-disaster business recovery, it is important to understand how disasters impact businesses; how businesses recover; and how they might better prepare for extreme events.

Larger, older, and more financially stable businesses, often having previous disaster experience, are more likely than smaller businesses to engage in preparedness activities prior to a disaster event and to recover from such events (Chang and Falit-Baiamonte 2002; Dalhamer and Tierney 1998; Flynn 2007; Graham 2007; Runyan 2006; Tierney 1997; Yoshida & Deyle 2005). New businesses establishing themselves shortly after a disaster incident, when information concerning the event is still vivid in the minds of the communities, have a tendency to better prepare for such events.

Large businesses or chains often have redundant systems in place. Small, single-location businesses are more vulnerable because they lack such redundancy (Tierney, 1997). Small business owners who know about hazards of concern; have knowledge in business management, tax laws, and regulations; and have a business continuity plan are most likely to be able to recover from disaster incidents.

Small businesses typically have more difficulty managing the costs associated with rebuilding after a disaster. They are less able to meet the costs of engaging in structural mitigation and risk reduction, or

even the costs of seeking advice on how to begin the process of rebuilding the business. Even businesses that suffer no direct loss associated with a disaster, or minimal impact from which they quickly recover, continue to see impacts months afterward due to residents' lack of discretionary spending.

Economic losses at the local level impact jurisdictions in multiple ways, including loss of supplies, food, clothing, as well as economic impact supporting local governments through tax bases. Limited data were available in review of the local jurisdictional plans about hazard impacts on the economy.

5.5.6 History of Disaster Declarations

Declared Events and Related Costs

Table 5-4 provides an itemized list of state and federal disaster declarations for the Commonwealth. It includes a summary of assistance funding disbursed as a result of each past disaster declaration. The funding is distributed in the following categories:

- Public Assistance (PA) Project grants—Supplemental disaster assistance to states, local governments, and private non-profit organizations after declared disasters or emergencies.
- Hazard Mitigation Grant Program (HMGP) Project grants—To prevent future losses of lives and property due to disasters. Presidential declaration of a major disaster or emergency designated for hazard mitigation assistance.
- Individual Household Program (IHP; formerly named IFG)—Grants to individuals to provide funds for the serious needs and necessary expenses of disaster victims. NOTE: Individual assistance funding includes loans and grants under the FEMA Disaster Housing, state IFG Program and/or SBA Home and Business Loan Programs.
- Community Development Block Grant (CDBG) Project grants—Community development-type activities for long-term recovery needs (residential/commercial buildings) are covered.

TABLE 5-4.
HISTORY OF DISASTER DECLARATIONS

Disaster Name/ Disaster No.[a]	Date of Event	Declared Areas	Assistance Type[b]	Funds Disbursed		
				Federal	State	Total
Hurricane Bob/ FEMA-914-DR-MA	August 1991	Counties of Barnstable, Bristol, Dukes, Essex, Hampden, Middlesex, Plymouth, Nantucket, Norfolk, Suffolk	PA	$28,166,029	$3,924,237	$32,090,266
			HMGP	$651,881		$651,881
Severe Coastal Storm/ FEMA –920-DR-MA	October 1991	Counties of Barnstable, Bristol, Dukes, Essex, Middlesex, Plymouth, Nantucket, Norfolk, Suffolk	PA	$7,737,086	$983,661	$8,720,747
			IHP	$36,225,970	$581,924	$36,807,894
			HMGP	$626,406		$626,406
Winter Coastal Storm/ FEMA-975-DR-MA	December 1992	Counties of Barnstable, Dukes, Essex, Plymouth, Suffolk	PA	$11,929,598	$1,620,619	$13,550,217
			HMGP	$400,943		$400,943
Blizzard/ FEMA-3103-EM	March 1993	All 14 Counties	PA	$1,284,873	$183,649	$1,468,522
Microburst Storm/ state-declared	July 1994	Town of Greenfield	PA		$59,701	$59,701

TABLE 5-4.
HISTORY OF DISASTER DECLARATIONS

Disaster Name/ Disaster No.[a]	Date of Event	Declared Areas	Assistance Type[b]	Funds Disbursed		
				Federal	State	Total
Berkshire Tornado/ state-declared	May 1995	Towns of Egermont, Great Barrington, and Monterey; DEM and National Guard	PA		$871,633	$871,633
Russell Fire/ FEMA-2116-EM	September 1995	DEM and National Guard	PA	$79,665		$79,665
Russell Fire/ state-declared	September 1995	Towns of Russell, Blandford, Cummington, Huntington, Montgomery, and Southampton	PA		$100,000	$100,000
Blizzard/ FEMA-1090-EM	January 1996	All 14 Counties	PA	$16,177,860		$16,177,860
Windstorm/ state-declared	May 1996	Counties of Plymouth, Norfolk, and Bristol (inclusive of 27 communities)	PA		$774,388	$774,388
Franklin Co. Rainstorm	June 1996	Towns of Montague, Leverett, Shutesbury, Conway, Wendell, DEM, and National Guard			$2,267,236	$2,267,236
Severe Storms, Flood/ FEMA-1142-DR-MA	October 1996	Counties of Essex, Middlesex, Plymouth, Norfolk, and Suffolk	PA	$21.547.026	$3,430,009	$24,977,035
			IFG	$37,065,539	$478,072	$37,543,611
			HMGP	$12,262,500		$12,262,500
			CDBG FY 97	$4,259,911		$4,259,911
Heavy Rain, Flood/ FEMA-1224-DR-MA	June 1998	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, and Worcester	IFG	$20,034,025	$237.243	$20,034,025
			HMGP	$1,769,145		$1,769,145
			CDBG FY 98	$1,500,000		$1,500,000
Worcester Fire/ FEMA-3153-EM	December 1999	City of Worcester, State Fire Mobilization Communities, and various state agencies	PA	$2,733,435		
Tropical Storm Floyd/ state-declared	September 1999	Counties of Hampden, Hampshire, Franklin, Worcester (23 Communities)	PA		$1,690,539.91	$1,690,539.91
Rainstorm/ state-declared	June 25, 2000	Towns of Adams, Cheshire, New Ashford, North Adams, and Williamstown	PA		$316,210.61	$316,210.61
Rainstorm/ state-declared	July 2000	Town of Heath	PA		$180,000.00	$180,000.00
Severe Storms and Flooding/ FEMA-1364-DR-MA	March 2001	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester	IFG	$18,000,000	$213,039.00	$18,213,039.00
			HMGP	$1,562,356.00		$1,562,356.00

TABLE 5-4.
HISTORY OF DISASTER DECLARATIONS

Disaster Name/ Disaster No.[a]	Date of Event	Declared Areas	Assistance Type[b]	Funds Disbursed Federal	State	Total
Snowstorm/ FEMA-3165-EM	March 2001	Counties of Berkshire, Essex, Franklin, Hampshire, Middlesex, Norfolk, and Worcester. The cost share is 75% federal and 25% local.	PA	$21,065,441.93		$21,065,441.93
Tropical Storm Allison/ state-declared	June 2001	Towns of Hampden, Leominster, Monson, Princeton, and Wilbraham	PA		$635,534.00	$635,534.00
Rainstorm/ state-declared	June/July 2001	Towns of Bellingham, Millis, and Walpole	PA		$254,968.02	$254,968.02
Terrorist Attack/ FEMA-1391	September 11, 2001	Massachusetts residents who requested crisis counseling services following September 11.	IFG	$1,500,000.00		$1,500,000.00
Snowstorm/ FEMA-3175-EM	February 2003	All 14 Counties. The cost share is 75% federal and 25% local	PA	$28,868,815.75		$28,868,815.75
Snowstorm/ FEMA-3191-EM	December 2003	Counties of Barnstable, Berkshire, Bristol, Essex, Franklin, Hampden, Hampshire, Middlesex, Norfolk, Plymouth, Suffolk, and Worcester	PA	$35,683,865.83		$35,683,865.83
Flooding/ FEMA-1512-DR	April 2004	Counties of Essex, Middlesex, Norfolk, Suffolk, and Worcester	IFG	$2,249,944.41	$62,457.61	$2,566,783.49
			HMGP	$243,225.00		$243,225.00
Snow/ FEMA-3201-EM	January 2005	All 14 Counties	PA	$49,945,087.29		$49,945,087.29
Hurricane Katrina/ FEMA-3252-EM	August 2005	All 14 Counties- 100% federally funded	PA	$5,855,580.73		$5,855,580.73
Severe Storms and Flooding/ FEMA-3264-EM	October 2005	Bristol County (Taunton Dam)	PA	$595,026.34	$56,819.60	$651,845.94
Severe Storms and Flooding/ FEMA-1614-DR-MA	October 2005	Counties of Berkshire, Franklin, Hampden, Hampshire, Worcester	PA	$6,731,194.23	$712, 674.43	$7,443,868.66
		Counties of Berkshire, Franklin, Hampden, Hampshire, Worcester, Middlesex, Plymouth, Bristol, Norfolk	IHP	$3,452,361.47	$146,281.79	$3,598,643.26
		All 14 Counties ($710,875 total as of 5/1/2009)	HMGP	$67,175.63		$67,175.63
Severe Storms and Flooding/ FEMA-1642-DR-MA	May 2006	Essex and Middlesex Counties	PA	$17,285,547.98	$5,530,431.10	$22,815,979.08
		Essex, Middlesex, Suffolk Counties	IHP	$18,355,115.63	$452,777.98	$18,807,893.61
		All 14 Counties ($2,321,506 total as of 5/1/2009)	HMGP	$240,510.00		$240,510.00
Severe Storms	April 2007		PA	$8,769,388.54	$2,805,305.76	$11,574,694.30

TABLE 5-4.
HISTORY OF DISASTER DECLARATIONS

Disaster Name/ Disaster No.[a]	Date of Event	Declared Areas	Assistance Type[b]	Funds Disbursed Federal	State	Total
& Inland, Coastal Flooding/ FEMA-1701-DR-MA		All 14 Counties ($491,440 total as of 5/1/2009)	HMGP	TBD		TBD
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	Berkshire, Essex, Franklin, Hampden, Hampshire, Middlesex, and Worcester. ****Figure as of 9/8/2009	PA	$66,509,713.79	TBD	TBD
		All 14 Counties (6 month lock-in $7,200,000)	HMGP			
Severe Storms and Flooding/ FEMA-1895-DR-MA	March-April 2010	Bristol, Essex, Middlesex, Norfolk, Plymouth, Suffolk, Worcester	IHP	$58,954,565.86		
			PA	$25,876,403.39		
Severe Winter Storm and Snowstorm/ FEMA-1959-DR-MA	January 2011	Berkshire, Essex, Hampden, Hampshire, Middlesex, Norfolk, Suffolk	PA	$25,944,166.24		
Severe Storms and Tornadoes/ FEMA-1994-DR-MA	June 2011	Hampden, Worcester	IHP	$4,909,121.70		
			HA	$3,001,547.65		
			ON	$1,907,574.05		
Tropical Storm Irene/ FEMA-4028-DR-MA	August 2011	Barnstable, Berkshire, Bristol, Dukes, Franklin, Hampden, Hampshire, Norfolk, Plymouth	IHP	$5,551,834.20		
			HA	$5,296,447.24		
			ON	$255,386.96		
Severe Storm and Snowstorm/ FEMA-4051-DR-MA	October 2011	Berkshire, Franklin, Hampden, Hampshire, Middlesex, Worcester	PA	$71,796,736.97		
Hurricane Sandy/ FEMA-4097-DR-MA	October-November 2012	Barnstable, Bristol, Dukes, Nantucket, Plymouth, Suffolk		TBD	TBD	TBD

a. Disaster numbers are coded as follows: EM = Emergency Declaration; DR = Major Disaster Declaration; FM = Fire Management Assistance.
b. Assistance types are coded as follows: CDBG = Community Development Block Grant; HMGP = Hazard Mitigation Grant Program; IFG = Individual and Family Grant; IHP = Individual Household Program; PA = Public Assistance.

The following programs provide funding associated with disasters:

- **Special Appropriations**:
  - **Following State Disasters—**Following presidential disaster declarations, the Commonwealth may contribute half, or 12.5 percent, of the 25-percent local share of federal infrastructure support funds.
  - **Non-Federally Declared Disaster Assistance**—Although there is no separate state disaster relief fund in Massachusetts, the state legislature may enact special appropriations for communities sustaining damage following a natural disaster that are not large enough for a presidential disaster declaration. Since 1991, Massachusetts has issued 15 state disaster declarations and has provided in excess of $7 million in funding to aid communities affected by natural disasters.
- **State Revolving Fund—**This statewide loan program through the Executive Office of Environmental Affairs assists communities in funding local stormwater management projects that help to minimize or eliminate flooding in poor drainage areas.
- **State Land Acquisition & Conservation Program—**Through the Massachusetts Executive Office of Energy & Environmental Affairs, this annual multi-million dollar program purchases private property for open space, wetland protection, and floodplain preservation purposes. For instance, in 1998, the Commonwealth set a goal of protecting 200,000 acres of open space in the Commonwealth by 2010. In August 2001, less than three years later, the Commonwealth and its land protection partners had reached the halfway mark in achieving that goal (100,000 acres).
- **Major Flood Control Projects—**The Commonwealth provides 50 percent of the non-federal share on the costs of major flood control projects developed in conjunction with the U.S. Army Corps of Engineers. This program is managed by DCR.
- **Natural Resource Conservation Service PL 566 Flood Control Dams—**The Commonwealth funds the necessary engineering technical assistance and funding to operate and maintain the 25 PL 566 flood control dams located on state property.
- **National Flood Insurance Program Staff Funding—**The Commonwealth matches one staff position to FEMA's funding of National Flood Insurance Program staffing, translating to two full-time staff positions in the Flood Hazard Management Program within the DCR. These positions report directly to the federally funded NFIP manager and help implement the NFIP program in Massachusetts.

5.6 LOCAL HAZARD IDENTIFICATION AND RANKING

The 2013 risk assessment incorporates information from local hazard mitigation plans to help determine which jurisdictions are at greatest risk from the various hazards. This section describes the process of incorporating information from these plans. Descriptions of the type of analysis conducted by the local jurisdiction plans are included in plan review synopses provided in Appendix F.

5.6.1 Overview of Regional Planning Agencies

There are 13 planning regions in Massachusetts, established in 1963 under Chapter 40B of the Massachusetts General Laws. The commissions are regional advisory boards consisting of representatives from each member community. They work with partnering jurisdictions and organizations to complete mitigation plans and other planning efforts. Table 5-5 identifies the counties served by each commission. In some instances, the planning commissions cross over into other counties. In some instances, these various regions represent the geographic boundaries associated with the information captured below, and are often the agencies developing the respective hazard mitigation plan.

5.6.2 Local Jurisdiction Hazards of Concern

Review of the risk assessments in these plans shows the following:

- 83 percent of local plans list flood as a hazard of high frequency and impact.
- 94 percent of local plans list hurricanes and tropical storms as hazards of moderate or greater frequency and impact.
- 94 percent of local plans list snow and blizzard as hazards of moderate to high frequency and impact; most of these plans also list nor'easters and ice storms as hazards of moderate or greater frequency and impact.
- 67 percent of local plans list tornadoes as hazards of moderate or greater frequency and impact; most of these plans also list thunderstorms as hazards of moderate or greater frequency and impact.
- 89 percent of local plans list earthquakes as hazards of low or very low frequency and impact.
- Local plans that include an analysis of coastal hazards list coastal hazards as being of moderate or greater impact and frequency.

TABLE 5-5.
PLANNING COMMISSIONS BY COUNTY REPRESENTATION

	Barnstable	Berkshire	Bristol	Dukes	Essex	Franklin	Hampden	Hampshire	Middlesex	Nantucket	Norfolk	Plymouth	Suffolk	Worcester
Berkshire Regional Planning Commission		X												
Cape Cod Commission	X													
Central Massachusetts Regional Planning Commission														X
Franklin Regional Council of Governments						X								
Martha's Vineyard Commission				X										
Merrimack Valley Planning Commission					X									
Metropolitan Area Planning Council					X				X		X	X	X	X
Montachusett Regional Planning Commission									X					X
Nantucket Planning & Economic Development Commission										X				
Northern Middlesex Council of Governments									X					
Old Colony Planning Council			X								X	X		
Pioneer Valley Planning Commission							X	X						
Southeastern Regional Planning & Economic Development District			X								X	X		

Figure 5-2 identifies the most common hazards addressed in the local plans.

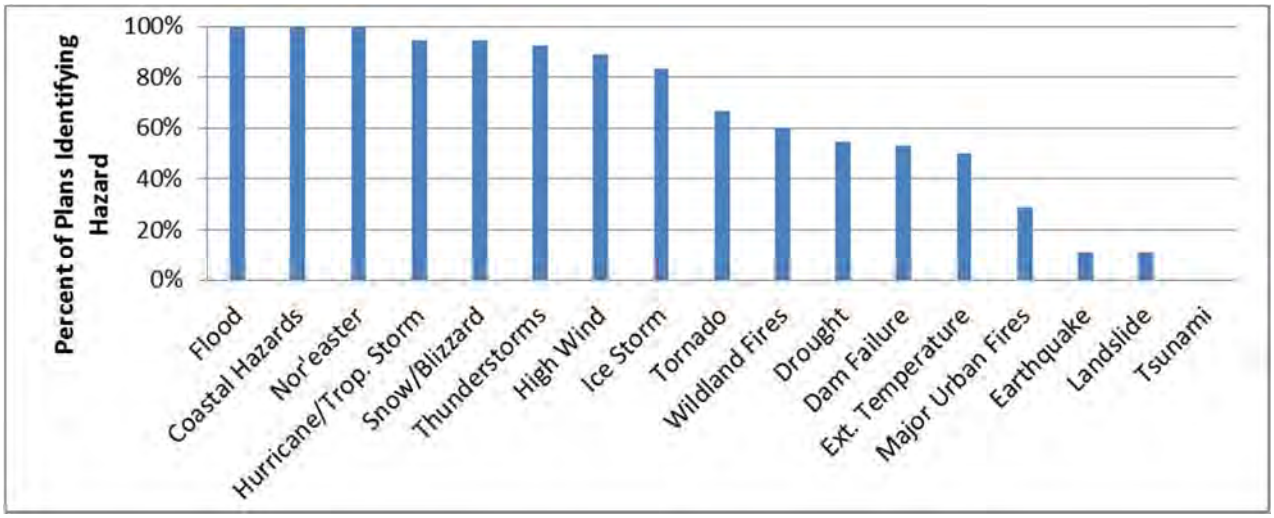


Figure 5-2. Hazards Identified in Local Plans

The top 10 hazards identified in the local plans are as follows:

- Flood: moderate risk or greater in 100% of plans
- Coastal Hazards: moderate risk or greater in 100% of plans
- Nor'easter: moderate risk or greater in 100% of plans
- Hurricane/Trop. Storm: moderate risk or greater in 94.4% of plans
- Snow/Blizzard: moderate risk or greater in 94.4% of plans
- Thunderstorms: moderate risk or greater in 92.3% of plans
- High Wind: moderate risk or greater in 88.9% of plans
- Ice Storm: moderate risk or greater in 83.3% of plans
- Tornado: moderate risk or greater in 66.7% of plans
- Wildland Fires: moderate risk or greater in 60.0% of plans

A review was conducted of risk assessments by each planning commission, and a limited number of local plans were incorporated. Where a regional plan was developed, its hazard ranking was used. Where multiple single jurisdiction plans were developed, the most commonly indicated rank was used. This subjective assessment represented the best available science. This is the same process previously followed for the 2010 plan update. Table 5-6 summarizes the findings of the review.

TABLE 5-6.
HAZARD FREQUENCY TOTALS, REGIONAL PLANNING COMMISSIONS

	Flood	Dam Failure	Coastal Hazards	High Wind	Hurricanes/ Tropical Storms	Thunderstorms	Tornado	Nor'easter	Snow and Blizzard	Ice Storm	Major Urban Fires	Wildland Fires	Drought	Extreme Temperatures	Earthquake	Landslide	Tsunami	**Hazard Rank Total**
Statewide	4	1	4	4	3	4	3	4	4	3	2	3	2	3	1	3	1	**49**
Berkshire	4	3			3	3	2		4	4		3	1		1			**28**
Cape Cod	4		4	3	3	3	2	3	3			2	2		2			**31**
Franklin County	3	1		4	3	4	3	4	4	4		3			2			**35**
MAPC (Average)	4	3		3	3	3	3	4	4	4	2	3	2	2	2	2		**44**
Merrimack Valley	4	3	4		3		2	4	4	4	3	3	3		2	2		**41**
Nantucket	4		4	2	2	3	3	4	4	3	2	3		2	2			**38**
Northern Middlesex	4	3		3	3	3	3	3	4	3			3	3	2			**37**
Old Colony	4	4	4	4	4	4	4	4	4			4			1	3	2	**46**
SRPEDD	4	3	3	3	3	3	3	3	3			3	3		2	2		**38**
Martha's Vineyard	3	1	4		3	3	1	4	2	1		2	3		1	1		**29**
PVPC Hampden County	4	2			3		3		4	4		2	2		2			**26**
PVPC Hampshire County	4	2			3		3		4	4		2	2		2			**26**
Montachusett Region	4	3			3	4	3		4	3	3	4	3		3	2		**39**
Central MA Regional Planning Commission	3	2			3	2	3	3	3	2	2	2	3	3	2	1	1	**35**

Hazard Coding: 1. Very Low | 2. Low | 3. Medium | 4. High | Not Ranked

5.6.3 County-by-County Hazard Ranking

Review of the plan demonstrates that the local jurisdictions assessed risk in various ways, as well as addressing different hazards of concern. Many used a methodology similar to that used for the state hazard-ranking (see Section 5.4). The Northeast Middlesex Council of Governments assessed hazards based on a scale of low, low-moderate, moderate, moderate-high, and high, with data from local Comprehensive Emergency Management Plans (NMCOG, 2012). Others used significantly different methods, establishing point systems and different groupings of hazards. To overcome these variations, risk assessment results from local plans were compared to the analysis using the criteria of high-medium-low and very-low at the county level (coordinating with the 4, 3, 2, 1-based analysis). The information represented at the county level was extracted during plan review.

Table 5-7 indicates whether the hazard is identified in each local plan, to what level the hazard is ranked (high, medium, low, very low), and whether the Commonwealth's analysis found the hazard to be of concern within the county as a result of the Commonwealth's assessment.

TABLE 5-7.
HAZARD RANKING COMPARISON

	Barnstable	Berkshire	Bristol	Dukes	Essex	Franklin	Hampden	Hampshire	Middlesex	Nantucket	Norfolk	Plymouth	Suffolk	Worcester
Flood														
State	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Local	H	H	H	M	H	M	H	H	H	H	H	H	H	M
Coastal Hazards														
State	Y	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	N
Local	H	N/R	M	H	H	N/R	N/R	N/R	N/R	H	N/R	H	N/R	N/R
High Wind														
State	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Local	M	N/R	M	N/R	N/R	H	N/R	N/R	M	L	M	H	M	N/R
Hurricane/ Tropical Storms														
State	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Local	M	M	M	M	M	M	M	M	M	L	M	H	M	M
Thunderstorms														
State	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Local	M	M	M	M	N/R	H	N/R	N/R	M	M	M	H	M	M
Tornado														
State	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y
Local	L	L	M	VL	L	M	M	M	M	M	M	H	M	M
Nor'easter														
State	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Local	M	N/R	M	H	H	H	N/R	N/R	M	H	H	H	M	M
Wildland Fires														
State	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Local	L	M	M	L	M	M	L	L	M	M	M	H	M	L
Earthquake														
State	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Local	L	VL	L	VL	L	L	L	L	L	L	VL	VL	L	L
Landslide														
State	N	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Local	N/R	N/R	L	VL	L	N/R	N/R	N/R	L	N/R	VL	M	L	VL

N/R = Not Ranked by Local Jurisdiction's Hazard Mitigation Plan; H= High Hazard Ranking, M = Medium Hazard Ranking, L = Low Hazard Ranking, VL = Very Low Hazard Ranking

If there is a level of risk determined, there is an indication of "Y" for yes. If there was no indication of risk associated, there is an indication of "N" for no. In some instances, the Commonwealth's risk assessment determined that a jurisdiction was vulnerable to the hazard, while the jurisdiction did not address the hazard or assessed "no risk" to the hazard. Based on limited response to some of the hazards, only the top 10 hazards of concern identified by the local jurisdictions are compared.

5.6.4 Review of Previous Disaster Events

Table 5-8 shows the distribution of federal and state disaster declarations by affected county. In some instances, the state emergency declaration did evolve into a federal declaration, so the incidents may be indicated twice within the table.

TABLE 5-8.
HISTORY OF FEDERAL DISASTER DECLARATIONS, 1953 – 2012

Disaster No. [a]	Disaster Type	Date	Incident Period	Barnstable	Berkshire	Bristol	Dukes	Essex	Franklin	Hampden	Hampshire	Middlesex	Nantucket	Norfolk	Plymouth	Suffolk	Worcester	**Total by Disaster**
EM-3350	Hurricane Sandy	10/28/12	10/27/12 - 11/8/12	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3343	Severe Storm	11/01/11	10/29/11 - 10/30/11		X			X	X	X	X	X		X			X	**8**
EM-3330	Hurricane Irene	08/26/11	8/26/11 - 9/5/11	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3315	Hurricane Earl	09/02/10	9/1/10 - 9/4/10	X		X	X	X				X	X	X	X	X	X	**10**
EM-3312	Water Main Break	05/03/10	5/1/10 - 5/5/10					X				X		X		X		**4**
EM-3296	Severe Winter Storm	12/13/08	12/11/08 - 12/18/08		X	X		X	X	X	X	X				X	X	**9**
EM-3264	Severe Storms and Flooding	10/19/05	10/7/05 - 10/22/05			X												**1**
EM-3252	Hurricane Katrina Evacuation	09/13/05	8/29/05 - 10/1/05	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3201	Snow	02/17/05	1/22/05 - 1/23/05	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3191	Snow	01/15/04	12/6/03 - 12/7/03	X	X	X		X	X	X	X	X		X	X	X	X	**12**
EM-3175	Snowstorm	03/11/03	2/17/03 - 2/18/03	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3165	Snowstorm	03/28/01	3/5/01 - 3/7/01		X			X	X		X	X		X			X	**7**
EM-3153	Fire	12/06/99	12/3/99 - 12/13/99					X				X		X	X	X	X	**6**
EM-3119	Extreme Weather/ Flooding	10/23/96	10/20/96 - 10/25/96															**0**
EM-3103	Blizzards, High Winds and Record Snowfall	03/16/93	3/13/93 - 3/17/93	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3059	Blizzard and Snowstorm	02/07/78	02/07/78													X		**1**

TABLE 5-8.
HISTORY OF FEDERAL DISASTER DECLARATIONS, 1953 – 2012

Disaster No. [a]	Disaster Type	Date	Incident Period	Barnstable	Berkshire	Bristol	Dukes	Essex	Franklin	Hampden	Hampshire	Middlesex	Nantucket	Norfolk	Plymouth	Suffolk	Worcester	**Total by Disaster**
FM-2116	Russell Fire	09/12/95	09/05/95															**0**
DR-4097	Hurricane Sandy	12/19/12	10/27/12 - 11/8/12	X		X	X						X		X	X		**6**
DR-4051	Severe Storm And Snowstorm	01/06/12	10/29/11 - 10/30/11		X				X	X	X	X					X	**6**
DR-4028	Tropical Storm Irene	09/03/11	8/27/11 - 8/29/11	X	X	X	X		X	X	X			X	X			**9**
DR-1994	Severe Storms and Tornadoes	06/15/11	06/01/11							X							X	**2**
DR-1959	Severe Winter Storm and Snowstorm	03/07/11	1/11/11 - 1/12/11		X			X		X	X	X		X		X		**7**
DR-1895	Severe Storm and Flooding	03/29/10	3/12/10 - 4/26/10			X		X				X		X	X	X	X	**7**
DR-1813	Severe Winter Storm and Flooding	01/05/09	12/11/08 - 12/18/08		X			X	X	X	X	X					X	**7**
DR-1701	Severe Storms, Inland & Coastal Flooding	05/16/07	4/15/07 - 4/25/07	X	X		X	X	X	X	X				X			**8**
DR-1642	Severe Storms and Flooding	05/25/06	5/12/06 - 5/23/06					X				X				X		**3**
DR-1614	Severe Storms and Flooding	11/10/05	10/7/05 - 10/16/05		X	X			X	X	X	X		X	X		X	**9**
DR-1512	Flooding	04/21/04	4/1/04 - 4/30/04					X				X		X		X	X	**5**
DR-1364	Severe Storms & Flooding	04/10/01	3/5/01 - 4/16/01			X		X				X		X	X	X	X	**7**
DR-1224	Heavy Rain And Flooding	06/23/98	6/13/98 - 7/6/98			X		X				X		X	X	X	X	**7**
DR-1142	Severe Storm/ Flooding	10/25/96	10/20/96 - 10/25/96					X				X		X	X	X		**5**
DR-1090	Blizzard	01/24/96	1/7/96 - 1/13/96	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
DR-975	Winter Coastal Storm	12/21/92	12/11/92 - 12/13/92	X			X	X				X	X	X	X	X	X	**9**
DR-920	Severe Coastal Storm	11/04/91	10/30/91 - 11/2/91	X			X	X					X	X	X	X		**7**
DR-914	Hurricane Bob	08/26/91	08/19/91	X		X	X	X		X		X	X	X	X	X	X	**11**

TABLE 5-8.
HISTORY OF FEDERAL DISASTER DECLARATIONS, 1953 – 2012

Disaster No. [a]	Disaster Type	Date	Incident Period	Barnstable	Berkshire	Bristol	Dukes	Essex	Franklin	Hampden	Hampshire	Middlesex	Nantucket	Norfolk	Plymouth	Suffolk	Worcester	**Total by Disaster**
DR-790	Severe Storms, Flooding	04/18/87	3/30/87 - 4/13/87		X			X	X	X	X	X		X			X	**8**
DR-751	Hurricane Gloria	10/28/85	09/27/85	X	X	X	X	X	X	X	X	X		X	X	X	X	**13**
DR-650	Urban Fire	12/03/81	12/03/81					X										**1**
DR-546	Coastal Storms, Flood, Ice, Snow	02/10/78	2/6/78 - 2/8/78	X		X	X	X					X	X	X	X		**8**
DR-405	Fire (City of Chelsea)	10/16/73	10/16/73													X		**1**
DR-357	Toxic Algae in Coastal Waters	09/28/72	09/28/72	X		X	X	X					X	X	X	X		**8**
DR-325	Severe Storms, Flooding	03/06/72	03/06/72					X						X	X	X		**4**
DR-43	Hurricane/ Floods	08/20/55	08/20/55															**0**
DR-22	Hurricanes	09/02/54	09/02/54															**0**
DR-7	Tornado	06/11/53	06/11/53															**0**
			Total	**18**	**19**	**21**	**17**	**33**	**18**	**20**	**19**	**28**	**14**	**29**	**25**	**29**	**25**	
			Major Disaster Declaration	**10**	**9**	**11**	**10**	**20**	**8**	**11**	**9**	**15**	**7**	**17**	**16**	**17**	**13**	**28**

a. Disaster numbers are coded as follows: EM = Emergency Declaration; DR = Major Disaster Declaration; FM = Fire Management Assistance. Some EM declarations may have become major federal declarations and are listed in both categories.

When determining the level of risk to which a jurisdiction is susceptible, consideration must also be given to events that do not rise to the level of a FEMA or state-declared disaster event. Review of National Climatic Data Center (NCDC) data for various hazards demonstrates a higher number of events that have occurred than those which rose to the level of a state- or federal-declared event. Review of the online Spatial Hazard Event and Losses Database demonstrates similar data.

Information in this section is obtained from sources including local plans, FEMA website, state disaster data, NOAA, NCDC, and reports and studies on the state's drought assessment, climate change, and various fire analyses. These data demonstrate that, while FEMA disaster declarations are customarily used to determine a jurisdiction's level of risk, most jurisdictions sustain damage much more frequently for incidents that are not recognized declared disasters, but nonetheless have significant impacts. The following are examples of costs associated with disasters not declared:

- The Commonwealth as a whole has never sustained a state or federal drought declaration, but the 2010 analysis recognized six counties for drought incidents. Analysis for this update found that jurisdictions in 10 counties (Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, Suffolk, and Worcester Counties) sustained drought impacts since 2010.

- Four counties have sustained significant urban fires, but only two were state or federal declared disasters. Worcester County listed two major urban fires in its plan. Since 2010, one additional event occurred in the county, as well as three incidents in Berkshire, Eastern Hampden, and Western Norfolk. While several fires are designated by multiple counties, only one has risen to the level of a FEMA declaration for fire management assistance—the 1995 Russell Fire (FM-2116), and two for disaster declarations—the 1981 Urban Fire (DR-650), and the 1973 City of Chelsea Fire (DR-405).
- Main water supply lines (Massachusetts Water Resources Authority) were impacted in four counties, causing the need to boil water throughout the greater Boston area on May 1, 2010, which rose to the level of a state declaration.

Eight counties have sustained a disaster declaration for fish loss due to toxic algae blooms, which resulted in an "estimate of economic impact due directly to lost shellfish sales in Massachusetts and Maine as a result of imposed closures at approximately $20 million (based on historical state and NOAA National Marine Fisheries Service annual harvest data)" (Council on Environmental Quality, 2008). The NCDC database lists eight events in Berkshire County. Two rose to the level of state or federal declarations (DR-1895 and DR-4028); the remainder were events that caused flooding over roadways. In one case a public park was partially flooded and structures with basements experienced some minor flooding. Since 1953, there have been 45 federally declared disaster events: 16 emergency declarations; one fire management declaration; and 28 major disaster declarations. A breakdown of those events is as follows (the total is greater than 45 because disaster events may fall into more than one category):

- 20 primarily involved flooding
- 3 primarily involved tornadoes
- 12 were blizzards, major snowstorms or severe winter storms
- 11 were severe weather events
- 2 were major fires.

This information indicates that while some areas may not reach the level of a disaster declaration, they are, in fact, significantly impacted by hazard events, increasing their level of vulnerability. In general, there has been minimal change in hazard risk or any increased risk by a jurisdiction since completion of the 2010 plan, but additional events in the past three years have increased overall impact.

5.7 LOCAL PLAN LOSS ESTIMATION APPROACH

The previous section assessed and ranked the natural hazards that are most likely to occur in Massachusetts. This section provides additional information on how natural hazards may impact a particular jurisdiction.

5.7.1 Limitations of Local Plan Loss Estimates

Since each region or local community analyzed losses differently (if at all), it is not possible to represent the information comparatively across the Commonwealth. The Commonwealth has endeavored during the 2013 update, to demonstrate loss data in different ways to ensure that adequate information of varying types is available to help fulfill the requirement to the best level possible based on available data. This includes, where possible, loss estimations captured from within the local plans selected for integration within this portion of the plan.

Due to the number of plans in place, information from randomly selected plans was incorporated within this section. While a range of plans were reviewed, that range includes the largest City within the Commonwealth, Boston, down to some of its smallest cities so as to provide a well-rounded perspective. Selected plans show variety with respect to: the hazards identified, type of risk assessment completed, availability of dollar loss estimations, risk matrices (where available) to rank the hazards of concern, as well as review of the goals and mitigation actions identified.

Use of loss data from local hazard mitigation plans is restricted by three major factors: absence of loss data in the local plans, inconsistent methods for determining losses, and inconsistent designations of critical facilities. These limitations are described in the sections below.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(2)(ii & iii), which state the following:

To be effective the plan must include:

- An overview and analysis of the State's vulnerability to the hazards described in this paragraph §201.4(c)(2), based on estimates provided in local risk assessments as well as the State risk assessment. The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events. State owned or operated critical facilities located in the identified hazard areas shall also be addressed.
- An overview and analysis of potential losses to the identified vulnerable structures, based on estimates provided in local risk assessments as well as the State risk assessment. The State shall estimate the potential dollar losses to State owned or operated buildings, infrastructure, and critical facilities located in the identified hazard areas.

Absence of Local Loss Data

The SHMP is required to provide an overview and analysis of potential losses to identified structures based on estimates from local risk assessments (44 CFR 201.4.c.2.iii); however, the local plans lack the necessary detail and consistency for such an analysis to be performed. Few of the local plans include loss information because it is not a requirement under FEMA planning regulations (44 CFR 201.6.c.2.ii). Local plans are required to provide only a summary of each hazard and its impact on communities.

Variations in Methodology

For some jurisdictions that do provide dollar loss estimates, the methodology used is not appropriate for use in this SHMP. For example, one jurisdiction assumed 100-percent destruction for all hazards, which results in excessively high estimates of loss. Other jurisdictions used only the Hazus loss estimates for content value, yielding very low estimates of loss. Measures that can be used to estimate hazard loss levels include historical impact based on payouts, vulnerable populations, structures or critical facilities in hazard areas, and projected population growth. Other methods of analysis used for local hazard plans that were reviewed include the following:

- Loss estimate for all properties within the 100-year floodplain based on assessor's values
- Loss estimate for all properties within the 100-year floodplain based on a median home value from census data
- Qualitative estimates based on the number of critical facilities in a 100-year floodplain.
- Qualitative estimates based on the number of residential structures in a 100-year A or V flood zone.
- Qualitative estimates based on the number of critical facilities located in a SLOSH zone.
- Number of structures in 100-year, 500-year or SLOSH (compounded)
- Number of repetitive-loss properties

- Total value of NFIP flood claims paid
- Number of NFIP flood claims paid
- Number of NFIP policies in force
- Average building values per acre for flood/SLOSH
- Average building values per acre for winter weather
- Average building values per acre for wind.
- Average building values per acre for landslide.

Critical Facilities

Some jurisdictions had difficulties assessing the risk to critical facilities in hazard areas. Some local plans used only the standard five facility types identified in Hazus (emergency operations centers, fire and police stations, schools/colleges, and hospitals); others identified many additional structures:

- Access roads to all listed facilities
- Bridges
- City or town offices
- Communication facilities
- Correctional facilities
- Dams
- Daycare facilities with more than five children
- Electric power substations
- Emergency operations centers
- Emergency shelters
- Evacuation routes
- Flood gates
- Gas pipelines/storage sites
- Hospitals
- Municipal wells
- Nuclear sites
- Nursing homes/elderly housing/senior centers
- Police and fire stations
- Power plants
- Problem areas based on local knowledge
- Public works garages
- Schools and colleges
- Sewage pumping stations
- Transportation hubs
- Water and wastewater treatment plants

- Water pumping stations and tanks.

While all of these structures are valid for treatment as critical facilities, difficulties in assessing dollar losses for critical infrastructure at the local level arise due to the variation of data included. Similarly, as the plans are developed, no standard methodology is used for assessing values to the critical facilities. Depending solely on Hazus default data rather than enhanced local datasets has not been consistently reliable, even though for most jurisdictions it is the best available science and meets requirements.

5.7.2 Selected Approach for Local Loss Estimates

Description of Selected Loss Estimation Approach

Given the data and methodology limitations of loss estimates from current local hazard mitigation plans, an overall vulnerability analysis using information from local plans was not possible in the risk assessment of this plan. Therefore, the Commonwealth elected to incorporate a county-by-county breakdown of impact in its risk analysis. To address inconsistencies in defining critical facilities, the Commonwealth used the five Hazus-defined default facilities within its analysis; however, the analysis used state GIS data, which, when validated, proved to be more accurate than the Hazus default data. For purposes of this assessment, public infrastructure was defined to include: roads, bridges, trains, and airports. Essential services included: utilities, hospitals, schools, police and fire stations, and emergency operations centers.

During review of the local plans, hazard ranking data were captured so as to allow for analysis between the Commonwealth's assessment and that determined by the local jurisdictions. The results of the loss estimation are presented in the hazard profiles in Sections 6 through 16. Where Hazus was used, this analysis is based on the Level 1 Hazus-defined data. Analyses were performed using the best available data.

Future Benefits of Selected Loss Estimation Approach

MEMA is taking proactive measures to help local jurisdictions determine risk loss in dollar values in a more consistent manner. All risk analysis work performed for this update, including Hazus and GIS models, will be available to local jurisdictions for enhancements and use during future plan development. This will provide a more uniform methodology for determining loss estimations, so as to provide enhanced capabilities for future planning efforts in capturing information from local plans. In addition, MEMA and DCR will provide training in a systematic approach to risk assessments that includes dollar losses, so that future plan editions will include better data for use in statewide loss estimates.

MEMA and DCR will continue to support the enhancement of data to support the development of a more robust risk assessment. Projects such as the landslide data enhancement project currently underway will provide relevant information to enhance the ability for local jurisdictions to perform GIS risk analysis that provides loss information. MEMA and DCR will look to other avenues over the life cycle of this plan to enhance data for use by local jurisdictions. A new survey for use by local jurisdictions, developed at the beginning of the planning process, will serve two purposes: it will give local jurisdictions information and concepts to include in their plans; and, when returned to MEMA, it will help MEMA capture relevant information for use in future state plan updates. A sample of the survey is included in Appendix E.

5.7.3 Growth and Development

The SHMP assesses jurisdictions and the changes in development that may impact vulnerability by either increasing or decreasing risk. Statewide population growth estimates, projections, and land use data was used to determine if the vulnerability has changed or is expected to change. In Section 4, the plan demonstrates that land uses, development trends, transportation, economy, and population were assessed to obtain a statewide picture of changes to vulnerability. As suggested in the guidance, this information is presented using text, graphics, and maps. In addition, this plan incorporates the development trends provided in local mitigation plans.

The analysis shows that there has not been a significant change in population, land use, economy, or transportation within the past three years that impacts that state's vulnerability to hazards. Most of the state saw a historical change in development from the 1960s to the 1990s.

Damage and losses in most communities are generally associated with existing infrastructure and buildings rather than new growth. Building codes and land use regulations, described in Section 17, limit development in hazard areas or require construction to meet higher standards within hazard areas. This provides a reduction of risk in areas where new development is occurring. In addition, infrastructure improvements, such as the Accelerated Bridge Program, outlined in Section 4.7.3, also strengthen the Commonwealth's resilience by providing enhancements and improvements above existing conditions.

However, jurisdictions experiencing growth and development in the future may have an increase in vulnerability to and impact from some hazards. For example, increased areas of impervious surfaces associated with development do have the potential to increase urban flooding. Jurisdictions approving new development will use mitigation tools such as low-impact development standards, Wetlands Protection Act, and Storm water Management ordnances and by-laws to mitigate any possible increase to their risk. To continue with the analysis of development that could occur and what codes and regulations exist to mitigate new growth the SHMT with continue to partner with the SHMIC to analyze statewide growth and how it relates to risk. Section 17 outlines the states specific goals and actions to achieve this coordination.

The SHMT looked at changes in growth and development as summarized in local mitigation plans. An analysis was performed of the total number of housing units, estimated housing values, estimated housing unit growth from 2000 through 2011, total population, and estimated population change from 2000 through 2011. Table 5-9 and Table 5-10 present the results. Additional data are provided in Section 4.

TABLE 5-9.
U.S. CENSUS HOUSING UNIT STATISTICS BY COUNTY

	Number of Housing Units				Change In Housing Units			
County	2000	2009	2010	2011	2010-2011	2000-2011	Average Annual	Average Value
Barnstable	147,463	155,686	160,281	161,001	720	13,538	1,231	$193,101
Berkshire	66,354	68,539	68,508	68,497	-11	2,143	195	$160,020
Bristol	217,090	225,670	230,535	231,083	548	13,993	1,272	$127,761
Dukes	14,886	16,381	17,188	17,385	197	2,499	227	$135,570
Essex	287,423	299,508	306,754	307,559	805	20,136	1,831	$148,912
Franklin	31,960	33,362	33,758	33,806	48	1,846	168	$123,156
Hampden	185,982	191,380	192,175	192,197	22	6,215	565	$144,859
Hampshire	58,732	61,949	62,603	62,766	163	4,034	367	$140,233
Middlesex	577,269	598,481	612,004	614,036	2,032	36,767	3,342	$155,303
Nantucket	9,258	10,657	11,618	11,776	158	2,518	229	$293,002
Norfolk	255,449	266,793	270,359	271,502	1,143	16,053	1,459	$180,494
Plymouth	181,843	194,237	200,161	201,419	1,258	19,576	1,780	$134,366
Suffolk	292,633	305,127	315,522	317,327	1,805	24,694	2,245	$121,392
Worcester	298,729	320,551	326,788	328,586	1,798	29,857	2,714	$136,488

TABLE 5-10.
POPULATION GROWTH PROJECTIONS BY COUNTY

	Population			Population Change		2020 Projection	
	2000	2009	2011	2009-2011	2000-2011	Population	Change from 2011
Barnstable	222,230	221,151	215,769	-5,382	-6,461	299,035	39%
Berkshire	134,953	129,288	130,458	1,170	-4,495	118,452	-9%
Bristol	534,678	547,433	548,922	1,489	14,244	576,868	5%
Dukes	14,987	15,974	16,766	792	1,779	21,822	30%
Essex	723,419	742,582	748,930	6,348	25,511	787,032	5%
Franklin	71,535	74,778	71,599	-3,179	64	73,806	3%
Hampden	456,228	471,081	463,783	-7,298	7,555	453,115	-2%
Hampshire	152,251	156,044	157,822	1,778	5,571	163,233	3%
Middlesex	1,465,396	1,505,006	1,518,171	13,165	52,775	1,469,494	-3%
Nantucket	9,520	11,322	10,142	-1,180	622	14,426	42%
Norfolk	650,308	666,303	675,436	9,133	25,128	652,440	-3%
Plymouth	472,822	498,344	497,579	-765	24,757	517,664	4%
Suffolk	689,807	753,580	730,932	-22,648	41,125	776,811	6%
Worcester	750,963	803,701	801,227	-2,474	50,264	843,534	5%
State Total	**6,349,097**	**6,596,587**	**6,587,536**	**-9,051**	**238,439**	**6,767,732**	**3%**

Based on these estimates, it is not likely that the natural hazard risks statewide will increase rapidly during the next three years. However, in the jurisdictions experiencing growth, the hazards may be locally exacerbated. The local plans reviewed indicate minimal short-term changes in risk, and the state review found similar results. Based on particular land use or development patterns locally, while there have been some areas of growth, limited increases in natural hazard risks have occurred to date.

5.7.4 Disaster Financial Aid by Jurisdiction

Losses based on previous disaster events are also a good indicator of potential future damage. Since 1991, more than $650 million in federal and disaster assistance has been obligated to Massachusetts in the last 15 years. MEMA maintains an archive listing all declared disaster events and the financial aid received. Table 5-11 summarizes public assistance funding by jurisdiction for four recent disaster declarations. This funding stream includes state agencies, private non-profits, and other eligible applicants whose physical damage is in more than one county or cannot be geographically identified. Since 2010, the county with the highest amount of FEMA Public Assistance Recovery eligible work losses is Hampden County, with $87,909,754 in recorded losses. In the 2010 plan, Worcester County had the highest losses amount, totaling $22,769,578.

TABLE 5-11.
PA PROGRAM FUNDING FOR DISASTER RECOVERY
ASSOCIATED WITH DR-4051, DR-4028, DR-1994, AND DR-1959

	Type of Hazard				
County	Severe Storm and Snow Storm 2011 DR-4051	Hurricane Irene 2011 DR 4028	Severe Storm and Tornadoes 2011 DR 1994	Severe Winter Storm and Snow Storm 2011 DR 1959	**Total Losses**
Barnstable	0	$1,178,043	0	0	**$1,178,043**
Berkshire	$404,015	$5,374,753	0	$687,684	**$6,466,453**
Bristol	0	$1,979,451	0	0	**$1,979,451**
Dukes	0	$49,249	0	0	**$49,249**
Essex	0	0	0	$3,440,957	**$3,440,957**
Franklin	0	$9,367,903	0	0	**$9,367,903**
Hampden	$53,528,269	$1,856,512	$30,887,637	$1,637,335	**$87,909,754**
Hampshire	$3,008,378	$877,145	0	$636,070	**$4,521,595**
Middlesex	$4,514,832	0	0	$6,737,510	**$11,252,342**
Nantucket	0	0	0	0	**0**
Norfolk	0	0	0	$3,097,204	**$3,097,204**
Plymouth	0	$2,082,031	0	0	**$2,082,031**
Suffolk	0	0	0	$2,784,768	**$2,784,768**
Worcester	$6,778,798	0	$311,152	0	**$7,089,951**
State	$1,960,662	$1,024,263	$3,182,410	$6,798,306	**$12,965,642**

As of the writing of this 2013 update, Hurricane Sandy figures are still pending, and therefore not included in this analysis. As more informative data are developed, this information will be enhanced for the next planning cycle. With the exception of Hurricane Sandy, Nantucket was not declared for any disaster events for this update (2010-2012).

5.7.5 Summary

The risk assessments of the local plans were reviewed for specific local information that would improve the SHMP assessment of vulnerability, as well as determination of which jurisdictions were at greatest risk from the natural hazards addressed in the plan. Review of the local and statewide risk assessment provides the following general conclusions:

- Middlesex and Essex Counties have had the highest number of declared flood events. The 2012 Northern Middlesex Hazard Mitigation Plan identifies 53 flood events from 1950 through July 2010. Review since 2010 shows one additional flood event in Middlesex since that time related to a hurricane.
- According to a 1999 study of U.S. Army Corps of Engineers and FEMA data, of the nation's 3,043 counties, Worcester County has the greatest number of dams, 425. Many of these dams are over 100 years old. The age of a dam increases the level of risk with associated failures. Similarly, land use development trends change, and dam inundation since the dams' original construction can have much greater impact than previously. Development of dam inundation zones and safety plans are the responsibility of the dam owners. In many instances, data

concerning this information are not provided by the dam owners to jurisdictions for planning purposes.

- Historically, Farmington River-West Branch, Marsh Brook, Millers River, Quaboag River, and Westfield River-Middle Branch have had the greatest risk of ice jams.
- As indicated in the risk assessment and hazard profiles, each area of the coast is impacted differently by each type of coastal hazard and has varying vulnerability. The coastal zones are North Shore, Boston Harbor/Massachusetts Bay, South Shore, Cape Cod and Islands, and South Coast.
- Based on wind analysis, the coastal area is most frequently impacted by damage due to high wind events.
- The entire Commonwealth is vulnerable to hurricanes and tropical storms, dependent on the storm's track. The coastal areas are more susceptible to damage from these storms.
- The area at greatest risk for a tornado touchdown runs from central to northeastern Massachusetts.
- Higher snow accumulations are more prevalent at higher elevations in Western and Central Massachusetts, and along the coast where snowfall can be enhanced by additional ocean moisture.
- Ice storms occur more frequently in the higher elevations of Western and Central Massachusetts.
- The southeastern parts of Massachusetts—Plymouth County to the Southern coast of Bristol County, Cape Cod, and Martha's Vineyard—are more susceptible to wildland fires due to the availability of fuel, impact from offshore winds, and past events.
- Colder temperatures and weather variations are more common at higher elevations.
- Western Massachusetts may be more vulnerable than eastern Massachusetts to severe drought.
- Northeastern Massachusetts, especially along the Massachusetts coastline from the northern portion of Plymouth County through the Boston metropolitan area to the New Hampshire border, has greater vulnerability to potential earthquake activity than the rest of the Commonwealth.
- The Connecticut River Valley in western Massachusetts and the greater Boston area have the highest risk for landslide.
- All of the coastal areas of Massachusetts are exposed to the threat of tsunamis.

Many local plans used information from the SHMP's risk assessment or from the same sources. While the SHMP is an excellent source of information, it also has drawbacks, as jurisdictions are not necessarily reviewing the hazard profiles at jurisdiction-specific level, but rather statewide. It is hoped that with the inclusion of county-specific data in the 2013 updated risk assessment, more locally specific assessments will occur during the next updates of local plans.

Local plans used a variety of methodologies to assess their vulnerability to hazards, which makes it difficult to incorporate data from the local plans into the Commonwealth's risk assessment element. Many plans rated hazards through a three-tier, *high—medium or moderate—low* vulnerability system. Still, the hazards of greatest concern to local jurisdictions remain consistent with previous editions of the local plans and with the current SHMP.

The review of local plans does not indicate the need for any revisions to the 2013 SHMP risk assessment, as the hazards remain consistent between the last planning cycle and this planning cycle. The exception is

the inclusion by some local jurisdictions of technological hazards, as well as consideration of the potential impacts of climate change, coastal erosion, and sea level rise. It is anticipated that the number of plans that address these issues will increase during the next planning cycle.

SECTION 6. COASTAL EROSION AND SHORELINE CHANGE

6.1 GENERAL BACKGROUND

Erosion and flooding are the primary coastal hazards that lead to the loss of lives or damage to property and infrastructure in developed coastal areas. Coastal storms are an intricate combination of events that impact a coastal area. A coastal storm can occur any time of the year and at varying levels of severity. One of the greatest threats from a coastal storm is coastal flooding due to storm surge. This is the inundation of land areas along the oceanic coast and estuarine shoreline by seawaters over and above normal tidal action.

Many natural factors affect erosion of the shoreline, including shore and nearshore geology, nearshore bathymetry, shoreline orientation, and climate change through increased storm frequency, temperature, and precipitation. Coastal shorelines change constantly in response to wind, waves, tides, sea level fluctuation, seasonal and climatic variations, human alteration, and other factors that influence the movement of sand and material within a shoreline system. High winds, erosion, heavy surf, and unsafe tidal conditions are ordinary coastal hazard phenomena. Some or all of these can occur during a coastal storm, often resulting in detrimental impacts on the surrounding coastline. Storms, including nor'easters and hurricanes, decreased sediment supplies, and sea-level rise contribute to these coastal hazards.

Loss (erosion) and gain (accretion) of coastal land are visible results of the way these conditions reshape shorelines (www.mass.gov/czm/hazards/shoreline_change/shorelinechangeproject.htm). Shorelines tend to change seasonally, accreting slowly during summer when sediments are deposited by relatively low energy waves and eroding dramatically during winter when sediments are moved offshore by high-energy storm waves, such as those generated by nor'easters. Regardless of the season, coastal storms typically cause erosion. With anticipated changes in climate, an increase in intensity of storms is expected (Emanuel, 2013). This will increase the likelihood of severe erosion along the Massachusetts coast.

Coastal erosion and shoreline change can result in significant economic loss through the destruction of buildings, roads, infrastructure, natural resources, and wildlife habitats. Damage often results from the combination of an episodic event with severe storm waves and dune or bluff erosion. Some of the methods used by property owners to stop, or slow down, coastal erosion or shoreline change can actually exacerbate the problem. Attempting to halt the natural process of erosion with seawalls and other hard structures typically worsens the erosion in front of the structure, prevents any sediment behind the structure from supplying down drift properties with sediment, and subjects down drift beaches to increased erosion. Without the sediment transport associated with erosion, some of the Commonwealth's greatest assets and attractions—beaches, dunes, barrier beaches, salt marshes, and estuaries—are threatened and will slowly disappear as the sediment sources that feed and sustain them are eliminated.

The Office of Coastal Zone Management (CZM) is the lead for coastal policy and technical assistance in the Commonwealth. The CZM has been collecting new data and studying and monitoring shoreline change for an extended time; it is beyond the scope of this document to provide all of relevant data captured during this process; however, as appropriate, information has been included within this risk assessment which is relevant, as well as in the various other portions of this document which support mitigation efforts, such as the capabilities matrix and other relevant hazard profiles. Likewise, additional information on shoreline change may also be found in CZM's *Fact Sheet on Massachusetts Shoreline Change Project* at http://www.mass.gov/czm/hazards/shoreline_change/shorelinechangeproject.htm.

In 2001, CZM completed an update of the Shoreline Change Project, using 1994 National Oceanic and Atmospheric Administration (NOAA) aerial photographs of the Massachusetts shoreline. CZM established an agreement with the U.S. Geological Survey (USGS), the Woods Hole Oceanographic

Institution Sea Grant Program, and Cape Cod Cooperative Extension to produce a 1994 shoreline map, add it to the previous project, and update the statistics and calculate erosion rates. The work was conducted by Rob Thieler and Courtney Schupp at the USGS and Jim O'Connell at the Woods Hole Oceanographic Institution Sea Grant Program and Cape Cod Cooperative Extension. The maps and statistical analysis of shoreline change now cover the time period from the mid-1800s to 1994.

In 2013, through collaboration with the USGS, CZM completed an updated of the Massachusetts Shoreline Change Project with a new shoreline that spans 2007 to 2009. The USGS delineated and analyzed this latest shoreline with other shorelines at 50-meter intervals to compute long-term (approximately 150-year) and short-term (approximately 30 year) rates of shoreline change. Other shorelines added as part of this update include a 2000 shoreline derived by USGS that covers most of the ocean-facing coastline, as well as a 2001 shoreline for the South Shore that was delineated by Applied Coastal Research and Engineering. New shorelines and more than 26,000 transects with updated change rates, uncertainty values, and net distances of shoreline movement have been added to the Massachusetts Ocean Resources Information System Shoreline Change Browser.

Figure 6-1 is an example map created using the Massachusetts Ocean Resources Information System Shoreline Change Browser for an area in Winthrop, Massachusetts. Local communities may refer to the Shoreline Change Browser for a more detailed look at the shoreline and associated data: http://maps.massgis.state.ma.us/map_ol/czm_shorelines.php.

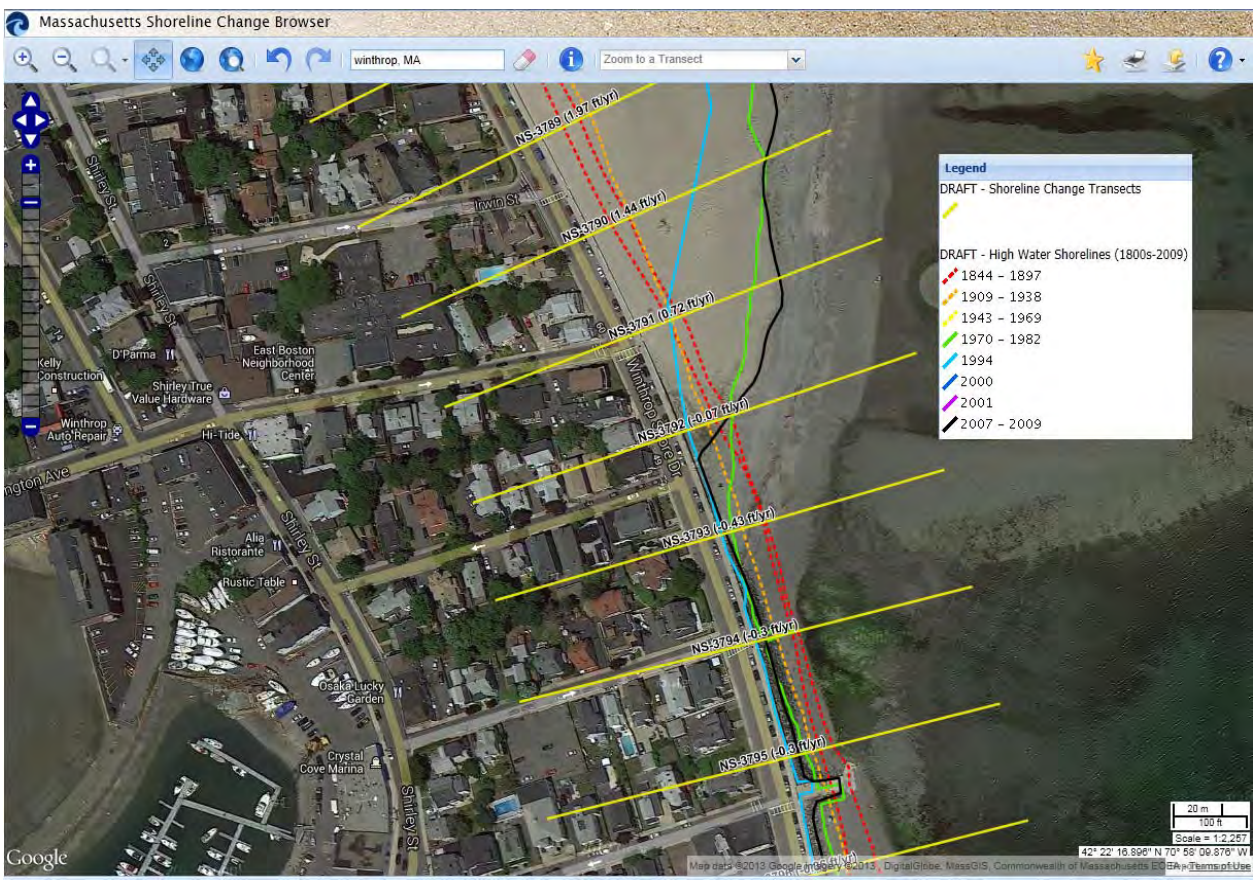


Figure 6-1. Map Generated Using Massachusetts Shoreline Change Browser

6.1.1 Challenges in Interpreting Shoreline Change Data

To interpret and apply the shoreline change data, both general shoreline trends and long- and short-term rates must be analyzed and evaluated in light of current shoreline conditions, recent changes in shoreline

uses, and the effects of human-induced alterations to natural shoreline movement. In areas that show shoreline change reversals (i.e., where the shoreline fluctuates between erosion and accretion) and areas that have been extensively altered by human activities (e.g., seawalls and jetties), professional judgment and knowledge of natural and human impacts are typically required for proper data interpretation and incorporation of the data into project planning and design.

For example, a group of 10 transects along Sankaty Head on Nantucket indicate a generally stable (close to zero) long-term trend of shoreline change from 1846 to 2009. The beach is not stable, however, as illustrated by the short-term erosion rates of approximately -9.5 feet per year and the approximately 300-feet of erosion experienced in this area from 1978 to 2009. In this particular example, the beach was accreting up until the 1950s, when it began to erode rapidly. The accretion and erosion in essence mathematically "cancel each other out," leaving a long-term shoreline change rate of around zero.

Where the shoreline has been armored with sea walls, revetments, and other structures, the shoreline change data must be looked at very closely to determine the effects of the structures. The natural sources of beach sand for North Scituate Beach were severely diminished by seawall and revetment construction during the 1940s through the 1970s. Consequently, the trend of erosion is not only continuing in this area—it is increasing from approximately -0.5 to -2.5 feet per year.

Transects on Scusset Beach in Bourne show long-term accretion rates of more than 7 feet per year. However, the short-term accretion rates of about 5 feet per year are more reflective of current shoreline trends. The north jetty of the Cape Cod Canal was constructed in the early 1900s and resulted in an initial rapid growth of Scusset Beach, contributing to the higher long-term rates that have since leveled off.

In addition, the shorelines were derived from different historical maps, aerial photographs, and LIDAR (light detection and ranging) data sources. Each shoreline was assigned an uncertainty value based on an estimate of errors inherent in the source material and method used to delineate the local high water line. These estimates of total shoreline position uncertainty, which ranged from 11.6 meters (38.1 feet) for 1800s shorelines to 1.27 meters (4.17 feet) for LIDAR-derived shorelines, should be considered when analyzing shoreline movement over time and were included in the calculation of uncertainty at each transect. Each transect has long- and short-term rates, with estimated uncertainty values for those rates. The shoreline change rates should be looked at as a range, particularly for transects with uncertainty values greater than the shoreline change rate. For example, for a transect with an erosion rate of -1.0 foot per year with an uncertainty range of ±2.5 feet per year, the range for the shoreline change rate would be +1.5 to -3.5 feet per year—meaning that the area may be either eroding or accreting. To protect coastal properties in the long term, the greatest rate of erosion over the expected life of the structure should be used for design (http://www.mass.gov/czm/hazards/shoreline_change/shorelinechangeproject.htm).

Human activity is not the sole reason for trend reversals and shoreline changes. In some areas, such as the southeastern shore of Nantucket, natural processes are responsible for large trend reversals (accretion to erosion back to accretion to erosion) over the 150-year study period. In this area, the data reveal that the shoreline has fluctuated between 50 to 100 feet of both erosion and accretion resulting in a long-term average suggesting stability. The shoreline is, however, exceptionally variable.

6.1.2 Decreased Sediment

Coastal landforms such as coastal banks are essential to maintaining a supply of sediment to beaches and dunes. Where engineered structures are used to stabilize shorelines, the natural process of erosion is interrupted, decreasing the amount of sediment available and causing erosion to adjacent areas. Under conditions of reduced sediment, the ability of coastal resource areas such as dunes and beaches to provide storm damage prevention and flood control benefits is continually reduced. A major challenge is to ensure that regional sediment supplies are managed effectively and in ways that allow the beneficial storm damage prevention and flood control functions of natural coastal processes to continue—both for future projects and, where possible, existing coastal development.

6.1.3 Sea-Level Rise

Local sea level rise is produced by the combined effects of global sea level rise and local factors such as the following:

- Vertical land deformation, caused by phenomena such as:
  - Tectonic movement
  - Subsidence
  - Isostatic rebound in response to climate change after removal of a load from glaciers, not only in New England but also globally (e.g., Greenland and Antarctica)
- Seasonal ocean elevation changes due to atmospheric effects
- Glacial melt
- Thermal expansion of the ocean
- Ocean currents

The melting of glaciers, thermal expansion of the ocean, vertical land deformation (tectonics, subsidence, isostatic rebound), atmospheric effects, and ocean currents will likely continue to increase sea level for many hundreds of years into the future. For instance, there is increasing evidence that the collapse of the West Antarctic Ice Sheet will produce a 25-percent additional sea level rise along the Atlantic coast above the global average due to redistribution of mass in the asthenosphere, change in polar rotation axis and loss of gravitational attraction of water to the ice sheet when large ice sheets melt (Bamber et al., 2009). Figure 6-2 depicts some of the causes associated with sea level rise.

Source: Douglas et al, 2010

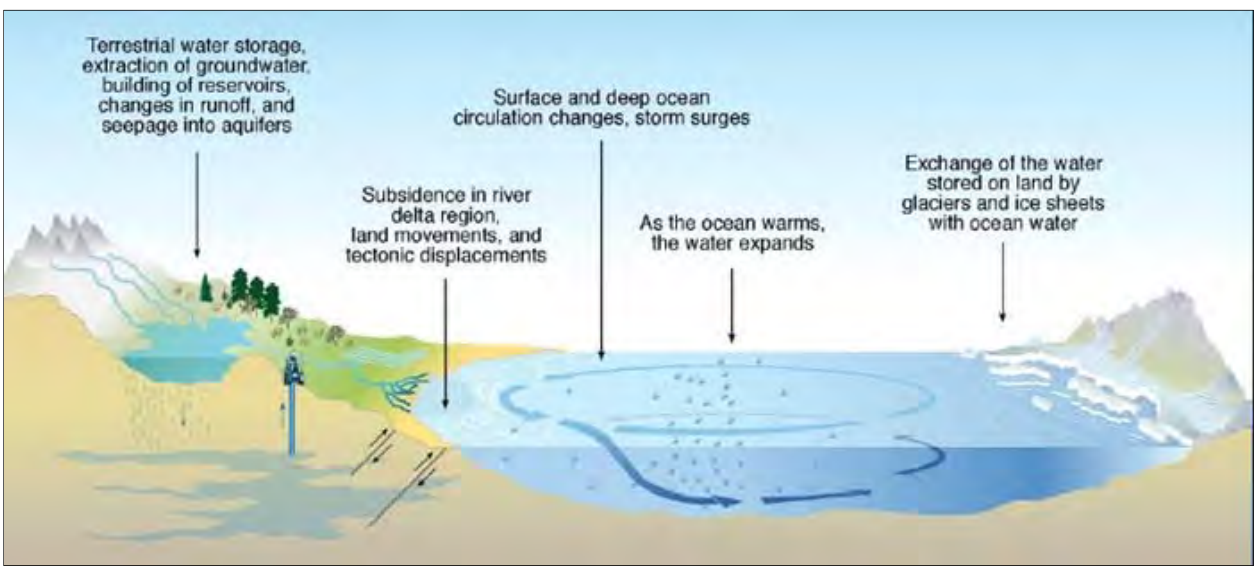


Figure 6-2. What Causes the Sea Level to Change?

The *Fourth Assessment Report of the Intergovernmental Panel on Climate Change* projects global sea level rise over the course of this century to be between 7 and 15 inches for the lowest emissions scenario, and between 10 and 23 inches for the highest emissions scenario. According to the Intergovernmental Panel on Climate Change (IPCC), current model projections indicate substantial variability in future sea level rise between different locations. Some locations could experience sea level rise higher than the global average projection, while others could have a fall in sea level. The same factors that currently cause sea level to rise more rapidly along the Mid-Atlantic and Gulf Coasts, and less rapidly in parts of

the Pacific Northwest, are likely to continue. Changes in winds, atmospheric pressure, and ocean currents will also cause regional variations in sea level rise - but those variations cannot be reliably predicted.

Since the Fourth Assessment Report of the Intergovernmental Panel on Climate Change was published in 2007, the climate has continued to change with resulting effects on the U.S. The trends described in the IPCC Fourth Assessment Report have continued and the U.S. average temperature has increased by 1.5 degrees Fahrenheit since 1895; more than 80 percent of this increase has occurred since 1980. The most recent decade was the nation's hottest on record. Through most regions of the U.S. are experiencing warming, the changes in temperature are not uniform. In general, temperatures are rising more quickly at higher latitudes, but there is considerable observed variability across the regions of the U.S.

U.S. temperatures will continue to rise, with the next few decades projected to see another 2ºF to 4ºF of warming in most areas. The warming by the end of the century is projected to correspond closely to the cumulative global emissions of greenhouse gases up to that time: roughly 3 to 5 degrees Fahrenheit under a lower emissions scenario involving substantial reductions in emissions after 2050 (referred to as the "B1 scenario"), and 5 to 10 degrees Fahrenheit for a higher emissions scenario assuming continued increased in emissions (referred to as the "A2 scenario") (National Climate Assessment Development Advisory Committee, 2013). This increase in temperature has wide-ranging impacts throughout the world, including sea-level rises, changing precipitation patterns, and an increase in extreme weather events. Figure 6-3 demonstrates the predicted sea level rise associated with increasing world temperatures.

Source: Douglas et al, 2010

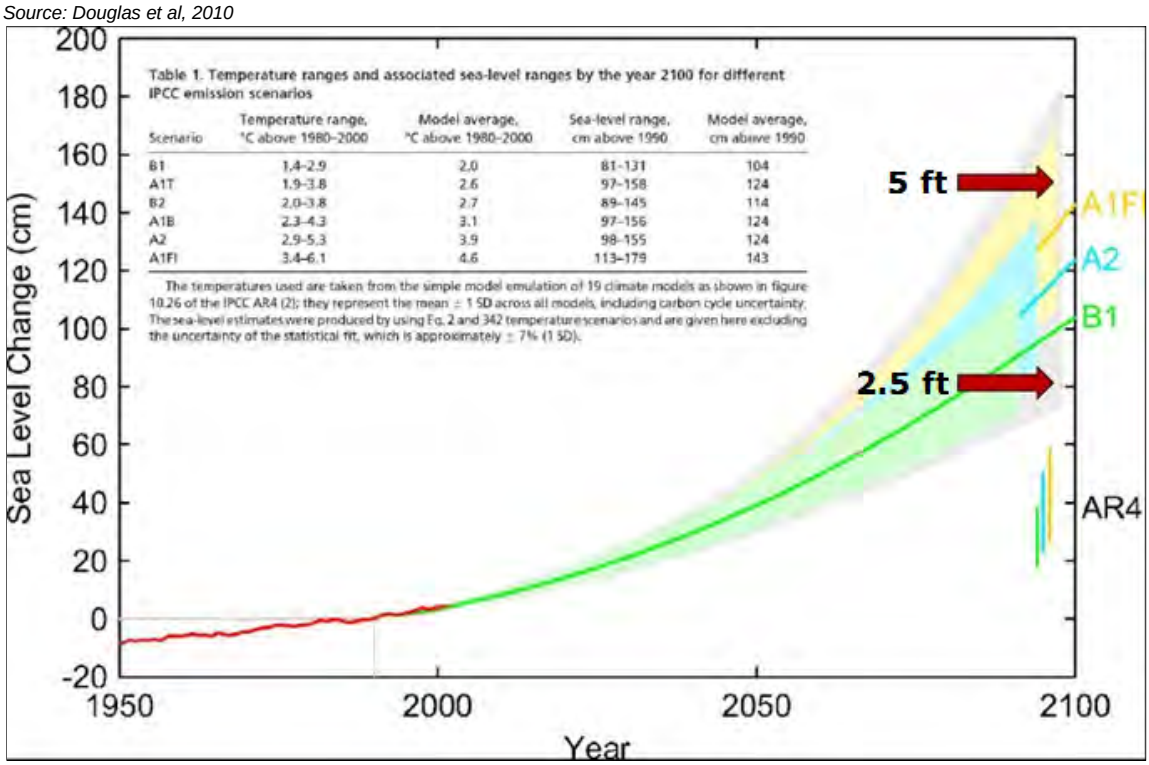


Figure 6-3. Sea-Level Rise Projections

Based on current science, the IPCC has estimated the sea level rise for the Massachusetts coast line to be 19 inches over the next 100 years which is an accelerated rate over what has been observed over the last 100 years (10 inches). The seas along the East Coast from North Carolina to New England are rising three to four times faster than the global average, and coastal cities, utilities, beaches, and wetlands are increasingly vulnerable to flooding, especially from storm surges, according to the US Geological Survey.

As a result of sea level rise, low-lying coastal areas will eventually be inundated by seawater or periodically over-washed by waves and storm surges. Coastal wetlands will become increasingly brackish

as seawater inundates freshwater wetlands. New brackish and freshwater wetland areas will be created as seawater inundates low-lying inland areas or as the freshwater table is pushed upward by the higher stand of seawater.

Some of the potential impacts of sea level rise on the coast of Massachusetts are as follows:

- Loss of coastal habitats and resources
- Increased beach-bluff-dune-marsh erosion
- Loss of recreation resources (beaches, marshes)
- Salt–water intrusion to water wells, septic systems
- Elevated storm-surge flooding levels
- Greater, more frequent coastal inundation
- Increased risk to urban infrastructure
- Greater risk to human safety & development

6.2 HAZARD PROFILE

6.2.1 Location

Massachusetts and its 68 coastal communities are vulnerable to the damaging impacts of major storms, such as nor'easters and hurricanes, along more than 1,500 miles of varied coastline. Figure 6-4 shows the Massachusetts coastal communities. As development and re-development increases along shorelines, less-intense storms that occur more regularly and predicted sea-level rise will lead to periods of increased occurrence.

For the purposes of this Plan, the wetland types identified in the MassDEP wetlands spatial layer (barrier beach, coastal beach, coastal dune, coastal bank, rocky intertidal shore, salt marsh, and tidal flat) are considered areas that are likely to be impacted by coastal erosion. Figure 6-5 shows the estimated potential coastal erosion hazard area. Each area of the coast is impacted differently by each type of coastal hazard and has varying vulnerability.

North Shore

Following the coastline from Salisbury to Revere, industrial activity is moderate in comparison to other portions of the coast. The Merrimack River carries industrial effluent, including treated sewage and industrial process water, to the ocean waters of this region. Merrimack River, Cape Ann, and Salem Sound areas are homeport to significant fleets of fishing and tourism vessels, and the Annisquam River is also heavily used for tourism and recreational fishing purposes. The waters between Nahant and Manchester and between Gloucester and Rockport are the two most productively fished areas in the region, making up a large percentage of the total state lobster catch. Great Marsh is a major recreational destination. North of Cape Ann is characterized by public beaches of regional and national significance.

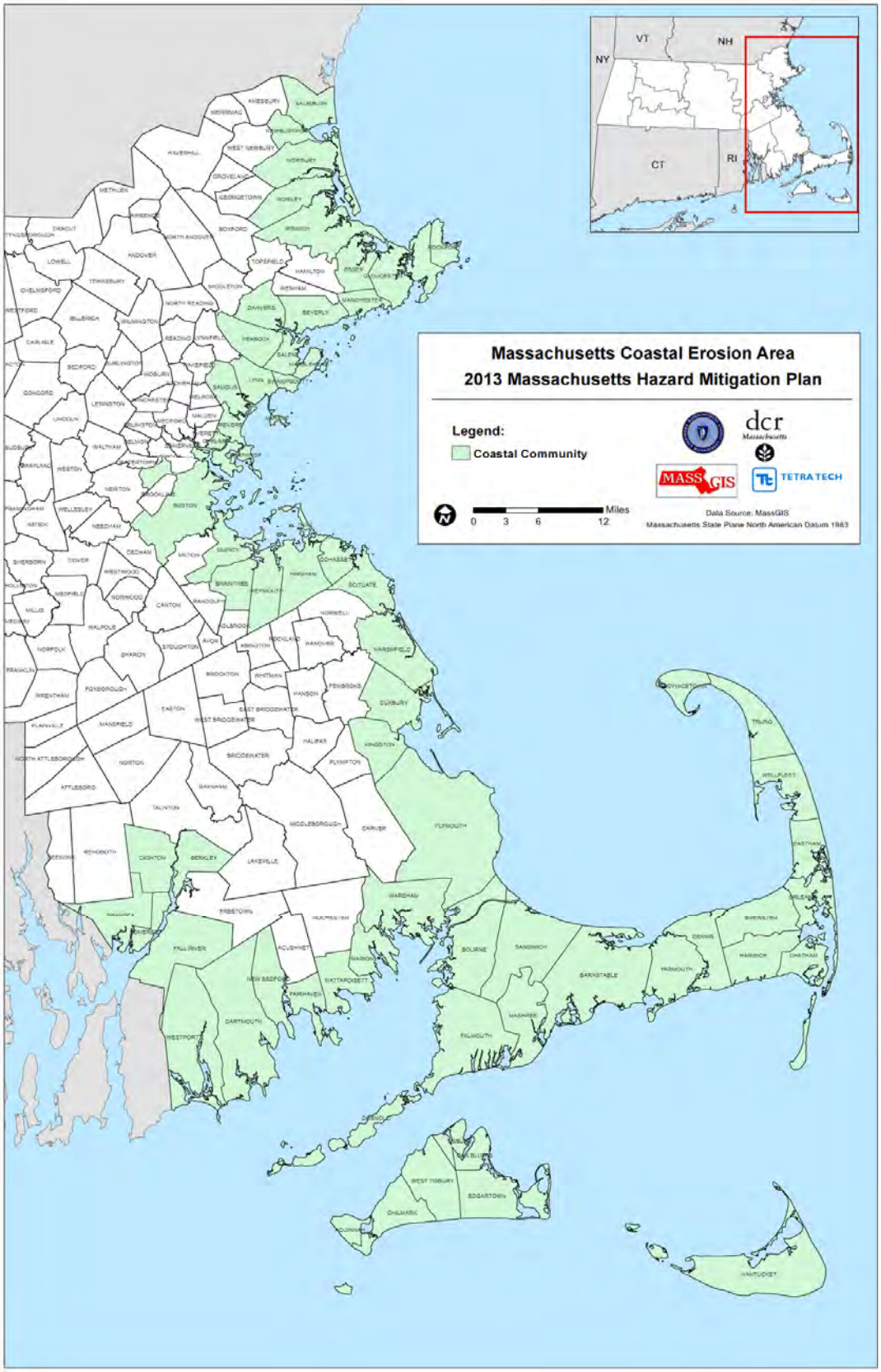


Figure 6-4. Massachusetts Coastal Communities

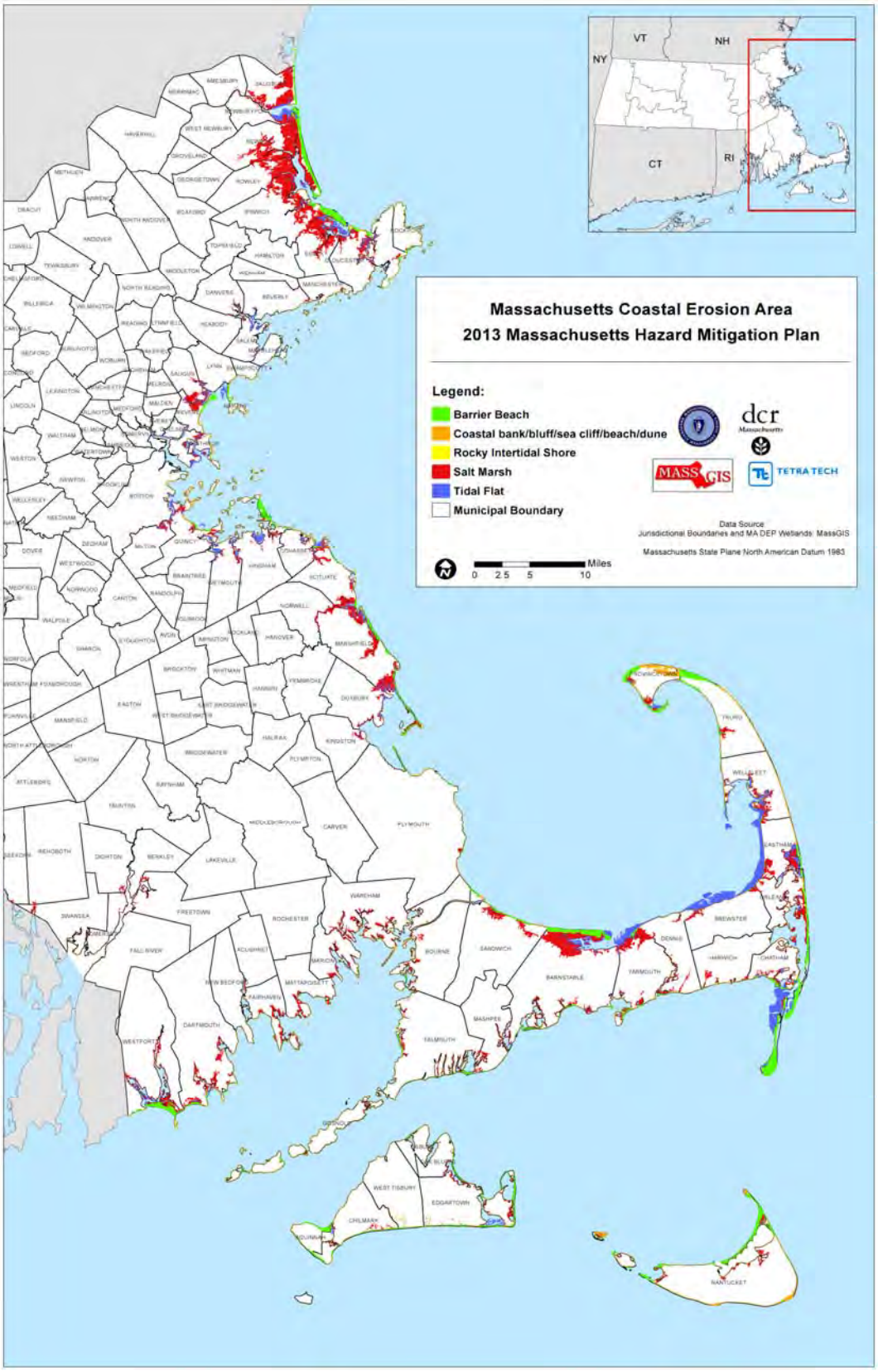


Figure 6-5. Coastal Erosion Hazard Area

Boston Harbor/Massachusetts Bay

Covering the coastal communities from Winthrop to Weymouth, inclusive of the City of Boston. The Massachusetts Water Resources Authority treatment plant treats sewage from metropolitan Boston communities and releases treated effluent nine miles offshore. The Stellwagen Bank National Marine Sanctuary, which is eastward of the state ocean waters of this region, is a highly productive area of nutrient upwelling that provides abundant food for a variety of species of fish, marine mammals, and sea birds, including the endangered humpback and northern right whales.

Industrial activity and shipping are heavy in this region. The Port of Boston is a maritime industrial hub for New England, and it has direct calls by large container vessels from Europe and the Far East. Fourteen million tons of bulk cargo enter its waters each year. In 2002, 250,000 cruise passengers and more than 100,000 automobiles came across its docks. The Port of Boston is estimated to have an $8 billion impact on the economy, producing more than 9,000 direct jobs. The Conley container terminal, the complex of uses on the Mystic River, Logan Airport, and Chelsea Creek are major industrial features. The Weymouth Back River, with its gas pipeline and ships carrying petroleum products, is an area of localized industrial activity. A natural gas pipeline (the Hubline) extends from Weymouth to Salem, and two offshore liquefied natural gas ports have pipelines that connect to the Hubline east of Marblehead. Recreational boating is significant throughout Massachusetts Bay. Major destinations include Stellwagen Bank for fishing and whale watching and the Boston Harbor Islands for boating, hiking, fishing, and diving. Figure 6-6 demonstrates the mean sea level trend as established at a NOAA Station within Boston.

Source: http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8443970

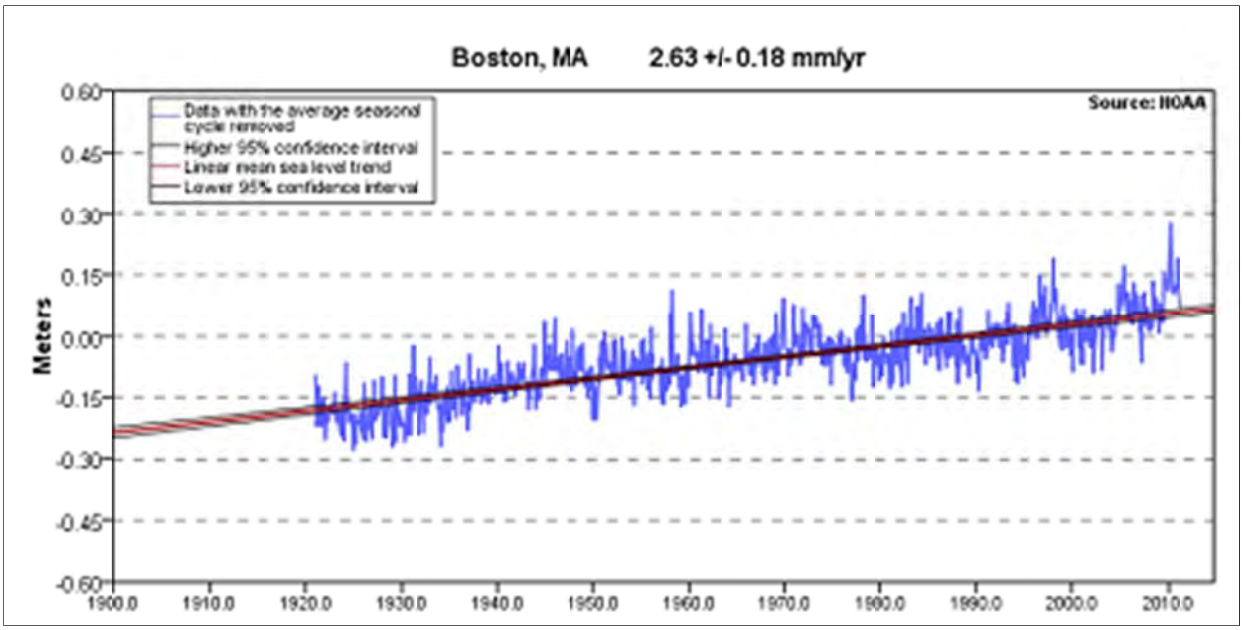


Figure 6-6. Mean Sea Level Trend at the NOAA Station 8443970 in Boston

The NOAA station in Boston (8443970) indicates a rise in sea level since 1921. The mean sea level trend is 2.63 millimeters/year with a 95-percent confidence interval of +/- 0.18 mm/year based on monthly mean sea level data from 1921 to 2006 which is equivalent to a change of 0.86 feet in 100 years.

Projections of sea-level rise for Boston range from 2 feet to as much as 6 feet by the end of the century, depending on how fast ice in Greenland and Antarctica melt (see Figure 6-7). For additional data on sea-level rise in Boston, please refer to Section 1.5.4 and to: http://www.tbha.org/preparing-rising-tide-report

Source: http://www.cityofboston.gov/climate/sealevelriseboston.asp

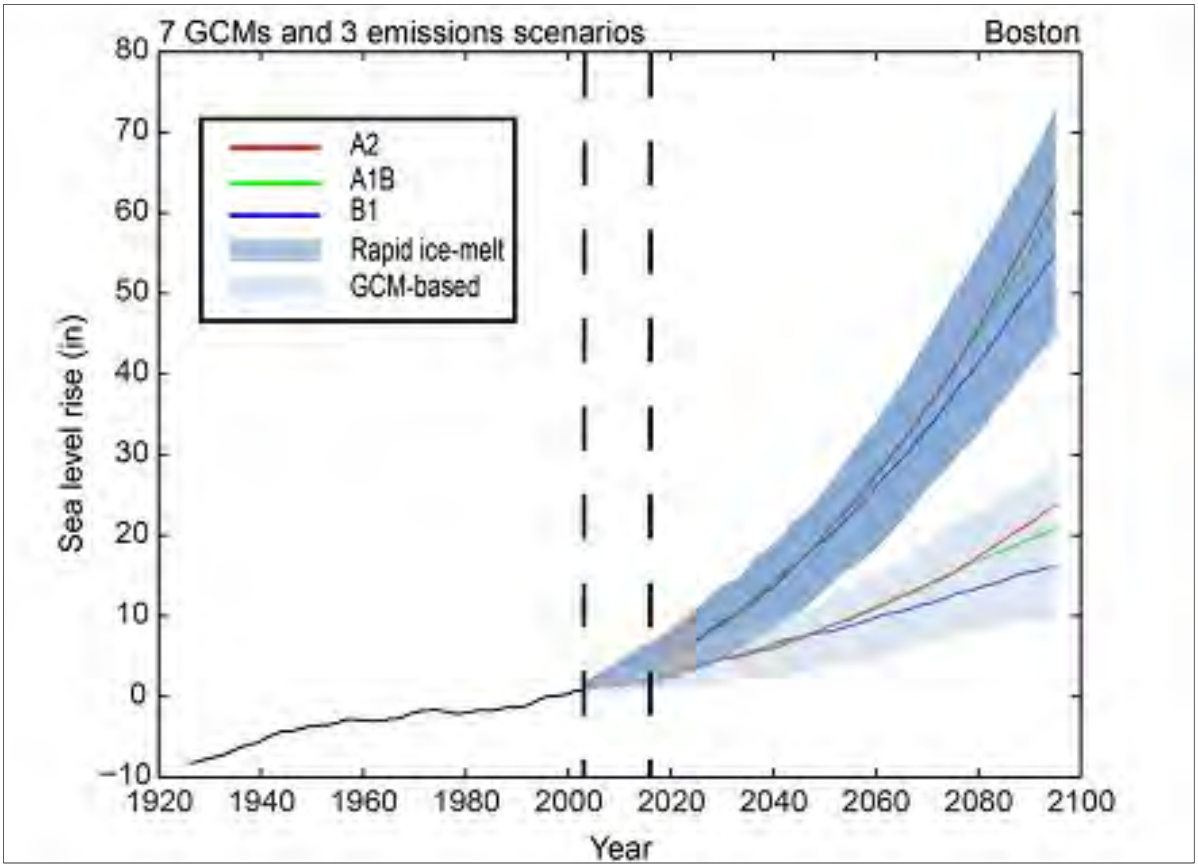


Figure 6-7. Sea-level Rise Projections for Boston

South Shore

Extending from Hingham to Plymouth, the South Shore beaches are composed of mixed sand, gravel, and cobble. Erosion is an issue, particularly on these beaches and coastal banks. A large portion of Cape Cod Bay is designated critical habitat for northern right whales, which typically inhabit the waters during winter and early spring, although individual whales may periodically stay on later in the year. There are relatively few industrial uses on the South Shore and in Cape Cod Bay. The water-cooled Pilgrim Nuclear Power Station in Plymouth is the only major industrial facility in the region. Small commercial boating, including fishing operations, whale watching, sightseeing, and commuter ferry service out of Hingham, are major uses in this region.

Cape Cod and Islands

This region covers Cape Cod Bay from Bourne to Provincetown, Martha's Vineyard, and Nantucket. Cape Cod and the Islands are characterized by sandy barrier beaches backed by coastal dunes and banks along much of the coast. There are thousands of acres of salt marsh, and the area is significant to several endangered species of birds and vegetation. Cape Cod Bay is critical habitat for the endangered northern right whale. Other species of whales, marine mammals, and turtles also inhabit the bay. Water quality is generally good and locally excellent (e.g., Wellfleet Harbor is designated as a body of outstanding Resource Water.) Industrial uses of the area are primarily related to fuel transport and storage. There are tank facilities in Vineyard Haven, Gosnold, and Nantucket. Fuel is transported by barge to these facilities in significant quantities. There are also industrial transport activities associated with the year-round ferry service to the islands from Hyannis and Woods Hole. Woods Hole also supports a fleet of deep-sea research vessels and fisheries vessels operated by the National Oceanic and Atmospheric Administration

and National Marine Fisheries Service. Commercial fishing takes place with various fleet sizes in many of the harbors across the Cape and the Islands. The entire region is largely dependent on tourism.

South Coast

Covering the coastal communities westward of Cape Cod includes all of Buzzards Bay. Buzzards Bay is a relatively shallow estuary, and it receives relatively warm waters from the south through the Gulf Stream. It is home to some of the richest shellfish resources in the Commonwealth. Buzzards Bay provides vital habitat for endangered and rare species, including piping plovers, leatherback turtles, diamondback terrapins, and more than half of the North American population of the endangered roseate tern. The industrial ports of New Bedford and Fall River are significant economic engines for the region. Focusing on New Bedford, the port is predominated by approximately 400 large fishing vessels, but also receives cargo ships and, increasingly, cruise vessels. New Bedford is also home to a large and vibrant fish-processing center that not only processes catch landed locally, but also large quantities of fish from around the globe brought in by freighter and airplane. In addition, there are significant large boat repair operations within the harbor.

Buzzards Bay is the center of extensive shipping activity, serving as the southern funnel to the Cape Cod Canal, through which pass vast quantities of petroleum and cargo bound for Boston and other ports farther north. It is estimated that approximately 2 billion gallons of petroleum products pass through Buzzards Bay each year. Since 2000, New Bedford has been ranked the highest dollar-value fishing port in the nation, with the annual fish landings valued at more than $268 million in 2007.

6.2.2 Previous Occurrences

Hurricanes (DR-22)—September 1954

Two hurricanes 12 days apart in 1954 caused widespread coastal damage in southern New England.

Hurricane Carol

On the morning of August 31, 1954 Hurricane Carol, the most destructive hurricane to strike Southern New England since the Great New England Hurricane of 1938, came crashing ashore near Old Saybrook, Connecticut, leaving 65 people dead in her wake. Sustained winds of 80 to 100 mph roared through the eastern half of Connecticut, all of Rhode Island, and most of eastern Massachusetts. Scores of trees and miles of power lines were blown down. Strong winds also devastated crops in the region. Nearly 40 percent of apple, corn, peach, and tomato crops were ruined from eastern Connecticut to Cape Cod. Hurricane Carol arrived shortly after high tide, causing widespread tidal flooding. Narragansett Bay and New Bedford Harbor received the largest surge values of over 14 feet in the upper reaches of both water ways. On Narragansett Bay, just north of the South Street Station site, the surge was recorded at 14.4 feet, surpassing that of the 1938 Hurricane. However, since Hurricane Carol arrived after high tide, the resulting storm tide was lower. The heaviest amounts of rainfall, up to 6 inches, occurred in the New London, Connecticut area in the vicinity of landfall, and across extreme north central Massachusetts. Hurricane Carol destroyed nearly 4,000 homes, along with 3,500 automobiles and over 3,000 boats. All of Rhode Island, much of eastern Connecticut, and much of eastern Massachusetts lost electrical power. In addition, as much as 95 percent of all phone power was interrupted in these locations. Carol is estimated to have been a Category 3 Hurricane (NOAA, 2013 (a)).

Hurricane Edna

Following closely on the heels of Hurricane Carol was Hurricane Edna. Edna made landfall during the morning of September 11, passing over Martha's Vineyard and Nantucket, then across the eastern tip of Cape Cod, Massachusetts. Hurricane force winds of 75 to 95 mph buffeted all of eastern Massachusetts and coastal Rhode Island. Inland, sustained winds of 50 to 70 mph were common west of the Connecticut

River Valley. Peak wind gusts included 120 mph on Martha's Vineyard, 110 mph on Block Island, and 100 mph at Hyannis, Massachusetts. The strong winds knocked out electrical power across sections of Rhode Island, eastern Massachusetts, and nearly all of Cape Cod and the Islands. The lowest recorded pressure was 28.02 inches at Edgartown on Martha's Vineyard. Edna arrived during a rising tide and resulted in severe flooding across Martha's Vineyard, Nantucket, and Cape Cod, where storm surges of over 6 feet were common. Farther west, storm surge values were 4 feet or less, resulting in storm tides that remained below flood stage. Damage to the boating community was severe across Cape Cod, but was much less across the remainder of Massachusetts and Rhode Island. Edna's track across the extreme eastern part of the region did result in heavy rainfall and inland flooding.

Rainfall amounts of 3 to 6 inches were common, with over seven inches across northeastern Massachusetts. This rainfall aggravated the already saturated conditions caused by Hurricane Carol ten days earlier. The total combined rainfall for Carol and Edna ranged from 5 to 7 inches along and west of the Connecticut River and over Cape Cod, to as much as 11 inches from southeast Connecticut, across most of Rhode Island, to northeast Massachusetts. Considerable urban and small stream flooding occurred. Numerous street washouts were common, along with some major river flooding in Rhode Island and northeast Massachusetts, where rivers rose several feet above flood stage. Edna was responsible for 21 deaths across the region (Vallee and Dion, Date Unknown).

Coastal Storms, Flood, Ice, Snow (DR-546)—February 1978

The February 1978 Blizzard remains as the benchmark storm for comparison by all subsequent nor'easters. This life-threatening nor'easter crippled most of the Commonwealth with blizzard conditions, extraordinarily heavy snow, high winds, and devastating coastal flooding. The storm claimed 73 lives in Massachusetts and 26 in neighboring Rhode Island. Over 10,000 people had to be sheltered. An unprecedented ban on non-emergency vehicle traffic lasted for a week in much of eastern Massachusetts.

The combination of strong northeast winds and a slow moving storm system along with astronomically high tides brought in a large fetch of water along coastal communities. This caused serious coastal flooding and beach erosion problems resulting in broken seawalls and massive property loss (Strauss, Date Unknown). This event resulted in a federal disaster declaration (DR-546) (Strauss, date unknown).

Hurricane Bob (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 were sustained at 115 mph, impacting North Carolina, Mid-Atlantic States, New England, and Atlantic Canada, causing 15 fatalities. This event resulted in a federal disaster declaration (DR-914).

Severe Coastal Storm (DR-920)—October-November 1991

This storm was 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. Winds from this event were measured over 80 MPH, with and waves over 30 feet in some parts of the coastline. This storm caused flooding and wind damage in several counties. This event resulted in a federal disaster declaration (DR-920).

Coastal Storm (DR-975)—December 1992

This event caused more than $12.6 million in public infrastructure damage (roads, bridges, public utilities, etc.) and resulted in 1,874 NFIP claims in Massachusetts at a cost of nearly $12.7 million.

Severe Storms and Flooding (DR-1364)—March-April 2001

A series of storms occurred in Massachusetts between March 5 and April 16. These events included a major winter storm, heavy rainfall, and melting snow. On March 5, a major winter storm impacted Massachusetts with near-blizzard conditions, high winds, and coastal flooding. Over 2 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 2 and 30 inches across Massachusetts. High tides ran 2 to 3 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, flooding occurred throughout Massachusetts as a result of melting snow and heavy rainfall. The most severe flooding occurred in the Merrimack Valley. An event on March 30, with heavy snow in parts of interior Massachusetts and heavy rain and strong winds in coastal communities, caused flooding along rivers and streams in the eastern portion. Over 6 inches of rain fell in some areas. This series of flooding events resulted in a federal disaster declaration (DR-1364).

Nor'easter (Not Declared)—January 2005

The January 2005 Nor'easter event impacted the entire Commonwealth of Massachusetts. This storm was rated by the National Weather Service as a "top 5" in historical snowfall events in the U.S. The snow was very powdery and drifted, as it occurred with very low temperatures and high winds.

Coastal Storm / Nor'easter (DR-1614)—October 2005

A strong Nor'easter, combined with the remnants of Tropical Storm Wilma, brought heavy rainfall, damaging winds, and coastal flooding to the eastern portion of Massachusetts. Rainfall totals ranged between two and 2.5 inches. The high winds brought down limbs, trees, and wires, resulting in power outages to thousands of people. This event caused approximately $733,000 in property damage.

Severe Storms and Inland and Coastal Flooding (DR-1701)—April 2007

An intense coastal storm (April 15-16, 2007) brought wet snow, sleet, and rain to parts of western Massachusetts. Rainfall totals ranged between three and six includes and lead to minor flooding across the affected areas. Heavy rain and snowmelt also led to minor flooding of small streams and creeks in parts of the Commonwealth as well. This event resulted in a federal disaster declaration (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.

Tropical Storm Irene (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). These heavy rains caused flooding throughout the Commonwealth and a presidential disaster was declared (DR-4028). Tropical Storm Irene was closely followed by the remnants of Tropical Storm Lee, which brought additional heavy rain to Massachusetts and extended flooding. Severe river erosion occurred in northwestern Massachusetts, closing State Route 2. Landslides were also triggered by the heavy rain and wet soil in this area of steep slopes containing layers of glacial lake clay. The Commonwealth received over $31 million in individual and public assistance from FEMA.

Hurricane Sandy (DR-4097)—October-November 2012

Hurricane Sandy was the largest Atlantic hurricane on record, with winds spanning 1,100 miles in diameter, reaching sustained forces of 110 mph. Estimated losses due to damage and business interruption are still being calculated, but are estimated to exceed $65 billion. At present count (December 2012), at least 253 people were killed along the path of the storm, with 131 of those deaths occurring within the U.S. although no deaths occurred in Massachusetts.

Tide Records

Hurricanes and Nor'easters have varied impact on the coast, depending on a number of variables. There are three gauge stations, Boston, Woods Hole, and Nantucket, measuring tide and surge in Massachusetts. Each gauge has a varied recording history, Boston dates back to 1922, Woods Hole 1933, and Nantucket only to 1965; however, the information provides relevant comparisons. An analysis was conducted to rank the top, or highest, tides for each gauge. Table 6-1 shows the top 10 highest tides for each gauge.

TABLE 6-1.
TOP 10 HIGHEST TIDES AT MASSACHUSETTS GAUGES

Station:	8443970	**Begin Date:**	19001024
Name:	Boston, MA	**End Date:**	20130422
Product:	High/Low	**Units:**	Feet
Datum:	StnDatum	**Quality:**	Verified

Rank	Highest	Highest	Date	Zone	Lowest	Lowest	Date	Zone
1	18.62	19780207	10:36	LST	-0.20	19280125	00:00	LST
2	17.72	19870102	12:18	LST	-0.20	19400324	00:00	LST
3	17.66	19911030	16:54	LST	-0.10	19230403	00:00	LST
4	17.56	19790125	00:00	LST	0.00	19300314	00:00	LST
5	17.55	19921212	12:42	LST	0.00	19220213	00:00	LST
6	17.32	20070418	03:48	GMT	0.00	19241226	00:00	LST
7	17.30	20050525	04:36	GMT	0.13	19771210	00:00	LST
8	17.22	20101227	08:18	GMT	0.15	19800319	06:54	LST
9	17.19	20050526	05:24	GMT	0.20	19220116	00:00	LST
10	17.10	20120605	03:54	GMT	0.20	19361228	00:00	LST

The top tides shared by all three gauges, occurred during wintertime (October-May) northeast storms. The Woods Hole gauge's top five storms are hurricanes occurring in August and September and did not typically generate top tides in Boston or Nantucket.

Erosion

Section 6.1.1 discusses the historical shoreline change data available for the Commonwealth.

6.2.3 Frequency

Coastal erosion is measured as the rate of change in the position or horizontal displacement of a shoreline over a specific period of time, measured in units of feet or meters per year. Erosion rates vary as a function of shoreline type and are influenced primarily by episodic events. Monitoring of shoreline change based on a relatively short period of record does not always reflect actual conditions and can misrepresent long-term erosion rates. The long-term patterns of coastal erosion are difficult to detect because of substantial and rapid changes in coastlines in the short-term (that is, over days or weeks from storms and natural tidal processes). It is usually severe short-term erosion events, occurring either singly or cumulatively over a few years, that cause concern and lead to attempts to influence the natural processes. Analysis of both long- and short-term shoreline changes are required to determine which is more reflective of the potential future shoreline configuration.

The return period of an episodic erosion event is directly related to the return period of a coastal storm, hurricane or tropical storm. The one-percent annual chance erosion event can be determined using a predictive model that establishes the one-percent annual chance tide and water surface level, or surge

elevation and the resulting wave heights. Storm wave heights, periods and directions have specific impacts on the tides, currents, and other erosion processes. Analyses of coastal erosion impacts from the one-percent annual chance flood event are included in high-hazard zone determinations shown on NFIP maps. The impacts may vary for each reach of coastline.

A more significant measure of coastal erosion is the average annual erosion rate. Erosion rates can be used in land-use and hazard management to define areas in which development should be limited or where special construction measures should be used. The average annual erosion rate is based on analysis of historical shorelines derived from maps, charts, surveys, and aerial photography obtained over a period of record.

6.2.4 Severity

Coastal erosion is measured at the rate of change in the position or horizontal displacement of a shoreline over a period of time. A number of factors determine whether a community exhibits greater long-term erosion or accretion:

- Exposure to high-energy storm waves,
- Sediment size and composition of eroding coastal landforms feeding adjacent beaches,
- Near-shore bathymetric variations which direct wave approach,
- Alongshore variations in wave energy and sediment transport rates,
- Relative sea level rise,
- Frequency and severity of storm events, and
- Human interference with sediment supply (e.g. revetments, seawalls, jetties).

Such erosion may be exacerbated by activities such as boat wakes, shoreline hardening or dredging.

Natural recovery after erosive episodes can take months or years. If a dune or beach does not recover quickly enough via natural processes, coastal and upland property may be exposed to further damage in subsequent events. Coastal erosion can cause the destruction of buildings and infrastructure.

6.2.5 Warning Time

Meteorologists can often predict the likelihood of weather events which can impact shoreline communities, and ultimately the shoreline. NOAA's National Weather Service monitors potential events, and provides forecasts and information, in advance of a storm through multiple means varying in system characteristics and time issued. The National Weather Service provides early notification through its Hazardous Weather Outlook, which is a narrative statement produced and issued on a routine basis, to provide information regarding the potential of significant weather expected during the next 1 to 5 days (NWS, 2009). Additionally, for nor'easters the National Weather Service issues Coastal Flood Advisories when minor flooding is possible; Coastal Flood Watches when flooding with significant impacts is possible; or Coastal Flood Warnings when flooding that will pose a serious threat to life and property is occurring, imminent or highly likely (NWS, 2009). For tropical, subtropical, or post-tropical systems the National Weather Service will issue a Hurricane or Tropical Storm Warning 36 hours in advance of the anticipated onset of tropical-storm-force winds or a Hurricane or Tropical Storm Watch 48 hours in advance of the anticipated onset of tropical-storm-force winds (NWS, 2013).

The National Weather Service uses common terms like minor, moderate, major, and severe to categorize the severity of forecasted beach erosion in statements, advisories, watches, and warnings. Although commonly used, no formal definition exists within the National Weather Service Glossary for these descriptors.

With shore structures increasing along the coastline, the shoreline becomes increasingly modified. Impact from weather incidents will continue to influence the Commonwealth's coastal areas, intensifying and exacerbating the situation.

6.2.6 Secondary Hazards

Windstorm events can blow beach and dune sand overland into adjacent low-lying marshes, upland habitats, inland bays, and communities. Flooding from extreme rainfall events can scour and erode dunes as inland floodwaters return through the dunes and beach face into the ocean.

Shore protection structures such as seawalls and revetments often are built to attempt to stabilize the upland property. However, typically, they eliminate natural wave run-up and sand deposition processes and can increase reflected wave action and currents at the waterline. Increase wave action can cause localized scour in front of structures and prevent settlement of suspended sediment.

6.3 CLIMATE CHANGE IMPACTS

Coastal shores change constantly due to wind, waves, tides, sea level fluctuation, seasonal and climatic variation, human alteration, and other factors that influence the movement of sand and material within a shoreline system.

Climatic trends can change a beach from naturally accreting to eroding due to increased episodic erosion events caused by waves from an above-average number of storms and high tides, or the long-term effects of fluctuations in sea or lake level. The coastal zone is being severely impacted by erosion and flooding due in part to climate change and sea-level rise. It is likely that the impact will increase in the future as sea levels continue to rise at the current rate or rises at an accelerated rate.

Impacts of climate change can lead to shoreline erosion, coastal flooding, and water pollution, affecting man-made coastal infrastructure and coastal ecosystems (http://www.epa.gov/climatechange/impacts-adaptation/coasts.html). Coastal areas may be impacted by climate change in different ways. Coastal areas are sensitive to sea level rise, changes in the frequency and intensity of storms, increase in precipitation, and warmer ocean temperatures. Additionally, oceans are absorbing more carbon dioxide, due to the rising atmospheric concentrations of the gas, and the oceans are becoming more acidic. This could have significant impacts on coastal and marine ecosystems (http://www.epa.gov/climatechange/impacts-adaptation/coasts.html).

6.3.1 Change in Coastal Geology

The cumulative impacts of global climate change and sea level rise will drastically change the coastal landscape of the coastlines around the world. The primary factors and processes driving changes are:

- Geologic framework and character
- Coastal plain geomorphology and slope
- Relative sea-level change
- Global change, land subsidence/uplift
- Major storm events, tropical storms/ hurricanes, extra-tropical storms nor'easters
- Seasonal coastal processes
  - Waves and tidal currents
  - Winds
  - Cold fronts and local storms
- Sediment budgets

  - Sediment sources (headlands, bluffs)
  - Sediment sinks (wash-over, inlets)
- Human activities
  - Coastal engineering structures
  - Dredging channels, inlets, canals
  - River modification (dams, levees)
  - Fluid (oil-gas-water) extraction
  - Climate change (sea-level rise, storms)

One component changing coastal landscape is coastal erosion. Coastal erosion is caused by scour of wave action against the sandy beaches and dunes of the coast line. This wave action can cause both aggregation and degradation. Sea level rise increases coastal erosion in several ways. First, as the sea level rises, wave action moves higher onto the beach. The surf washes sand and dunes out to sea or make the sand migrate parallel to the shoreline. The loss of the beach equals a loss in a buffer zone between the land and the sea, and this can lead to erosion of inland areas.

The loss of coastal wetlands also contributes to coastal erosion. Some IPCC models suggest that 33 percent of the global coastal wetlands will be under water by the year 2080. Areas with small tide ranges, such as sandy beaches, will see the greatest effect. The waves, tides, and currents erode beaches, dunes, and banks, resulting in landward retreat of these landforms, reducing the buffer they provide to existing development. More sediment is washed out to sea, rather than settling on the shore.

Storms are the biggest factor in coastal erosion. The intensity, number, and duration of the storms affect how much of the shore is eroded. The increase in the intensity and number of storms in the past few decades has eroded a number of coastlines. Storm surge and wave height increases devastate beaches. The higher the sea level, the further the storm surge moves onto the beach. Humans contribute to the increase in coastal erosion through engineering techniques used to protect homes. Many times, humans move sand dunes in an attempt to protect a specific structure, only to have the dune wash away. Sea walls can protect structures but often lead to complete loss of beaches, dunes, and banks. The Massachusetts Wetlands Protection Act and associated regulations, protect the ability of sand dunes and wetlands to migrate naturally, without human inference. The intent behind this theory is by allowing nature to take its course, less coastal loss will occur over time.

6.4 EXPOSURE

Coastal erosion, shoreline change, and sea-level rise are a significant concern to the Commonwealth because of the large number of communities and cultural resources located along the coast. Healthy beaches, dunes, and banks serve as a buffer and protect the built environment and other natural resources on the mainland from coastal storm events such as hurricanes, tropical storms and nor'easters which can cause shoreline erosion or accretion.

To understand risk, the assets exposed to the hazard areas are identified. For the purposes of this Plan, the wetland types in the MassDEP wetlands spatial layer (barrier beach, coastal beach, coastal dune, coastal bank, rocky intertidal shore, salt marsh, and tidal flat) are considered coastal resource areas that may be impacted by coastal erosion. This section discusses exposure of the following to coastal erosion:

- Population
- State facilities
- Critical facilities
- Economy.

Shoreline change, whether erosion or accretion, is dependent upon several factors including location (e.g., open-ocean facing shore) and exposure to high-energy storm waves. The coastal high hazard area (or V zone where "V" stands for velocity wave action) is the most hazardous part of the coastal floodplain due to its exposure to wave effects. Storm surge inundation can exceed regulatory floodplain boundaries (V and A zones), which also can contribute to coastal erosion. More information is available in Section 10, which discusses assets in the V zone and exposed to storm surge. Sea-level rise inundation and depth grids were not available to conduct a quantitative analysis for this plan update. The coastal hazard is discussed qualitatively below.

6.4.1 Population

To estimate the population exposed to the shoreline change hazard, the 2010 Census blocks with their centroid in the identified MassDEP coastal resource areas identified as vulnerable to coastal erosion were determined. Please note Census blocks do not follow the boundary of the wetland types, and the results of this methodology should only be used as an estimate. This figure does not account for the increase in population (both residents and tourists) during the summer months. Table 6-2 summarizes the estimated 2010 U.S. Census population exposed to the coastal erosion hazard by County.

TABLE 6-2.
ESTIMATED POPULATION EXPOSED TO THE COASTAL EROSION HAZARD

County	Total Population	Estimated Population Exposed	% of Total
Barnstable	215,888	4,281	2.0
Berkshire	131,219	—	—
Bristol	548,285	1,224	0.2
Dukes	16,535	78	0.5
Essex	743,159	9,870	1.3
Franklin	71,372	—	—
Hampden	463,490	—	—
Hampshire	158,080	—	—
Middlesex	1,503,085	0	—
Nantucket	10,172	8	0.1
Norfolk	670,850	3,515	0.5
Plymouth	494,919	12,748	2.6
Suffolk	722,023	4,985	0.7
Worcester	798,552	—	—
Total	**6,547,629**	**36,709**	**0.6**

Source: U.S. Census, 2010; MassGIS, 2012

6.4.2 State Facilities

To assess the exposure of the state-owned and leased facilities provided by DCAMM and the Office of Leasing, an analysis was conducted with the identified MassDEP coastal resource areas identified as vulnerable to coastal erosion. Using ArcMap, GIS software, the selected wetland types were overlaid with the state facility data to estimate the number of state facilities exposed to coastal erosion. Table 6-3 summarizes these state facilities by County. Figure 6-8 illustrates these facilities.

TABLE 6-3.
NUMBER OF STATE-OWNED AND STATE-LEASED BUILDINGS

County	State-Owned Buildings	State-Leased Buildings	**Total**
Barnstable	15	—	**15**
Berkshire	—	—	**—**
Bristol	23	—	**23**
Dukes	—	—	**—**
Essex	6	—	**6**
Franklin	—	—	**—**
Hampden	—	—	**—**
Hampshire	—	—	**—**
Middlesex	—	—	**—**
Nantucket	—	—	**—**
Norfolk	—	—	**—**
Plymouth	14	—	**14**
Suffolk	—	—	**—**
Worcester	—	—	**—**
Total	**58**	**0—**	**58**

Source: DCAMM, 2012; MassGIS, 2012
Note: Building data are updated as agencies change or modify them. The state-owned building information is current as of October 3, 2012, and the state-leased building information is current as of October 10, 2010 with a total of 6,765 buildings.

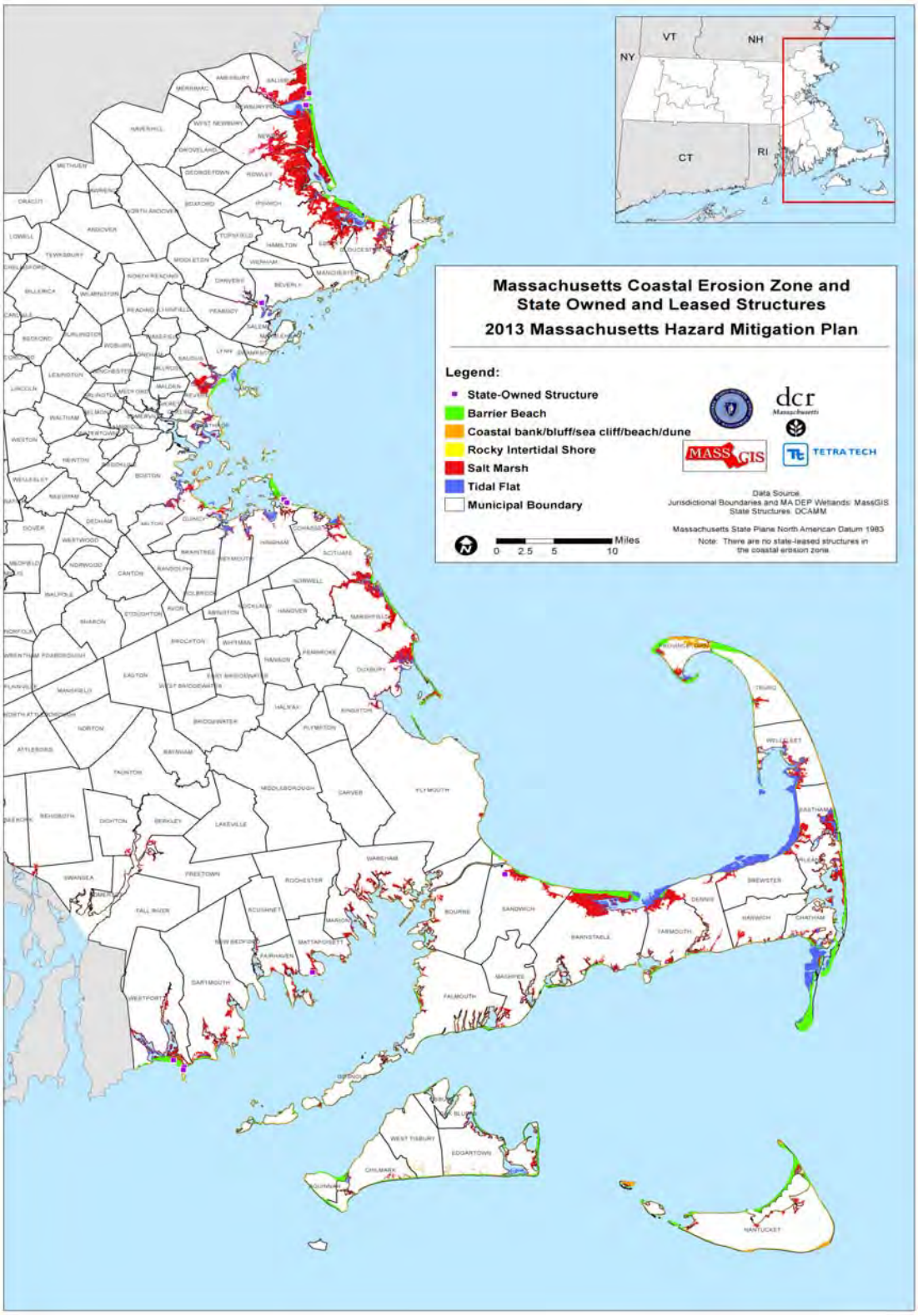


Figure 6-8. State-Owned and State-Leased Facilities Exposed to the Coastal Erosion Hazard

6.4.3 Critical Facilities

Wetland types identified as vulnerable to the coastal erosion hazard were analyzed in order to assess the exposure of critical facilities. Using GIS software, the selected coastal resource areas identified as vulnerable to coastal erosion were overlaid with critical facility data provided by MassGIS to determine the number of facilities within this area. Table 6-4 summarizes the number of critical facilities exposed to the coastal erosion hazard by County.

TABLE 6-4.
NUMBER OF CRITICAL FACILITIES EXPOSED TO THE COASTAL EROSION HAZARD

County	Police	Fire	Hospital	Emergency Operation Center	School	Colleges
Barnstable	—	—	—	—	1	—
Berkshire	—	—	—	—	—	—
Bristol	—	—	—	—	—	—
Dukes	—	—	—	—	—	—
Essex	—	—	—	—	—	—
Franklin	—	—	—	—	—	—
Hampden	—	—	—	—	—	—
Hampshire	—	—	—	—	—	—
Middlesex	—	—	—	—	—	—
Nantucket	—	—	—	—	—	—
Norfolk	—	—	—	—	—	—
Plymouth	—	2	—	—	1	—
Suffolk	—	1	—	—	—	—
Worcester	—	—	—	—	—	—
Total	**0**	**3**	**0**	**0**	**2**	**0**

Source: MassGIS, 2012

Coastal erosion can also severely impact roads and infrastructure. As the coastline evolves, evacuation and emergency routes need to be considered. The number of highway bridges in the wetland types identified as vulnerable to coastal erosion was determined by County, as summarized in Table 6-5. Please note this analysis may underestimate the number of bridges identified as exposed because in some instances the defined coastal erosion hazard area may not extend across the water where the bridge point is located.

TABLE 6-5.
NUMBER OF BRIDGES EXPOSED TO THE COASTAL EROSION HAZARD

County	Total Bridges Exposed	Federal	State	Local
Barnstable	12	—	4	8
Berkshire	—	—	—	—
Bristol	1	—	1	—
Dukes	1	—	1	—
Essex	8	—	3	5
Franklin	—	—	—	—
Hampden	—	—	—	—
Hampshire	—	—	—	—
Middlesex	—	—	—	—
Nantucket	1	—	—	1
Norfolk	1	—	1	—
Plymouth	2	—	1	1
Suffolk	2	—	2	—
Worcester	—	—	—	—
Total	**28**	**0**	**13**	**15**

Source: Hazus-MH v. 2.1; MassGIS, 2012

6.4.4 Economy

As noted earlier, the beaches, parks, and natural resources along the Massachusetts coast greatly contribute to the local economy especially during the summer season where the population can more than double. Figure 6-9 illustrates the greater than 200 linear miles of public and semi-public beaches in the Commonwealth that attract residents and tourists and contribute to the local economy.

> "Massachusetts's coastal and ocean areas include abundant natural, recreational, and economic resources that have shaped the state's history, economy, and way of life."
>
> *– Massachusetts Office of Coastal Zone Management, 2011*

Numerous natural coastal resources that protect the shoreline and have enormous ecological and economic value. Another valuable coastal resource and line of defense from coastal erosion are the barrier beaches. There are 29.6-square miles (or nearly 19,000 acres) of state-designated barrier beach in the Commonwealth. Figure 6-10 displays the locations of the state-designated barrier beaches.

Salt marshes are another coastal resource that protects the shoreline from coastal storms, flooding, erosion, and sea level rise. One such example is illustrated in Figure 6-11 for the Parker River/Essex Bay Area of Critical Environmental Concern project. The purpose of the project was to develop a regional picture of past, current, and potential restoration sites along with supporting information to help future restoration planning (MassGIS, 2012).

Source: MassGIS, 2012

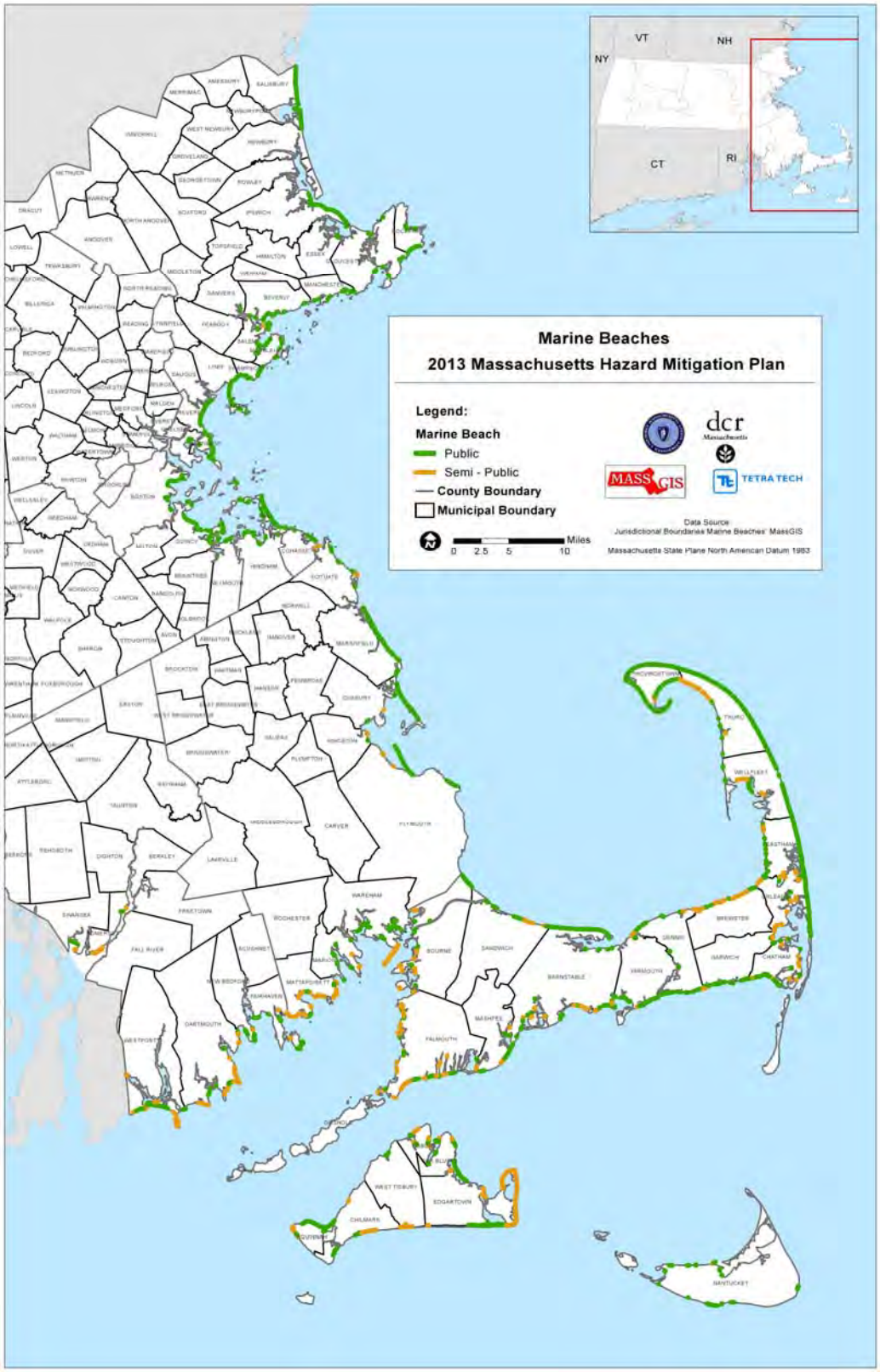


Figure 6-9. Marine Beaches in the Commonwealth of Massachusetts

Source: MassGIS, 2012

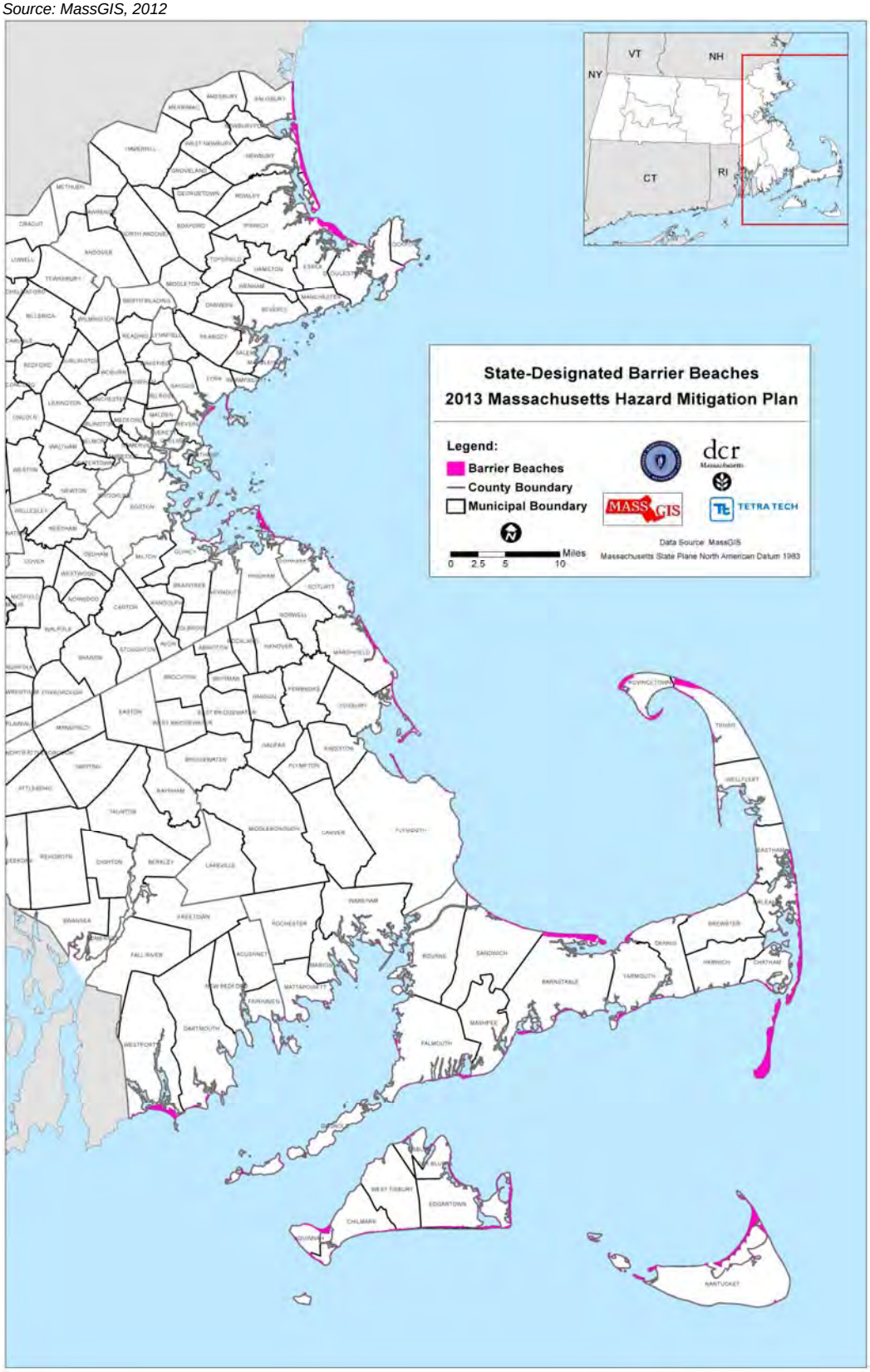


Figure 6-10. State-Designated Barrier Beaches

Source: MassGIS, 2012

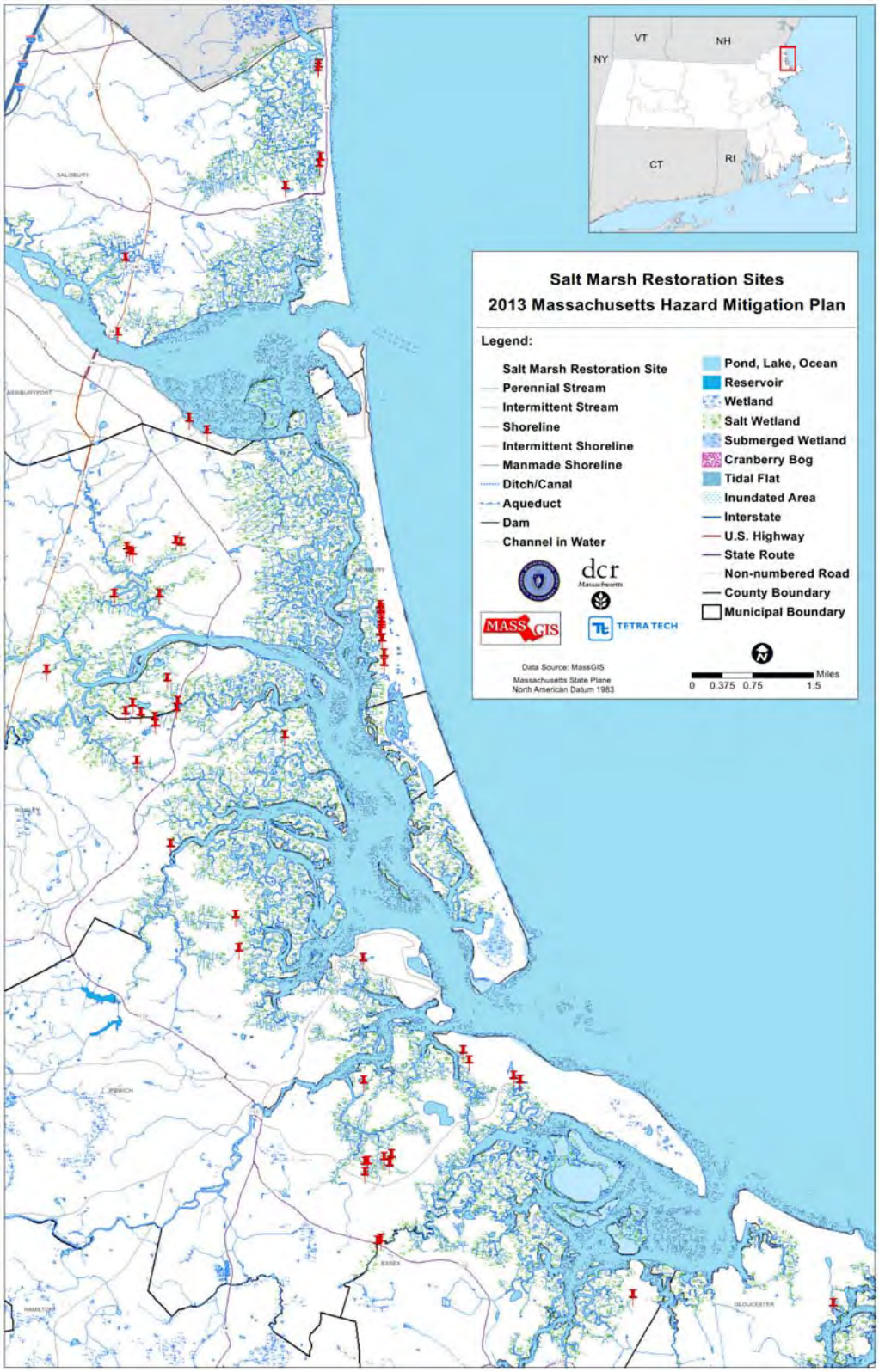


Figure 6-11. Salt Marsh Restoration Sites

6.5 VULNERABILITY

6.5.1 Population

Coastal erosion is not generally considered an imminent threat to public safety when the changes are gradual over many years. However, drastic changes to the shoreline may occur as a result of a single storm event which can threaten homes and public safety. The population exposed is also considered vulnerable to this hazard. Refer to Subsection 6.4.1.

6.5.2 State Facilities

To estimate the potential losses to state-owned and state-leased structures, the exposure analysis methodology was used. As discussed, there are 6,765 state-owned/leased structures in the Commonwealth and a total of 58 state-owned structures in the coastal resource area identified as vulnerable to coastal erosion. Table 6-6 identifies a total risk exposure of greater than $57 billion for state-owned and leased buildings in the Massachusetts coastal resource area. This figure assumes 100-percent loss to each structure and its contents. This estimate is considered high because coastal erosion generally occurs in increments of inches to feet per year along the coastline and would not occur across the entire coastal resource area at the same time from one event. Nonetheless, the total replacement cost value of state facilities within this area represents an estimated total loss value for facilities in the Massachusetts coastal resource area.

TABLE 6-6.
ESTIMATED REPLACEMENT COST VALUE OF STATE-OWNED AND STATE-LEASED BUILDINGS EXPOSED TO THE COASTAL EROSION HAZARD

County	Total Inventory Replacement Cost Value	Value Exposed			
		Own	Lease	Total	% of Inventory Total
Barnstable	$1,146,314,361	$15,263,116	—	$15,263,116	1.3
Berkshire	$1,852,000,832	—	—	—	—
Bristol	$3,012,210,350	$10,018,954	—	$10,018,954	0.3
Dukes	$16,224,048	—	—	—	—
Essex	$4,473,201,429	$24,660,411	—	$24,660,411	0.6
Franklin	$813,236,929	—	—	—	—
Hampden	$5,051,650,248	—	—	—	—
Hampshire	$4,687,387,853	—	—	—	—
Middlesex	$9,881,996,655	—	—	—	—
Nantucket	$31,381,244	—	—	—	—
Norfolk	$5,141,831,256	—	—	—	—
Plymouth	$3,182,404,153	$32,348,396	—	$32,348,396	1.0
Suffolk	$8,283,073,730	—	—	—	—
Worcester	$9,444,698,995	—	—	—	—
Total	**$57,017,612,082**	**$82,290,876**	**—**	**$82,290,876**	**0.1**

Source: DCAMM, 2012: MassGIS, 2012

Note: Building data are updated as agencies change or modify them. The state-owned building information is current as of October 3, 2012, and the state-leased building information is current as of October 10, 2010 with a total of 6,765 buildings.

6.5.3 Critical Facilities

Similar to the state facilities, to estimate potential losses to critical facilities and infrastructure, the exposure analysis methodology was used. The replacement cost values for critical facilities were not available for this planning effort. A total risk exposure would equal to the full replacement value of each critical facility exposed. As these data becomes available, the Commonwealth will update this section of the plan with new information. In terms of highway bridges, the Hazus-MH v. 2.1 default replacement cost value for the bridges estimated as exposed to coastal erosion is $308,051,240.

6.5.4 Economy

The Commonwealth's coastal resources are an enormous driver to the local economy and losses can greatly impact the Commonwealth's tax base and the local industries (i.e., tourism). Massachusetts' coastline and state ocean waters support 152,000 jobs and generate $4.3 billion in income each year, in addition to providing recreational opportunities (Durrant, 2008).

Building damage can impact a community's economy and tax base. To evaluate this impact, the building inventory estimated as exposed to coastal erosion was estimated using the Hazus-MH default general building stock inventory by 2000 U.S. Census block. The Census blocks with centroids in identified wetland types vulnerable to coastal erosion were determined. . Please note Census blocks do not follow the boundary of the wetland types and the results of this methodology should only be used as an estimate. Based on this estimate, there is $7 Billion of building (structure and content) replacement cost value exposed to the coastal erosion hazard, less than one-percent of the total in the Commonwealth. Table 6-7 summarizes the building inventory exposed to the coastal erosion hazard by County.

TABLE 6-7.
REPLACEMENT COST VALUE EXPOSED TO THE COASTAL EROSION HAZARD

County	Total Building and Content Replacement Cost Value	Replacement Cost Value in Coastal Zone	
		Value	% of Total
Barnstable	$47,450,250,000	$1,310,985,000	2.8
Berkshire	$20,566,219,000	—	—
Bristol	$74,946,506,000	$293,940,000	0.4
Dukes	$4,894,499,000	$64,469,000	1.3
Essex	$100,099,771,000	$1,697,707,000	1.7
Franklin	$10,130,548,000	—	—
Hampden	$67,212,508,000	—	—
Hampshire	$20,961,384,000	—	—
Middlesex	$244,161,008,000	—	—
Nantucket	$3,610,072,000	$55,594,000	1.5
Norfolk	$111,344,832,000	$609,038,000	0.5
Plymouth	$70,614,087,000	$2,460,079,000	3.5
Suffolk	$115,439,212,000	$764,897,000	0.7
Worcester	$112,858,251,000	—	—
Total	**$1,004,289,147,000**	**$7,256,709,000**	**0.7**

Source: Hazus-MH v. 2.1; MassGIS, 2012

Additional data is available to examine coastal vulnerability such as the USGS Open-File Report 99-593. However this study conducted an assessment on the national scale. The limitations of using results at this

scale to identify more local vulnerabilities of the Commonwealth's shoreline are recognized. The Massachusetts Shoreline Change Project discussed earlier, which is currently being updated by USGS, is much more detailed. As noted, this report was not available in time for the 2013 planning effort and its results will be available for future plan updates.

Additional data on historical costs incurred to reconstruct buildings or infrastructure due to coastal erosion impacts would assist in estimating future losses. Studies addressing sea-level rise throughout the Commonwealth are summarized below.

The Boston Harbor Association examined Boston's vulnerability to coastal flooding for three scenarios (see Figure 6-12 through Figure 6-14):

- Mean higher high water (MHHW) + 2.5 feet (equal to an elevation of 7.3 feet in the North American Vertical Datum (NAVD))
- MHHW + 5 feet (9.8 feet NAVD)
- MHHW + 7.5 feet (12.3 feet NAVD).

The results probably underestimate the extent of flooding from higher sea levels because they do not include wave heights and other effects. For each coastal flooding scenario, the square footage of land affected by flooding was calculated, considering only parcel size and the amount of flooded area. Scenario 1 estimates flooding at the mid-day high tide on October 29, 2012 (5½ hours before Hurricane Sandy's maximum storm surge hit). No further vulnerability analysis was conducted. Scenario 2 estimates that 6.6 percent of Boston could be flooded, which approximates the current 100-year coastal storm surge at high tide. Scenario 2 estimates that more than 30 percent of Boston could be flooded. This approximates the 100-year coastal storm surge at high tide when sea levels are 2.5 feet higher, sometime after mid-century (The Boston Harbor Association, 2013). For more information, see: http://www.tbha.org/sites/tbha.org/files/documents/preparing_for_the_rising_tide_final.pdf.

According to the 2011 Massachusetts Climate Change Adaptation Plan, a sea level rise of 0.65 meters (26 inches) in Boston by 2050 could damage assets worth an estimated $463 billion (Lenton et al., 2009). Evacuation costs alone in the Northeast region resulting from sea level rise and storms during a single event could range between $2 billion and $6.5 billion (Ruth et al., 2007)

The Buzzards Bay Estuary Program and the CZM are expanding the existing FEMA 100-year floodplain using Flood Insurance Rate Map base flood elevations for Buzzards Bay municipalities (Fairhaven, Westport, Dartmouth, New Bedford, Mattapoisett, Marion, and Wareham) with 1-foot, 2-foot, and 4-foot increases in sea level. Using a recent assessor's data set, the number of buildings, their assessed values, and municipal structures are being enumerated within these various sea level rise expansion scenarios. For more detailed information on the study, the status of the reports and maps, see: http://buzzardsbay.org/floodzone-expansion-slr.html. This project has been listed in the Plan Maintenance section as one to potentially review in future plan updates.

A 2004 study conducted by Kirshen et al., examined impacts under two relative sea-level rise scenarios for 2100: 0.6 meters and 1.0 meters. The impacts for the period 2000 to 2100 were determined. Further details regarding the assumptions made and their methodology may be found in their 2004 paper in *Climatic Change*. Table 6-8 summarizes the estimated losses as a result of sea-level rise to property owners, and as a result of emergency and adaptation actions for the four modeled scenarios.

Figure 6-12. Estimated Flooding in Boston at MHHW + 2.5 feet/7.3 feet NAVD

Source: The Boston Harbor Association, 2013

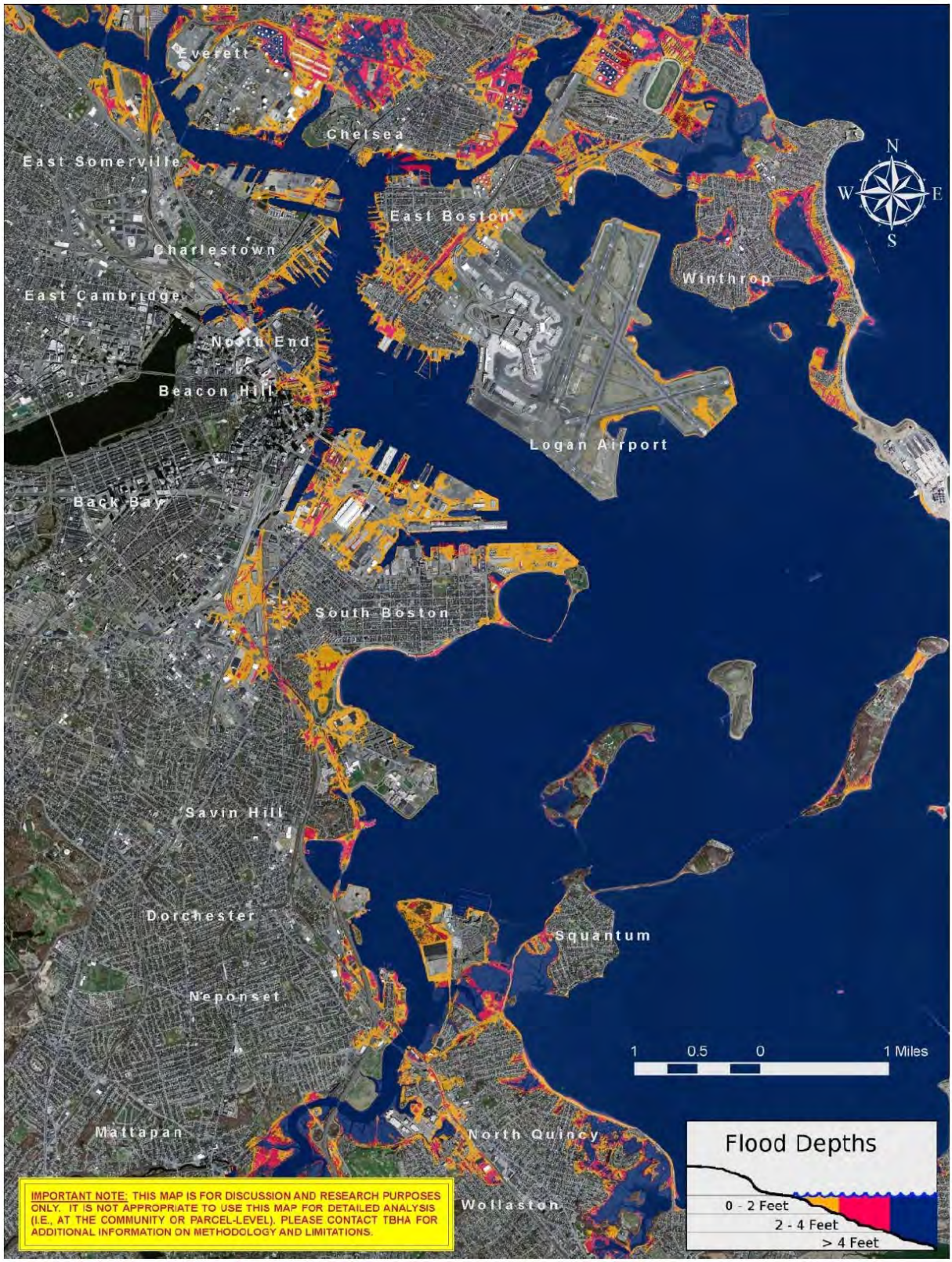


Figure 6-13. Estimated Flooding in Boston at MHHW + 5 feet/9.8 feet NAVD

Source: The Boston Harbor Association, 2013

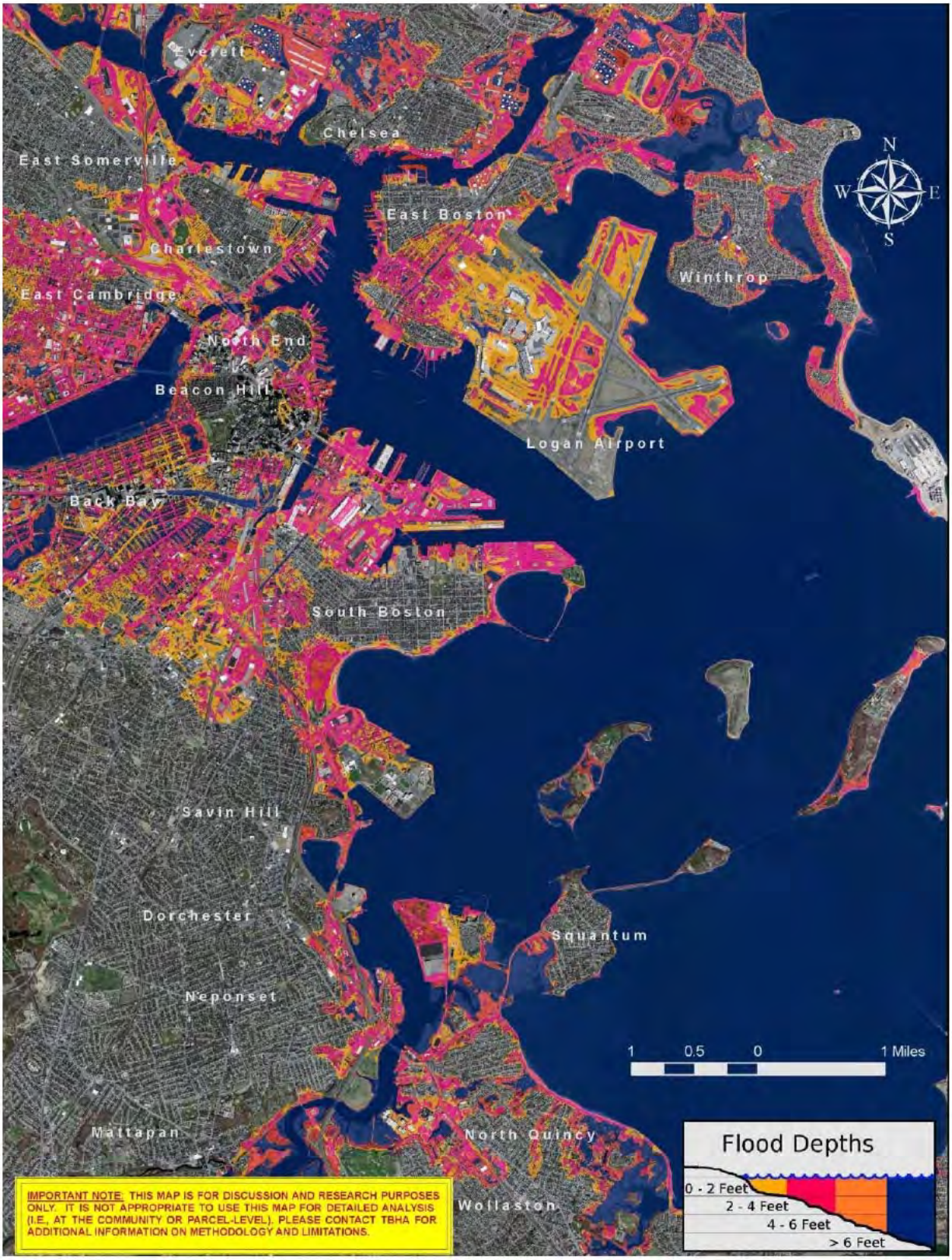


Figure 6-14. Estimated Flooding in Boston at a Sea-Level of MHHW + 7.5 feet/12.3 feet NAVD

TABLE 6-8.
ESTIMATED LOSSES FROM EACH SEA-LEVEL RISE SCENARIO ($ MILLIONS)

		Estimated Losses by Land Use				
Model Run		Residential	Commercial /Industrial	Emergency	Adaptation	**Total**
1	Baseline—no growth, one event	1,087	4,023	869	0	5,979
2	Baseline—no growth, three events	1,452	5,354	1,157	0	7,963
3	Baseline—growth, one event	1,205	4,305	937	0	6,447
4	Baseline—growth, three events	1,616	5,735	1,250	0	8,601
5	Ride-It-Out—0.6 m SLR, one event	3,563	13,525	2,905	0	19,993
6	Build-Your-Way-Out—0.6 m SLR, one event	1,091	3,984	863	3,462	9,400
7	Green—0.6 m SLR, one event	756	2,697	587	1,766	5,806
8	Retreat—0.6 m SLR, one event	5,093	9,142	2,420	500	17,155
9	Ride-It-Out—0.6 m SLR, three events	7,993	29,776	6,421	0	44,190
10	Build-Your-Way-Out—0.6 m SLR, three events	1,924	6,925	1,504	3,462	13,815
11	Green—0.6 m SLR, three events	1,649	5,945	1,291	3,391	12,276
12	Retreat—0.6 m SLR, three events	5,164	9,244	2,449	646	17,503
13	Ride-It-Out—1 m SLR, one event	6,131	25,014	5,295	0	36,440
14	Build-Your-Way-Out—1 m SLR, one event	969	3,613	779	3,462	8,823
15	Green—1 m SLR, one event	1,268	4,959	1,059	2,897	10,183
16	Retreat—1 m SLR, one event	5,564	9,632	2,583	546	18,325
17	Ride-It-Out—1 m SLR, three events	16,140	64,250	13,666	0	94,056
18	Build-Your-Way-Out—1 m SLR, three events	1,820	6,703	1,449	3,462	13,434
19	Green—1 m SLR, three events	3,272	12,760	2,726	6,798	25,556
20	Retreat—1 m SLR, three events	5,651	9,632	2,598	558	18,439

Source: Kirshen et al, 2004

Ride-It-Out: Assumes that existing buildings will be repaired to current conditions after each flood over the 100 year period with no additional flood-proofing. All growth in the present 100-year floodplain is flood-proofed 100-percent effectively so there is no damage to this property if flooded by any event. It is assumed that increased cost of flood-proofing new structures is insignificant compared to the total cost of new construction. There are no requirements for flood-proofing in the present 500 year floodplain.

Green: Requires that all growth in the current 100 and 500 year floodplains be flood-proofed at the time of construction and assume that flood-proofing new residential, commercial, and industrial structures only nominally adds to the cost of construction.

Build-Your-Way-Out: Unregulated growth is allowed in all floodplains because all current and future development is protected with retrofit or new coastal protection structures

Retreat: Assumes that no more residential, commercial, or industrial development is allowed in floodplains and that no rebuilding after flooded is permitted; there is no damage threshold below which an owner can repair instead of abandon. This scenario is distinctly different from the other scenarios because in this scenario property owners are forced to vacate the floodplain or not build in it. It is assumed that when a property is flooded, the owner loses the value of the building, contents, and the land.

In summary, this study estimates the cumulative 2000 to 2100 damage and adaptation costs of coastal flooding in metro Boston ranges from approximately $6 billion to $94 billion. These costs depend on numerous factors including the rate of sea-level rise, how quickly property owners rebuild after storms, and the adaptation scenario employed. In comparison, the cumulative costs for the present flood management strategy over that period but with subsidence only, no eustatic sea-level rise, is approximately $6 billion to $9 billion. It is noted that these costs do not include operation and maintenance costs, environmental costs or the distribution of costs among different socioeconomic groups (Kirshen, et al, 2004).

SECTION 7. DAM FAILURE

7.1 GENERAL BACKGROUND

7.1.1 Causes of Dam Failure

A "dam" is an artificial barrier that has the ability to impound water, wastewater, or any liquid-borne material for the purpose of storage or control of water. Dam failure is a catastrophic type of failure characterized by the sudden, rapid, and uncontrolled release of impounded water or the likelihood of such an uncontrolled release. Dams can fail for one or a combination of the following reasons:

- Overtopping caused by floods that exceed the capacity of the dam
- Deliberate acts of sabotage
- Structural failure of materials used in dam construction
- Movement and/or failure of the foundation supporting the dam
- Settlement and cracking of concrete or embankment dams
- Piping and internal erosion of soil in embankment dams
- Inadequate maintenance and upkeep.

DEFINITIONS

Dam—Any artificial barrier and/or any controlling works, together with appurtenant works, that can or does impound or divert water.

Dam Failure—An uncontrolled release of impounded water due to structural deficiencies in dam.

Emergency Action Plan—A document that identifies potential emergency conditions at a dam and specifies actions to be followed to minimize property damage and loss of life. The plan specifies actions the dam owner should take to alleviate problems at a dam. It contains procedures and information to assist the dam owner in issuing early warning and notification messages to responsible downstream emergency management authorities of the emergency situation. It also contains inundation maps to show emergency management authorities the critical areas for action in case of an emergency. (FEMA 64)

High Hazard Dam—Dams where failure or operational error will probably cause loss of human life. (FEMA 333)

Significant Hazard Dam—Dams where failure or operational error will result in no probable loss of human life but can cause economic loss, environmental damage or disruption of lifeline facilities, or can impact other concerns. Significant hazard dams are often located in rural or agricultural areas but could be located in areas with population and significant infrastructure. (FEMA 333)

Dam failures in the United States typically occur in one of four ways:

- Overtopping of the primary dam structure, which accounts for 34 percent of all dam failures, can occur due to inadequate spillway design, settlement of the dam crest, blockage of spillways, and other factors.
- Foundation defects due to differential settlement, slides, slope instability, uplift pressures, and foundation seepage can also cause dam failure. These account for 30 percent of all dam failures.
- Failure due to piping and seepage accounts for 20 percent of all failures. These are caused by internal erosion due to piping and seepage, erosion along hydraulic structures such as spillways, erosion due to animal burrows, and cracks in the dam structure.
- Failure due to problems with conduits and valves, typically caused by the piping of embankment material into conduits through joints or cracks, constitutes 10 percent of all failures.

The remaining 6 percent of U.S. dam failures are due to miscellaneous causes. Many dam failures in the United States have been secondary results of other disasters. The prominent causes are earthquakes,

landslides, extreme storms, massive snowmelt, equipment malfunction, structural damage, foundation failures, and sabotage. Poor construction, lack of maintenance and repair, and deficient operational procedures are preventable or correctable by a program of regular inspections. Terrorism and vandalism are serious concerns that all operators of public facilities must plan for; these threats are under continuous review by public safety agencies.

7.1.2 Regulatory Oversight

The potential for catastrophic flooding due to dam failures led to passage of the National Dam Safety Act (Public Law 92-367). The National Dam Safety Program requires a periodic engineering analysis of every major dam in the country. The goal of this FEMA-monitored effort is to identify and mitigate the risk of dam failure so as to protect the lives and property of the public.

Massachusetts Department of Conservation and Recreation Office of Dam Safety

The Office of Dam Safety maintains records of dams located throughout the Commonwealth, ensures compliance with acceptable practices pertaining to dam inspection, maintenance, operation, and repair of dams. The current regulations, dated June 29, 2009, were promulgated in accordance with 2002 revisions of the Dam Safety Statute (MGL Chapter 253 §§ 44-50) identify the responsibilities of dam owners to register, inspect, develop emergency action plans for high hazard potential dams, and maintain dams in good operating conditions. Amendments to Dam Safety Regulations 302 CMR 10.00-10.16 became effective November 4, 2005 with minor revisions in 2009 and are reflective of the 2002 statutory changes.

In accordance with MGL Chapter 235, Section 45, and 302 CMR 10.05, dam owners must add their dams to the public record by completing a Dam Registration Form provided by the Office of Dam Safety. Upon receipt of the completed form, the Office of Dam Safety issues a Dam Registration Certificate to dam owners. The dam owner must record the certificate at the applicable registry of deeds as an attachment to the record deed that describes the parcel where the dam is located at provide the Office with a copy of the recorded certificate. When land ownership is transferred, a revised form must be submitted to the Office to initiate issuance of an updated Dam Registration Certificate that must be recorded.

The Office of Dam Safety has made available documents that serve as a template and guidelines for conducting compliant dam safety field inspections and filing complaint Dam Safety Phase I Inspection Reports. Owners of dams are required by 302 CMR 10.07 to hire a qualified engineer to inspect and report results every two years for high hazard dams, every five years for significant dams, and every 10 years for low hazard dams.

U.S. Army Corps of Engineers Dam Safety Program

The U.S. Army Corps of Engineers is responsible for safety inspections of some federal and non-federal dams in the United States that meet the size and storage limitations specified in the National Dam Safety Act. The Corps has inventoried dams; surveyed each state and federal agency's capabilities, practices and regulations regarding design, construction, operation, and maintenance of the dams; and developed guidelines for inspection and evaluation of dam safety (U.S. Army Corps of Engineers, 1997).

Federal Energy Regulatory Commission Dam Safety Program

The Federal Energy Regulatory Commission (FERC) has the largest dam safety program in the United States. The FERC cooperates with a large number of federal and state agencies to ensure and promote dam safety and, more recently, homeland security. There are 3,036 dams that are part of regulated hydroelectric projects are in the FERC program. Two-thirds of these are more than 50 years old. As dams age, concern about their safety and integrity grows, so oversight and regular inspection are important. FERC staff inspects hydroelectric projects on an unscheduled basis to investigate the following:

- Potential dam safety problems

- Complaints about constructing and operating a project
- Safety concerns related to natural disasters
- Issues concerning compliance with the terms and conditions of a license.

Every five years, an independent consulting engineer, approved by the FERC, must inspect and evaluate projects with dams higher than 32.8 feet or with a total storage capacity of more than 2,000 acre-feet.

FERC staff monitors and evaluates seismic research in geographic areas where there are concerns about seismic activity. This information is applied in investigating and performing structural analyses of hydroelectric projects in these areas. FERC staff also evaluates the effects of potential and actual large floods on the safety of dams. During and following floods, FERC staff visits dams and licensed projects, determines the extent of damage, if any, and directs any necessary studies or remedial measures the licensee must undertake. The FERC publication *Engineering Guidelines for the Evaluation of Hydropower Projects* guides the FERC engineering staff and licensees in evaluating dam safety. The publication is frequently revised to reflect current information and methodologies.

The FERC requires licensees to prepare emergency action plans and conducts training sessions on how to develop and test these plans. The plans outline an early warning system if there is an actual or potential sudden release of water from a dam due to failure. The plans include operational procedures that may be used, such as reducing reservoir levels and reducing downstream flows, as well as procedures for notifying affected residents and agencies responsible for emergency management. These plans are frequently updated and tested to ensure that everyone knows what to do in emergency situations.

7.2 HAZARD PROFILE

7.2.1 Location

There are 2,901 public and privately owned dams across Massachusetts. As infrastructure ages and maintenance and inspection costs increase, there is good reason to believe that there may be an increased risk for dam breaches or partial breaches.

The Massachusetts Office of Dam Safety, which is within the Department of Conservation and Recreation (DCR), maintains a database of all the publicly and privately owned dams in the Commonwealth. This information includes all the high-hazard dams currently listed the National Dam Inventory which is has been developed as part of the National Dam Safety Program under the U.S. Army Corps of Engineers (per Public Law 92-367). According to the spatial layer maintained by Office of Dam Safety and provided by MassGIS there are 2,901 dams located throughout the Commonwealth of Massachusetts. Table 7-1 represents the breakdown of dam hazard class by ownership type and Table 7-2 summarizes the number of dams by County. Figure 7-1 illustrates their locations.

TABLE 7-1.
NUMBER OF DAMS BY OWNER AND HAZARD IN MASSACHUSETTS

Owner	High Hazard	Significant Hazard	Low Hazard	NA	**Total**
Federal Agency	12	2	2	0	**16**
State	57	102	90	110	**359**
Municipality	174	295	146	248	**863**
Political Subdivision	14	10	5	5	**34**
Private	70	319	269	896	**1,554**
Private Association or other non-profit	3	17	18	37	**75**
Total	**330**	**745**	**530**	**1,296**	**2,901**

Source: MassGIS
Note: Two additional dams were provided in the GIS shape file, however they were located outside the state boundary.

TABLE 7-2.
NUMBER OF DAMS BY COUNTY IN MASSACHUSETTS

County	High Hazard	Significant Hazard	Low Hazard	N/A	Total
Barnstable	0	14	11	32	57
Berkshire	41	41	52	103	237
Bristol	25	45	31	53	154
Dukes	0	1	5	11	17
Essex	32	56	49	102	239
Franklin	14	43	28	73	158
Hampden	24	49	46	113	232
Hampshire	19	33	28	77	157
Middlesex	44	84	55	71	254
Nantucket	0	0	0	0	0
Norfolk	17	57	38	44	156
Plymouth	11	73	52	234	370
Suffolk	1	3	0	2	6
Worcester	102	246	135	381	864
Total	**330**	**745**	**530**	**1,296**	**2,901**

Source: MassGIS, 2012
Note: Two additional dams were provided in the GIS shape file, however they were located outside the state boundary.

Source: MassGIS, 2012

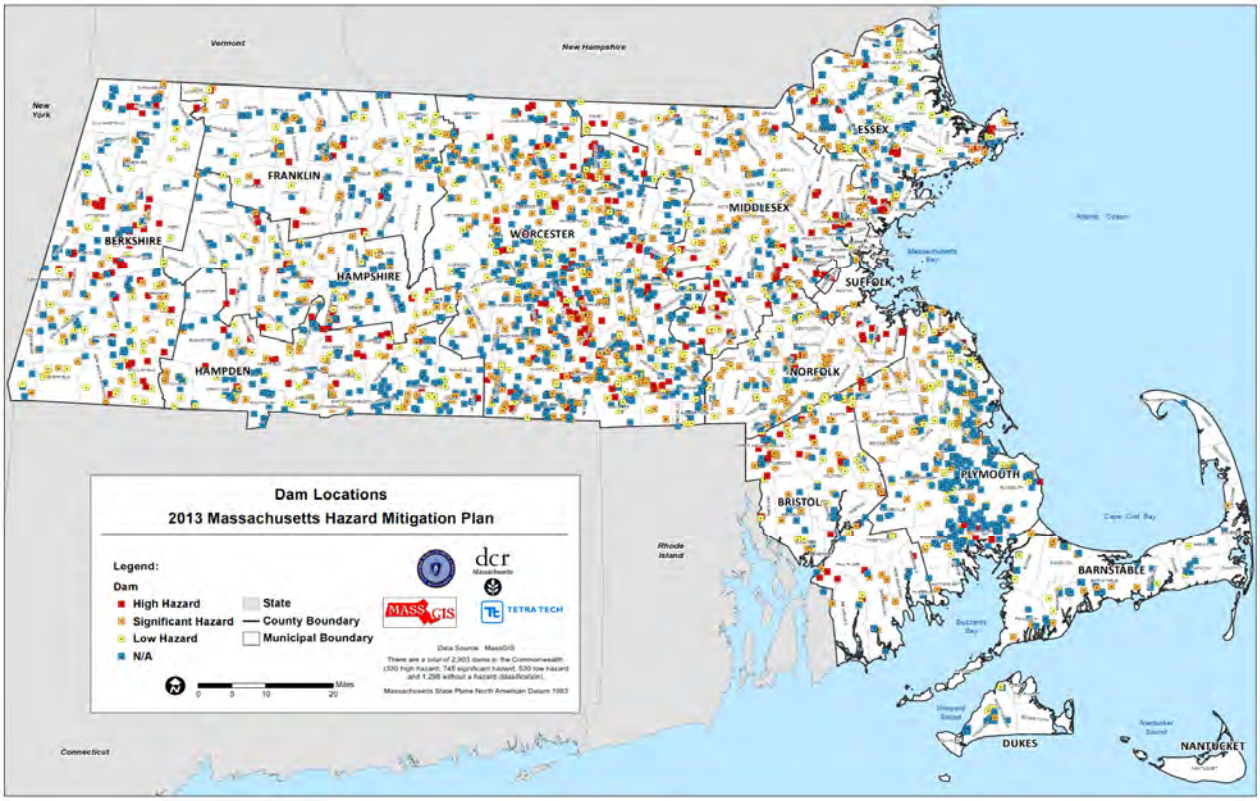


Figure 7-1 Dam Locations in the Commonwealth of Massachusetts.

Each dam is classified by hazard potential as follows:

- High Hazard Potential dam refers to dams located where failure will likely cause loss of life and serious damage to homes, industrial or commercial facilities, important public utilities, main highways, or railroads.
- Significant Hazard Potential dam refers to dams located where failure may cause loss of life and damage homes, industrial or commercial facilities, secondary highways, or railroads or cause interruption of use or service of relatively important facilities.
- Low Hazard Potential dam refers to dams located where failure may cause minimal property damage to others. Loss of life is not expected.

7.2.2 Previous Occurrences

There is no reliable or consistent information on complete dam failures that would be pertinent to this analysis at this time; however, several noteworthy events have influenced the analysis for this section.

On 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.

On 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.

On January 7, 1909, the Ashley Dam in Massachusetts failed due to piping during the first filling. No additional information regarding this failure was provided.

On 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.

During 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.

On April 4, 2004, the 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.

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.

Forge Pond Dam, Freetown, is an earth filled dam more than 200 years old. In February 2010, heavy rains caused the dam to overtop and become unsafe. The DCR Office of 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.

7.2.3 Frequency

Dam failure events are infrequent and usually coincide with events that cause them, such as earthquakes, landslides, excessive rainfall, and snowmelt. There is a “residual risk” associated with dams. Residual risk is the risk that remains after safeguards have been implemented. For dams, the residual risk is associated with events beyond those that the facility was designed to withstand. However, the probability of any type of dam failure is low in today’s regulatory and dam safety oversight environment.

7.2.4 Severity

The U.S. Army Corps of Engineers developed the classification system shown in Table 7-3 for the hazard potential of dam failures. The Corps of Engineers hazard rating systems is based only on the potential consequences of a dam failure; it does not take into account the probability of such failures.

TABLE 7-3.
CORPS OF ENGINEERS HAZARD POTENTIAL CLASSIFICATION

Hazard Category[a]	Direct Loss of Life[b]	Lifeline Losses[c]	Property Losses[d]	Environmental Losses[e]
Low	None (rural location, no permanent structures for human habitation)	No disruption of services (cosmetic or rapidly repairable damage)	Private agricultural lands, equipment, and isolated buildings	Minimal incremental damage

Significant	Rural location, only transient or day-use facilities	Disruption of essential facilities and access	Major public and private facilities	Major mitigation required
High	Certain (one or more) extensive residential, commercial, or industrial development	Disruption of essential facilities and access	Extensive public and private facilities	Extensive mitigation cost or impossible to mitigate

a. Categories are assigned to overall projects, not individual structures at a project.
b. Loss of life potential is based on inundation mapping of area downstream of the project. Analyses of loss of life potential should take into account the population at risk, time of flood wave travel, and warning time.
c. Indirect threats to life caused by the interruption of lifeline services due to project failure or operational disruption; for example, loss of critical medical facilities or access to them.
d. Damage to project facilities and downstream property and indirect impact due to loss of project services, such as impact due to loss of a dam and navigation pool, or impact due to loss of water or power supply.
e. Environmental impact downstream caused by the incremental flood wave produced by the project failure, beyond what would normally be expected for the magnitude flood event under which the failure occurs.

Source: U.S. Army Corps of Engineers, 1995

7.2.5 Warning Time

Warning time for dam failure varies depending on the cause of the failure. In events of extreme precipitation or massive snowmelt, evacuations can be planned with sufficient time. In the event of a structural failure due to earthquake, there may be no warning time. A dam's structural type also affects warning time. Earthen dams do not tend to fail completely or instantaneously. Once a breach is initiated, discharging water erodes the breach until either the reservoir water is depleted or the breach resists further erosion. Concrete gravity dams also tend to have a partial breach as one or more monolith sections are forced apart by escaping water. The time of breach formation ranges from a few minutes to a few hours (U.S. Army Corps of Engineers, 1997).

Dam owners are required to have established protocols for flood warning and response to imminent dam failure in the flood warning portion of its adopted emergency operations plan. These protocols are tied to the emergency action plans also created by the dam owners. These documents are customarily maintained as confidential information, although copies are required to be provided to the Commonwealth of Massachusetts for response purposes.

7.3 SECONDARY HAZARDS

Dam failure can cause severe downstream flooding, depending on the magnitude of the failure. Other potential secondary hazards of dam failure are landslides around the reservoir perimeter, bank erosion on the rivers, and destruction of downstream habitat.

7.4 CLIMATE CHANGE IMPACTS

Dams are designed partly based on assumptions about a river's flow behavior, expressed as hydrographs. Changes in weather patterns can have significant effects on the hydrograph used for the design of a dam. If the hygrograph changes, it is conceivable that the dam can lose some or all of its designed margin of safety, also known as freeboard. If freeboard is reduced, dam operators may be forced to release increased volumes earlier in a storm cycle in order to maintain the required margins of safety. Such early releases of increased volumes can increase flood potential downstream. Throughout the west, communities downstream of dams are already increases in stream flows from earlier releases from dams.

Dams are constructed with safety features known as "spillways." Spillways are put in place on dams as a safety measure in the event of the reservoir filling too quickly. Spillway overflow events, often referred to

as "design failures," result in increased discharges downstream and increased flooding potential. Although climate change will not increase the probability of catastrophic dam failure, it may increase the probability of design failures.

7.5 EXPOSURE

To understand risk, the assets exposed to the hazard areas are identified. Dam failure inundation maps and downstream hazard areas are considered sensitive information and were not available to conduct a quantitative risk assessment. The following discusses the Commonwealth of Massachusetts' exposure, in a qualitative nature, to the dam failure hazard including:

- Population
- State facilities
- Critical facilities
- Economy

7.5.1 Population

All populations in a dam failure inundation zone would be exposed to the risk of a dam failure. The potential for loss of life is affected by the capacity and number of evacuation routes available to populations living in areas of potential inundation.

7.5.2 State Facilities

All state-owned and state-leased facilities in a dam failure inundation zone would be exposed to the risk of a dam failure.

7.5.3 Critical Facilities

All critical facilities and infrastructure in a dam failure inundation zone would be exposed to the risk of a dam failure.

7.5.4 Economy

All buildings and infrastructure located in the dam failure inundation zone are considered exposed and vulnerable. Figure 7-2 illustrates the location of the high hazard dams throughout the Commonwealth. Refer to Table 7-2, which summarizes the number of high hazard dams in each County. In summary, Worcester County has the greatest number of high hazard dams compared to the remainder of the Commonwealth (102 high hazard dams).

Reservoirs held behind dams affect many ecological aspects of a river. River topography and dynamics depend on a wide range of flows, but rivers below dams often experience long periods of very stable flow conditions or saw-tooth flow patterns caused by releases followed by no releases. Water releases from dams usually contain very little suspended sediment; this can lead to scouring of river beds and banks.

The environment would be exposed to a number of risks in the event of dam failure. The inundation could introduce many foreign elements into local waterways. This could result in destruction of downstream habitat and could have detrimental effects on many species of animals.

7.6 VULNERABILITY

A quantitative vulnerability assessment could not be completed to estimate potential losses from a dam failure event. The Commonwealth's vulnerability to the dam failure hazard is discussed qualitatively below.

7.6.1 Population

Vulnerable populations are all populations downstream from dam failures that are incapable of escaping the area within the needed time frame. This population includes the elderly and young who may be unable to get themselves out of the inundation area. Economically disadvantaged populations are more vulnerable because they are likely to evaluate their risk and make decisions to evacuate based on the net economic impact to their family. The population over the age of 65 is also highly vulnerable because they are more likely to seek or need medical attention which may not be available due to isolation during a flood event and they may have more difficulty evacuating.

Source: MassGIS

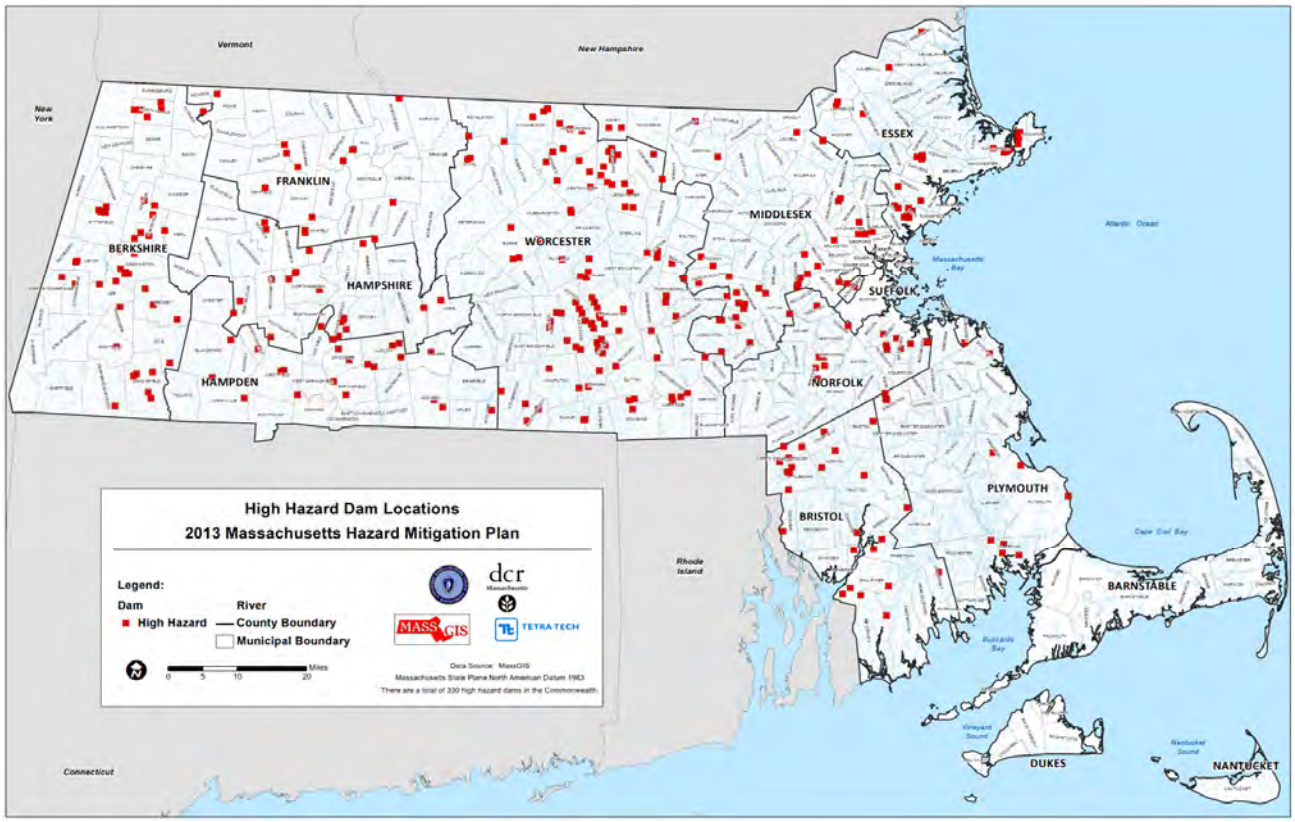


Figure 7-2. High Hazard Dams in the Commonwealth

There is often limited warning time for a dam failure event. While dam failure is rare, when events do occur, they are frequently associated with other natural hazard events such as earthquakes, landslides, or severe weather, which limits their predictability and compounds the hazard. Populations without adequate warning of the event from a television or radio emergency warning system are highly vulnerable to this hazard.

7.6.2 State Facilities

All state facilities in the dam failure inundation zone are vulnerable to damage. Buildings and property located closest to the dam inundation zone have the greatest potential to experience the largest, most destructive surge of water.

7.6.3 Critical Facilities

All critical facilities and transportation infrastructures in the dam failure inundation zone are vulnerable to damage. Flood waters may potentially cut off evacuation routes, limit emergency access, and create

isolation issues. Utilities such as overhead power lines, cable and phone lines in the inundation zone are also vulnerable. Loss of these utilities could create additional isolation issues for the inundation zones.

7.6.4 Economy

Damage to buildings can impact a community's economy and tax base. As previously stated, buildings and property located closest to the dam inundation zone have the greatest potential to experience the largest, most destructive surge of water.

SECTION 8. EARTHQUAKE

8.1 GENERAL BACKGROUND

An earthquake is the vibration, sometimes violent, of the earth's surface that follows a release of energy in the earth's crust due to fault fracture and movement. A fault is a fracture in the earth's crust along which two blocks of the crust have slipped with respect to each other. Faults are divided into three main groups, depending on how they move. Normal faults occur in response to pulling or tension: the overlying block moves down the inclined dip of the fault plane. Thrust (reverse) faults occur in response to squeezing or compression: the overlying block moves up the inclined dip of the fault plane. Strike-slip (lateral) faults occur in response to either type of stress; the blocks move horizontally along a vertical fault past one another. Most faulting along spreading zones is the normal type, along subduction zones is thrust type, and along transform faults is strike-slip.

The focal depth of an earthquake is the depth from the surface to the region where the earthquake's energy originates (the focus). 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. The focuses of most earthquakes are concentrated in the upper 20 miles of the earth's crust. 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, and the focus is the area of the fault where a sudden rupture initiates. The location of an earthquake is commonly described by the geographic position of its epicenter and by its focal depth. Earthquakes beneath the ocean floor sometimes generate immense sea waves or tsunamis if the earthquake causes upward or downward movement of the sea floor. The tsunami originates where this movement takes place.

The cause of earthquakes in eastern North America is the forces moving the tectonic plates over the surface of the Earth. New England is located in the middle of the North American Plate. One edge of the North American plate is along the west coast where the plate is pushing against the Pacific Ocean 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 European and African plates. New England's earthquakes appear to be the result of the cracking of the crustal rocks due to compression as the North American plate is being very slowly squeezed by the global plate movements.

Seismic waves are the vibrations from earthquakes that travel through the Earth and are recorded on instruments called seismographs. The magnitude or extent of an earthquake is a seismograph-measured value of the amplitude of the seismic waves. The Richter magnitude scale (Richter scale) was developed in 1932 as a mathematical device to compare the sizes of earthquakes. The Richter scale is the most widely known scale that measures earthquake magnitude. It has no upper limit and is not used to 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. Table 8-1 summarizes Richter scale magnitudes and corresponding earthquake effects. Effects listed are more applicable at lower levels to California than to Massachusetts. For example, earthquakes in the 2 to 2.5 range are typically felt in Massachusetts and throughout the eastern United States. Generally, earthquakes in the eastern U.S. are felt over a larger area than those in the western U.S., as depicted in Figure 8-1. The difference between seismic shaking in the East versus the West is due in part to the geologic structure and rock properties that allow seismic waves to travel farther without weakening (USGS, 2012).

TABLE 8-1.
RICHTER SCALE

Richter Magnitude	Earthquake Effects
2.5 or less	Not felt or felt mildly near the epicenter, but can be recorded by seismographs
2.5 to 5.4	Often felt, but only causes minor damage
5.5 to 6.0	Slight damage to buildings and other structures
6.1 to 6.9	May cause a lot of damage in very populated areas
7.0 to 7.9	Major earthquake; serious damage
8.0 or greater	Great earthquake; can totally destroy communities near the epicenter

Source: (USGS, 2012)

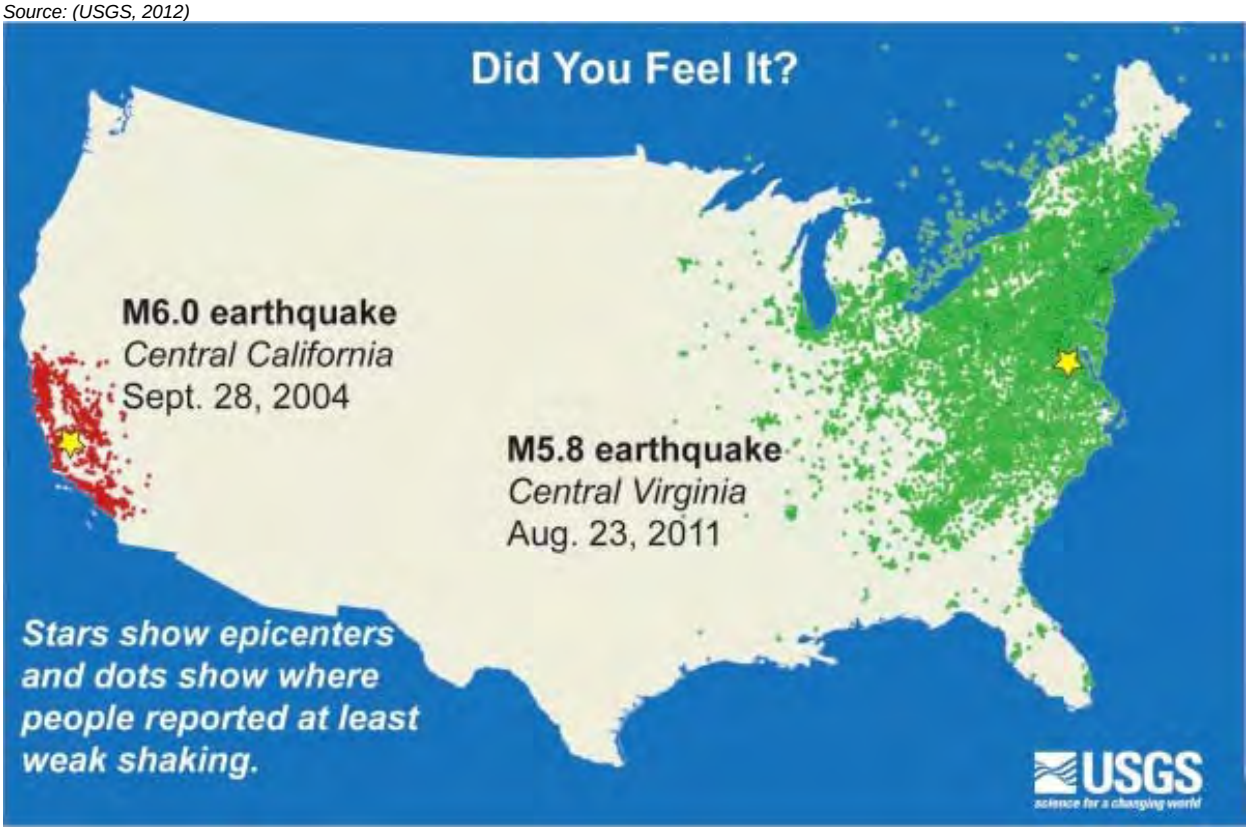


Figure 8-1. USGS "Did you Feel It?" Data from Magnitude 5.8 Earthquake in Central Virginia (green) and from an Earthquake of Similar Magnitude and Depth in California (red)

The intensity of an earthquake is based on the observed effects of ground shaking on people, buildings, and natural features, and varies with location. Intensity is expressed by the Modified Mercalli Scale; a subjective measure that describes how strongly an earthquake was felt at a particular location. The Modified Mercalli Scale expresses the intensity of an earthquake's effects in a given locality in values ranging from I to XII. Table 8-2 summarizes earthquake intensity as expressed by the Modified Mercalli Scale. Table 8-3 displays the Modified Mercalli Scale and peak ground acceleration equivalent.

TABLE 8-2.
MODIFIED MERCALLI INTENSITY SCALE

Mercalli Intensity	Description
I	Felt by very few people; barely noticeable.
II	Felt by few people, especially on upper floors.
III	Noticeable indoors, especially on upper floors, but may not be recognized as an earthquake.
IV	Felt by many indoors, few outdoors. May feel like passing truck.
V	Felt by almost everyone, some people awakened. Small objects move, trees and poles may shake.
VI	Felt by everyone; people have trouble standing. Heavy furniture can move; plaster can fall off walls. Chimneys may be slightly damaged.
VII	People have difficulty standing. Drivers feel cars shaking. Some furniture breaks. Loose bricks fall from buildings. Damage is slight to moderate in well-built buildings; considerable in poorly built buildings.
VIII	Buildings suffer slight damage if well-built, severe damage if poorly built. Some walls collapse.
IX	Considerable damage to specially built structures; buildings shift off their foundations. The ground cracks. Landslides may occur.
X	Most buildings and their foundations are destroyed. Some bridges are destroyed. Dams are seriously damaged. Large landslides occur. Water is thrown on the banks of canals, rivers, lakes. The ground cracks in large areas.
XI	Most buildings collapse. Some bridges are destroyed. Large cracks appear in the ground. Underground pipelines are destroyed.
XII	Almost everything is destroyed. Objects are thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move.

TABLE 8-3.
MODIFIED MERCALLI INTENSITY (MMI) AND PGA EQUIVALENTS

MMI	Acceleration (%g) (PGA)	Perceived Shaking	Potential Damage
I	< .17	Not Felt	None
II	.17 – 1.4	Weak	None
III	.17 – 1.4	Weak	None
IV	1.4 – 3.9	Light	None
V	3.9 – 9.2	Moderate	Very Light
VI	9.2 – 18	Strong	Light
VII	18 – 34	Very Strong	Moderate
VIII	34 – 65	Severe	Moderate to Heavy
IX	65-124	Violent	Heavy
X	>124	Extreme	Very Heavy
XI	>124	Extreme	Very Heavy
XII	>124	Extreme	Very Heavy

Source: Commonwealth of Virginia, 2010

Seismic hazards are often expressed in terms of Peak Ground Acceleration (PGA) and Spectral Acceleration (SA). USGS defines PGA and SA as the following: 'PGA is what is experienced by a particle on the ground. Spectral Acceleration (SA) is approximately what is experienced by a building, as modeled by a particle mass on a massless vertical rod having the same natural period of vibration as the building'. Both PGA and SA can be measured in *g* (the acceleration due to gravity) or expressed as a percent acceleration force of gravity (%g). PGA and SA hazard maps provide insight into location specific vulnerabilities.

More specifically, a PGA earthquake measurement shows three things: the geographic area affected, the probability of an earthquake of each given level of severity, and the strength of ground movement (severity) expressed in terms of percent of acceleration force of gravity (%g). In other words, PGA expresses the severity of an earthquake and is a measure of how hard the earth shakes (or accelerates) in a given geographic area.

For the 2013 plan update, a probabilistic assessment was conducted for the 100-, 500-, 1,000-, and 2,500-year mean return periods (MRP) through a Level 2 analysis in Hazus-MH 2.1 to analyze the earthquake hazard for the Commonwealth. The Hazus analysis evaluates the statistical likelihood that a specific event will occur and what consequences will occur. For example, 100-year MRP event is an earthquake with a 1% chance that the mapped ground motion levels (PGA) will be exceeded in any given year. Figure 8-2 through Figure 8-5 show the geographic distribution of PGA (%*g*) across Massachusetts for 100-, 500-, 1,000-, and 2,500-year MRP events at the U.S. 2000 Census-tract level.

Ground shaking is the primary cause of earthquake damage to man-made structures. This damage can be increased due to the fact that soft soils amplify ground shaking. A contributor to site amplification is the velocity at which the rock or soil transmits shear waves (S-waves). The National Earthquake Hazard Reduction Program (NEHRP) developed five soil classifications defined by their shear-wave velocity that impact the severity of an earthquake. 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 damage and losses. NEHRP soil classifications are available for only a portion of the Commonwealth at the time of this analysis: portions of Franklin, Hampden, and Hampshire Counties as provided by the state geologist. Figure 8-6 illustrates the NEHRP soils available in Massachusetts. The available NEHRP soils were incorporated into the Hazus-MH earthquake model for the risk assessment (discussed in further detail later in this section). Where NEHRP soils were not available, the Hazus default soil type 'D' was used.

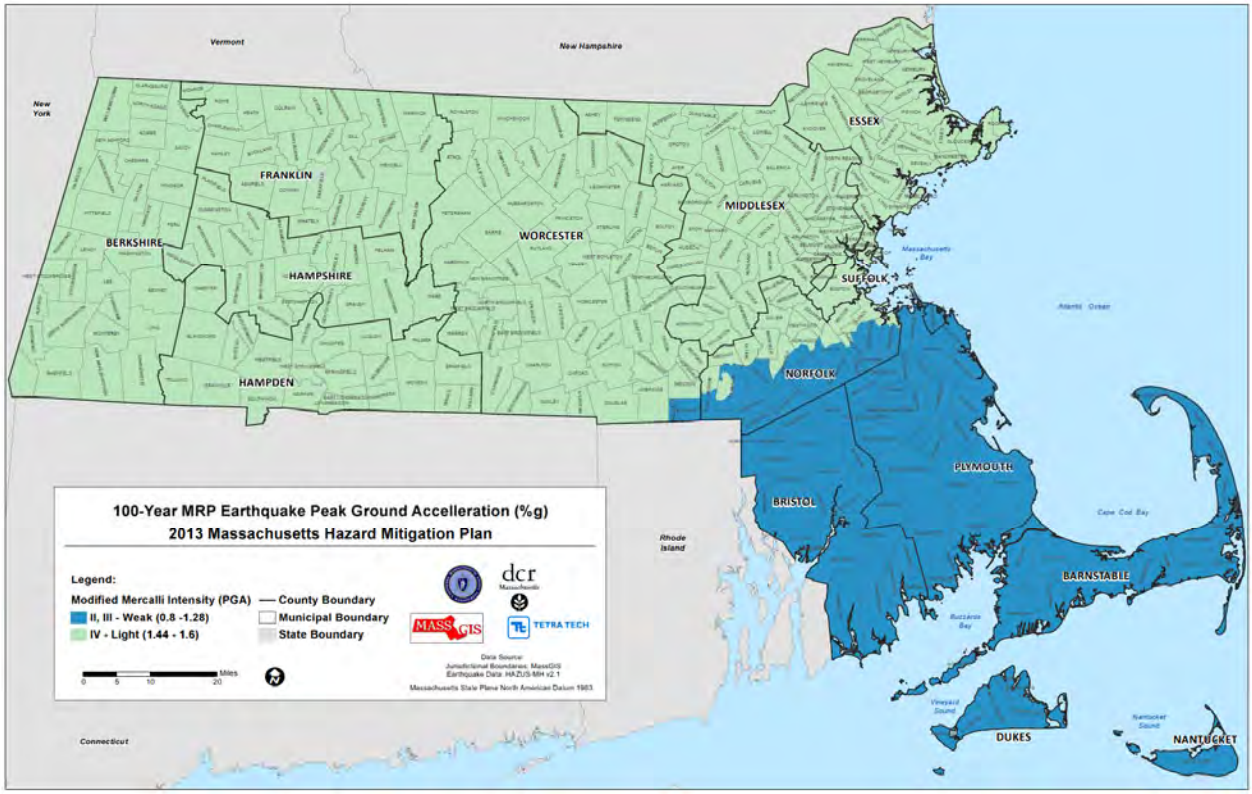


Figure 8-2. Peak Ground Acceleration Modified Mercalli Scale for a 100-Year MRP Earthquake Event

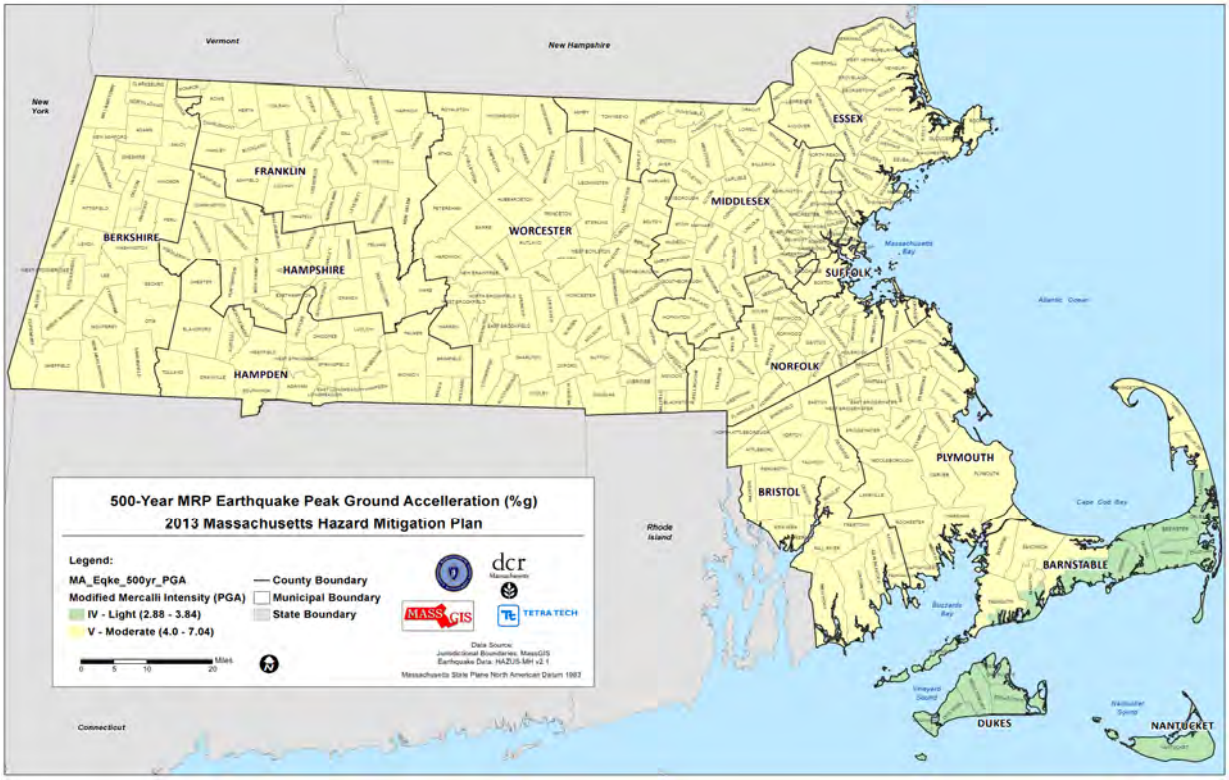


Figure 8-3. Peak Ground Acceleration Modified Mercalli Scale for a 500-Year MRP Earthquake Event

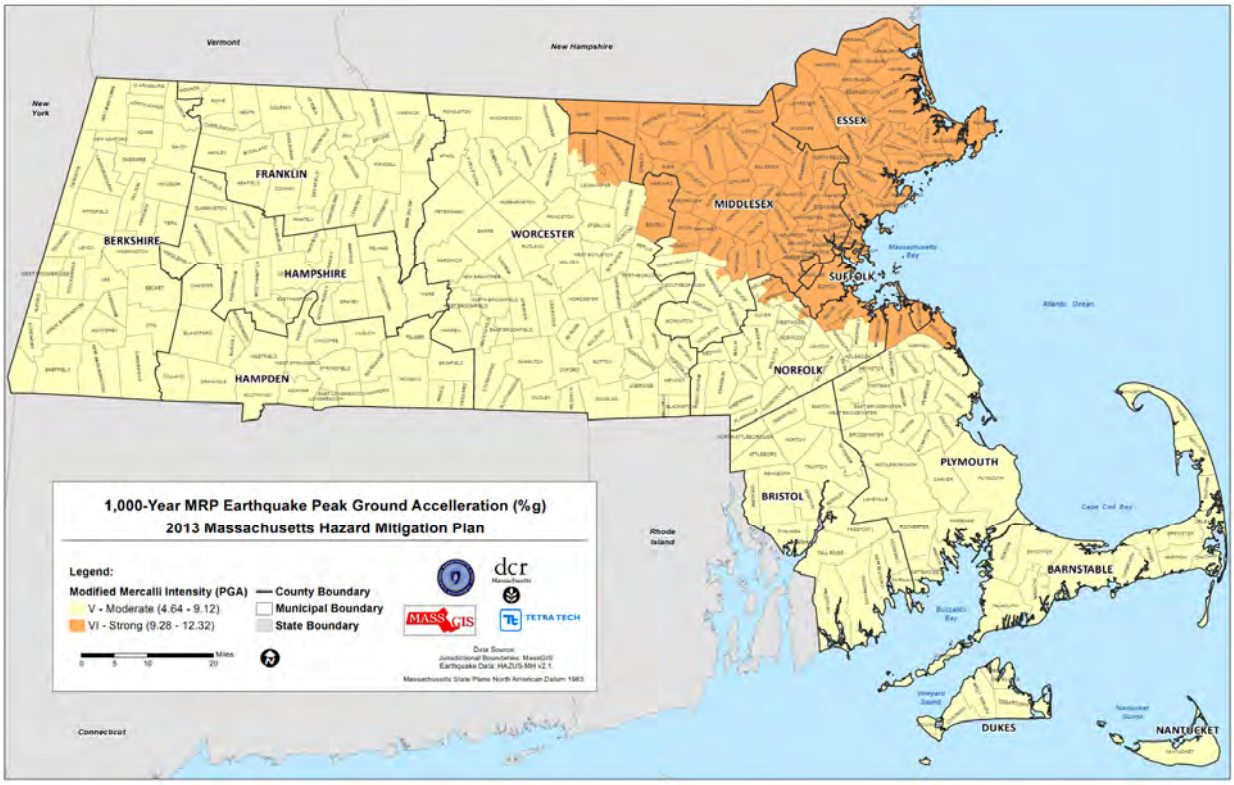


Figure 8-4. Peak Ground Acceleration Modified Mercalli Scale for a 1,000-Year MRP Earthquake Event

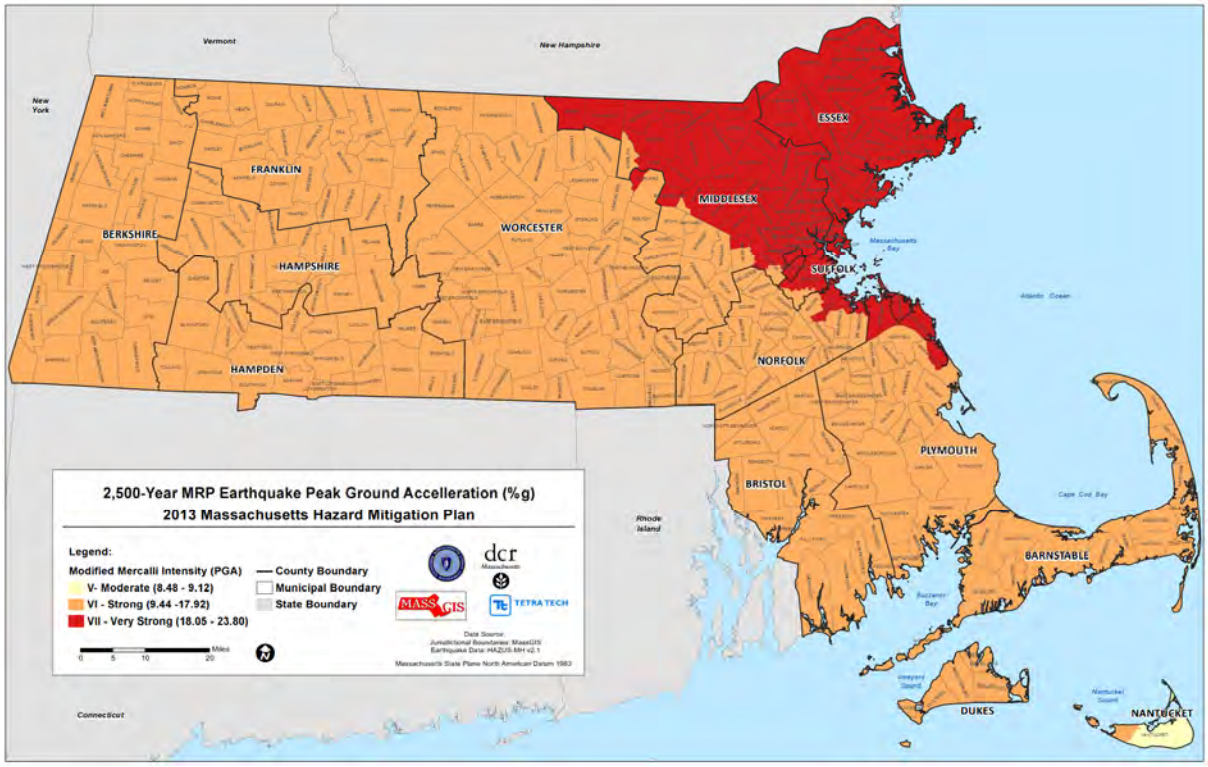


Figure 8-5. Peak Ground Acceleration Modified Mercalli Scale for a 2,500-Year MRP Earthquake Event

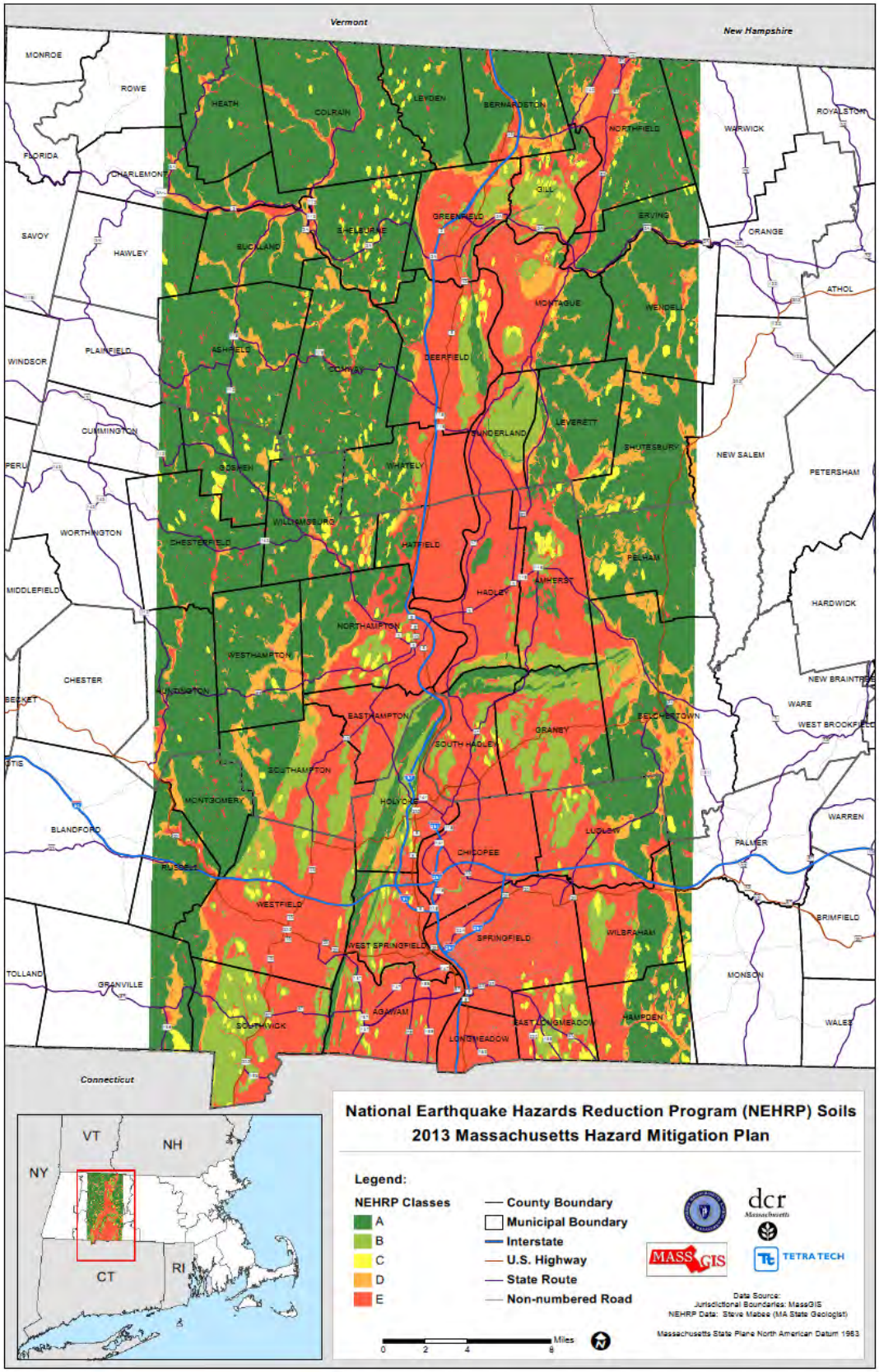


Figure 8-6. National Earthquake Hazards Reduction Program Soils in Massachusetts

8.2 HAZARD PROFILE

8.2.1 Location

Review of available data reveals that the New England epicenters do not follow the major mapped faults of the region, nor are they confined to particular geologic structures or terrains. As opposed to plate boundary regions similar to the West Coast in California, Washington or Oregon where many of the earthquakes align along known geologic faults, New England's earthquakes to date have not aligned along mapped faults. Because earthquakes have been detected all over New England, seismologists suspect that a strong earthquake could be centered anywhere in the region. Furthermore, the mapped geologic faults of New England currently do not provide any indications detailing specific locations where strong earthquakes are most likely to be centered. The GIS analysis included in this analysis represent the locations of earthquake epicenters occurring between 1638-2008 with the magnitude of each event depicted by a graduated symbol, fault locations, and Peak Ground Acceleration (PGA) zones, expressed as percentages of gravity with a two percent probability of the depicted PGA being exceeded in a 50-year period.

In an attempt to quantify the risk of damage due to an earthquake throughout the United States, the USGS through the Earthquake Hazard Program, has developed national maps displaying likely levels of ground motion due to future earthquakes. When developing these maps, the USGS considered the potential magnitude and locations of future earthquakes based on historical data and geological information on the recurrence intervals of fault ruptures. Using these data, the extent of potential ground shaking with a 10 percent, 5 percent, and 2 percent chance of being exceeded in a 50-year period has been calculated, and color maps displaying these ground-motion values on a national scale have been prepared. Information about the nation's seismic hazard maps is available from the USGS Earthquake Hazards Program website: http://eqhazmaps.usgs.gov/. The highest percentages of PGA areas in the Commonwealth are located in Northern Middlesex and Essex Counties; however, the PGA percentages are very low compared to the national averages.

The most commonly used method to quantify potential ground motion is in terms of peak ground acceleration (PGA), which measures the strength of a potential earthquake in terms of the greatest acceleration value of ground movement. The potential damage due to earthquake ground shaking increases as the acceleration of ground movement increases. Peak ground acceleration is expressed as a percentage of a known acceleration, the acceleration of gravity, and is commonly referred to as "%g" in the national seismic hazard maps.

Major damage can occur in earthquakes due to secondary effects triggered by strong earthquake ground shaking. The Richter magnitude scale is a mathematical device to compare the size of earthquakes. The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs. The Richter scale does not reflect damage caused by an earthquake.

A secondary effect that is often observed in low-lying areas near water bodies is ground liquefaction. Liquefaction is the conversion of water-saturated soil into a fluid-like mass. This can occur when loosely packed, waterlogged sediments lose their strength in response to strong shaking. Liquefaction may occur along the shorelines of the ocean, rivers, and lakes, and they can also happen in low-lying areas away from water bodies but where the ground water is near the Earth's surface. Landslides and land slumps are other secondary effects that can be induced by earthquake shaking and that can be very damaging.

A U.S. Geological Survey National Earthquake Hazard Reduction Program study was funded to conduct a detailed study to characterize the surface and subsurface distribution of potentially liquefiable sediments and artificial fill in the City of Boston. Several areas in the study region, including a majority of downtown Boston are 'underlain by extensive regions of non-engineered artificial fill that, when saturated, are susceptible to liquefaction during seismic loading' (Baise and Brankman, 2004). 'Holocene alluvial and marsh deposits in the region are also moderately to highly susceptible to liquefaction. Much

of the outlying area is underlain by Pleistocene and Quaternary glacial and glacio-fluvial deposits, which have low to moderate susceptibility to liquefaction' (Brankman and Baise, 2008). Figure 8-7 illustrates the liquefaction susceptibility of the Boston, Massachusetts metropolitan area (Baise and Brankman,

Although it is well documented that the zone of greatest seismic activity in the United States is along the Pacific Coast in Alaska and California, it may be surprising to most people that an average of six earthquakes are felt each year somewhere in New England, and that damaging earthquakes have taken place in historical time in New England.

New England has had a long history of earthquakes, starting with that recorded by the Plymouth Pilgrims and other early settlers in 1638. Of the over 5,000 earthquakes recorded in the Northeast Earthquake Catalog through 2008, 1,530 occurred within the boundaries of the six New England States, with 366 earthquakes recorded for Massachusetts between 1627 and 2008. Between 1924 and 2008, there have been 101 earthquakes in the Northeast with a magnitude of 4.5 or greater on the Richter scale. Out of these 101 earthquakes, 8 were within the six New England States and the other 93 within New York State or the Province of Quebec. Many of these earthquakes were so strong that they were felt throughout all of New England.

Based on the data provided by Weston Observatory and on the national earthquake hazards map, it appears that northeastern Massachusetts, especially along the Massachusetts coastline from the northern portion of Plymouth County through the Boston Metropolitan area to the New Hampshire border, has greater vulnerability to potential earthquake activity than the rest of the Commonwealth. There are very few earthquakes in western Massachusetts. However, the shaking from earthquakes in eastern New York State can affect western Massachusetts, so all of the Commonwealth has some measure of earthquake hazard.

Earthquakes above about magnitude 5.0 have the potential for causing damage near their epicenters, and larger magnitude earthquakes have the potential for causing damage over larger wider areas. A 1994 report by the USGS, based on a meeting of experts at the Massachusetts Institute of Technology, 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%-15%. This probability rises to about 41% to 56% for a 50-year period. 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.

In some places in New England, including Massachusetts, small earthquakes seem to occur with some regularity. For example, since 1985 there has been a small earthquake experienced approximately every 2.5 years within a few miles of Littleton, Massachusetts. It is not clear why some localities experience such clustering of earthquakes, but a possibility suggested by John Ebel of Boston College's Weston Observatory is that these clusters occur where strong earthquakes were centered in the prehistoric past. The clusters may indicate locations where there is an increased likelihood of future earthquake activity. Figure 8-8 illustrates the major fault lines and historical earthquake epicenters across the Commonwealth from 1638 to 2009.

According to the Northeast States Emergency Consortium, the USGS is increasing the number of seismic stations in New England. Their goal is to reduce uncertainties and to improve procedures for locating smaller earthquakes (Fratto, email, 2012). Figure 8-9 illustrates the seismic stations located throughout New England.

Source: Baise and Brankman, 2004

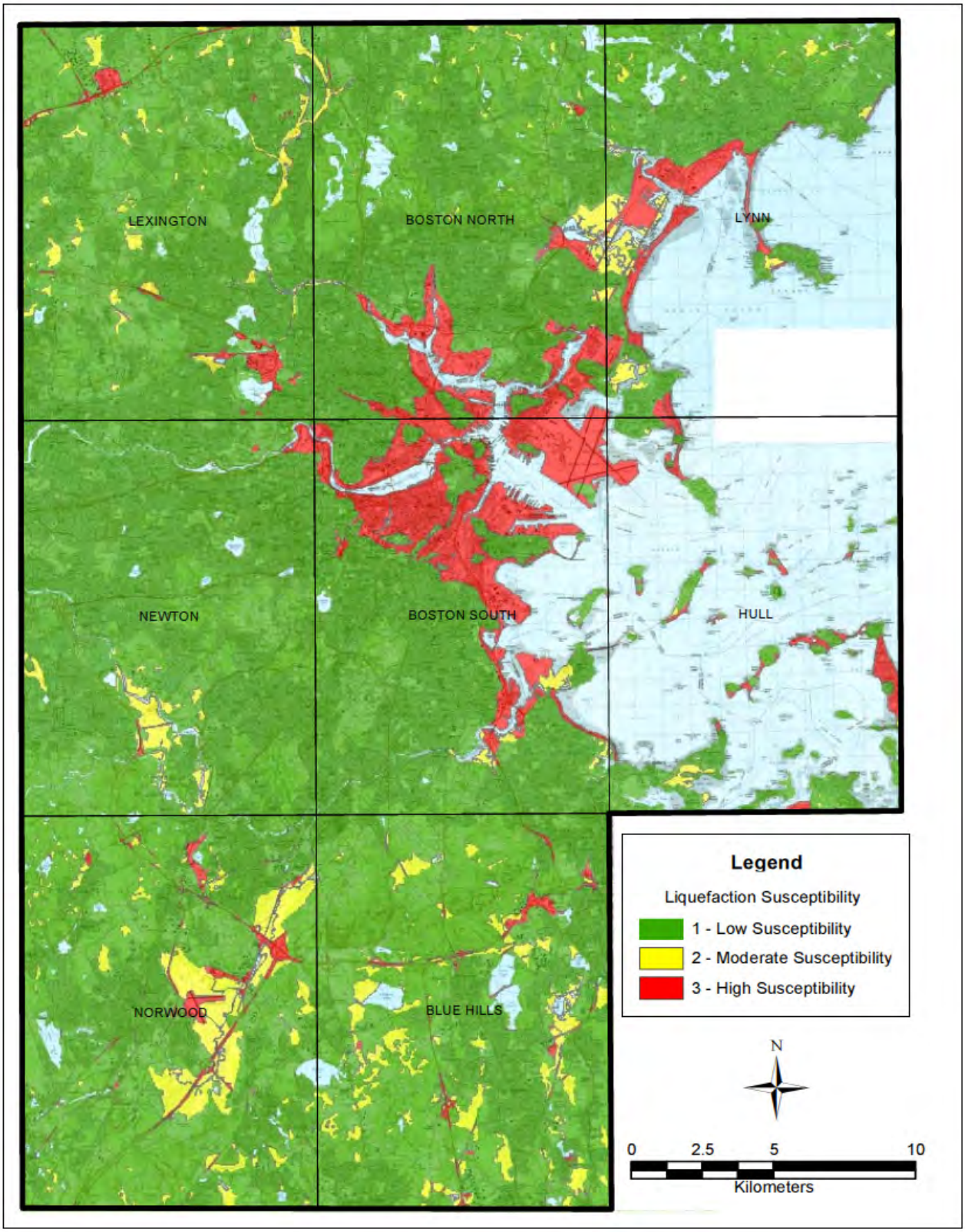


Figure 8-7. Liquefaction Susceptibility of the Boston Metropolitan Area

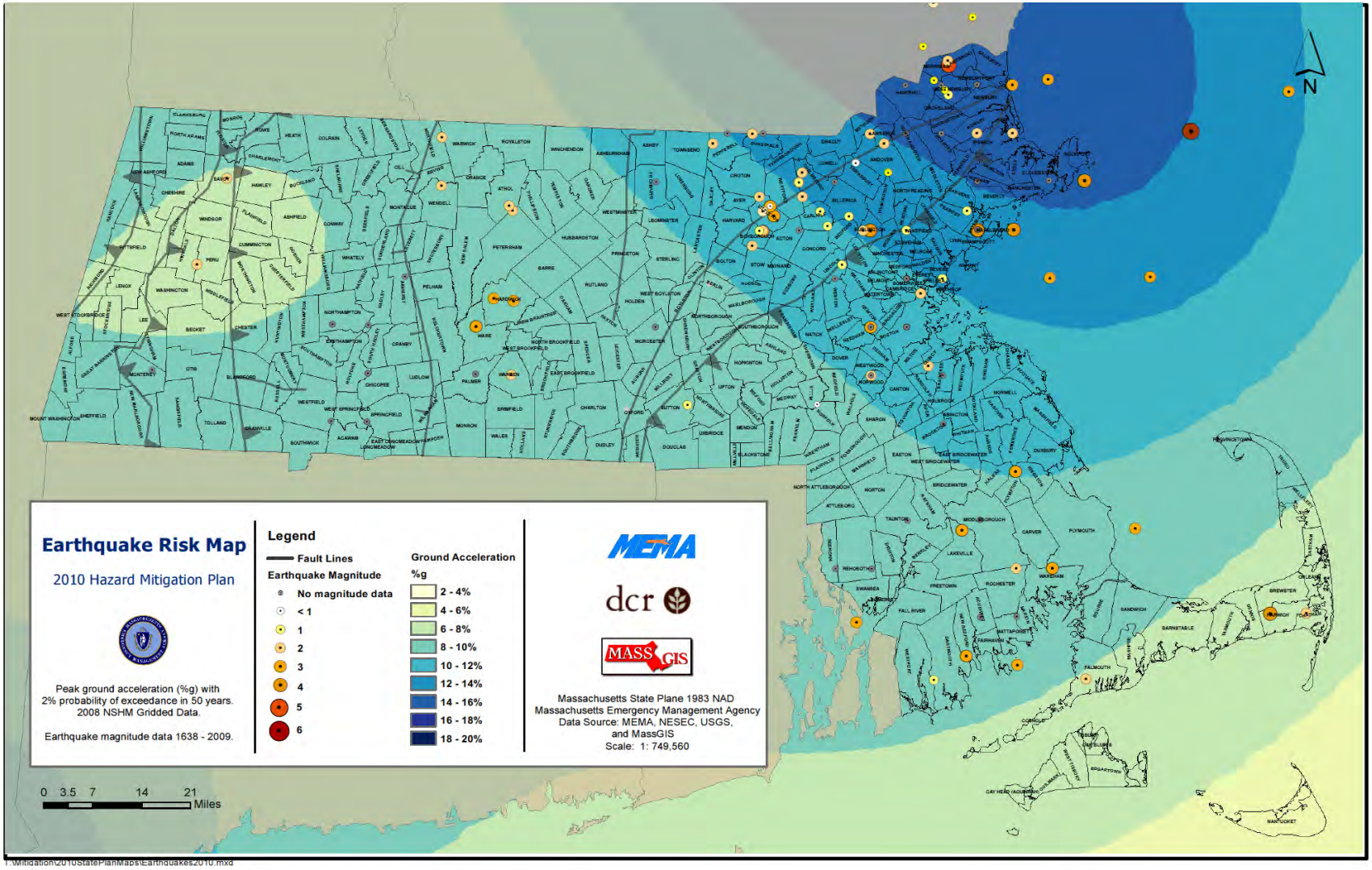


Figure 8-8. Earthquake Risk Map of the Commonwealth of Massachusetts

Source: http://www.bc.edu/content/bc/research/westonobservatory/northeast/eqmaps.html

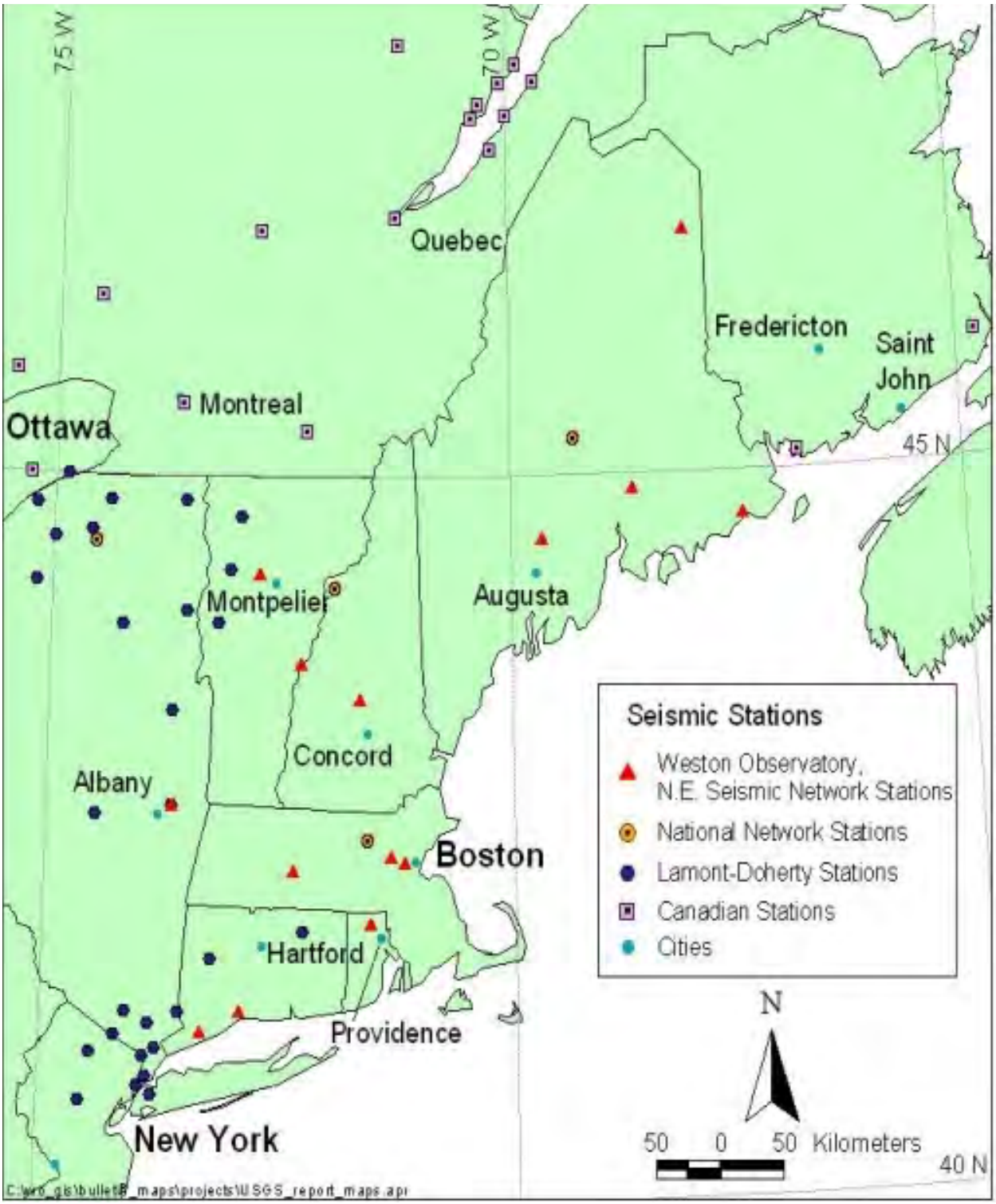


Figure 8-9. New England Seismic Map Station

8.2.2 Previous Occurrences

Since the Plymouth Pilgrims and other early settlers recorded an earthquake in 1638, New England has been a common location for earthquake activity. Since then, over 5,000 earthquakes have been recorded in the Weston Observatory Northeast Earthquake Catalog, which accounts for New England and adjacent regions. Over 1,530 earthquakes occurred within the boundaries of the six New England States and 366 were recorded to have epicenters in Massachusetts. Generally, most earthquakes that occur in the Northeast U.S. tend to be small in magnitude and cause little damage, however; 104 earthquakes between 1924 and 2012 have measured a magnitude 4.5 or greater on the Richter scale. Out of these 104 earthquakes, 10 were centered within New England and the other 94 occurred within New York State and the Province of Quebec. Due to the geologic composition and rock structure of the Northeast U.S. seismic shaking for many of these earthquakes were felt throughout all of New England.

Historically, moderately damaging earthquakes strike somewhere in the region every few decades, and smaller earthquakes are felt approximately twice per year. The Boston area was damaged three times within 28 years in the middle 1700s, and New York City was damaged in 1737 and 1884. The largest known New England earthquakes occurred in 1638 (magnitude 6.5) in Vermont or New Hampshire, and in 1755 (magnitude 5.8) offshore from Cape Ann northeast of Boston. The Cape Ann earthquake caused severe damage to the Boston waterfront. The most recent New England earthquake to cause moderate damage occurred in 1940 (magnitude 5.6) in central New Hampshire.

Moderate earthquakes in 1847 (August 8), 1852 (November 27), 1854 (December 10), 1876 (September 21), 1880 (May 12), 1903 (January 21 and April 24), 1907 (October 15), 1925 (January 7 and April 24), 1940 (January 28), and 1963 (October 16 and 30), were felt over limited areas of eastern Massachusetts. The epicenter of the January 7, 1925, earthquake was off Cape Ann; the reported felt area extended from Providence, Rhode Island, to Kennebunk, Maine. The October 16, 1963, earthquake caused some plaster to fall in Somerville, and a wall was reported cracked and stones fell from a building foundation (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 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.

The most recent earthquake in the region (through 2012) occurred on December 30, 2012, when a Magnitude-1.2 earthquake occurred about 7 miles south of Gardner (Weston Observatory of Boston College, 2013). In 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.

8.2.3 Probability of Future Occurrences

Earthquakes cannot be predicted and may occur any time of the day, any time of the year. PGA maps are used as tools to determine the likelihood an earthquake of a given intensity may be exceeded over a period of time. Figure 8-10 shows the PGA values (6 percent to 16 percent of g) for the Commonwealth that have a 2-percent chance of being exceeded in 50 years. If it were to occur, this earthquake would likely have moderate to strong perceived shaking and very light to light potential damage (refer to Table 8-3 earlier in this profile – Modified Mercalli Intensity and PGA Equivalents).

The Weston Observatory at Boston College conducted an analysis on spatial earthquake probabilities in the New England region. According to that analysis, there is a 66-percent chance that the next earthquake with a magnitude of 2.7 or greater in New England will occur in one of the green areas on Figure 8-11.

Source: http://earthquake.usgs.gov/earthquakes/states/massachusetts/hazards.php

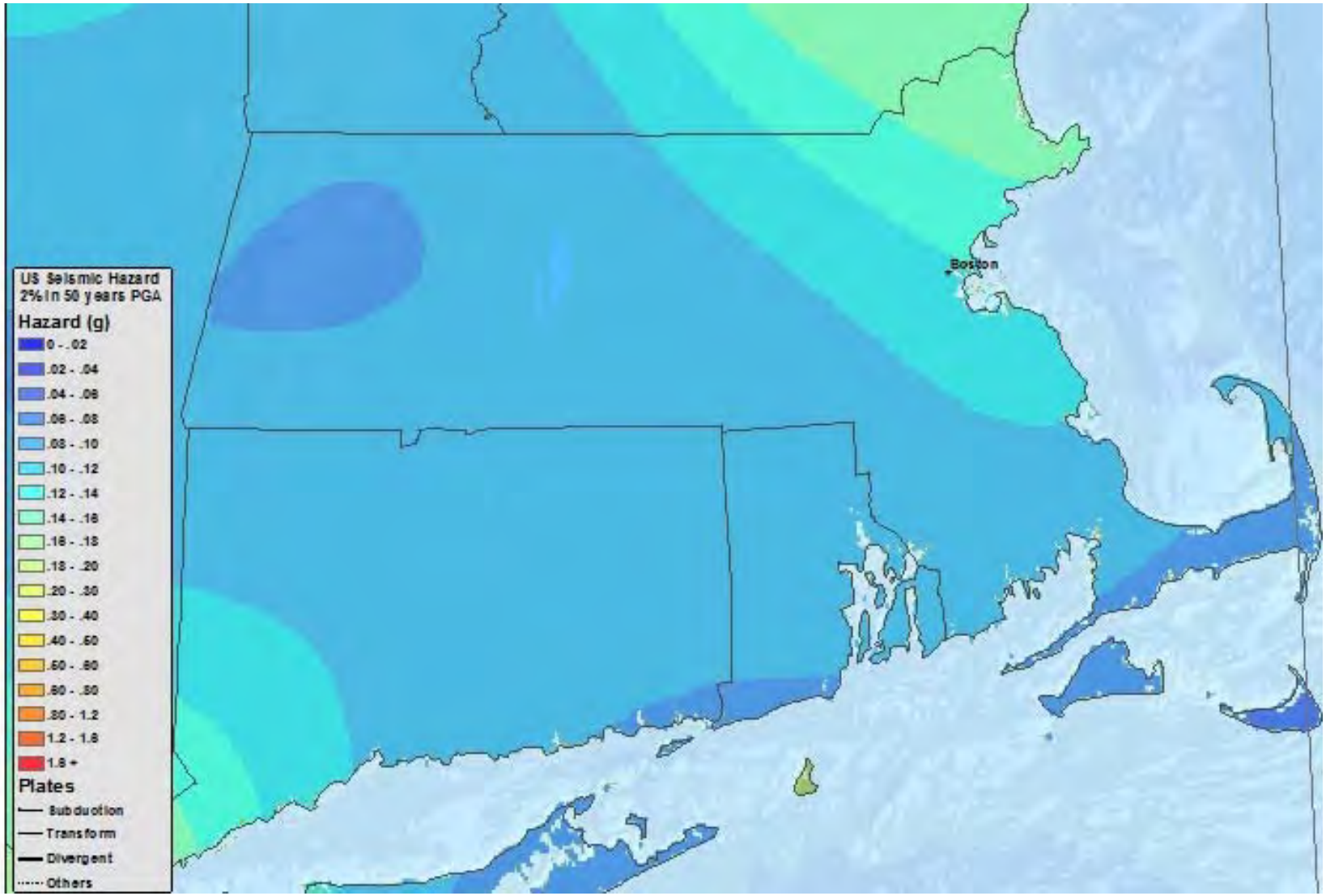


Figure 8-10. Seismic Hazard Map for Massachusetts

Source: Weston Observatory at Boston College
http://www.bc.edu/content/bc/research/westonobservatory/northeast/eqprobability.html

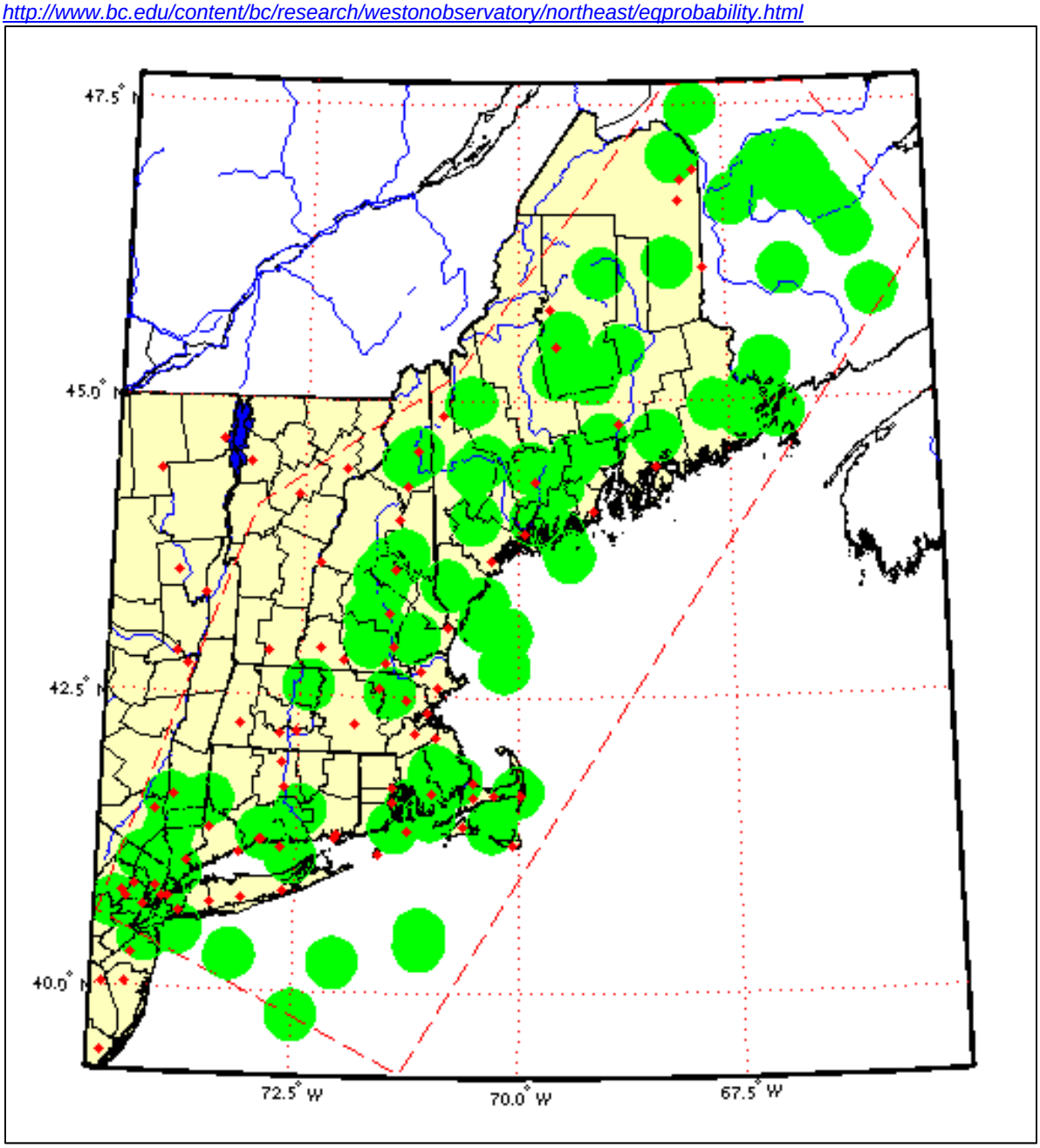


Figure 8-11. Spatial Earthquake Probabilities in New England

There have been no earthquake declared disasters for the Commonwealth; therefore the entire historical record was consulted. The historical record indicates 366 earthquakes recorded for Massachusetts from 1627 to 2012. However, according to Ed Fratto, Executive Director of the Northeast States Emergency Consortium and SHMT member, only recently have earthquakes been recorded instrumentally in New England. In the 17th, 18th, 19th, and part of the 20th centuries, earthquakes were only documented in populated developed areas, thus concluding that seismic activity was inadequately documented during those centuries. Since the emergence of proper recording instruments in the 20th century, documentation of earthquake occurrences has increased. Therefore, it is difficult to estimate the probability of future occurrence defined by the number of events that have historically occurred from 1627 to 2012.

8.2.4 Severity

According to USGS data, damage due to an earthquake will begin at a level of ground shaking of approximately 0.1 g. The MMI intensity scale associates damage with levels of earthquakes. According to this scale, the damage that can be expected from this range of ground shaking will vary from plaster cracking and disruption of building contents, to moderate damage to poorly constructed buildings. It should be noted, however, that the expected probability of such a level of ground shaking is extremely low, and according to the USGS data can be expected to occur once every 2,476 years.

Because of this low frequency of occurrence and the relatively low levels of ground shaking that would be experienced, the entire Commonwealth can be expected to have a low to moderate risk to earthquake damage as compared to other areas of the country. However, the impacts at the local level can vary based on types of construction, building density, soil type among other factors. This is demonstrated in the Hazus analysis summarized below.

8.2.5 Warning Time

There is currently no reliable way to predict the day or month that an earthquake will occur at any given location. Research is being done with early-warning systems that use the low energy waves that precede major earthquake to issue an alert that earthquake shaking is about to be felt. These potential early-warning systems can give up to approximately 40-60 seconds notice that earthquake shaking is about to be experienced, with shorter warning times for places closer to the earthquake epicenter. Although the warning time is very short, it could allow for immediate safety measures such as getting under a desk, stepping away from a hazardous material, or shutting down a computer system to prevent damage.

8.3 SECONDARY HAZARDS

Secondary hazard can occur to all forms of critical infrastructure and key resources as a result of earthquake. Earthquakes can cause large and sometimes disastrous landslides and mudslides. River valleys are vulnerable to slope failure, often as a result of loss of cohesion in clay-rich soils. Soil liquefaction 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 what was previously solid ground. Unless properly secured, hazardous materials can be released, causing significant damage to the environment and people. Earthen dams and levees are highly susceptible to seismic events and the impacts of their eventual failures can be considered secondary risks for earthquakes.

8.4 CLIMATE CHANGE IMPACTS

The impacts of global climate change on earthquake probability are unknown. Some scientists feel that melting glaciers could induce tectonic activity. As ice melts and water runs off, tremendous amounts of weight are shifted on the earth's crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity according to research into prehistoric earthquakes and volcanic activity. NASA and USGS scientists found that retreating glaciers in southern Alaska might be opening the way for future earthquakes.

Secondary impacts of earthquakes could be magnified by climate change. Soils saturated by repetitive storms could experience liquefaction during seismic activity due to the increased saturation. Dams storing increased volumes of water due to changes in the hydrograph could fail during seismic events. There are currently no models available to estimate these impacts.

8.5 EXPOSURE

To understand risk, the assets exposed to the hazard areas are identified. For the earthquake hazard, the entire Commonwealth of Massachusetts is exposed. However, some locations, building types, and

infrastructure types are at greater risk than others are, due to the surrounding soils or their manner of construction. This section discusses exposure of the following to the earthquake hazard:

- Population
- State facilities
- Critical facilities
- Economy

8.5.1 Population

The entire population of Massachusetts is potentially exposed to direct and indirect impacts from earthquakes. The degree of exposure is dependent on many factors, including the age and construction type of the structures people live in, the soil type their homes are constructed on, their proximity to fault location, etc. Further, the time of day also exposes different sectors of the community to the hazard. For example, Hazus considers the residential occupancy at its maximum at 2:00 a.m., where the educational, commercial, and industrial sectors are at their maximum at 2:00 p.m., and peak commute time is at 5:00 p.m. Whether directly impacted or indirectly impact, the entire population will have to deal with the consequences of earthquakes to some degree. Business interruption could keep people from working, road closures could isolate populations, and loss of functions of utilities could impact populations that suffered no direct damage from an event itself.

8.5.2 State Facilities

All 6,765 Commonwealth of Massachusetts-owned and leased buildings are exposed to the earthquake hazard. Table 8-4. summarizes the total replacement cost value of these facilities.

NEHRP soil classifications affect earthquake severity. The classifications range from A to E, where A is hard rock that reduces ground motions and E is soft soil that amplifies ground shaking and increases building losses. NEHRP soil classes D and E can amplify ground shaking to damaging levels even in a moderate earthquake (NYCEM, 2003). Table 8-5. summarizes the number of state-owned and state-leased buildings on soil classes A through E (where data are available). Figure 8-12 illustrates the state-owned and leased facilities located on NEHRP soil classes D and E.

8.5.3 Critical Facilities

All critical facilities in the planning area are exposed to the earthquake hazard. In addition, there is increased risk associated with hazardous materials releases, which have the potential to occur during an earthquake from fixed facilities, transportation-related incidents (vehicle transportation), and pipeline distribution. Transportation corridors and pipelines can be disrupted during an earthquake, leading to the release of materials to the surrounding environment, and disrupting services well beyond the primary area of impact. Facilities holding hazardous materials are of particular concern because of possible isolation of surrounding neighborhoods. During an earthquake, structures storing these materials could rupture and leak into the surrounding area or an adjacent waterway, having a disastrous effect on the environment.

TABLE 8-4.
STATE BUILDING EXPOSURE TO EARTHQUAKE HAZARD (STRUCTURE AND CONTENTS)

County	Value of Owned Facilities	Value of Leased Facilities	Total Replacement Cost Value
Barnstable	$1,129,133,087	$17,181,274	$1,146,314,361
Berkshire	$1,810,562,200	$41,438,632	$1,852,000,832
Bristol	$2,862,545,772	$149,664,578	$3,012,210,350

TABLE 8-4.
STATE BUILDING EXPOSURE TO EARTHQUAKE HAZARD (STRUCTURE AND CONTENTS)

County	Value of Owned Facilities	Value of Leased Facilities	Total Replacement Cost Value
Dukes	$9,965,088	$6,258,960	$16,224,048
Essex	$4,336,334,705	$136,866,724	$4,473,201,429
Franklin	$789,074,575	$24,162,354	$813,236,929
Hampden	$4,896,066,804	$155,583,444	$5,051,650,248
Hampshire	$4,654,345,657	$33,042,196	$4,687,387,853
Middlesex	$9,556,026,897	$325,969,758	$9,881,996,655
Nantucket	$30,440,058	$941,186	$31,381,244
Norfolk	$4,994,008,904	$147,822,352	$5,141,831,256
Plymouth	$3,089,420,567	$92,983,586	$3,182,404,153
Suffolk	$7,795,245,796	$487,827,934	$8,283,073,730
Worcester	$9,226,864,179	$217,834,816	$9,444,698,995
Total	**$55,180,034,288**	**$1,837,577,794**	**$57,017,612,082**

Note: Building data are updated as agencies change or modify. The state-owned building information is current as of October 3, 2012, and the state-leased building information is current as of October 10, 2010, with a total of 6,765 buildings.

TABLE 8-5.
NUMBER OF STATE-OWNED AND LEASED BUILDINGS PER NEHRP SOIL CLASS

County	Class A	Class B	Class C	Class D	Class E	No data available	Total
Barnstable	—	—	—	—	—	309	309
Berkshire	—	—	—	—	—	358	358
Bristol	—	—	—	—	—	482	482
Dukes	—	—	—	—	—	13	13
Essex	—	—	—	—	—	538	538
Franklin	21	19	0	40	68	63	211
Hampden	13	54	0	0	245	154	466
Hampshire	217	46	18	24	179	78	562
Middlesex	—	—	—	—	—	1,107	1,107
Nantucket	—	—	—	—	—	5	5
Norfolk	—	—	—	—	—	680	680
Plymouth	—	—	—	—	—	542	542
Suffolk	—	—	—	—	—	399	399
Worcester	—	—	—	—	—	1,093	1,093
Total	**251**	**119**	**18**	**64**	**492**	**5,821**	**6,765**

Note: Building data are updated as agencies change or modify. The state-owned building information is current as of October 3, 2012, and the state-leased building information is current as of October 10, 2010, with a total of 6,765 buildings.

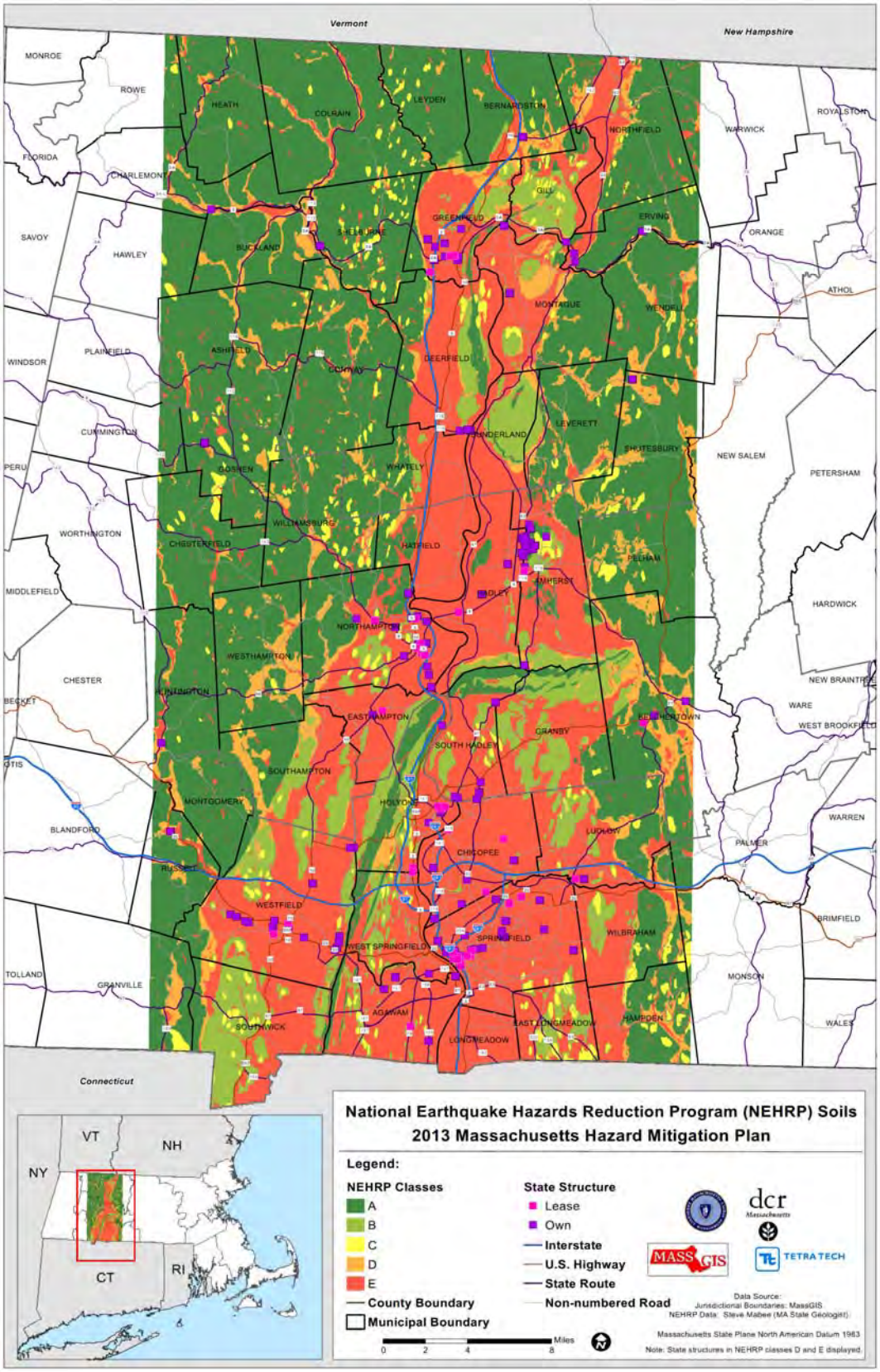


Figure 8-12. State-Owned and State-Leased Facilities on NEHRP Soils D and E

As mentioned earlier, softer soils can amplify and magnify ground shaking and increase building damage and losses. Table 8-6 summarizes the critical facilities and the NEHRP soil class upon which they are located (where data are available).

TABLE 8-6.
NUMBER OF CRITICAL FACILITIES PER NEHRP SOIL CLASS

County	Class A	Class B	Class C	Class D	Class E	**Total**
Police Stations						
Franklin	5	2	1	3	11	**26**
Hampden	0	1	0	1	17	**28**
Hampshire	3	2	0	2	9	**23**
Total	***8***	***5***	***1***	***6***	***37***	***437***
Fire Stations						
Franklin	7	1	0	4	12	**31**
Hampden	2	2	0	2	32	**51**
Hampshire	7	3	0	2	10	**28**
Total	***16***	***6***	***0***	***8***	***54***	***789***
Emergency Operation Centers						
Hampden	0	1	0	0	0	**1**
Total	***0***	***1***	***0***	***0***	***0***	***1***
Hospitals						
Franklin	0	0	0	0	1	**1**
Hampden	0	0	0	0	5	**6**
Hampshire	0	0	0	0	1	**2**
Total	***0***	***0***	***0***	***0***	***7***	***82***
Schools						
Franklin	6	2	0	10	28	**53**
Hampden	0	13	19	4	166	**217**
Hampshire	9	4	6	4	82	**113**
Total	***15***	***19***	***25***	***18***	***276***	***2,767***
Colleges						
Franklin	0	1	0	2	0	**3**
Hampden	0	0	1	15	0	**16**
Hampshire	0	1	2	2	0	**5**
Total	***181***	***2***	***3***	***19***	***0***	***205***
Grand Total	**259**	**66**	**58**	**102**	**748**	**4,885**

Earthquake events can significantly impact road bridges. A key factor in the degree of vulnerability will be the age of the bridge, which will help indicate to which standards the bridge was built. Table 8-7 summarizes the number of highway bridges located on each NEHRP soil classification. Due to limited NEHRP soils data, all bridges listed are in Franklin, Hampden, and Hampshire Counties, only where NEHRP soil data are available (see Figure 8-12).

TABLE 8-7.
NUMBER OF HIGHWAY BRIDGES LOCATED ON EACH NEHRP SOIL TYPE

Owner	A	B	C	D	E	Total Exposed
Federal	0	0	0	0	2	2
State	25	25	3	40	322	415
Local	65	7	0	49	157	278
Total	**90**	**32**	**3**	**89**	**481**	**695**

Source: Hazus-MH v. 2.1 default highway bridge inventory; Mabee, 2012

8.5.4 Economy

Earthquakes losses can include structural and non-structural damage to buildings, loss of business function, damage to inventory, relocation costs, wage loss, and rental loss due to the repair/replacement of buildings. Roads that cross earthquake-prone soils have the potential to be significantly damaged during an earthquake event, potentially impacting commodity flows. Access to major roads is crucial to life and safety after a disaster event, as well as to response and recovery operations. Further, water and sewer infrastructure would likely suffer considerable damage in the event of an earthquake. It should be assumed that these systems are exposed to potential breakage and failure.

8.6 VULNERABILITY

To assess the Commonwealth's vulnerability to the earthquake hazard, probabilistic analyses were run in Hazus for the 100-, 500-, 1,000-, and 2,500-year mean return period events. The Hazus-MH model was used to estimate potential losses to these events.

8.6.1 Population

The populations most vulnerable to an earthquake event include persons over the age of 65 and those living below the Census poverty threshold. These socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a hazard, the location and construction quality of their housing, and the ability to be self-sustaining for prolonged periods of time after an incident due to limited ability to stockpile supplies. Refer to Section 4, which summarizes the Commonwealth's demographics by County, as well as further information contained within Section 3, Local Plan Coordination.

Residents may be displaced or require temporary to long-term sheltering due to the event. The number of people requiring shelter is generally less than the number displaced as some displaced persons use hotels or stay with family or friends following a disaster event. Impacts on persons and households in the planning area were estimated for the 100-, 500-, 1,000-, and 2,500-year earthquakes through the Level 2 Hazus-MH analysis. Table 8-8. summarizes the results.

Hazus-MH 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. Table 8-9 summarizes the estimates for the 100-, 500-, 1,000-, and 2,500-year MRP earthquake events. No injuries or casualties are estimated for the 100-year event.

TABLE 8-8.
ESTIMATED SHELTER REQUIREMENTS HAZUS-MH PROBABILISTIC SCENARIOS

	100-Year MRP		500-Year MRP		1,000-Year MRP		2,500-Year MRP	
County	Displaced Households	Short-Term Sheltering Needs	Displaced Households	Short-Term Sheltering Needs	Displaced Households	Short-Term Sheltering Needs	Displaced Households	Short-Term Sheltering Needs
Barnstable	0	0	9	5	29	16	125	70
Berkshire	0	0	26	16	76	48	271	170
Bristol	0	0	72	48	236	158	1,094	731
Dukes	0	0	0	0	1	1	5	3
Essex	0	0	200	136	642	436	3,045	2,058
Franklin	0	0	13	8	37	23	132	81
Hampden	0	0	78	60	236	183	898	694
Hampshire	0	0	24	18	72	53	266	197
Middlesex	0	0	373	222	1,192	707	4,770	2,835
Nantucket	0	0	0	0	1	0	3	2
Norfolk	0	0	110	59	364	195	1,461	785
Plymouth	0	0	41	28	142	97	618	417
Suffolk	0	0	294	211	952	685	3,735	2,687
Worcester	0	0	138	93	426	287	1,619	1,090
Total	**0**	**0**	**1,378**	**905**	**4,406**	**2,888**	**18,041**	**11,821**

TABLE 8-9.
ESTIMATED NUMBER OF INJURIES AND CASUALTIES, HAZUS-MH

	100-Year MRP Event			500-Year MRP Event			1,000-Year MRP Event			2,500-Year MRP Event		
	2 a.m.	2 p.m.	5 p.m.	2 a.m.	2 p.m.	5 p.m.	2 a.m.	2 p.m.	5 p.m.	2 a.m.	2 p.m.	5 p.m.
Barnstable												
Injuries	0	0	0	5	6	5	14	17	14	51	68	55
Hospitalization	0	0	0	0	1	1	1	2	2	6	11	9
Casualties	0	0	0	0	0	0	0	0	0	1	2	1
Berkshire												
Injuries	0	0	0	7	7	6	19	19	17	58	67	58
Hospitalization	0	0	0	1	1	1	2	3	2	9	12	11
Casualties	0	0	0	0	0	0	0	0	0	1	2	2
Bristol												
Injuries	0	0	0	19	16	15	56	50	46	210	216	195
Hospitalization	0	0	0	2	2	2	7	7	7	32	39	39
Casualties	0	0	0	0	0	0	1	1	1	5	7	6
Dukes												
Injuries	0	0	0	0	1		1	2	1	3	6	4
Hospitalization	0	0	0	0	0	0	0	0	0	0	1	1
Casualties	0	0	0	0	0	0	0	0	0	0		

TABLE 8-9.
ESTIMATED NUMBER OF INJURIES AND CASUALTIES, HAZUS-MH

	100-Year MRP Event			500-Year MRP Event			1,000-Year MRP Event			2,500-Year MRP Event		
	2 a.m.	2 p.m.	5 p.m.	2 a.m.	2 p.m.	5 p.m.	2 a.m.	2 p.m.	5 p.m.	2 a.m.	2 p.m.	5 p.m.
Essex												
Injuries	0	0	0	49	47	43	141	140	127	522	616	535
Hospitalization	0	0	0	5	6	5	18	22	20	91	123	119
Casualties	0	0	0	1	1	1	3	3	3	16	24	21
Franklin												
Injuries	0	0	0	4	3	3	10	8	8	29	28	26
Hospitalization	0	0	0	0	0	0	1	1	1	4	5	5
Casualties	0	0	0	0	0	0	0	0	0	1	1	1
Hampden												
Injuries	0	0	0	21	20	18	58	57	50	186	213	182
Hospitalization	0	0	0	2	2	2	8	9	8	28	39	39
Casualties	0	0	0	0	0	0	1	1	1	4	7	6
Hampshire												
Injuries	0	0	0	8	6	7	20	17	18	65	62	62
Hospitalization	0	0	0	1	1	1	2	2	2	10	11	12
Casualties	0	0	0	0	0	0	0	0	0	2	2	2
Middlesex												
Injuries	0	0	0	90	97	87	255	285	255	830	1117	952
Hospitalization	0	0	0	11	13	13	34	44	44	137	214	204
Casualties	0	0	0	1	2	2	5	7	6	23	39	36
Nantucket												
Injuries	0	0	0	0	0	0	0	1	0	1	2	2
Hospitalization	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	30	33	29	87	100	88	287	398	335
Hospitalization	0	0	0	3	4	3	11	15	14	45	73	71
Casualties	0	0	0	0	1	1	1	2	2	7	13	12
Plymouth												
Injuries	0	0	0	16	16	15	51	50	46	180	211	187
Hospitalization	0	0	0	2	2	2	5	8	7	26	38	41
Casualties	0	0	0	0	0	0	1	1	1	4	7	6
Suffolk												
Injuries	0	0	0	52	65	53	150	193	156	492	749	583
Hospitalization	0	0	0	6	9	8	22	29	25	88	143	126
Casualties	0	0	0	1	1	1	3	5	4	16	26	22
Worcester												
Injuries	0	0	0	37	34	32	102	97	90	322	363	321
Hospitalization	0	0	0	4	4	4	13	14	14	50	66	68
Casualties	0	0	0	1	1	1	2	2	2	8	12	11
Total	**0**	**0**	**0**	**379**	**402**	**361**	**1,105**	**1,214**	**1,082**	**3,850**	**5,033**	**4,368**

8.6.2 State Facilities

Hazus-MH does not estimate potential dollar losses to facilities at this time. When this capability is available, the Commonwealth can enhance this section of the plan. For the purposes of the 2013 plan update, to estimate potential losses to the state-owned and leased buildings, the exposure analysis methodology was used. As mentioned earlier, all buildings are exposed to an earthquake; however, those located on NEHRP soil classes D and E may have increased potential for building damage and losses. Refer to Table 8-6 for the number of critical facilities on NEHRP soil classes D and E (in areas for which data are available). A total risk exposure would equal to the full replacement value of each state facility exposed. Table 8-10 summarizes the replacement cost value of the state-owned and leased buildings located on each NEHRP soil class by County. Table 8-11 summarizes the replacement cost value of buildings located on each NEHRP soil class by state agency.

TABLE 8-10.
STATE-OWNED AND LEASED BUILDING REPLACEMENT COST VALUE BY COUNTY AND NEHRP SOIL CLASS

	State-Owned and Leased Building Replacement Cost Value						
County	Class A	Class B	Class C	Class D	Class E	No Soil Classification Data	**Total**
Barnstable	—	—	—	—	—	$1,146,314,361	**$1,146,314,361**
Berkshire	—	—	—	—	—	$1,852,000,832	**$1,852,000,832**
Bristol	—	—	—	—	—	$3,012,210,350	**$3,012,210,350**
Dukes	—	—	—	—	—	$16,224,048	**$16,224,048**
Essex	—	—	—	—	—	$4,473,201,429	**$4,473,201,429**
Franklin	$38,921,952	$14,020,165	$0	$83,735,368	$517,037,985	$159,521,459	**$813,236,929**
Hampden	$1,473,865	$1,223,200,695	$0	$0	$2,648,853,750	$1,178,121,938	**$5,051,650,248**
Hampshire	$2,284,863,881	$341,662,602	$257,871,490	$47,822,859	$1,689,568,762	$65,598,259	**$4,687,387,853**
Middlesex	—	—	—	—	—	$9,881,996,655	**$9,881,996,655**
Nantucket	—	—	—	—	—	$31,381,244	**$31,381,244**
Norfolk	—	—	—	—	—	$5,141,831,256	**$5,141,831,256**
Plymouth	—	—	—	—	—	$3,182,404,153	**$3,182,404,153**
Suffolk	—	—	—	—	—	$8,283,073,730	**$8,283,073,730**
Worcester	—	—	—	—	—	$9,444,698,995	**$9,444,698,995**
Total	**$2,325,259,698**	**$1,578,883,461**	**$257,871,490**	**$131,558,227**	**$4,855,460,497**	**$47,868,578,708**	**$57,017,612,082**

TABLE 8-11.
STATE-OWNED AND LEASED BUILDING REPLACEMENT COST VALUE BY AGENCY AND NEHRP SOIL CLASS

State Agency	Class A	Class B	Class C	Class D	Class E	**Total**
Attorney General						**$2,149,464**
Replacement Cost Value	—	—	—	—	$2,149,464	
% of Total	—	—	—	—	100	
Bureau of State Buildings						**$33,722,612**
Replacement Cost Value	—	—	—	—	$33,722,612	
% of Total	—	—	—	—	100	
Committee for Public Counsel Services						**$4,504,654**
Replacement Cost Value	—	—	—	—	$4,504,654	
% of Total	—	—	—	—	100	
Department of Agricultural Resources						**$641,232**
Replacement Cost Value	—	—	—	—	$641,232	
% of Total	—	—	—	—	100	
Department of Children and Families						**$24,500,940**
Replacement Cost Value	—	—	—	—	$24,500,940	
% of Total	—	—	—	—	100	
Department of Conservation and Recreation						**$206,419,815**
Replacement Cost Value	$32,424,201	$3,109,912	—	$22,983,110	$147,902,592	
% of Total	15.7	1.5	—	11.1	71.7	
Department of Developmental Services						**$44,957,634**
Replacement Cost Value	—	—	—	$8,903,612	$36,054,022	
% of Total	—	—	—	19.8	80.2	
Department of Environmental Protection						**$26,698,134**
Replacement Cost Value	—	—	—	—	$26,698,134	
% of Total	—	—	—	—	100	
Department of Fish and Game						**$23,268,004**
Replacement Cost Value	$145,034				$23,122,970	
% of Total	0.6				99.4	
Department of Food and Agriculture						**$4,528,850**
Replacement Cost Value	—	—	—	—	$4,528,850	
% of Total	—	—	—	—	100	
Department of Mental Health						**$377,113,387**
Replacement Cost Value	—	—	—	—	$377,113,387	
% of Total	—	—	—	—	100	
Department of Public Health						**$5,101,241**
Replacement Cost Value	—	$1,515,380	—	—	$3,585,861	
% of Total	—	29.7	—	—	70.3	
Department of State Police						**$136,643,668**
Replacement Cost Value	$1,704,452	—	—	—	$134,939,216	
% of Total	1.2	—	—	—	98.8	
Department of Transitional Assistance						**$19,675,136**
Replacement Cost Value	—	—	—	—	$19,675,136	
% of Total	—	—	—	—	100	
Department of Transportation						**$415,691,948**
Replacement Cost Value	$7,519,396	$5,809,914	—	$92,672,725	$309,689,913	
% of Total	1.8	1.4	—	22.3	74.5	
Department of Veterans Services						**$7,192,502**
Replacement Cost Value	—	—	—	—	$7,192,502	

TABLE 8-11.
STATE-OWNED AND LEASED BUILDING REPLACEMENT COST VALUE BY AGENCY AND NEHRP SOIL CLASS

State Agency	Class A	Class B	Class C	Class D	Class E	**Total**
% of Total	—	—	—	—	100	
Department of Youth Services						**$30,353,600**
Replacement Cost Value	—	—	—	—	$30,353,600	
% of Total	—	—	—	—	100	
Department of Workforce Development						**$4,685,536**
Replacement Cost Value	—	—	—	—	$4,685,536	
% of Total	—	—	—	—	100	
Division of Capital Asset Management						**$27,514,446**
Replacement Cost Value	$1,870,260	—	—	—	$25,644,186	
% of Total	6.8	—	—	—	93.2	
Emergency Management Agency						**$3,160,504**
Replacement Cost Value	—	—	—	—	$3,160,504	
% of Total	—	—	—	—	100	
Executive Office of Health & Human Services						**$3,282,306**
Replacement Cost Value	—	—	—	—	$3,282,306	
% of Total	—	—	—	—	100	
Greenfield Community College						**$202,317,832**
Replacement Cost Value	—	—	—	—	$202,317,832	
% of Total	—	—	—	—	100	
Holyoke Community College						**$408,181,944**
Replacement Cost Value	—	$403,189,126	—	—	$4,992,818	
% of Total	—	98.8	—	—	1.2	
Holyoke Soldiers' Home						**$210,550,728**
Replacement Cost Value	—	$210,550,728	—	—	—	
% of Total	—	100	—	—	—	
Information Technology Division						**$21,182,030**
Replacement Cost Value	—	—	—	—	$21,182,030	
% of Total	—	—	—	—	100	
Massachusetts Department of Revenue						**$3,900,828**
Replacement Cost Value	—	—	—	—	$3,900,828	
% of Total	—	—	—	—	100	
Massachusetts State Lottery Commission						**$1,637,012**
Replacement Cost Value	—	—	—	—	$1,637,012	
% of Total	—	—	—	—	100	
Massachusetts National Guard						**$816,248**
Replacement Cost Value	—	—	—	—	$816,248	
% of Total	—	—	—	—	100	
Massachusetts Rehabilitation Commission						**$4,447,744**
Replacement Cost Value	—	—	—	—	$4,447,744	
% of Total	—	—	—	—	100	
Massachusetts Teachers' Retirement System						**$710,966**
Replacement Cost Value	—	—	—	—	$710,966	
% of Total	—	—	—	—	100	
Military Division						**$205,031,491**
Replacement Cost Value	—	—	—	—	$205,031,491	
% of Total	—	—	—	—	100	

TABLE 8-11.
STATE-OWNED AND LEASED BUILDING REPLACEMENT COST VALUE BY AGENCY AND NEHRP SOIL CLASS

State Agency	Class A	Class B	Class C	Class D	Class E	**Total**
Office of the Chief Medical Examiner						**$830,130**
Replacement Cost Value	—	—	—	—	$830,130	
% of Total	—	—	—	—	100	
Office of the D.A. Hampden						**$3,168,488**
Replacement Cost Value	—	—	—	—	$3,168,488	
% of Total	—	—	—	—	100	
Office of the D.A. Northwestern						**$7,491,192**
Replacement Cost Value	—	—	—	—	$7,491,192	
% of Total	—	—	—	—	100	
Office of the State Auditor						**$648,980**
Replacement Cost Value	—	—	—	—	$648,980	
% of Total	—	—	—	—	100	
Sheriff's Department Franklin						**$102,865,098**
Replacement Cost Value	—	—	—	—	$102,865,098	
% of Total	—	—	—	—	100	
Sheriff's Department Hampden						**$700,865,566**
Replacement Cost Value	—	$607,535,874	—	—	$93,329,692	
% of Total	—	86.7	—	—	13.3	
Sheriff's Department Hampshire						**$97,011,962**
Replacement Cost Value	—	$94,653,804	—	—	$2,358,158	
% of Total	—	97.6	—	—	2.4	
Springfield Technical Community College						**$1,154,896,536**
Replacement Cost Value	—	—	—	—	$1,154,896,536	
% of Total	—	—	—	—	100	
Trial Court						**$216,744,257**
Replacement Cost Value	—	—	—	$6,998,780	$209,745,477	
% of Total	—	—	—	3.2	96.8	
University of Massachusetts at Amherst						**$3,822,019,809**
Replacement Cost Value	$2,281,596,355	$252,518,724	$257,871,490	—	$1,030,033,240	
% of Total	59.7	6.6	6.7	—	26.9	
Westfield State University						**$581,908,920**
Replacement Cost Value	—	—	—	—	$581,908,920	
% of Total	—	—	—	—	100	
Total						**$9,149,033,373**
Replacement Cost Value	**$2,325,259,698**	**$1,578,883,461**	**$257,871,490**	**$131,558,227**	**$4,855,460,497**	
% of Total	**25.4**	**17.3**	**2.8**	**1.4**	**53.1**	

8.6.3 State Critical Facilities

Hazus-MH does not estimate potential dollar losses to critical facilities at this time. When this capability is available, the Commonwealth can enhance this section of the plan. For this update, the exposure analysis methodology was used to estimate potential losses to critical facilities and infrastructure. Critical facilities and infrastructure located on NEHRP soil classes D and E may have increased building damage and losses. Table 8-6 lists critical facilities on NEHRP soil classes D and E (where data are available). The replacement cost values for critical facilities and infrastructure were not available for this planning effort. A total risk exposure would equal to the full replacement value of each critical facility exposed.

Hazus-MH estimates the extent of damage and cost to repair highway bridges as a result of each probabilistic scenario. Table 8-12 summarizes the total loss to highway bridges across the Commonwealth (4,835 bridges total) for each probabilistic scenario.

TABLE 8-12.
ESTIMATED COST TO REPAIR HIGHWAY BRIDGES FOR PROBABILISTIC EARTHQUAKE EVENTS

Scenario	100-Year	500-Year	1,000-Year	2,500-Year
Number Requiring Repair/Loss	0	1,490	4,835	4,835
Number Completely Destroyed	0	0	0	1
Loss	$130,397	$21,012,253	$117,497,068	$684,184,238

Source: Hazus-MH v. 2.1

8.6.4 Economy

Earthquakes also have impacts on the economy, including: loss of business function, damage to inventory, relocation costs, wage loss, and rental loss due to the repair/replacement of buildings. Hazus-MH estimates the total economic loss associated with each earthquake scenario, which includes building- and lifeline-related losses (transportation and utility losses) based on the available inventory (facility [or GIS point] data only). Direct building losses are the estimated costs to repair or replace the damage caused to the building. Refer to Table 8-13 which summarizes the estimated potential losses to all of the buildings in the Commonwealth per earthquake scenario per County.

Lifeline-related losses include the direct repair cost to transportation and utility systems and are reported in terms of the probability of reaching or exceeding a specified level of damage when subjected to a given level of ground motion. Additionally, economic loss include business interruption losses associated with the inability to operate a business due to the damage sustained during the earthquake, as well as temporary living expenses for those displaced. These losses are presented in Table 8-14.

In 2011, the New England Shake Map/Hazus Working Group estimated losses from 11 New England scenario earthquakes, three of which have epicenters in or offshore of Massachusetts:

- 1727 Newburyport, MA (Moment Magnitude 5.8);
- Littleton, MA (Moment Magnitude 5.0); and
- 1755 Cape Ann Offshore, MA (Moment Magnitude 6.5).

Hazus-MH version 2.0 was used for this analysis, and detailed loss summaries for each state in New England are included in the report. The estimated direct economic losses (structural and non-structural damage to buildings) for these three scenarios are shown in Figure 8-13 through Figure 8-15.

The report indicates that the estimates are low, particularly for the Cape Ann earthquake, because the extensive inventory of unreinforced masonry buildings in the Boston area is understated in the Hazus-MH model. In addition, the fill and alluvial areas in Boston have not been incorporated into the NEHRP site class map. ‘The losses should be considered preliminary first-order estimates that can be improved with future improvements in the NEHRP incorporation of a site class map and building inventories’ (FEMA, 2012). Additional loss information pertaining to these three and other earthquake scenarios for Massachusetts and all of New England can be found in the report entitled ‘HAZUS Analyses of Eleven Scenario Earthquakes in New England’ prepared for FEMA in 2012.

TABLE 8-13.
EARTHQUAKE ESTIMATED POTENTIAL LOSSES TO BUILDINGS (STRUCTURE AND CONTENTS) HAZUS-MH PROBABILISTIC SCENARIOS

County	100-Year MRP	500-Year MRP	1,000-Year MRP	2,500-Year MRP
Barnstable	$0	$23,010,003	$85,379,039	$366,462,378
Berkshire	$0	$23,423,146	$70,788,093	$240,840,054
Bristol	$0	$54,738,967	$204,386,297	$884,379,688
Dukes	$0	$2,007,951	$7,559,777	$30,853,998
Essex	$0	$166,341,965	$563,000,060	$2,178,399,281
Franklin	$0	$12,226,591	$36,359,908	$121,288,736
Hampden	$0	$67,617,917	$218,279,715	$792,727,328
Hampshire	$0	$22,984,509	$71,173,359	$248,402,385
Middlesex	$0	$337,025,347	$1,139,891,816	$4,143,316,406
Nantucket	$0	$824,179	$3,363,189	$15,030,312
Norfolk	$0	$120,136,983	$421,461,487	$1,593,539,418
Plymouth	$0	$60,019,177	$224,156,207	$917,075,021
Suffolk	$0	$157,946,629	$551,143,237	$2,037,692,334
Worcester	$0	$127,094,194	$409,848,891	$1,466,297,635
Total	**$0**	**$1,175,397,557**	**$4,006,791,076**	**$15,036,304,973**

Notes: Building losses include structural and non-structural damage estimates.
Source: Default general building stock data in Hazus-MH v. 2.1

TABLE 8-14.
ESTIMATED POTENTIAL ECONOMIC LOSSES FOR THE COMMONWEALTH OF MASSACHUSETTS

	100-Year MRP	500-Year MRP	1,000-Year MRP	2,500-Year MRP
Income Losses				
Wage	0	$77,890,000	$234,250,000	$953,160,000
Capital-Related	0	$55,800,000	$174,600,000	$713,930,000
Rental	0	$88,620,000	$250,520,000	$880,570,000
Relocation	0	$129,190,000	$390,360,000	$1,465,390,000
Subtotal	***0***	***$351,500,000***	***$1,049,730,000***	***$4,013,050,000***
Capital Stock Losses				
Structural	0	$230,380,000	$656,250,000	$2,306,430,000
Non-Structural	0	$724,610,000	$2,454,080,000	$9,039,290,000
Content	0	$220,410,000	$896,460,000	$3,690,590,000
Inventory	0	$6,490,000	$24,690,000	$94,210,000
Subtotal	***0***	***$1,181,890,000***	***$4,031,480,000***	***$15,130,520,000***
Total	**0**	**$1,533,390,000**	**$5,081,210,000**	**$19,143,570,000**

Source: Hazus-MH v. 2.1

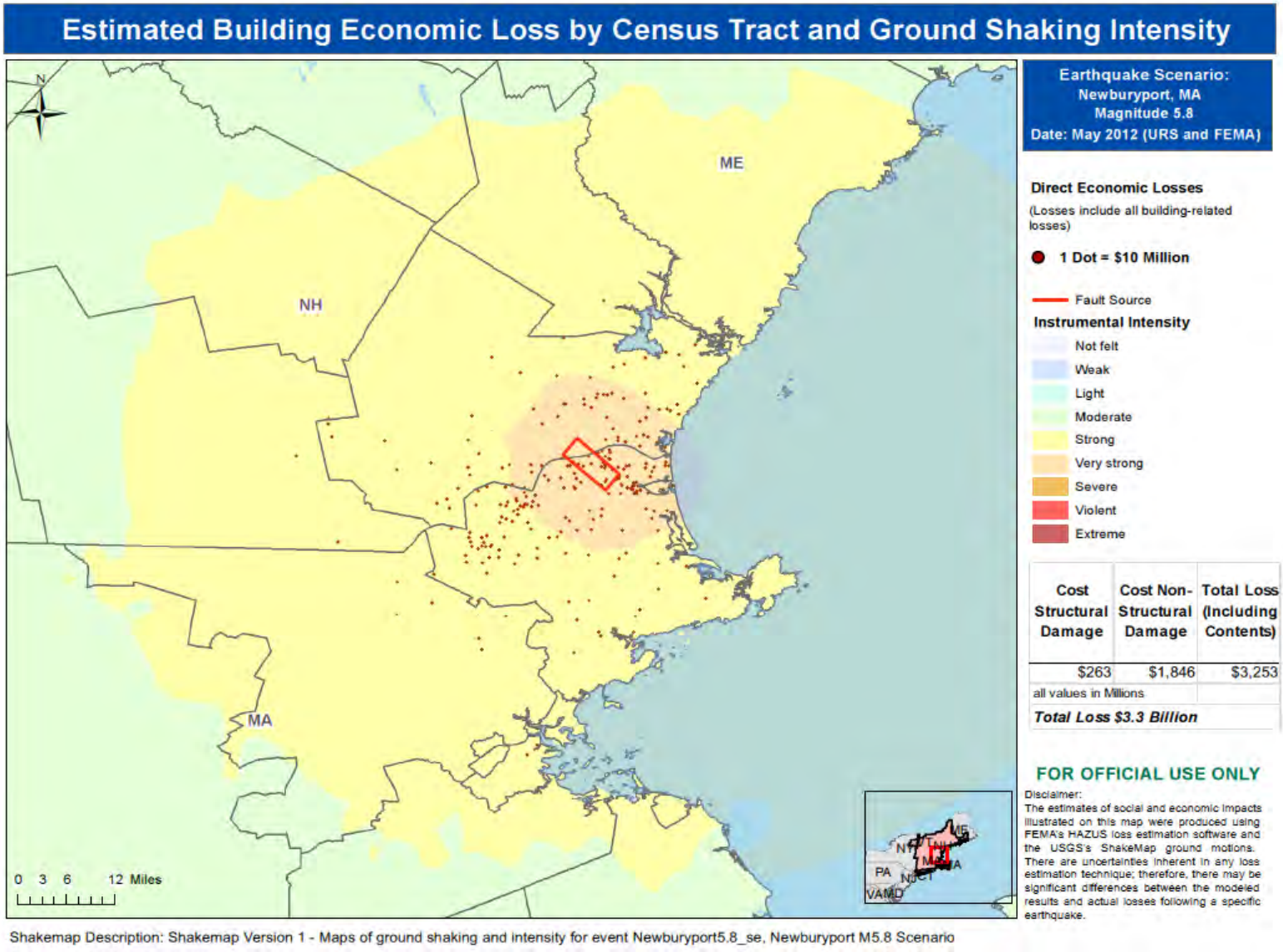


Figure 8-13. Estimated Building Damage from the Newburyport Magnitude 5.8 Scenario

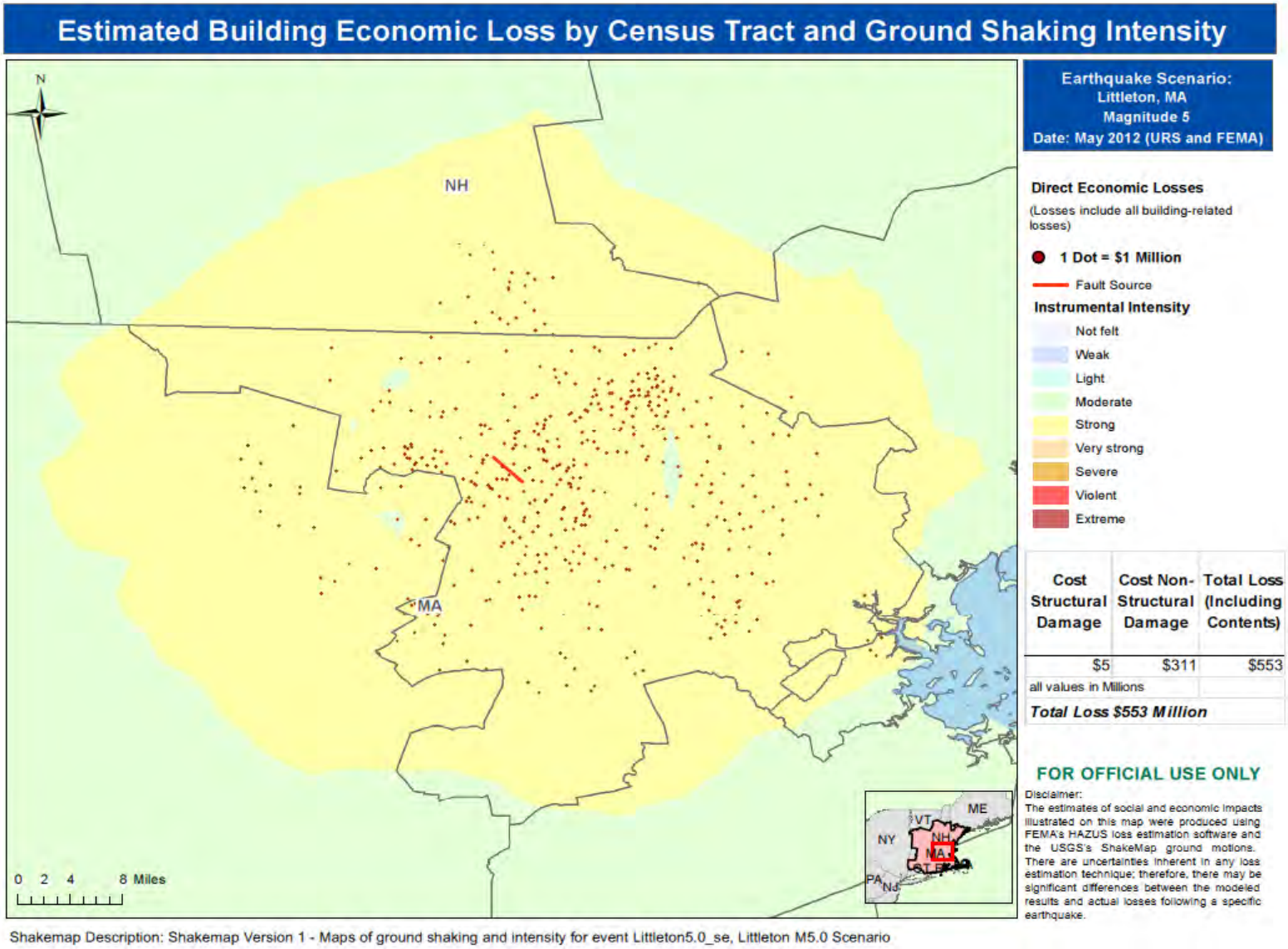


Figure 8-14. Estimated Building Damage from the Littleton, MA Scenario

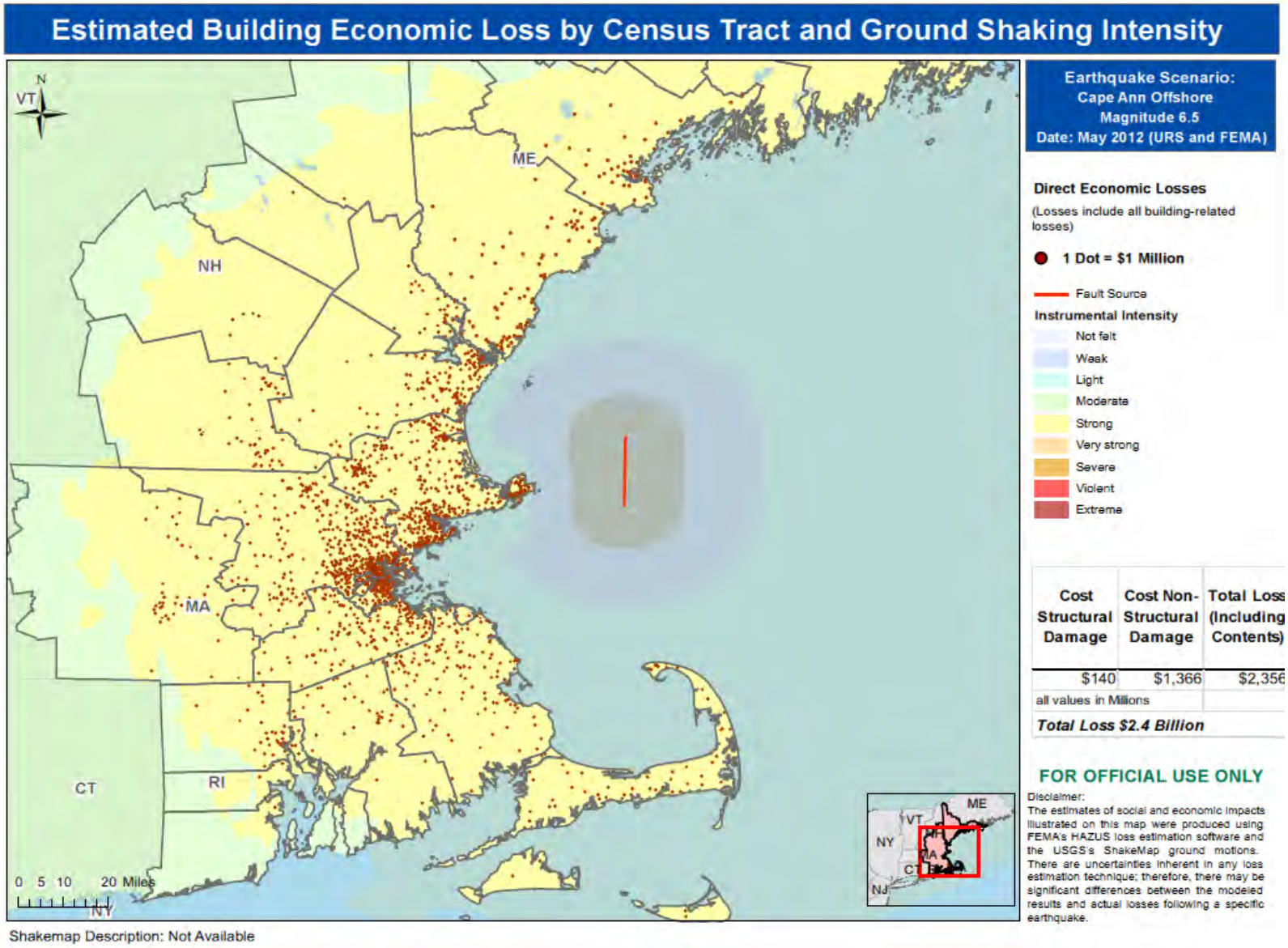


Figure 8-15. Estimated Building Damage from the 1755 Cape Ann Offshore Magnitude 5.9 Scenario

SECTION 9. FIRE

9.1 GENERAL BACKGROUND

This portion of the Commonwealth's plan assesses two types of fire events: urban fires and wildfires (both intermix and interface).

An overview for both types of fire events, urban fire and wildfire is presented in Table 9-1, which summarizes the Massachusetts fire experience from 2005 through 2011. The table summarizes individual fire reports submitted by numerous Massachusetts fire departments and fire districts and published in Massachusetts Division of Fire Safety Annual Reports. Information contained in Table 9-1 includes fire data categorized by type (structure, motor vehicle, and other) and highlights the total number of fires; deaths, injuries, and property damage caused by fires; and the number of arsons reported each year. It is apparent from the table below that statistics based on each category vary from year to year.

9.1.1 Urban Fire

A major urban fire or conflagration is a large destructive, often uncontrollable, fire that spreads substantial destruction. Although fires can start from numerous causes, major fires are often the result of other hazards, such as storms, earthquakes, gas leaks, transportation accidents, hazardous material spills, criminal activity (arson), or terrorism. Small structural fires, which occur more frequently, can result from mundane events such as cooking, smoking, equipment/appliance malfunctions, etc.

Nationally, the leading causes of urban fires are arson, open flames, and cooking. The leading causes of fire deaths are smoking, arson, and heating, with urban fires causing the most fire deaths and injuries. Between 70 and 80 percent of deaths result from residential fires. People under the age of 5 and over the age of 55 have a much higher death rate than the average population, accounting for more than one-third of all deaths nationally.

Over the past several years, structure fires account for the majority of fire deaths, injuries, and property loss within the Commonwealth. In Massachusetts, 83 percent of building fires and 69 percent of fire deaths in 2010 took place in residential occupancies, with more fire deaths occurring in one-and two-family homes than in all other residential occupancies combined. Cooking and heating were the leading cause of fires in one-and two-family homes. Cooking was the leading cause of fires overall in every residential occupancy. Though frequent, cooking fires are not among the most deadly; in 2010, the improper or unsafe disposal of smoking materials was the leading cause (40 percent) of residential fire deaths. In 2011, electrical fires were the leading cause of residential fire deaths. This was the first time since the Massachusetts Division of Fire Safety started keeping records that smoking was not the leading cause of home fire deaths.

9.1.2 Wildfire

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

TABLE 9-1.
MASSACHUSETTS FIRE DATA AND STATISTICS (2005-2011)

Types of Fires	Total Number of Fires	% (+/-) from Previous Year	Deaths (C/FS)[a]	Injuries (C/FS)[a]	Property Damage	Arsons[b]
2011						
Year Overview	29,110	Down 11%	54 C / 2 FS	323 C / 422 FS	$217 M	979
Structure	18,178	Down 3%	42 C / 2 FS	248 C / 390 FS	$195 M	223
Motor Vehicle	2,997	Up 1%	10 C	24 C / 15 FS	$16.3 M	125
Other[c]	7,935	Down 29%	2 C	51 C / 17 FS	$5.6 M	631
2010						
Year Overview	32,680	Up 14%	36 C / 2 FS	366 C / 531 FS	$196 M	1,169
Structure	18,560	Up 4%	28 C / 2 FS	309 C / 491 FS	$177 M	268
Motor Vehicle	2,967	Down 4%	5 C	27 C / 13 FS	$15.5 M	115
Other[c]	11,153	Up 43%	3 C	30 C / 27 FS	$4 M	786
2009						
Year Overview	28,595	Down 5%	36 C	332 C / 460 FS	$183 M	1,184
Structure	17,773	Up 3%	30 C	290 C / 423 FS	$167 M	291
Motor Vehicle	3,069	Down 1%	5 C	14 C / 17 FS	$13.2 M	188
Other[c]	7,753	Down 22%	1 C	28 C / 20 FS	$3 M	705
2008						
Year Overview	30,136	Down 11%	49 C / 1 FS	337 C / 622 FS	$254 M	1,182
Structure	17,198	Up 2%	44 C	273 C / 582 FS	$235 M	280
Motor Vehicle	3,076	Down 8%	5 C / 1 FS	23 C / 16 FS	$14.8 M	150
Other[c]	9,862	Down 28%	None	41 C / 24 FS	$4.6 M	752
2007						
Year Overview	33,522	Up 11%	61 C / 3 FS	394 C / 675 FS	$287 M	1,212
Structure	16,722	Up 7%	47 C / 3 FS	332 C / 564 FS	$268 M	343
Motor Vehicle	3,317	Up 1%	10 C	20 C / 21 FS	$14.7 M	130
Other[c]	13,483	Up 18%	4 C	42 C / 90 FS	$4.1 M	739
2006						
Year Overview	30,198	Up 3%	44 C	386 C / 541 FS	$184 M	1,265
Structure	15,507	Up 4%	34 C	344 C / 488 FS	$165 M	325
Motor Vehicle	3,258	Down 12%	6 C	12 C / 21 FS	$16 M	159
Other[c]	11,433	Up 7%	4 C	30 C / 32 FS	$2.6 M	781
2005						
Year Overview	28,793	Down 3%	52 C	359 C / 523 FS	$222 M	1,219
Structure	14,662	Up 3%	41 C	301 C / 469 FS	$202 M	338
Motor Vehicle	3,666	Down 4%	7 C	27 C / 23 FS	$14.8 M	176
Other[c]	10,465	Up 13%	4 C	31 C / 31 FS	$5 M	705

Sources: Massachusetts Executive Office of Public Safety and Security: Division of Fire Safety, 2012

a. C = Civilian; FS = Fire Services; M = Million

b. For statistical purposes, a fire is considered arson when the cause is listed as intentional and age is not a factor or the person involved was over 18. This definition excludes many "suspicious" and juvenile-set fires.

c. Other includes brush, trash and other outside fires.

There are three classes of wildfires:

- A surface fire is the most common type, burning along the forest floor, moving slowly and killing or damaging trees
- A ground fire, usually induced by drought conditions, burns organic ground fuels below the forest floor;
- Crown fires spread rapidly by the wind, moving quickly by jumping along the treetops.

Because 95 percent of wildfires are started by negligent human behavior, such as smoking in forested areas or improperly extinguishing campfires, most are preventable; in 2011, 631 or approximately 8 percent of the outside and other fires were considered intentionally set. Wildfires often result in the destruction of forests, brush, field crops, grasslands, and personal property. Wildfires may cause secondary impacts on other hazards, such as flooding, the removal of vegetation, and the destruction of watersheds.

The wildfire season in Massachusetts usually begins in late March and typically culminates in early June, corresponding with the driest live fuel moisture periods of the year. April is historically the month in which wildfire danger is the highest. However, wildfires can occur every month of the year. Drought, snow pack, and local weather conditions can expand the length of the fire season. The early and late shoulders of the fire season usually are associated with human-caused fires.

9.1.3 Fire Ecology and Wildfire Behavior

The "wildfire behavior triangle" (see Figure 9-1) illustrates how three primary factors influence wildfire behavior: fuel, topography, and weather. Each point of the triangle represents one of the three factors; 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.

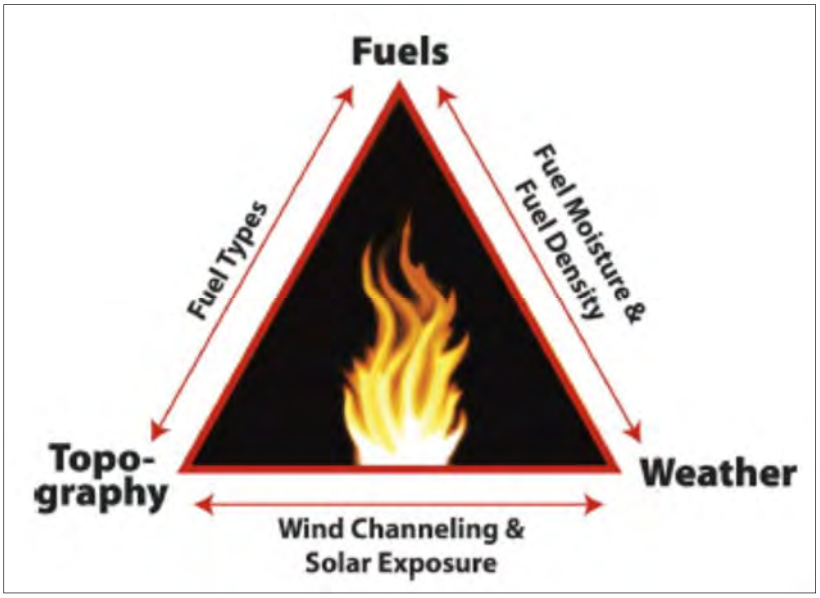


Figure 9-1. The Fire Triangle

A fire needs all three elements in the right combination to start and grow—a heat source, fuel, and oxygen. How a fire behaves primarily depends on the characteristics of available fuel, weather conditions, and terrain; included in this section as a potential source of influence is climate change.

- Fuel:

  - Lighter fuels such as grasses, leaves, and 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, dying, or become receptive to ignition when influenced by environmental factors, such as drought, low humidity, and warm temperatures.
- Weather:
  - Strong winds can exacerbate extreme fire conditions, especially wind events that persist for long periods, or ones with significant sustained wind speeds that quickly promote fire spread through the movement of embers or exposure within tree crowns.
  - Spring and summer drying months, many of which maintain drought-like conditions extending beyond normal season also can increase the normal fire season. Likewise, the passage of a dry, cold front through the region can result in sudden wind speed increases and change in wind direction affecting fire spread.
  - Thunderstorms in Massachusetts are usually accompanied by rainfall; however, during periods of drought, lightning from thunderstorm cells can result in fire ignition. Thunderstorms with little or no rainfall are rare in New England but have occurred.
- Terrain
  - Topography of a region or a local area influences the amount and moisture of fuel.
  - Barriers such as highways and lakes can affect spread of fire.
  - Elevation and slope of landforms—fire spreads more easily uphill compared to downhill.
- Climate Change
  - Without an increase in summer precipitation (greater than any predicted by climate models), future areas burned is very likely to increase.
  - Infestation from insects is also a concern as it may affect forest health. Potential insect populations may increase with warmer temperatures. In addition, infested trees may increase fuel amount.
  - Tree species composition will change as species respond uniquely to a changing climate.
  - Wildfires cause both short-term and long-term losses. Short-term losses can include destruction of timber, wildlife habitat, scenic vistas, and watersheds. Long-term effects include smaller timber harvests, reduced access to affected recreational areas, and the destruction of cultural and economic resources and community infrastructure.

The wildland-urban interface is the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels. Urban and suburban development in or near wildland vegetation poses a major threat to habitat loss, wildlife populations, and wildfire damage. There are a number of reasons that the wildland-urban interface has an increased risk to wildfire damage. The wildland-urban interface is an area where protection of structures from wildfires is difficult, due to access and fire suppression issues. The wildland-urban interface is also at risk for wildfires due to human-caused fire ignitions, which are very common. In these areas, homes are built among densely wooded areas, so humans are more likely to start a fire that will easily spread to the surrounding forested areas with plentiful vegetative fuels.

Fire is also being used more extensively as a land management tool to replicate natural fire cycles. This practice has been used for both fire dependent ecosystem restoration and hazard fuels mitigation

objectives on federal, state, municipal, and private lands in Massachusetts since the 1980s. Controlled burning as an agricultural tool dates to pre-European settlement. Between 2009 and 2012, over 1,300 acres of state and private partnership lands were treated with prescribed fire in the southeastern Massachusetts pitch pine and scrub oak fuel type in an effort to mitigate high hazard fuel loading in and around wildland-urban interface zones. There may be secondary negative impacts from the wildfire related to air quality, soil erosion resulting in siltation of streams and lakes, or mudslides. However, unless these fires occur in developed areas, they are rarely classified as disasters because they do not affect people or the developed environment. Wildfires, regardless of size, that burn primarily on federally managed lands are only rarely classified as disasters.

In Massachusetts, the DCR Bureau of Forest Fire Control is the state agency responsible for providing aid, assistance, and advice to the Commonwealth's cities and towns with the protection of 3.5 million acres of state, public and private wooded land since 1911. The Bureau is an active participant with all municipal fire departments in protecting forestlands through assistance and cooperation with fire departments, local law enforcement agencies, the Commonwealth's county and statewide civil defense agencies, and mutual aid assistance organizations.

Early detection of wildfires is a key part of the Bureau's overall effort. Early detection is achieved by trained Bureau observers who staff the statewide network of 42 operating fire towers. 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 for suppression of fires during their initial stage. Figure 9-2 displays the Bureau's 14 fire control districts and fire towers in Massachusetts.

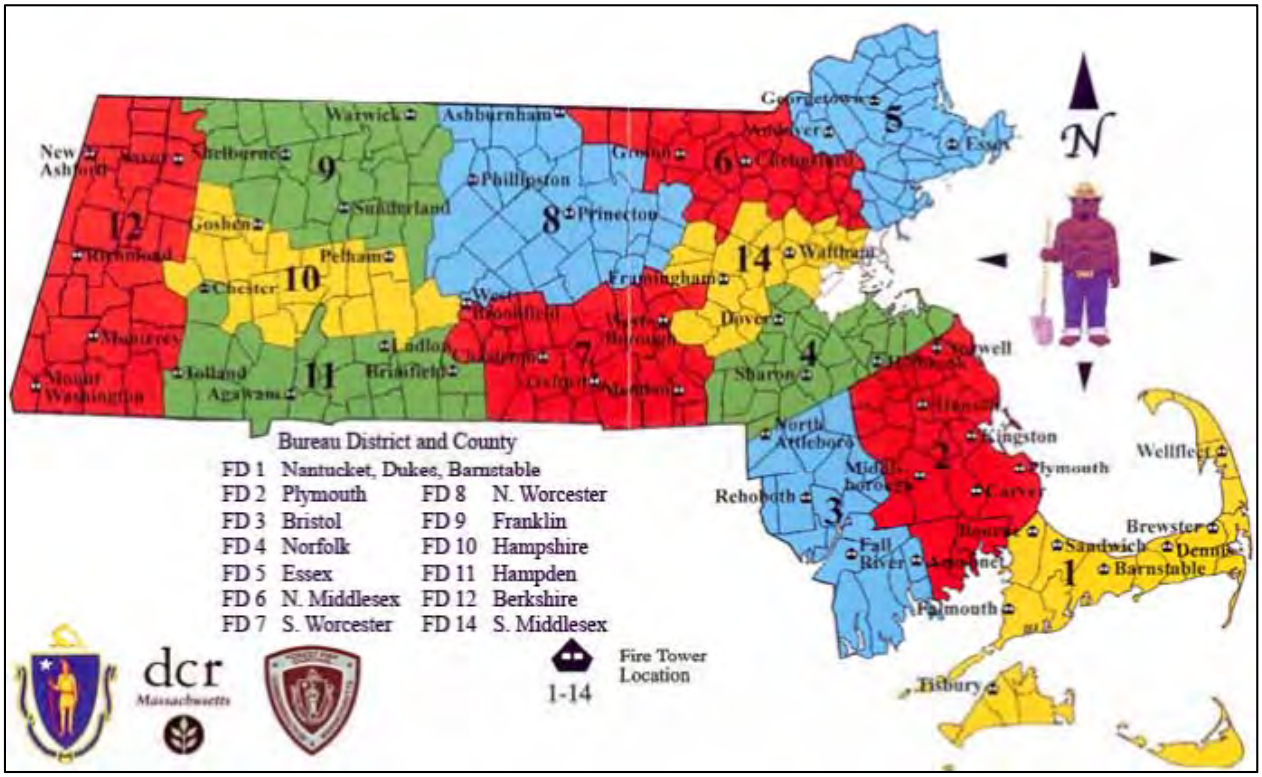


Figure 9-2. Massachusetts Bureau of Forest Fire Control Districts and Tower Network

Bureau units are used at all fires that occur on state-owned forestland and are available to municipal fire departments for mutual assistance. Bureau fire fighters are trained in the use of forestry tools, water pumps, brush breakers, and other motorized equipment, as well as fire behavior and fire safety. 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 between the New England states, New York, and four eastern Canadian Provinces to provide resources and assistance in the event of large wildfire activity. Massachusetts DCR also has a long-standing cooperative agreement with the USDA Forest Service for both providing qualified wildfire-fighters for assistance throughout the United States or receiving federal assistance within the Commonwealth.

Based on Bureau records, in 1911, more than 34 acres were burned on average during each wildfire. Since then, that figure has been reduced to 1.17 acres.

Massachusetts had approximately 1,121 wildfires on 1,143 acres in 2009 according to the DCR Bureau of Forest Fire Prevention. When comparing the 2007 season to 2009, there were 1,551 fewer wildfire incidents with 1,762 fewer acres burned. In the last five years, wildfires reported to DCR are trending generally downward.

The fire problem varies from region to region throughout the U.S. This often is a result of climate, poverty, education, demographics, and other causal factors. The national fire death rate in 2009 was 11.0 deaths per million population. In 2009, the fire death rate in Massachusetts was 5.3, which is one of the lowest rates in the U.S.

9.2 HAZARD PROFILE

9.2.1 Location

Urban Fire

The U.S. Fire Administration conducted a study on urban fires that occurred in metropolitan areas. In Massachusetts, the metropolitan area study was the Boston-Worcester-Lawrence Metropolitan Area. The study found that the leading cause of residential structure fires were cooking, heating, and electrical distribution. In non-residential structure fires, the lead causes were incendiary or suspicious origins, cooking, and electrical distribution. The leading causes of home fires that resulted in one or more fatalities were careless smoking, incendiary or suspicious origins, and cooking. The common causes of fires in which one or more injuries were sustained, were cooking, careless smoking, and electrical distribution.

The risk of urban fires exists in all developed areas of Massachusetts. Areas where there are larger concentrations of wood frame construction homes or businesses are more likely to experience large destructive fires. In addition, many former mill communities exist in Massachusetts, which have abandoned or vacant mills and warehouses. These structures are very susceptible to vandalism or accidental fires. Due to environmental impacts such as drought conditions, high winds, or inadequate on-site fire suppression equipment, as in vacant buildings, a fire in a densely developed area can quickly become a major hazard.

Wildfire

The ecosystems that are most susceptible to the hazard are pitch pine, scrub oak, and oak forests. These are the most flammable vegetative fuels. According to a U.S. Forest Service study, Barnstable and Plymouth Counties are more fire prone than southern California due to their sandy soil, drying winds, and fuel types (DCR, 2013, http://www.mass.gov/dc r/stewardship/firecont/facts.htm).

The southeastern part of Massachusetts—Plymouth County to the southern coast of Bristol County, Cape Cod, and Martha's Vineyard—is more susceptible to wildfires due to the availability of fuel, impact from off shore winds, and increasing development within the wildland areas. There are other wildland-urban interface areas scattered in the central and western portions of the Commonwealth; however, the risk is noted to be slightly lesser than the southeast. Figure 9-3 displays the wildland-urban interface throughout Massachusetts by U.S. Census block.

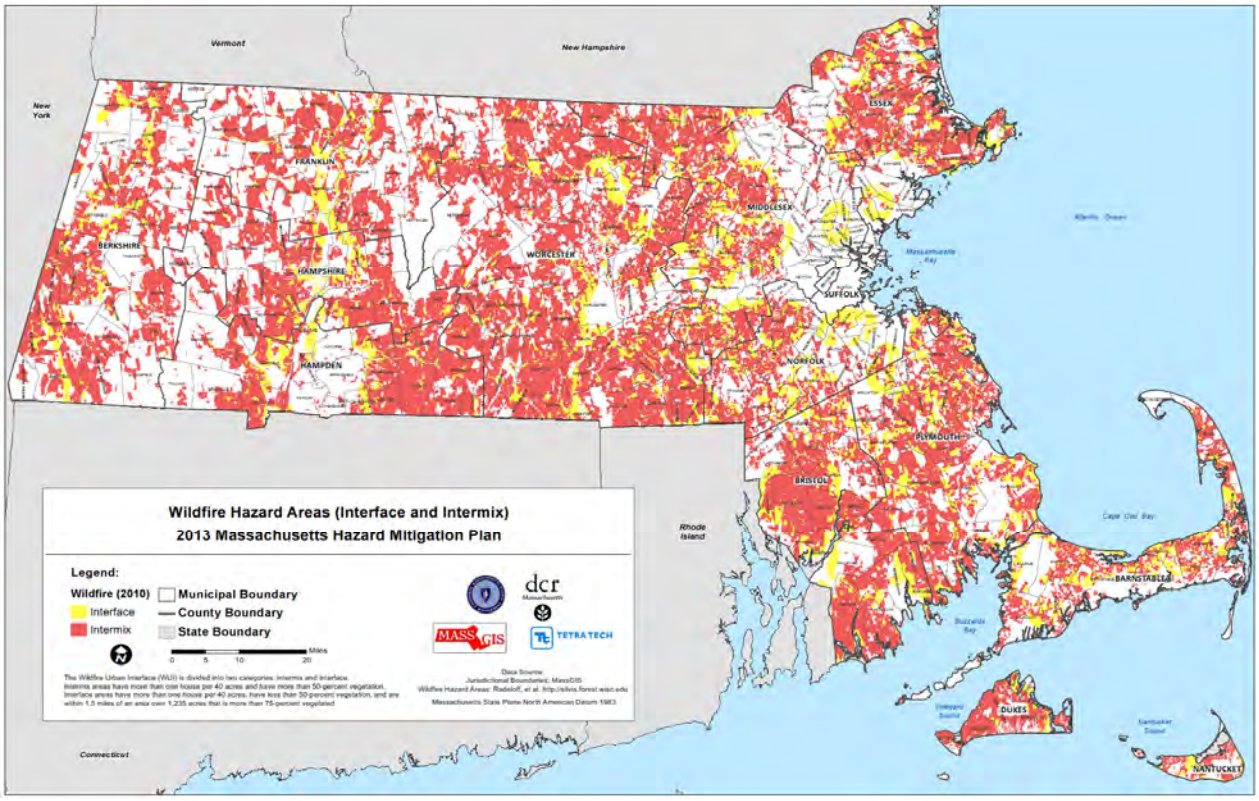


Figure 9-3. Wildland-Urban Interface and Intermix for the Commonwealth of Massachusetts

9.2.2 Previous Occurrences

Urban Fire

The following is a list of notable urban fires in Massachusetts, based on information available as of the drafting of this plan:

- Fall River, 1834
- Great Boston Fire, 1872
- Great Lynn Fire, 1889
- Chelsea Fire, 1903
- Great Salem Fire, 1914
- Hull Conflagration, 1923
- Strand Theater, Brockton, 1941
- Coconut Grove nightclub, Boston, 1942
- Hotel Vendome Fire, Boston, 1972
- Chelsea Fire, October 1973—Resulted in a FEMA disaster declaration (FEMA DR-405)
- Lynn, December 3, 1981—Resulted in a FEMA disaster declaration (FEMA DR-650)
- Worcester Fire, December 1999—Resulted in a FEMA emergency declaration (FEMA EM-3153); total public assistance grants issued by FEMA was $3,101,637.94

- Bernat Mills, Uxbridge, 2007
- Lawrence, February 14, 2008—A fire at a three-unit apartment building killed one person. Damage was estimated at $350,000.
- Northborough, March 25, 2008—A fire at a strip mall was caused by a Molotov cocktail and destroyed five businesses. Damage was estimated at $2.5 million.
- West Springfield, March 27, 2008—A fire at a motor vehicle repair shop was caused by a gas tank, injuring two people. Damage was estimated at $2 million.
- Brockton, April 8, 2008—An electrical fire at a business office injured seven firefighters. Damage was estimated at $1.8 million.
- Framingham, April 11, 2008—A fire at a 72-unit apartment building was caused when the lining of a plumbing chase was set fire. Two civilians and 13 firefighters were injured. Damage was estimated at $3 million.
- Peabody, May 29, 2008—A fire at a 38-unit apartment building was started by a bark mulch fire in the courtyard. Damage was estimated at $6.8 million.
- Lincoln, September 17, 2008—A two-family home was caused by a mechanical failure and damage was estimated at $2.85 million.
- Avon, October 13, 2008—A fire at a refrigerated storage facility had damage estimated at $7.25 million.
- Cambridge, November 25, 2008—A five-alarm fire at a six-unit apartment building killed one person and injured four people. Damage was estimated at $2.26 million.
- Braintree, January 12, 2009—An explosion and a fire at a foundry was reported and damage was estimated at $1 million.
- Worcester, March 5, 2009—A fire at a 10-unit apartment building injured six firefighters and spread to a church next door. The damage at the apartment building was estimated at $1.5 million and the church had damage estimated at $120,000.
- Quincy, March 25, 2009—An electrical fire at a six-unit apartment building killed three people and injured two. Damage was estimated at $200,000.
- Northampton, April 13, 2009—A fire at an eight-unit apartment building injured one civilian and two firefighters. Damage was estimated at $3.75 million.
- Middleborough, May 25, 2009—An electrical fire at a church injured three firefighters and caused an estimated $1.1 million in damage.
- Everett, July 2, 2009—A fire was reported at a steel recycling plant when lightning struck a conveyor belt. Damage was estimated at $4.4 million.
- Greenfield, November 8, 2009—A 16-unit apartment building caught fire, injuring one firefighter. Damage was estimated at $625,000.
- Weston, December 23, 2009—A fire was reported at the Gifford School, started when someone turned on a burner on a stove in a kitchen. Damage was estimated at $3 million.
- Quincy, December 26, 2009—A fire at a 150-unit apartment building killed one person and injured three firefighters. Damage was estimated at $200,000.
- Hadley, February 4, 2010—An electrical fire at a livestock production facility injured one firefighter. It spread to two other buildings and caused approximately $860,000 in damage.

- Lynn, February 13, 2010—A fire in a 99-unit apartment building killed one person. The fire was caused by someone smoking using oxygen.
- Fall River, April 16, 2010—A fire in a three-unit apartment building was caused by cooking liquids becoming ignited on a stovetop. One fatality and one injury were reported. Damage was estimated at $280,100.
- New Bedford, June 6, 2010—A fire at a fisheries facility caused an estimated $1.3 million in damage.
- Peabody, June 20, 2010—A fire at the J.D. Raymond Company mulch yard began in one of the large piles of mulch and spread to equipment that was used to handle the mulch. One firefighter was injured. Damage was estimated at $1.2 million.
- Lenox, December 22, 2010—A fire at a historic inn had damage estimated at $2.25 million.
- Saugus, January 16, 2011—An electrical fire in a four-unit apartment building killed one person and injured two firefighters. Damage was estimated at $105,000.
- Fall River, February 22, 2011—A fire at a six-unit apartment building killed one person and injured one person. Damage was estimated at $320,000.
- Ipswich, February 25, 2011—A fire in an apartment building killed one person and damage was estimated at $250,000.
- Middletown, March 13, 2011—An explosion and fire occurred at the Bostik adhesives manufacturing plant. Flammable gases from the chemicals used were ignited by a piece of equipment. Four injuries resulted from this event. Damage was estimated at $12 million.
- West Springfield, March 23, 2011—An explosion and fire at an auto dealership, killing one person and injuring one person. An employee looked inside a 55-gallon drum with a cigarette lighter and the flame from the lighter ignited the fumes and caused the explosion. Damage was estimated at $150,000.
- Easton, March 25, 2011—A fire at a warehouse injured three firefighters and damage was estimated at $5.9 million.
- West Springfield, April 30, 2011—A 24-unit apartment building caught fire, killing one person and injuring one person. Damage was estimated at $1 million.
- Waltham, April 30, 2011—A fire at a 24-unit apartment building injured three firefighters and damage was estimated at $1.62 million.
- Pittsfield, May 4, 2011—An electrical fire at a 22-unit apartment building. No injuries or deaths were reported. Damage was estimated at $1.4 million.
- Medford, May 13, 2011—A fire in a 175-unit apartment building killed one person and injured one firefighter. Damage was estimated at $200,000.
- Fitchburg, June 13, 2011—A 52-unit apartment building fire injured three firefighters and damage was estimated at $2.3 million.
- Quincy, July 9, 2011—A three-alarm fire was reported at a 24-unit apartment building, injuring one firefighter. Damage was estimated at $8.4 million.
- Saugus, July 23, 2011—A gasoline tanker crash caused a fire along Route 1, causing 14 exposure fires, nine motor vehicle fires, four building fires, and one brush fire. One person was killed and one person was injured. Damage was estimated at $2.94 million.

- Lawrence, October 7, 2011—An arson fire at a 90-unit apartment building killed one person and damage was estimated at $85,000.
- Hyannis, October 31, 2011—A fire at a 110-unit apartment building killed one person and injured five. Damage was estimated at $800,000.
- Worcester, December 8, 2011—A three-floor apartment building fire killing one firefighter and damage was estimated at $250,000.
- Peabody, December 23, 2011—An electrical fire at an eight-unit apartment building, killing one firefighter. Damage was estimated at $240,000.

Wildfire

Figure 9-4 shows the location of historical wildfires in the Commonwealth from 2001 to 2009, as well as the number of acres burned. 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 presidential declared disaster (FEMA FSA-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 were threatened in the Town of Russell.

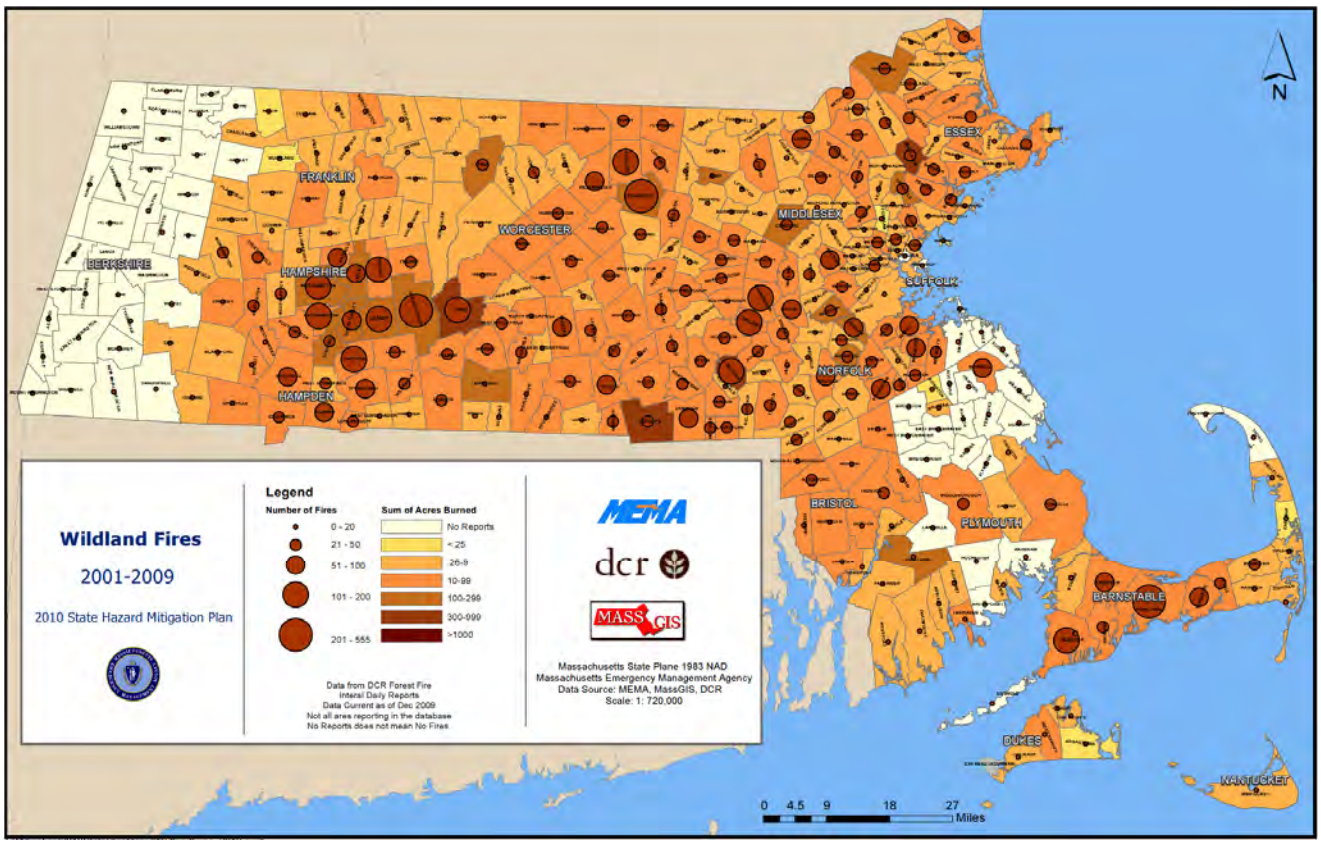


Figure 9-4. Locations of Historical Wildfires and Number of Acres Burned in the Commonwealth of Massachusetts (2001 to 2009)(data from 2001 to 2009 was not available to update this map)

One of the largest wildfires on record was in Plymouth in May 1957. This catastrophic fire burned 15,000 acres and destroyed about 40 structures. Another large fire in the same area in 1964 burned 5,500 acres and destroyed cottages on Charge Pond. The following is a list of wildfire occurrence history in Massachusetts through 2010:

- 1887: Bourne, 25,000 acres
- 1923: Bourne, 25,000 acres, 7 days
- 1927: Townsend State Forest into NH, 16,000 acres.
- 1927: Erving to Wendell, 7,000 acres
- 1927: Montague Plains Fire Destroys Village of Lake Pleasant
- 1937: Bourne, 300 acres, 2 firefighters killed
- 1937: Hyannis, 2000 acres
- 1941: Marshfield, 550 buildings destroyed
- 1957: Plymouth, 15,000 acres, 3000 fought fire, which had a 35 mile perimeter
- 1963: Plymouth, 530 acres
- 1964: Plymouth, 5500 acres, destroyed 26 buildings
- 1965: Sandwich, 5,000 acres
- 1966: Plymouth/Wareham 535 acres
- 1995: Russell, 500 acres, Mt. Tekoa
- 2000: South Hadley, 310 acres, 14 days, Lithia Springs Watershed
- 2000: Erving, 140 acres, 7 days, Hermit Mountain
- 2001: Ware, 400 acres
- 2010: Russell, 320 acres, Mt. Tekoa

According to the Geospatial Multi-Agency Coordinator Group, an internet-based mapping application, there were six wildfires in Massachusetts between 2002 and 2012:

- August 14, 2002, Devens Fire—wildfire located at the Devens Reserve Forces Training Area in Lancaster, MA
- November 16, 2003, 128 Fire—wildfire along Route 128 in Dedham, MA
- April 29, 2004, Bearsden Fire—120 acres burned near Athol Center, MA
- April 16-22, 2005, The Range Fire—wildfire near Leominster, MA
- April 19-26, 2008, Oscar Orange Fire—wildfire near Leominster, MA
- April 19-23, 2008, Widow White Peak Fire—wildfire near Lanesboro, MA
- April 11-15, 2010, Tekoa Mountain Fire—wildfire near Westfield, MA

The NOAA NCDC database lists the following wildfire events in the Commonwealth:

- July 5-7, 2002, Berkshire County—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, Eastern Hampden County—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 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, Northern Worcester County—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, Western Norfolk County—Dry conditions, along with gusty winds, cause a fire to spread near Route 128 on the Dedham-Boston line. Almost 100 acres of meadowlands burned.

9.2.3 Probability of Future Occurrences

For the purpose of this plan, the probability of future occurrences is defined by the number of events over a specified period. The historical record indicates the Commonwealth has experienced four federally declared urban and wildfire events from 1954 to 2012. This figure greatly underestimates how often fires occur and affect the Commonwealth.

9.2.4 Frequency

It is difficult to predict the likelihood of urban fires and wildfires in a probabilistic manner, such as, “there will be a catastrophic wildfire once every X number of years.” This is because a number of variable factors affect the potential for a fire to occur and because some conditions (for example, ongoing land use development patterns, location, fuel sources, construction, etc.) exert increasing pressure on the wildland-urban interface zone. Based on available data, urban fires and wildfires will continue to present a risk.

Given the numerous factors that can impact urban fire and wildfire potential, the likelihood of a fire event starting and sustaining itself should be gauged by professional fire managers on a daily basis using the methods and tools described above.

9.2.5 Severity

The greatest potential for significant damage to life and property from fire exists in areas designated as wildland-urban interface areas. A wildland-urban interface area defines the conditions where highly flammable vegetation is adjacent to developed areas.

Urban Fires

Differences in climate and building stock could play a factor in urban fires. It is likely that home fires related to heating occur more frequently in the northern areas of the U.S. In addition, heating equipment fires are usually one of the leading causes for fires in one-and two-family homes and not in other residential occupancies. This is because other residential occupancies tend to be more regulated by building and fired codes. Electrical distribution fires are likely to be more common in the northeast and south, where the building stocks are older, on average, than in the Midwest and west.

Wildfire

Potential losses from wildfire include human life, structures and other improvements, and natural resources. Given the immediate response times to reported wildfires, the likelihood of injuries and casualties is minimal. Smoke and air pollution from wildfires can be a health hazard, especially for sensitive populations including children, the elderly, and those with respiratory and cardiovascular diseases. Wildfire may also threaten the health and safety of those fighting the fires. First responders are exposed to the dangers from the initial incident and after-effects from smoke inhalation and heat stroke.

In addition, wildfire can lead to ancillary impacts such as landslides in steep ravine areas and flooding due to the impacts of silt in local watersheds.

9.2.6 Warning Time

Urban Fire

Early warning for urban fires is none or minimal at best. Smoke detectors provide early warning of a fire; however, they do not guarantee an escape. Residential sprinklers provide the best opportunity to escape safely from a fire. Federal studies have shown in a typical fire, one has only about 3 minutes to evacuate safely before unsustainable conditions are encountered. Warning signs for electrical problems include the following. Any of these signs may indicate a potential problem.

- Fuses blowing or circuit breakers tripping frequently
- Unusually warm or faulty outlets or switches
- A vague smell of something burning
- A sizzling sound in the wall

Wildfire

Wildfires are often caused by humans, intentionally or accidentally. There is no way to predict when one might break out. Since fireworks often cause brush fires, extra diligence is warranted around the Fourth of July when the use of fireworks is highest. Dry seasons and droughts are factors that greatly increase fire likelihood. Severe weather can be predicted, so special attention can be paid during weather events that may include lightning. Reliable National Weather Service lightning warnings are available on average 24 to 48 hours prior to a significant electrical storm.

If a fire breaks out and spreads rapidly, residents may need to evacuate within days or hours. A fire's peak burning period generally is between 1 p.m. and 6 p.m. Once a fire has started, fire alerting is reasonably rapid in most cases. The rapid spread of cellular and two-way radio communications in recent years has further contributed to a significant improvement in warning time.

9.3 SECONDARY HAZARDS

Wildfires can generate a range of secondary effects, which in some cases may cause more widespread and prolonged damage than the fire itself. Fires can cause direct economic losses in the reduction of harvestable timber and indirect economic losses in reduced tourism. Wildfires cause the contamination of reservoirs, destroy transmission lines, and contribute to flooding. They strip slopes of vegetation, exposing them to greater amounts of runoff. This in turn can weaken soils and cause failures on slopes. Major landslides can occur several years after a wildfire. Most wildfires burn hot and for long durations that can bake soils, especially those high in clay content, thus increasing the imperviousness of the ground. This increases the runoff generated by storm events, thus increasing the chance of flooding.

9.4 CLIMATE CHANGE IMPACTS

Fire is determined by climate variability, local topography, and human intervention. Climate change has the potential to affect multiple elements of the wildfire system: fire behavior, ignitions, fire management, and vegetation fuels. Hot dry spells create the highest fire risk. Increased temperatures may intensify wildfire danger by warming and drying out vegetation. When climate alters fuel loads and fuel moisture, forest susceptibility to wildfires changes. Climate change also may increase winds that spread fires. Faster fires are harder to contain, and thus are more likely to expand into residential neighborhoods.

Historically, drought patterns in the U.S. are related to macro-scale climate patterns in the Pacific and Atlantic oceans. The El Niño–Southern Oscillation in the Pacific varies on a 5- to 7-year cycle, the Pacific Decadal Oscillation varies on a 20- to 30-year cycle, and the Atlantic Multidecadal Oscillation varies on a

65- to 80-year cycle. As these large-scale ocean climate patterns vary in relation to each other, drought conditions in the U.S. shift from region to region.

Climate scenarios project summer temperature increases between 2ºC and 5ºC and precipitation decreases of up to 15 percent. Such conditions would exacerbate summer drought and further promote high-elevation wildfires, releasing stores of carbon and further contributing to the buildup of greenhouse gases. Forest response to increased atmospheric carbon dioxide—the so-called "fertilization effect"—could also contribute to more tree growth and thus more fuel for fires, but the effects of carbon dioxide on mature forests are still largely unknown.

9.5 EXPOSURE

To understand risk, the assets exposed to the hazard areas are identified. For the wildfire hazard, areas identified as hazard areas include the wildland-urban interface and intermix. The following discusses the Commonwealth of Massachusetts exposure to the wildfire hazard including:

- Population
- State facilities
- Critical facilities and infrastructure
- Economy

The Northeast Wildfire Risk Assessment Geospatial Work Group completed a geospatial analysis of fire risk in the 20-state U.S. Forest Service Northeastern Area. The assessment is comprised of three components: fuels, wildland-urban interface, and topography (slope and aspect) that are combined using a weighted overlay. These three characteristics are combined to identify wildfire-prone areas where hazard mitigation practices would be most effective. Figure 9-5 illustrates these areas as determined for the Commonwealth. This spatial dataset was not made available in time for inclusion in the 2013 plan. However, it is noted as data to be used to enhance the exposure and vulnerability assessment for further plan updates.

Source: Northeast Wildfire Risk Assessment Geospatial Work Group, 2009

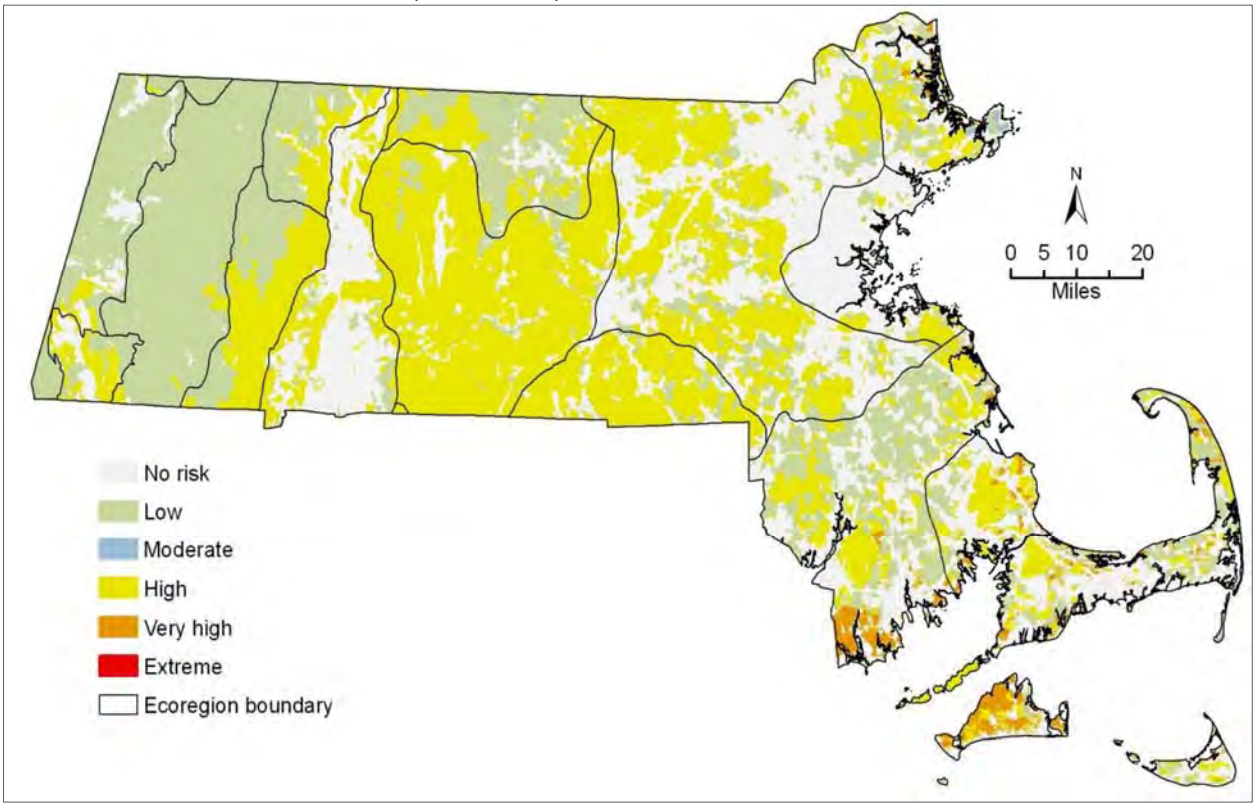


Figure 9-5. Wildfire Risk Areas for the Commonwealth of Massachusetts

For the purposes of this risk assessment, the interface and intermix obtained through the SILVIS Lab, Department of Forest Ecology and Management, University of Wisconsin-Madison defines the wildfire hazard area (Radeloff et al., 2011). The wildfire hazard areas are based on the 2010 Census, 2006 National Land Cover Database, and the Protected Areas Database. For the purposes of this risk assessment, the high-, medium-, and low-density interface areas were combined and used as the 'interface' hazard area and the high-, medium-, and low-density intermix areas were combined and used as the 'intermix' hazard areas. Figure 9-6 and Figure 9-3 display the 2010 wildland-urban interface by 2010 U.S. Census block for the U.S. and the Commonwealth, respectively.

http://silvis.forest.wisc.edu/maps/wui/2010/download

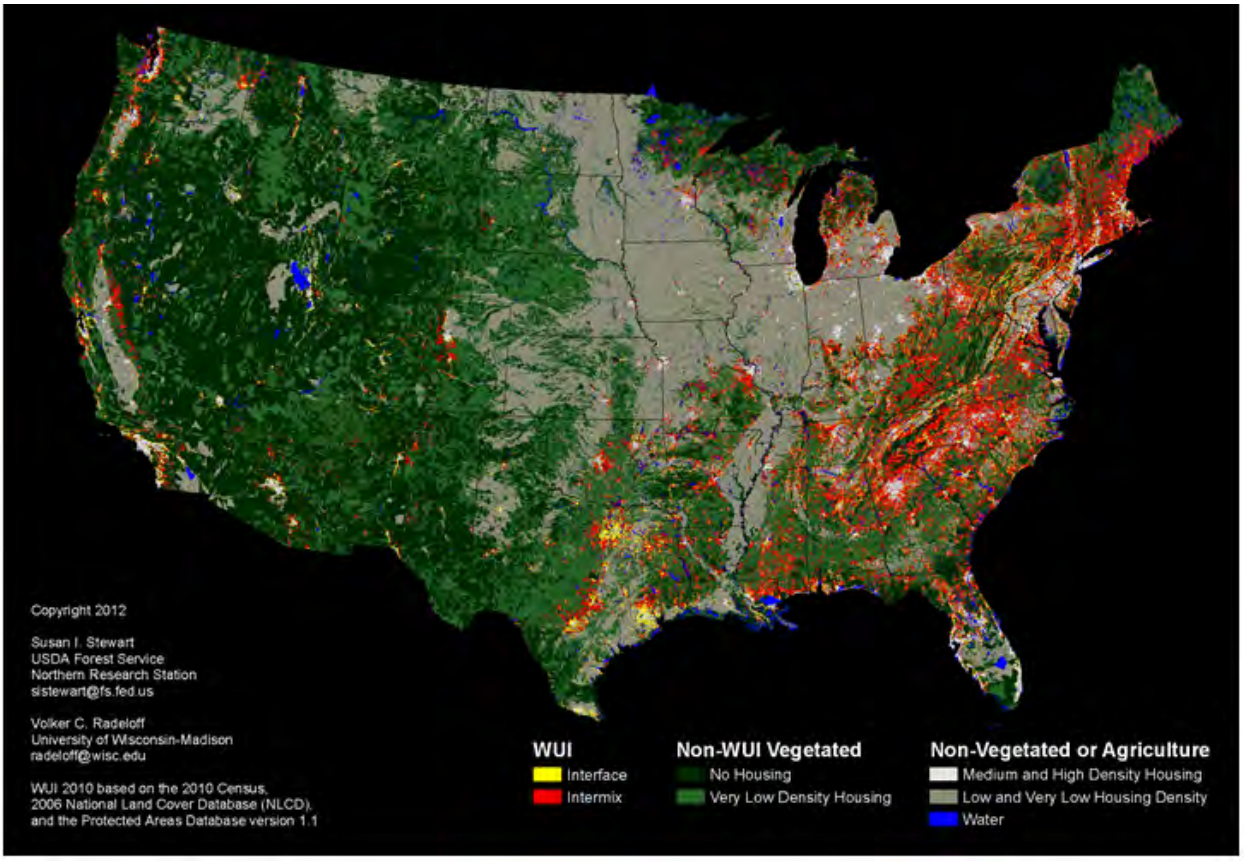


Figure 9-6. 2010 Wildland-Urban Interface for the U.S.

Inventoried assets (population, building stock, and critical facilities) were evaluated to determine exposure and potential impacts associated with this hazard. To determine what assets are exposed to wildfire, available and appropriate GIS data were overlaid on the hazard area. The limitations of this analysis are recognized, so the analysis is used only to provide a general estimate.

9.5.1 Population

As demonstrated by historical wildfire events, potential losses include human health and life of residents and responders. The most vulnerable populations include emergency responders and those within a short distance of the interface between the built environment and the wildland environment.

To estimate the population vulnerable to the wildfire hazard, the interface and intermix hazard areas were overlaid upon the 2010 Census population data (U.S. Census, 2010). The Census blocks identified as interface or intermix were used to calculate the estimated population exposed to the wildfire hazard. In total, there are an estimated 2.5 Million people in the wildland interface and intermix hazard areas (or nearly 40-percent of the Commonwealth's total population). Table 9-2 summarizes the estimated population within the defined hazard areas by County.

TABLE 9-2.
U.S. 2010 POPULATION IN THE WILDFIRE HAZARD AREAS

County	Total Population	Interface	% Total	Intermix	% Total
Barnstable	215,888	62,190	28.8	48,289	22.4

Berkshire	131,219	55,486	42.3	39,171	29.9
Bristol	548,285	150,890	27.5	116,462	21.2
Dukes	16,535	6,007	36.3	7,453	45.1
Essex	743,159	174,121	23.4	84,446	11.4
Franklin	71,372	31,267	43.8	27,093	38.0
Hampden	463,490	76,147	16.4	61,462	13.3
Hampshire	158,080	59,161	37.4	52,177	33.0
Middlesex	1,503,085	314,100	20.9	132,353	8.8
Nantucket	10,172	6,161	60.6	2,552	25.1
Norfolk	670,850	164,684	24.5	73,965	11.0
Plymouth	494,919	145,314	29.4	130,761	26.4
Suffolk	722,023	16,035	2.2	211	0.0
Worcester	798,552	294,657	36.9	233,872	29.3
Total	**6,547,629**	**1,556,220**	**23.8**	**1,010,267**	**15.4**

9.5.2 State Facilities

To assess the exposure of the state-owned and state-leased facilities provided by DCAMM and the Office of Leasing, an analysis was conducted with the wildfire interface and intermix hazard areas. Using ArcMap GIS software, the wildfire interface and intermix data were overlaid with the state facility data to determine which facilities are within the defined hazard areas. Table 9-3 and Table 9-4 summarize the number of state-owned and state-leased buildings in the wildfire hazard area by County and agency, respectively. Figure 9-7 illustrates the state-owned and leased buildings in the wildfire hazard areas.

TABLE 9-3.
STATE-OWNED AND LEASED BUILDINGS IN THE WILDFIRE HAZARD AREA BY COUNTY

County	Interface	Intermix	Total
Barnstable	38	104	**142**
Berkshire	103	85	**188**
Bristol	156	87	**243**
Dukes	2	2	**4**
Essex	56	123	**179**
Franklin	38	39	**77**
Hampden	54	125	**179**
Hampshire	73	107	**180**
Middlesex	118	66	**184**
Nantucket	3		**3**
Norfolk	65		**65**
Plymouth	93	63	**156**
Suffolk	16	93	**109**
Worcester	232	118	**350**
Total	**1,047**	**1,012**	**2,059**

TABLE 9-4.
STATE-OWNED AND LEASED BUILDINGS IN WILDFIRE HAZARD AREA BY STATE AGENCY

Agency Name	Interface	Intermix
Berkshire Community College	1	—
Bridgewater State University	28	—
Bristol Community College	12	—
Committee For Public Counsel Services	1	1
Department of Children and Families	5	2
Department of Conservation and Recreation	216	453
Department of Corrections	52	6
Department of Developmental Services	107	116
Department of Environmental Protection	2	—
Department of Fish and Game	32	53
Department of Fire Services	—	5
Department of Industrial Accidents	1	—
Department of Mental Health	14	10
Department of Public Health	2	1
Department of State Police	22	16
Department of Transitional Assistance	1	3
Department of Transportation	217	217
Department of Veterans Services	—	9

TABLE 9-4.
STATE-OWNED AND LEASED BUILDINGS IN WILDFIRE HAZARD AREA BY STATE AGENCY

Agency Name	Interface	Intermix
Department of Workforce Development	1	—
Division of Banks	1	—
Division of Capital Asset Management	9	36
Exec. Office of Energy & Environmental Affairs	1	2
Fitchburg State University	57	1
Greenfield Community College	1	—
Holyoke Community College	12	—
Massachusetts Department of Revenue	2	—
Massachusetts State Lottery Commission	1	3
Massachusetts College of Liberal Arts	16	2
Massachusetts Maritime Academy	1	—
Massachusetts National Guard	1	—
Massachusetts Rehabilitation Commission	4	2
Massasoit Community College	2	—
Military Division	25	2
Mount Wachusett Community College	13	—
Municipal Police Training Committee	1	—
Northern Essex Community College	—	12
Office of the Chief Medical Examiner	1	—
Office of the District Attorney Cape & Island	1	—
Office of the District Attorney Northern	2	—
Office of the District Attorney Northwestern	1	—
Office of the State Auditor	1	—
Quinsigamond Community College	1	—
Sheriff's Department Berkshire	3	—
Sheriff's Department Bristol	—	1
Sheriff's Department Essex	1	1
Sheriff's Department Franklin	4	—
Sheriff's Department Hampden	23	—
Sheriff's Department Hampshire	—	6
Sheriff's Department Worcester	1	—
State Reclamation and Mosquito Control B	—	2
Trial Court	16	6
University of Massachusetts at Amherst	75	44
University of Massachusetts at Dartmouth	33	—
Westfield State University	2	—
Worcester State University	21	—
Total	**1,047**	**1,012**

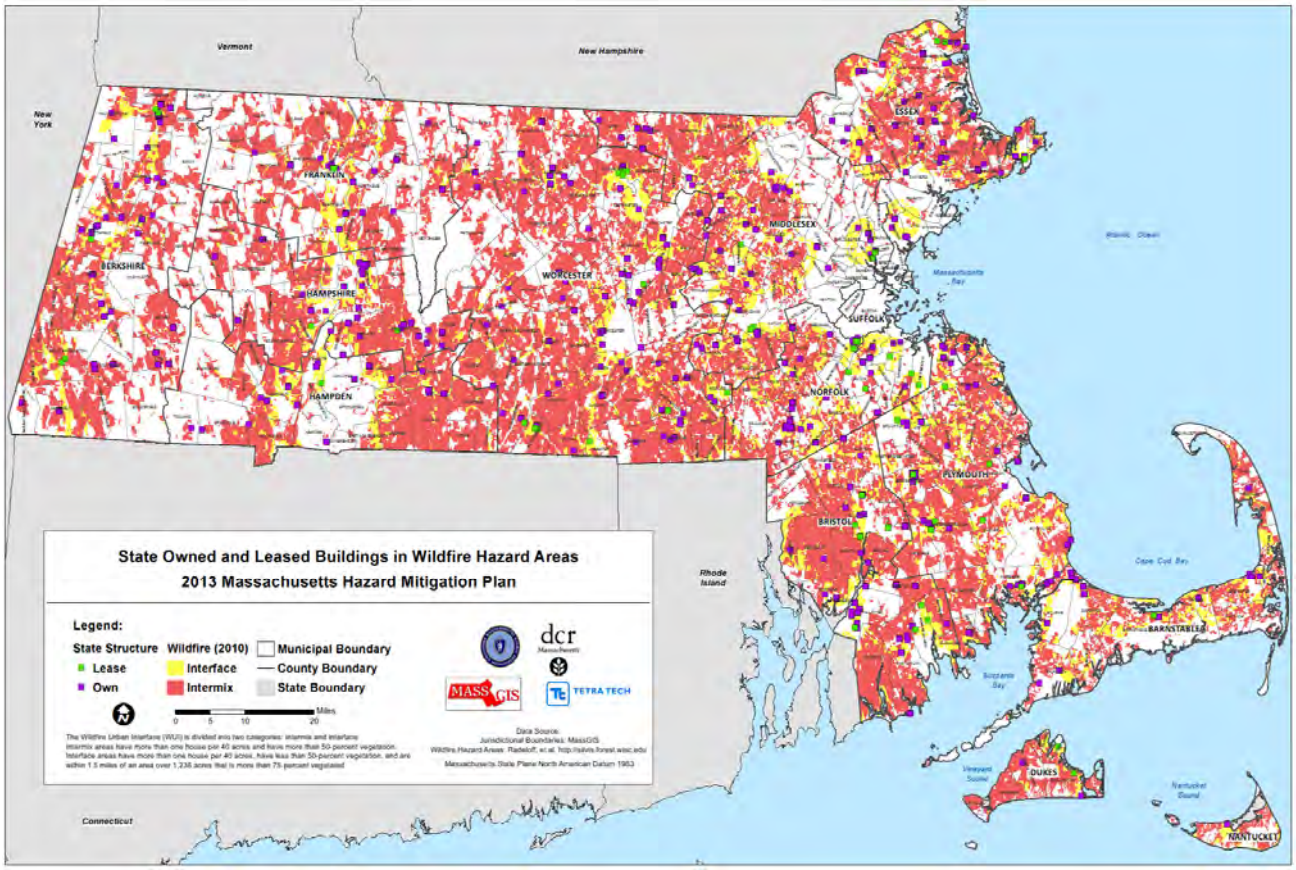


Figure 9-7. State Owned and Leased Buildings in Wildfire Hazard Areas

9.5.3 Critical Facilities

For the purposes of this planning effort, the critical facilities located in the wildland interface and intermix areas are exposed to the wildfire hazard. The number of critical facilities exposed to the wildfire hazard in the Commonwealth is summarized by county in Table 9-5 through Table 9-10.

During a wildfire event, hazardous materials at containment sites in wildfire risk zones could rupture due to excessive heat and act as fuel for the fire, causing rapid spreading and escalating the fire to unmanageable levels. In addition, they could leak into surrounding areas, saturating soils and seeping into surface waters, and have a disastrous effect on the environment.

In the event of wildfire, there would likely be little damage to the majority of infrastructure. Most road and railroads would be without damage except in the worst scenarios. Fires can create conditions that block or prevent access and can isolate residents and emergency service providers. Power lines are the most at risk to wildfire because most poles are made of wood and susceptible to burning. In the event of a wildfire, pipelines could provide a source of fuel and lead to a catastrophic explosion.

TABLE 9-5.
POLICE STATIONS EXPOSED TO THE WILDLAND INTERFACE AND INTERMIX

County	Total Number of Police Stations	Interface	Intermix
Barnstable	20	3	4
Berkshire	33	14	10
Bristol	27	7	6
Dukes	10	3	4
Essex	39	14	4
Franklin	26	8	12
Hampden	28	7	7
Hampshire	23	6	7
Middlesex	64	14	13
Nantucket	3	2	—
Norfolk	32	6	5
Plymouth	31	5	11
Suffolk	34	2	—
Worcester	67	29	21
Total	**437**	**120**	**104**

TABLE 9-6.
FIRE STATIONS EXPOSED TO THE WILDLAND INTERFACE AND INTERMIX

County	Total Number of Fire Stations	Interface	Intermix
Barnstable	37	6	13
Berkshire	46	19	18
Bristol	63	15	17
Dukes	8	2	5
Essex	82	29	10
Franklin	31	7	14
Hampden	51	12	9
Hampshire	28	8	13
Middlesex	164	32	26
Nantucket	1	1	—
Norfolk	59	14	7
Plymouth	67	22	18
Suffolk	47	2	—
Worcester	105	49	24
Total	**789**	**218**	**174**

TABLE 9-7.
EMERGENCY OPERATIONS CENTERS EXPOSED TO THE WILDLAND INTERFACE AND INTERMIX

County	Total Number of Emergency Operations Center	Interface	Intermix
Barnstable	—	—	—
Berkshire	—	—	—
Bristol	—	—	—
Dukes	—	—	—
Essex	—	—	—
Franklin	—	—	—
Hampden	1	—	—
Hampshire	—	—	—
Middlesex	1	—	—
Nantucket	—	—	—
Norfolk	—	—	—
Plymouth	—	—	—
Suffolk	—	—	—
Worcester	—	—	—
Total	**2**	**0**	**0**

TABLE 9-8.
HOSPITALS EXPOSED TO THE WILDLAND INTERFACE AND INTERMIX

County	Total Number of Hospitals	Interface	Intermix
Barnstable	2	—	—
Berkshire	4	1	1
Bristol	5	1	—
Dukes	1	—	—
Essex	10	2	—
Franklin	1	—	—
Hampden	6	2	—
Hampshire	2	1	—
Middlesex	16	2	—
Nantucket	1	1	—
Norfolk	5	3	—
Plymouth	4	1	—
Suffolk	15	—	—
Worcester	10	3	—
Total	**82**	**17**	**1**

TABLE 9-9.
SCHOOLS EXPOSED TO THE WILDLAND INTERFACE AND INTERMIX

County	Total Number of Schools	Interface	Intermix
Barnstable	82	18	19
Berkshire	76	22	27
Bristol	243	60	40
Dukes	10	2	5
Essex	309	65	49
Franklin	53	22	15
Hampden	217	25	26
Hampshire	113	35	18
Middlesex	576	125	47
Nantucket	4	3	1
Norfolk	286	70	35
Plymouth	197	41	54
Suffolk	244	5	—
Worcester	357	123	93
Total	**2,767**	**616**	**429**

TABLE 9-10.
COLLEGES EXPOSED TO THE WILDLAND INTERFACE AND INTERMIX

County	Total Number of Colleges	Interface	Intermix
Barnstable	6	1	1
Berkshire	6	3	1
Bristol	12	2	2
Dukes	—	—	—
Essex	13	—	2
Franklin	3	—	1
Hampden	16	1	—
Hampshire	5	1	—
Middlesex	47	2	2
Nantucket	1	—	1
Norfolk	21	2	1
Plymouth	6	1	—
Suffolk	48	1	—
Worcester	21	4	2
Total	**205**	**18**	**13**

The wildfire hazard typically does not have a major direct impact on bridges, but it can create conditions in which bridges are obstructed. The default Hazus-MH highway bridge inventory developed from the 2001 National Bridge Inventory database was used for this analysis. Table 9-11 identifies the number of highway bridges in the Hazus-MH default highway bridge inventory exposed to the wildland interface and intermix areas. The exposure analysis indicated 1,601 highway bridges located within the hazard areas or 33-percent of the total inventory in Hazus-MH (4,832 bridges).

9.5.4 Economy

Wildfire events can have major economic impacts on a community from the initial loss of structures and the subsequent loss of revenue from destroyed business and decrease in tourism. Wildfires can cost thousands of taxpayer dollars to suppress and control and involve hundreds of operating hours on fire apparatus and thousands of volunteer man-hours from the volunteer firefighters. There are 852.3 square miles (or 10 percent) of land in the Commonwealth in the interface hazard area, and 3,563.3 square miles (or 44 percent) of land in the intermix hazard area. There are also many direct and indirect costs to local businesses that excuse volunteers from work to fight these fires.

TABLE 9-11.
HIGHWAY BRIDGES LOCATED IN THE WILDFIRE HAZARD AREAS BY COUNTY

County	Total Number Exposed	Federal			State			Local		
		Interface	Intermix	**Total**	Interface	Intermix	**Total**	Interface	Intermix	**Total**
Barnstable	24	—	1	**1**	9	7	**16**	—	7	**7**
Berkshire	232	—	—	**—**	44	51	**95**	61	76	**137**
Bristol	98	—	—	**—**	29	35	**64**	10	24	**34**
Dukes	—	—	—	**—**	—	—	**—**	—	—	**—**
Essex	79	—	—	**—**	26	29	**55**	10	14	**24**
Franklin	153	—	1	**1**	31	36	**67**	26	59	**85**
Hampden	149	—	1	**1**	38	46	**84**	20	44	**64**
Hampshire	134	—	1	**1**	20	21	**41**	23	69	**92**
Middlesex	134	—	—	**—**	55	37	**92**	23	19	**42**
Nantucket	—	—	—	**—**	—	—	**—**	—	—	**—**
Norfolk	68	—	—	**—**	29	26	**55**	7	6	**13**
Plymouth	115	—	—	**—**	23	50	**73**	17	25	**42**
Suffolk	8	—	—	**—**	5	—	**5**	3	—	**3**
Worcester	407	1	3	**4**	111	127	**238**	60	105	**165**
Total	**1,601**	**1**	**7**	**8**	**420**	**465**	**885**	**260**	**448**	**708**

Source: Hazus-MH v. 2.1 default highway bridge inventory; Radeloff et.al, 2011
Note: The following owners are listed in the Hazus-MH default highway bridge inventory (total number of bridges for each category in parentheses): Federal (22)—National Park Service, Corps of Engineers; State (3,344)—State Highway Agency, State Park Reservation Agency, Bureau of Fish & Wildlife, Other State Agencies; Local (1,466)—Town Highway Agency, City Highway Agency, Local Park Reservation Agency, Local Toll Authority

9.6 VULNERABILITY

9.6.1 Population

Smoke and air pollution from wildfires can be a severe health hazard, especially for sensitive populations, including children, the elderly, and those with respiratory and cardiovascular diseases. Smoke generated by wildfire consists of visible and invisible emissions that contain particulate matter (soot, tar, water vapor, and minerals), gases (carbon monoxide, carbon dioxide, nitrogen oxides), and toxics (formaldehyde, 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. Public health impacts associated with wildfire include difficulty in breathing, odor, and reduction in visibility.

Wildfire may also threaten the health and safety of those fighting the fires. First responders are exposed to the dangers from the initial incident and after-effects from smoke inhalation and heat stroke.

9.6.2 State Facilities

The vulnerability of state facilities to fire-related hazards, especially wildfires, is currently difficult to determine based on the current, best available data. There is a lack of consistent data on previous wildfire and man-made fire occurrences.

To estimate the potential losses to state-owned and leased structures, the exposure analysis methodology was used. As discussed, there are 6,765 state-owned/leased structures in the Commonwealth. Table 9-12 identifies a total risk exposure of nearly $12 billion for state-owned and leased buildings located in the wildfire interface and intermix defined areas. 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; wildfire events are generally centered within one region. Table 9-13 shows the data by state agency.

TABLE 9-12.
STATE-OWNED AND LEASED BUILDING TOTAL REPLACEMENT COST VALUE IN THE WILDLAND INTERFACE AND INTERMIX HAZARD AREAS BY COUNTY

	Interface			Intermix			
County	Total	Lease	Own	Total	Lease	Own	**Total**
Barnstable	$44,637,882	$1,595,866	$43,042,016	$95,343,083	$491,878	$94,851,205	**$139,980,965**
Berkshire	$530,375,094	$13,284,214	$517,090,880	$127,765,291	—	$127,765,291	**$658,140,384**
Bristol	$1,534,740,918	$18,277,046	$1,516,463,872	$304,402,166	$26,656,280	$277,745,886	**$1,839,143,084**
Dukes	$464,164	$258,630	$205,534	$5,616,788	$5,600,628	$16,160	**$6,080,952**
Essex	$708,204,263	$4,049,738	$704,154,525	$527,884,186	$2,287,220	$525,596,966	**$1,236,088,449**
Franklin	$301,871,994	$6,694,462	$295,177,532	$51,106,274	$7,039,124	$44,067,150	**$352,978,268**
Hampden	$1,049,482,689	$365,236	$1,049,117,453	$1,218,620,128	—	$1,218,620,128	**$2,268,102,817**
Hampshire	$267,112,756	$2,511,492	$264,601,264	$403,629,950	$6,998,780	$396,631,170	**$670,742,706**
Middlesex	$583,738,604	$24,356,128	$559,382,476	$140,315,439	$35,195,000	$105,120,439	**$724,054,043**
Nantucket	$30,440,058	—	$30,440,058	—	—	—	**$30,440,058**
Norfolk	$165,630,179	$18,544,430	$147,085,749	$154,357,257	$34,979,740	$119,377,517	**$319,987,436**
Plymouth	$383,496,267	$29,754,132	$353,742,135	$88,823,186	$4,697,826	$84,125,360	**$472,319,452**
Suffolk	$59,166,953	$34,990,160	$24,176,793	—	—	—	**$59,166,953**
Worcester	$1,941,733,753	$66,047,410	$1,875,686,343	$1,275,536,057	$4,978,096	$1,270,557,961	**$3,217,269,810**
Total	**$7,601,095,574**	**$220,728,944**	**$7,380,366,630**	**$4,393,399,804**	**$128,924,572**	**$4,264,475,232**	**$11,994,495,378**

TABLE 9-12.
STATE-OWNED AND LEASED BUILDING TOTAL REPLACEMENT COST VALUE IN THE WILDLAND INTERFACE AND INTERMIX HAZARD AREAS BY COUNTY

Source: DCAMM, 2011; Radeloff et.al, 2011

TABLE 9-13.
STATE OWNED AND LEASED BUILDING TOTAL REPLACEMENT COST VALUE IN THE WILDFIRE INTERFACE AND INTERMIX HAZARD AREAS BY STATE AGENCY

Agency	Interface	% of Total	Intermix	% of Total	Grand Total
Berkshire Community College	$3,947,460	100%	—	—	$3,947,460
Bridgewater State University	$288,921,896	100%	—	—	$288,921,896
Bristol Community College	$374,953,386	100%	—	—	$374,953,386
Committee for Public Counsel Services	$1,328,686	73.0%	$491,878	27%	$1,820,564
Department of Children and Families	$18,519,580	66.7%	$9,253,244	33.3%	$27,772,824
Department of Conservation and Recreation	$423,153,212	39.0%	$661,499,872	61%	$1,084,653,084
Department of Corrections	$368,610,042	98.2%	$6,637,074	1.8%	$375,247,116
Department of Developmental Services	$419,033,633	30.3%	$962,115,024	69.7%	$1,381,148,657
Department of Environmental Protection	$36,697,708	100%	—	—	$36,697,708
Department of Fire Services	—	—	$24,773,903	100%	$24,773,903
Department of Fish and Game	$31,466,488	63.1%	$18,391,109	36.9%	$49,857,596
Department of Industrial Accidents	$2,608,746	100%	—	—	$2,608,746
Department of Mental Health	$224,884,797	61.9%	$138,475,854	38.1%	$363,360,651
Department of Public Health	$8,286,054	67.5%	$3,991,418	32.5%	$12,277,472
Department of State Police	$69,095,545	43.8%	$88,772,282	56.2%	$157,867,827
Department of Transitional Assistance	$1,916,482	16.3%	$9,862,148	83.7%	$11,778,630
Department of Transportation	$413,272,472	64.6%	$226,603,261	35.4%	$639,875,733
Department of Veterans Services	—	—	$12,463,486	100%	$12,463,486
Department of Workforce Development	$1,068,720	100%	—	—	$1,068,720
Division of Banks	$720,050	100%	—	—	$720,050
Division of Capital Asset Management	$21,089,904	5.9%	$336,162,314	94.1%	$357,252,218
Executive Office of Energy & Environmental Affairs	$391,418	100%	—	—	$391,418
Executive Office of Health & Human Services	—	—	$9,542,868	100%	$9,542,868
Fitchburg State University	$656,814,401	99.8%	$1,237,534	0.2%	$658,051,935
Greenfield Community College	$187,325	100%	—	—	$187,325
Holyoke Community College	$403,189,126	100%	—	—	$403,189,126
Massachusetts Department of Revenue	$9,430,654	100%	—	—	$9,430,654
Massachusetts State Lottery Commission	$1,238,380	3%	$39,520,196	97%	$40,758,576
Massachusetts College of Liberal Arts	$149,977,109	81.6%	$33,748,500	18.4%	$183,725,609
Massachusetts Maritime Academy	$82,214	100%	—	—	$82,214
Massachusetts National Guard	$383,440	100%	—	—	$383,440
Massachusetts Rehabilitation Commission	$3,935,294	60.6%	$2,561,454	39.4%	$6,496,748
Massasoit Community College	$4,381,321	100%	—	—	$4,381,321
Military Division	$149,669,355	98.2%	$2,816,978	1.8%	$152,486,333

TABLE 9-13.
STATE OWNED AND LEASED BUILDING TOTAL REPLACEMENT COST VALUE IN THE WILDFIRE INTERFACE AND INTERMIX HAZARD AREAS BY STATE AGENCY

Agency	Interface	% of Total	Intermix	% of Total	Grand Total
Mount Wachusett Community College	$465,331,139	100%	—	—	$465,331,139
Municipal Police Training Committee	$1,469,490	100%	—	—	$1,469,490
Northern Essex Community College	—	—	$236,707,604	100%	$236,707,604
Office of the Chief Medical Examiner	$365,236	100%	—	—	$365,236
Office of the D.A. Cape & Island	$1,595,866	100%	—	—	$1,595,866
Office of the D.A. Northern	$2,229,082	100%	—	—	$2,229,082
Office of the D.A. Northwestern	$3,067,760	100%	—	—	$3,067,760
Office of the State Auditor	$3,071,502	100%	—	—	$3,071,502
Quinsigamond Community College	$2,986,432	100%	—	—	$2,986,432
Sheriff's Department Berkshire	$171,337,298	100%	—	—	$171,337,298
Sheriff's Department Bristol	—	—	$59,784,324	100%	$59,784,324
Sheriff's Department Essex	$2,764,602	54.7%	$2,287,220	45.3%	$5,051,822
Sheriff's Department Franklin	$102,865,098	100%	—	—	$102,865,098
Sheriff's Department Hampden	$607,535,874	100%	—	—	$607,535,874
Sheriff's Department Hampshire	—	—	$94,653,804	100%	$94,653,804
Sheriff's Department Worcester	$2,156,850	100%	—	—	$2,156,850
State Reclamation and Mosquito Control Board	—	—	$2,624,508	100%	$2,624,508
Trial Court	$718,553,239	37.9%	$1,174,986,206	62.1%	$1,893,539,445
University of Massachusetts at Amherst	$266,570,526	53.3%	$233,435,740	46.7%	$500,006,266
University of Massachusetts at Dartmouth	$735,332,160	100%	—	—	$735,332,160
Westfield State University	$33,913,930	100%	—	—	$33,913,930
Worcester State University	$390,694,594	100%	—	—	$390,694,594
Total	**$7,601,095,574**	**63.4%**	**$4,393,399,804**	**36.6%**	**$11,994,495,378**

Source: DCAMM, 2011; Radeloff et.al, 2011

Given the limitations of this methodology, the mitigation strategy identifies activities to advance the accuracy of the wildfire potential loss estimates. This includes the state agency review and validation of the owned and leased structure data in terms of location, replacement cost value of structure and contents, and all relevant attributes for analysis.

9.6.3 Critical Facilities

Similar to the state facilities, to estimate potential losses to critical facilities and infrastructure, the exposure analysis methodology was used. The replacement cost values for critical facilities were not available for this planning effort. A total risk exposure would equal to the full replacement value of each critical facility exposed. As these data become available, the Commonwealth will update this section of the plan with new information. In terms of highway bridges, the Hazus-MH v. 2.1 default replacement cost value for the bridges in the wildfire hazard areas is $10.9 Billion (of the greater than $68 Billion total).

9.6.4 Economy

As stated earlier, wildfire events can have major economic impacts on a community from the initial loss of structures and the subsequent loss of revenue from destroyed business and decrease in tourism.

According to the wildland hazard areas from Radeloff, et al., based on the 2010 Census, the intermix hazard area contains 476,934 housing units (or approximately 17-percent of the total housing units in the Commonwealth).The interface hazard area contains 715,209 housing units (or approximately 26-percent of the total housing units in the Commonwealth).

To estimate the total potential loss of buildings in the Commonwealth, the wildfire hazard areas were overlaid upon the default general building stock in Hazus-MH based on the U.S. Census 2000 data. Table 9-14 summarizes the estimated replacement cost value of the general building stock in the Commonwealth located in the interface and intermix hazard areas, summarized by County.

TABLE 9-14
ESTIMATED POTENTIAL BUILDING LOSS (STRUCTURE AND CONTENT)
IN THE WILDLAND INTERFACE AND INTERMIX

	Replacement Cost Value				
County	Total	Interface	% of Total	Intermix	% of Total
Barnstable	$47,450,250,000	$21,304,885,000	44.9	$24,558,487,000	51.8
Berkshire	$20,566,219,000	$15,329,205,000	74.5	$12,350,966,000	60.1
Bristol	$74,946,506,000	$36,068,531,000	48.1	$30,293,572,000	40.4
Dukes	$4,894,499,000	$3,100,639,000	63.3	$3,219,756,000	65.8
Essex	$100,099,771,000	$38,480,980,000	38.4	$28,948,292,000	28.9
Franklin	$10,130,548,000	$8,464,330,000	83.6	$7,054,574,000	69.6
Hampden	$67,212,508,000	$19,614,174,000	29.2	$18,883,677,000	28.1
Hampshire	$20,961,384,000	$15,678,408,000	74.8	$11,679,123,000	55.7
Middlesex	$244,161,008,000	$79,306,788,000	32.5	$57,977,573,000	23.7
Nantucket	$3,610,072,000	$3,364,579,000	93.2	$1,627,659,000	45.1
Norfolk	$111,344,832,000	$42,949,345,000	38.6	$34,254,477,000	30.8
Plymouth	$70,614,087,000	$40,612,784,000	57.5	$40,616,831,000	57.5
Suffolk	$115,439,212,000	$2,307,078,000	2.0	$519,563,000	0.5
Worcester	$112,858,251,000	$69,937,235,000	62.0	$55,933,034,000	49.6
Total	**$1,004,289,147,000**	**396,518,961,000**	**39.5**	**327,917,584,000**	**32.7**

Source: Hazus-MH v. 2.1; Radeloff et.al, 2011

SECTION 10. FLOOD HAZARDS

10.1 GENERAL BACKGROUND

Floods are among the most frequent and costly natural disasters in terms of human hardship and economic loss—75 percent of federal disaster declarations are related to flooding. Property damage from flooding totals over $5 billion in the United States each year. Flooding often coincides with spring snowmelt and can be a direct result of other frequent weather events, which in Massachusetts include nor'easters, heavy rainstorms, tropical storms, and hurricanes.

For the 2013 update, this hazard profile was significantly enhanced to incorporate updated, best available data. This was done to provide additional information that can be used by state agencies in developing mitigation strategies and by local jurisdictions as they develop mitigation plans and risk assessments. A recap of each declared event has been provided, which includes information concerning severity based on stream gage data as appropriate for the event, when available. The profile also includes a comparison between historical data and current data to demonstrate the changes that have occurred within the State, such as in the case of Repetitive Flood Claims and Severe Repetitive Losses.

10.1.1 Common Types of Floods

The flood-related hazards most likely to affect Massachusetts are riverine (inland) flooding, coastal flooding, and flooding associated with ice jams. Each is described below, along with the sub-categories associated with each hazard type.

Riverine (Inland) Flooding

Riverine or inland flooding often occurs after heavy rain. 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 river flooding. Some of the worst riverine flooding in Massachusetts occurred without snowmelt and as a result of strong nor'easter storms and tropical storms. Tropical storms can produce very high rainfall rates and volumes of rain that can generate high runoff when soil infiltration rates are exceeded. Inland flooding in Massachusetts is forecast and classified by the National Weather Service's Northeast River Forecast Center as minor, moderate, or severe based upon the types of impacts that occur. Minor flooding is considered a "nuisance only" degree of flooding that causes impacts such as road closures and flooding of recreational areas and farmland. Moderate flooding can involve land with structures becoming inundated. Major flooding is a widespread, life-threatening event. River forecasts are made at many locations in the state containing USGS river gages, with established flood elevations and levels corresponding to each of the degrees of flooding.

Urban Drainage Flooding

Urban drainage flooding entails floods caused by increased water runoff due to urban development and drainage systems. 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 a closed conveyance system that channels water away from an urban area 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 the surface water takes to reach surrounding streams, flooding can occur more quickly and reach greater depths than if there were no urban development at all (Wright, 2008).

In urban areas, basement, roadway, and infrastructure flooding can result in significant damage due to poor or insufficient storm water drainage.

- ***Overbank flooding*** occurs when water in rivers and streams flows into the surrounding floodplain, or "any area of land susceptible to being inundated by floodwaters from any source." (FEMA, 2011b)
- ***Flash floods*** are characterized by "rapid and extreme flow of high water into a normally dry area, or a rapid rise in a stream or creek above a predetermined flood level." (FEMA, 2011b)

Coastal Flooding

Coastal flooding generally occurs along the coasts of oceans, bays, estuaries, coastal rivers and large lakes. Coastal floods are the submersion of land areas along the ocean coast and other inland waters caused by seawater over and above normal tide action. Coastal flooding is a result of the storm surge where local sea levels rise often resulting in weakening or destruction of coastal structures. Hurricanes and severe storms, including nor'easters, cause most coastal flooding. Nor'easters are severe storms that occur in the Atlantic basin that are extra-tropical in nature with winds out of the northeast (FEMA, Date Unknown). Coastal flooding not only results in the many problems identified for riverine flooding but could also include additional problems such as beach erosion, loss or submergence of wetlands and other coastal ecosystems, saltwater intrusion, high water tables, loss of coastal recreation areas, beaches, protective sand dunes, parks and open space, and loss of coastal structures (sea walls, piers, bulkheads, bridges, or buildings).

According to the 2011 Coastal Construction Manual, FEMA P-55, Zone V identifies the Coastal High Hazard Area, which is the portion of the special flood hazard area (SFHA) that extends from offshore to the inland limit of a primary frontal dune along an open coast and any other portion of the SFHA that is subject to high-velocity wave action from storms or seismic sources. The boundary of Zone V is generally based on wave heights (3 feet or greater) or wave run-up depths (3 feet or greater). Zone V can also be mapped based on the wave overtopping rate (when waves run up and over a dune or barrier). Zone A or AE, identify portions of the SFHA that are not within the Coastal High Hazard Area. These zones are used to designate both coastal and non-coastal SFHAs. Regulatory requirements of the National Flood Insurance Program (NFIP) for buildings located in Zone A are the same for both coastal and riverine flooding hazards. Zone AE in coastal areas is divided by the limit of moderate wave action (LiMWA). The LiMWA represents the landward limit of the 1.5-foot wave.

The area between the LiMWA and the Zone V limit is known as the Coastal A Zone for building codes and standard purposes and as the Moderate Wave Action area by FEMA flood mappers. This area is subject to wave heights between 1.5 and 3 feet during the base flood. The area between the LiMWA and the landward limit of Zone A due to coastal flooding is known as the Minimal Wave Action area, and is subject to wave heights less than 1.5 feet during the base flood (FEMA P-55, 2011). Figure 10-1 is a typical transect illustrating Zone V, the Coastal A Zone and Zone A, and the effects of energy dissipation and regeneration of a wave as it moves inland. Wave elevations are decreased by obstructions such as vegetation and rising ground elevation.

Source: FEMA P-55, 2011

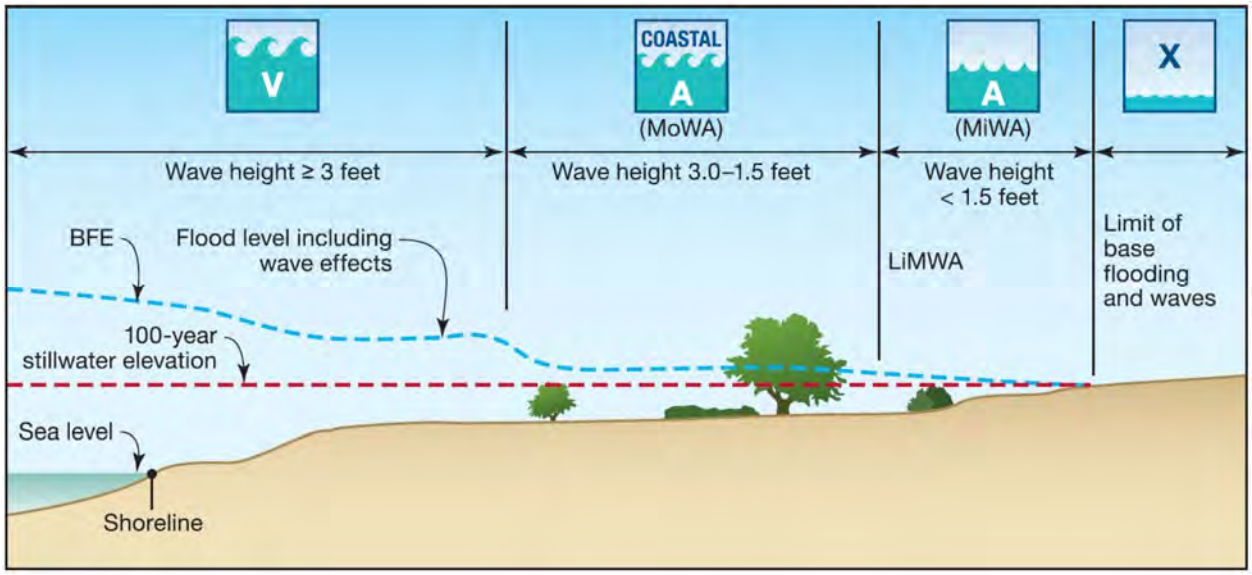


Figure 10-1. Typical Transect Schematic.

Ground Failures

Flooding and flood-related erosion can result from various types of ground failures, which include mud floods and mudflows, and to a much lesser degree subsidence, liquefaction, and fluvial erosion.

- ***Mud floods*** are floods that carry large amounts of sediment, which can at times exceed 50% of the mass of the flood, and often occur in drainage channels and adjacent to mountainous areas. Mudflows are a specific type of landslide that contain large amounts of water and can carry debris as large as boulders. Both mudflows and mud floods result from rain falling on exposed terrain, such as that impacted by wildfires or logging. Mud floods and mudflows can lead to large sediment deposits in drainage channels. In addition to causing damage, these events can exacerbate subsequent flooding by filling in rivers and streams.
- ***Subsidence*** is the process where the ground surface is lowered from natural processes, such as consolidation of subsurface materials and movements in the Earth's crust, or from manmade activities such as mining, inadequate fill after construction activity, and oil or water extraction. When ground subsides, it can lead to flooding by exposing low-lying areas to ground water, tides, storm surges, and areas with a high likelihood of overbank flooding.
- ***Liquefaction***, or when water-laden sediment behaves like a liquid during an earthquake, can result in floods of saturated soil, debris, and water if it occurs on slopes. Floods from liquefaction are especially common near very steep slopes.
- ***Fluvial Erosion*** is the process where the river undercuts a bank, usually on the outside bend of a meander, causing sloughing and collapse of the riverbank. Fluvial erosion can also include scouring and downcutting of the stream bottom, which can be a problem around bridge piers and abutments. In hillier terrain where streams may lack a floodplain, fluvial erosion may cause more property damage than inundation. Furthermore, fluvial erosion can often occur in areas that are not part of the 100 or 500 years floodplain.

Ice Jam

An ice jam is an accumulation of ice that acts as a natural dam and restricts flow of a body of water. There are two types of ice jams: a freeze up and a breakup jam. A freeze up jam usually occurs 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 break up jam forms as a result of the breakup of ice cover at ice-out, causing large pieces of ice to 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 often 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 (CRREL), currently consists of over 18,000 records from across the U.S.

10.1.2 Measuring Floods

The frequency and severity of flooding are measured using a discharge probability, which is the probability that a certain river discharge (flow) level will be equaled or exceeded in a given year. Flood studies use historical records to determine the probability of occurrence for the different discharge levels. The flood frequency equals 100 divided by the discharge probability. For example, the 100-year discharge has a 1-percent chance of being equaled or exceeded in any given year. The “annual flood” is the greatest flood event expected to occur in a typical year. These measurements reflect statistical averages only; it is possible for two or more floods with a 100-year or higher recurrence interval to occur in a short time period. The same flood can have different recurrence intervals at different points on a river.

Flood flows in Massachusetts are measured at numerous USGS stream gages. The gages operate routinely, but particular care is taken to measure flows during flood events to calibrate the stage-discharge relationships at each location and to document actual flood conditions. Typically in the aftermath of a flood event, USGS will determine the recurrence interval of the event using data from the gage’s period of historical record.

The 100-Year Flood

The term “100-year flood” is misleading. It is not the flood that will occur once every 100 years. Rather, it is the flood that has a one percent chance of being equaled or exceeded each year. Thus, the 100-year flood could occur more than once in a relatively short period of time. The 100-year flood, which is the standard used by most federal and state agencies, is used by the NFIP as the standard for floodplain management and to determine the need for flood insurance. A structure located within an SFHA shown on an NFIP map on average has a 26 percent chance of suffering flood damage during the term of a 30-year mortgage.

The extent of flooding associated with a 1-percent annual probability of occurrence (the base flood or 100-year flood) is used as the regulatory boundary by many agencies. Also referred to as the SFHA, this boundary is a convenient tool for assessing vulnerability and risk in flood-prone communities. Many communities have maps that show the extent and likely depth of flooding for the base flood. Corresponding water-surface elevations describe the elevation of water that will result from a given discharge level, which is one of the most important factors used in estimating flood damage.

The 500-Year Flood

The term “500-year flood” is the flood that has a 0.2-percent chance of being equaled or exceeded each year. The 500-year flood could occur more than once in a relatively short period of time. Statistically, the 0.2-percent (500-year) flood has a 6-percent chance of occurring during a 30-year period of time, the length of many mortgages.

For insurance purposes on FIRMS, areas outside the SFHA are identified as Zones X, B, or C. Zone B and shaded Zone X are areas within the 500-year floodplain. Zone C and unshaded Zone X are areas outside the 500-year floodplain. Areas protected by accredited levee systems are mapped as shaded Zone

X (FEMA P-55, 2011). Flood elevations or depths are not shown within this zone and insurance purchase is not required in this zone.

10.1.3 Floodplains

A floodplain is the area adjacent to a river, creek, or lake that becomes inundated during a flood. Floodplains may be broad, as when a river crosses an extensive flat landscape, or narrow, as when a river is confined in a canyon. In general, flooding can be defined as a rising and overflowing of a body of water onto normally dry land.

By their very nature, floodplains are the low, flat, periodically flooded lands adjacent to rivers, lakes, and oceans and subject to geomorphic (land-shaping) and hydrologic (water flow) processes. It is only during and after major flood events that the connections between a river and its floodplain become more apparent. These areas form a complex physical and biological system that not only supports a variety of natural resources, but also provides natural flood storage and erosion control. When a river is separated from its floodplain with levees and other flood control facilities, then natural, built-in benefits are lost, altered, or significantly reduced. Figure 10-2 depicts the flood hazard area, the flood fringe, and the floodway areas of a floodplain.

Source: North Carolina Department of Crime and Public Safety Floodplain Management Branch, 2008

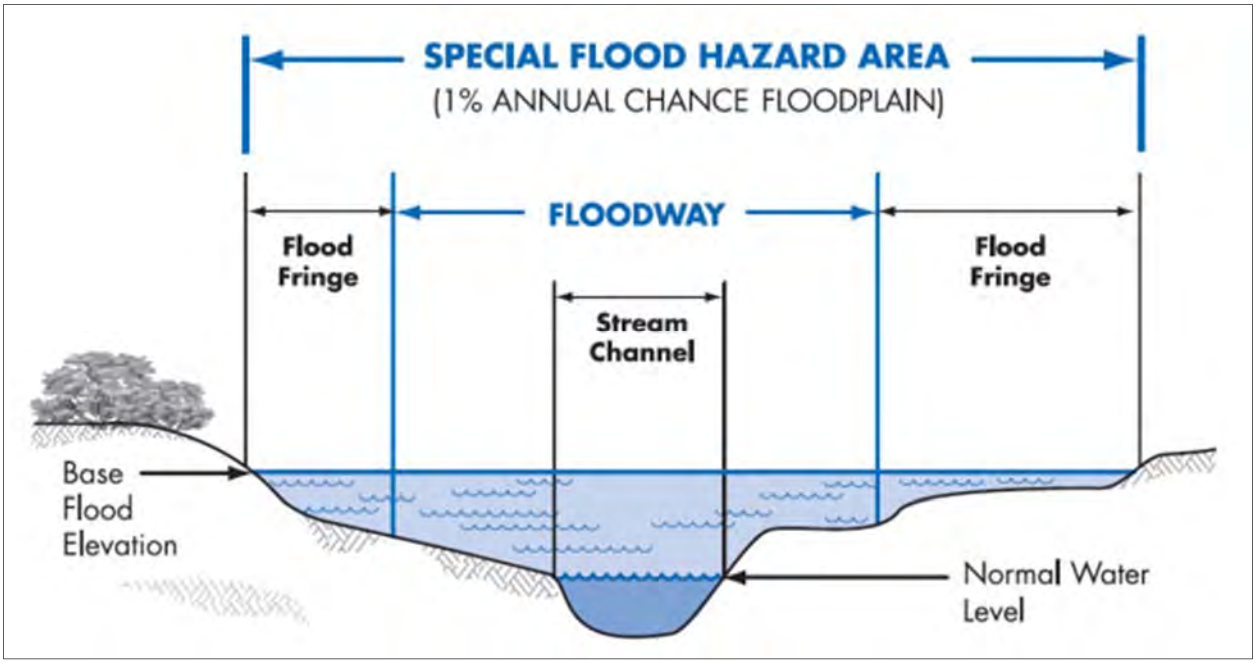


Figure 10-2. Special Flood Hazard Area

When floodwaters recede after a flood event, they leave behind layers of rock and mud. These gradually build up to create a new floor of the floodplain. Floodplains generally contain unconsolidated sediments known as alluvium (accumulations of sand, gravel, loam, silt, and/or clay), often extending below the bed of the stream. These sediments provide a natural filtering system, with water percolating back into the ground and replenishing groundwater. These are often important aquifers, the water drawn from them being filtered compared to the water in the stream.

Base flood elevations and the boundaries of the 1-percent annual chance (100-year) floodplains and the 0.2-percent annual chance (500-year) floodplains are shown on Flood Insurance Rate Maps, which are the principal tool for identifying the extent and location of the flood hazard. The FIRMs depict SFHAs—areas subject to inundation from the 1-percent-annual-chance flood (also known as the base flood or the 100-year flood). Those areas are defined as follows:

- Zones A1-30 and AE: SFHAs that are subject to inundation by the base flood, determined using detailed hydraulic analysis. Base Flood Elevations are shown within these zones.
- Zone A (Also known as Unnumbered A Zones): SFHAs where, because detailed hydraulic analyses have not been performed, no Base Flood Elevations or depths are shown.
- Limit of Moderate Wave Action: Zone AE in coastal areas is divided by the LiMWA. The LiMWA represents the landward limit of the 1.5-foot wave. The area between the LiMWA and the Zone V limit is known as the Coastal A Zone for building code and standard purposes and as the Moderate Wave Action area by FEMA flood mappers. This area is subject to wave heights between 1.5 and 3 feet during the base flood. The area between the LiMWA and the landward limit of Zone A due to coastal flooding is known as the Minimal Wave Action area, and is subject to wave heights less than 1.5 feet during the base flood.
- Zone AO: SFHAs that are subject to inundation by types of shallow flooding where average depths are between 1 and 3 feet. These are normally areas prone to shallow sheet flow flooding on sloping terrain.
- Zone VE, V1-30: also referred to as Coastal High Hazard Areas, are identified as the entire extent of the primary frontal dunes (dunes closest to the beach) and the areas with projected 3-foot or greater wave heights, and/or projected 3-foot or greater wave run-up depths (the rush of the breaking waves) during a 1% chance storm, and/or the wave overtopping splash zone (area extending 30 feet landward of a seawall overtopped by waves).
- Zone B and X (shaded): Zones where the land elevation as been determined to be above the Base Flood Elevation, but below the 500 year flood elevation. These zones are not SFHAs.
- Zones C and X (unshaded): Zones where the land elevation has been determined to be above both the Base Flood Elevation and the 500-year flood elevation. These zones are not SFHAs.

Floodplain Ecosystems

Floodplains can support ecosystems that are rich in plant and animal species. A floodplain can contain 100 or even 1,000 times as many species as a river. Wetting of the floodplain soil releases an immediate surge of nutrients: those left over from the last flood, and those that result from the rapid decomposition of organic matter that has accumulated since then. Microscopic organisms thrive and larger species enter a rapid breeding cycle. Opportunistic feeders (particularly birds) move in to take advantage. The production of nutrients peaks and falls away quickly, but the surge of new growth endures for some time. This makes floodplains valuable for agriculture. Species growing in floodplains are markedly different from those that grow outside floodplains. For instance, riparian trees (trees that grow in floodplains) tend to be very tolerant of root disturbance and very quick-growing compared to non-riparian trees.

Effects of Human Activities

Because they border water bodies, floodplains have historically been popular sites to establish settlements due to the sustenance they provide. Human activities tend to concentrate in floodplains for a number of reasons: water is readily available, land is fertile and suitable for farming, transportation by water is easily accessible, and land is flatter and easier to develop. In addition, during the Industrial Revolution, factories and cities were constructed along river corridors to take advantage of power that was generated by flowing water. This development pattern is particularly evident in Massachusetts, and many dams and canals constructed for industrial purposes remain in the landscape. As a result, Massachusetts' flood plains tend to be relatively heavily developed and highly populated. Human activity in floodplains frequently interferes with the natural function of floodplains. It can affect the distribution and timing of drainage, thereby increasing flood problems. Human development can create local flooding problems by altering or confining drainage channels. This increases flood potential in two ways: it reduces the stream's capacity to contain flows and it increases flow rates or velocities downstream during all stages of a flood

event. Human activities can interface effectively with a floodplain as long as steps are taken to mitigate the activities' adverse impacts on floodplain functions.

10.2 HAZARD PROFILE

10.2.1 Location

Flooding in Massachusetts is often the direct result of frequent weather events such as coastal storms, nor'easters, heavy rains, tropical storms, and hurricanes.

Riverine Flooding

Riverine, or inland flooding, affects the majority of communities in the Commonwealth. Massachusetts encompasses 28 watershed areas; (including the Atlantic Ocean); the largest watershed completely contained within the state is the Chicopee River Watershed, which covers more than 720 square miles. The Chicopee river basin contains the Massachusetts Water Resources Authority's Quabbin Reservoir, which is the largest public water supply reservoir in the Commonwealth, and serves approximately one-third of the state's entire population within the metropolitan Boston area. Also of note are two watersheds that contain regionally significant rivers: the Connecticut River, which flows south from the New Hampshire/Vermont state line, and flows through the state of Connecticut from Massachusetts. In Massachusetts, the Deerfield, Millers, Chicopee, and Westfield watersheds are all tributaries to the Connecticut River. These high-relief areas encompass much of central Massachusetts and have experienced less development as a result of steeper slopes. The Merrimack River flows south from the White Mountains of New Hampshire and into northeast Massachusetts before discharging to the Atlantic Ocean. Tributaries to the Merrimack River in Massachusetts include the Nashua and Shawsheen watersheds. In addition to the Merrimack, the Blackstone River in south central Massachusetts was highly industrialized and has a large number of dams. The Blackstone River flows into Rhode Island and ultimately discharges to Narragansett Bay. The watersheds of eastern Massachusetts tend to have lower elevations and relief, less winter snowpack development, and are less prone to riverine flooding. In particular, the south coastal, Cape Cod and Islands basins have very little vertical relief, are composed of thick sand deposits with high infiltration rates, and have less flashy and flood-prone rivers. Coastal flooding is generally more of a problem in these areas. Figure 10-3 displays the watersheds of the Commonwealth.

(http://www.mass.gov/eea/air-water-climate-change/preserving-water-resources/mass-watersheds/view-watersheds-by-region.html)

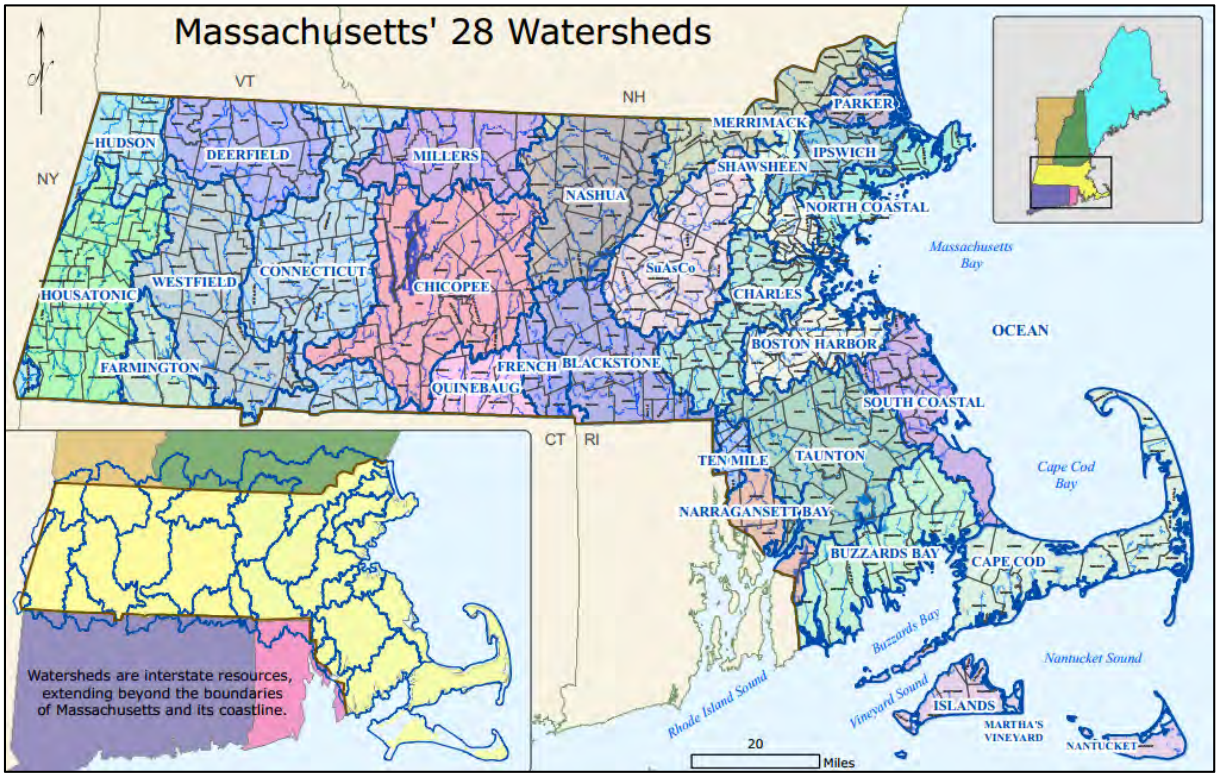


Figure 10-3. Watersheds of Massachusetts

Urban Flooding

Urban flooding resulting from stormwater runoff can occur in every community, and unfortunately, since many of the urban areas have aging infrastructure, poor or insufficient storm water drainage is a common occurrence subsequent to rain events. This problem is exacerbated by increasing development, which results in a loss of pervious surfaces (www.noaa.gov, 2006).

Ice Jams

Ice jams can occur across the entire northern United States on rivers and lakes of all sizes. Historically, Farmington River-West Branch, Marsh Brook, Millers River, Quaboag River, and Westfield River-Middle Branch have had the greatest risk of ice jamming. Very little information was available for the older jams. Most of the rivers where the jams occurred are in the western half of the state. Figure 10-4 shows ice jams in Massachusetts between 1934 and 2009.

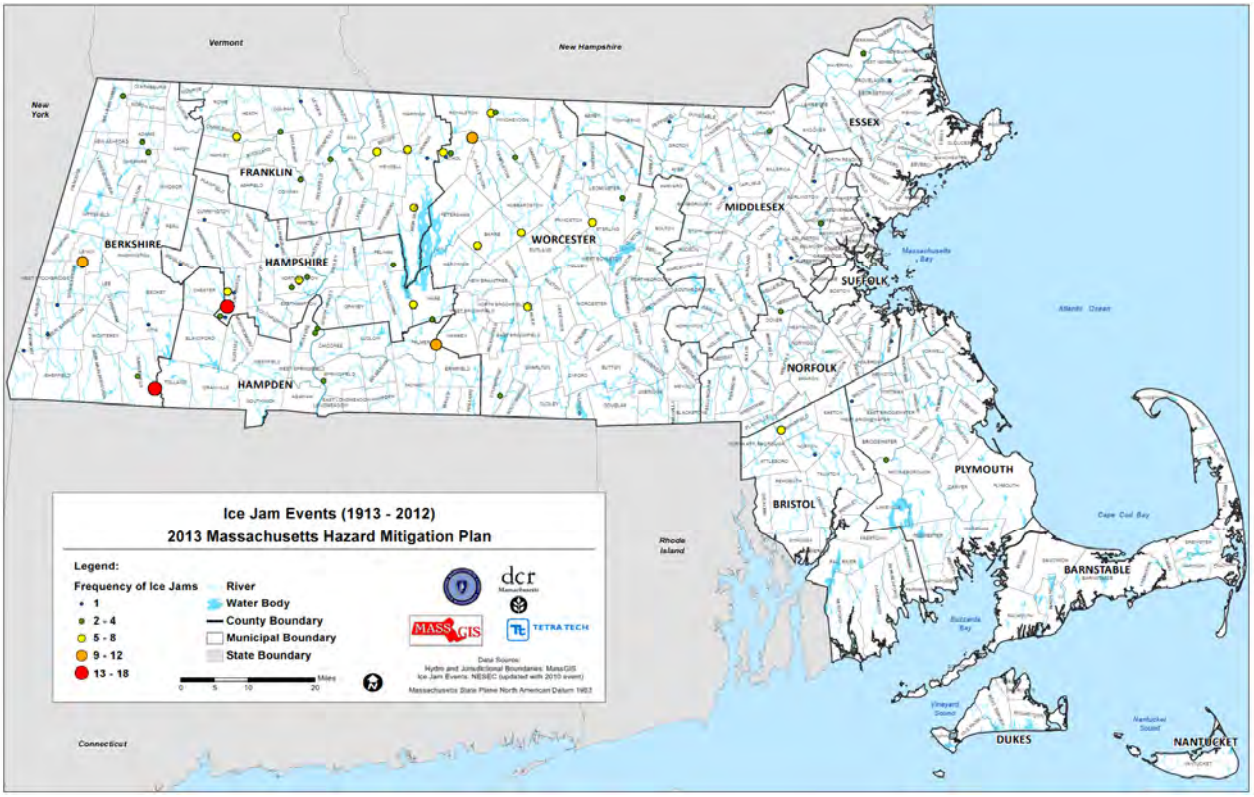


Figure 10-4. Ice Jam Events in Massachusetts (1934—2012)

10.2.2 Previous Occurrences

Flooding in Massachusetts is often the direct result of frequent weather events such as coastal storms, nor'easters, heavy rains, tropical storms, and hurricanes. Flooding in Massachusetts can be caused by one or a combination of factors. Heavy rainfall, snowmelt, and coastal flooding associated with high wind and wave action can all contribute to flooding. The state receives approximately 48 inches of rain per year on average, distributed nearly evenly over the 12 months. Average monthly rainfall is between 3 and 4 inches for all regions of the state. Heavy rainfall events have brought more than 10 inches of rain in a single storm. In almost any antecedent condition, this will result in river flooding.

Over the course of the last 50 years, there have been 20 major flood (or flood-related) events in Massachusetts, including Hurricane Sandy. Coastal counties have experienced the highest numbers of declared flood events. Essex County has had the highest number of declared flood events (16), with Norfolk and Plymouth each sustaining 14, Suffolk sustaining 13, and Middlesex sustaining 12 disaster declarations for flood events.

Riverine, or inland flooding, affects the majority of communities in the Commonwealth. Inland flooding is exacerbated by the effects of orographic lift enhancing precipitation amounts in the higher elevation areas of central and western Massachusetts. In addition, heavy precipitation associated with tropical storms is highest on the left (usually west) side of the tropical storm track, which tends to result in highest rainfall amounts associated with these coastal storms in central and western Massachusetts.

Based on all sources researched, known flooding events that have affected Massachusetts and were declared a FEMA disaster are identified in Table 10-1, which provides detailed information concerning the FEMA declarations for the Commonwealth. Figure 10-5 illustrates the number of FEMA declared disasters by County.

TABLE 10-1.
FEMA FLOOD-RELATED DISASTER DECLARATIONS (1954 TO 2012)

Disaster #	Disaster Type	Declaration Date	Incident Period	Barnstable	Berkshire	Bristol	Dukes	Essex	Franklin	Hampden	Hampshire	Middlesex	Nantucket	Norfolk	Plymouth	Suffolk	Worcester	Number of Counties Impacted
DR-4097	Hurricane Sandy	12/19/12	10/27/12 - 11/8/12	X		X	X						X		X	X		6
DR-4028	Tropical Storm Irene	09/03/11	8/27/11 - 8/29/11	X	X	X	X		X	X	X			X	X			9
DR-1895	Severe Storm and Flooding	03/29/10	3/12/10 - 4/26/10			X		X				X		X	X	X	X	7
DR-1813	Severe Winter Storm and Flooding	01/05/09	12/11/08 - 12/18/08		X			X	X	X	X	X					X	7
DR-1701	Severe Storms and Inland and Coastal Flooding	05/16/07	4/15/07 - 4/25/07	X	X		X	X	X	X	X				X			8
DR-1642	Severe Storms and Flooding	05/25/06	5/12/06 - 5/23/06					X				X				X		3
DR-1614	Severe Storms and Flooding	11/10/05	10/7/05 - 10/16/05		X	X		X	X	X	X	X		X	X		X	10
DR-1512	Flooding	04/21/04	4/1/04 - 4/30/04					X				X		X		X	X	5
DR-1364	Severe Storms & Flooding	04/10/01	3/5/01 - 4/16/01			X		X				X		X	X	X	X	7
DR-1224	Heavy Rain and Flooding	06/23/98	6/13/98 - 7/6/98			X		X				X		X	X	X	X	7
DR-1142	Severe Storms/Flooding	10/25/96	10/20/96 - 10/25/96					X				X		X	X	X		5
DR-975	Winter Coastal Storm	12/21/92	12/11/92 - 12/13/92	X			X	X				X	X	X	X	X	X	9
DR-920	Severe Coastal Storm	11/04/91	10/30/91 - 11/2/91	X			X	X					X	X	X	X		7
DR-914	Hurricane Bob	08/26/91	08/19/91	X		X	X	X		X		X	X	X	X	X	X	11
DR-790	Severe Storms, Flooding	04/18/87	3/30/87 - 4/13/87		X			X	X	X	X	X		X			X	8
DR-751	Hurricane Gloria	10/28/85	09/27/85	X	X	X	X	X	X	X	X	X		X	X	X	X	13
DR-546	Coastal Storms, Flood, Ice, Snow	02/10/78	2/6/78 - 2/8/78	X		X	X	X					X	X	X	X		8
DR-325	Severe Storms, Flooding	03/06/72	03/06/72					X						X	X	X		4
DR-43*	Hurricane, Flood	08/20/55	08/20/55															
DR-22*	Hurricanes	09/02/54	09/02/54															
Total				**8**	**6**	**9**	**8**	**16**	**6**	**7**	**6**	**12**	**5**	**14**	**14**	**13**	**10**	

Note: X indicates that particular county was declared.
* County-specific data not available for declarations prior to 1963

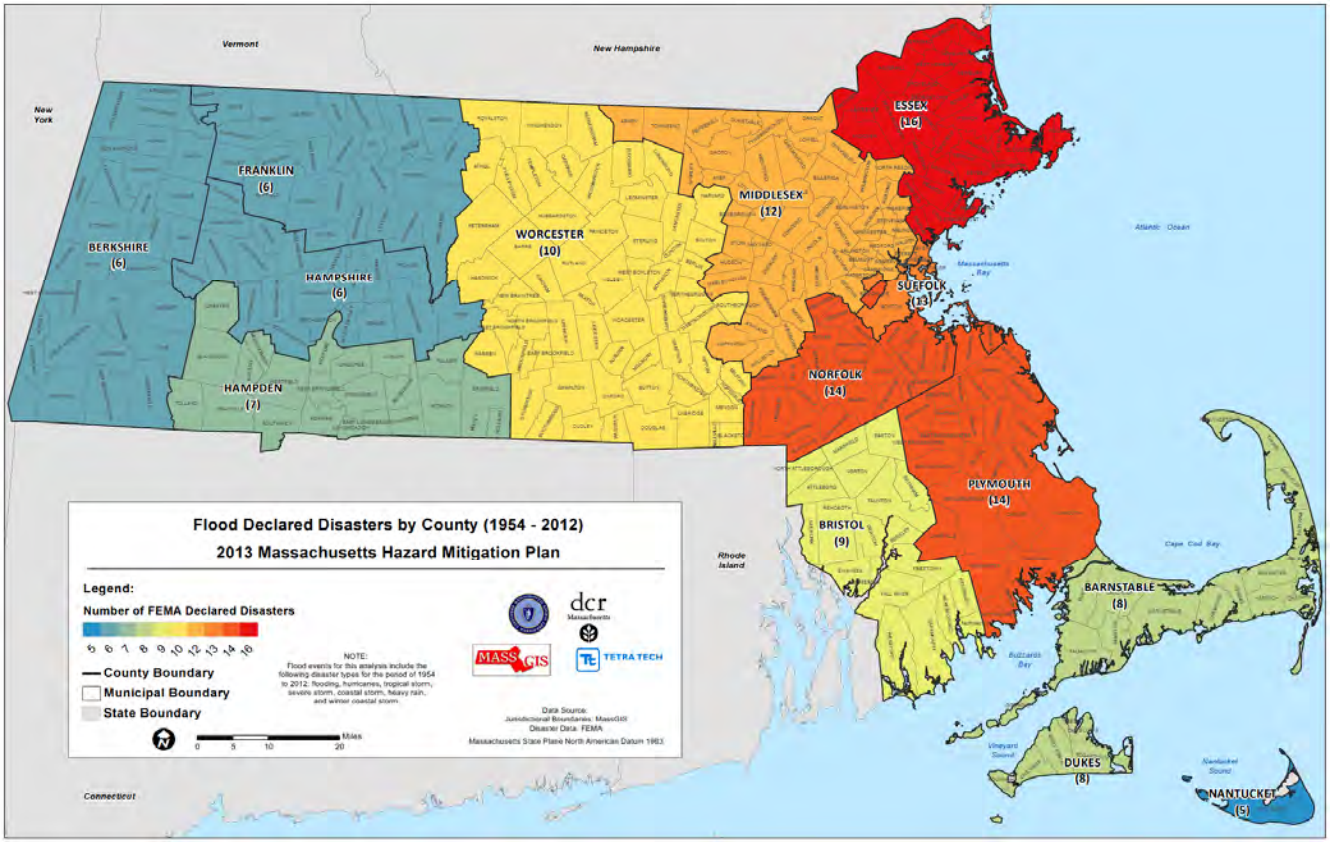


Figure 10-5. Number of FEMA Flood Declared Disasters by County

Hurricanes (FEMA-DR-22)—September 1954

During the summer of 1954, two hurricanes 12-days apart, resulted in widespread coastal damage in southern New England.

Hurricane Carol

On the morning of August 31, 1954 Hurricane Carol, the most destructive hurricane to strike Southern New England since the Great New England Hurricane of 1938, came crashing ashore near Old Saybrook, Connecticut, leaving 65 people dead in her wake. Sustained winds of 80 to 100 mph roared through the eastern half of Connecticut, all of Rhode Island, and most of eastern Massachusetts. Scores of trees and miles of power lines were blown down. Strong winds also devastated crops in the region. Nearly 40 percent of apple, corn, peach, and tomato crops were ruined from eastern Connecticut to Cape Cod. Hurricane Carol arrived shortly after high tide, causing widespread tidal flooding. Narragansett Bay and New Bedford Harbor received the largest surge values of over 14 feet in the upper reaches of both water ways. On Narragansett Bay, just north of the South Street Station site, the surge was recorded at 14.4 feet, surpassing that of the 1938 Hurricane. However, since Hurricane Carol arrived after high tide, the resulting storm tide was lower. The heaviest amounts of rainfall, up to 6 inches, occurred in the New London, Connecticut area in the vicinity of landfall, and across extreme north central Massachusetts. Hurricane Carol destroyed nearly 4,000 homes, along with 3,500 automobiles and over 3,000 boats. All of Rhode Island, much of eastern Connecticut, and much of eastern Massachusetts lost electrical power. In addition, as much as 95 percent of all phone power was interrupted in these locations. Carol is estimated to have been a Category 3 Hurricane [NOAA, 2013 (a)].

Hurricane Edna

Following closely on the heels of Hurricane Carol was Hurricane Edna. Edna made landfall during the morning of September 11, passing over Martha's Vineyard and Nantucket, then across the eastern tip of Cape Cod, Massachusetts. Hurricane force winds of 75 to 95 mph buffeted all of eastern Massachusetts and coastal Rhode Island. Inland, sustained winds of 50 to 70 mph were common west of the Connecticut River Valley. Peak wind gusts included 120 mph on Martha's Vineyard, 110 mph on Block Island, and 100 mph at Hyannis, Massachusetts. The strong winds knocked out electrical power across sections of Rhode Island, eastern Massachusetts, and nearly all of Cape Cod and the Islands. The lowest recorded pressure was 28.02 inches at Edgartown on Martha's Vineyard. Edna arrived during a rising tide and resulted in severe flooding across Martha's Vineyard, Nantucket, and Cape Cod, where storm surges of over 6 feet were common. Farther west, storm surge values were 4 feet or less, resulting in storm tides that remained below flood stage. Damage to the boating community was severe across Cape Cod, but was much less across the remainder of Massachusetts and Rhode Island. Edna's track across the extreme eastern part of the region did result in heavy rainfall and inland flooding.

Rainfall amounts of 3 to 6 inches were common, with over seven inches across northeastern Massachusetts. This rainfall aggravated the already saturated conditions caused by Hurricane Carol ten days earlier. The total combined rainfall for Carol and Edna ranged from 5 to 7 inches along and west of the Connecticut River and over Cape Cod, to as much as 11 inches from southeast Connecticut, across most of Rhode Island, to northeast Massachusetts. Considerable urban and small stream flooding occurred. Numerous street washouts were common, along with some major river flooding in Rhode Island and northeast Massachusetts, where rivers rose several feet above flood stage. Edna was responsible for 21 deaths across the region (Vallee and Dion, Date Unknown).

Hurricane Diane and Flooding (FEMA-DR-43)—August 1955

Hurricane Diane, a Category 3 event, was one of the costliest hurricanes in U.S. history, with estimated total damage exceeding $831 million. The storm brought strong winds (sustained winds of 120 mph) and approximately 16 inches of rain in many areas, which lead to extensive flooding in much of the New England region. Throughout the impacted areas, the hurricane caused between 184 and 200 deaths. In Massachusetts, this event resulted in a FEMA disaster declaration (FEMA-DR-43).

Severe Storms and Flooding (FEMA-DR-325)—March 1972

Detailed information regarding this event was not available. No reference and/or no damage reported. This event did result in a federal disaster declaration (FEMA-DR-325).

Coastal Storms, Flood, Ice, Snow (FEMA-DR-546)—February 1978

The February 1978 Blizzard remains as the benchmark storm for comparison by all subsequent nor'easters. This life-threatening nor'easter crippled most of the state with blizzard conditions, extraordinarily heavy snow, high winds, and devastating coastal flooding. The storm claimed 73 lives in Massachusetts and 26 in neighboring Rhode Island. Over 10,000 people had to be sheltered. An unprecedented ban on non-emergency vehicle traffic lasted for a week in much of eastern Massachusetts.

The timing of the storm exacerbated its impact. This blizzard grew to its full fury during the Monday evening rush hour and caused over 3500 vehicles to be stranded on route 128 alone in eastern Massachusetts with snowfall rates of at least 3 inches per hour and visibility near zero. Boston recorded a wind gust of 79 mph, and the wind peaked out at 93 mph in Chatham. Snowfall generally ranged from 1 to 3 feet with a large swath of 30+ inch amounts in the southwest suburbs of Boston. Snowfall reports included 32.5 inches in Rockport, 27.1 inches in Boston, 20.2 inches in Worcester, and 38.0 inches in Woonsocket, RI.

Major coastal flooding occurred over multiple high tide cycles and destroyed or severely damaged over 2000 homes. This storm set the all-time high water mark (to date) of 15.25 feet above Mean Lower Low

Water at the Boston Harbor National Ocean Service tide gage. Mariner accounts refer to waves in excess of 30 feet just offshore. The storm triggered many harrowing evacuations and rescues along both the North and South Shores. This event did result in a federal disaster declaration (FEMA-DR-546) (Strauss, date unknown).

Hurricane Gloria (FEMA-DR-751)—September 1985

Hurricane Gloria was a powerful Category 4 Cape Verde-type storm that prowled the Atlantic for 13 days, with highest winds of 145 mph. Hugging the coastline, as it made its way north, Gloria crossed Long Island, making landfall at Milford, Connecticut. As it continued northeastward through New England, it became extra tropical over Maine on the 28th. In spite of arriving during low tide, it did cause severe beach erosion along the New England coast, as well as the loss of many piers and coastal roads. There was a moderate storm surge of 6.8 feet in New Bedford, Mass. The storm left over 2,000,000 people without power. It dropped up to 6” of rain in Massachusetts, causing many flooding issues in the region. Overall, casualties were relatively low with 8 deaths, but damage reached $900 million. This event resulted in a federal disaster declaration (FEMA-DR-751).

Severe Storms and Flooding (FEMA-DR-790)—March-April 1987

A pair of spring storms occurring within a few days of one another in March and April 1987 combined with snowmelt to produce record flooding in Massachusetts, Maine, and New Hampshire. The events brought over 8 inches of rainfall to some areas of Massachusetts and combined with already high river conditions to produce major flooding in the Connecticut and Merrimack River basins. In addition, several of the Corps of Engineers dams recorded record pool levels (NOAA, date unknown). This March-April 1987 event resulted in a federal disaster declaration (FEMA-DR-790).

Hurricane Bob (FEMA-DR-914)—August 1991

Formed in the Bahamas, Hurricane Bob made landfall in New England near New Bedford, Mass. with 115 mph winds, cutting a path across Southeastern Massachusetts towards the Gulf of Maine. Peak winds of in excess of 100 mph were recorded in the Towns of Brewster and Truro on Cape Cod. Over 60% of the residents of Southeastern Massachusetts and Southeastern Rhode Island lost power. There were 4 different reports of tornados as Bob came ashore. Buzzards Bay saw a 10- to 15-foot storm surge. A number of south-facing beaches on the islands of Nantucket and Martha’s Vineyard lost 50 feet of beach to erosion. Up to 7” of rain was reported to have fallen throughout New England. Bob was blamed for 18 storm-related deaths. The damage total for Southern New England was set at $1 billion, with $2.5 billion overall damage from the storm. This event resulted in a federal disaster declaration (FEMA-DR-914).

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. Along the Massachusetts coastline, the storm produced 25 foot wave heights on top of a 4 foot high tide. In Boston, the highest tide was 14.3 feet, which was only 1 foot lower than the record from the blizzard of 1978. High waves on top of the storm tide reached about 30 feet. The storm produced heavy rainfall in southeastern Massachusetts, peaking at 5.5 inches. Coastal floods closed several roads, forcing hundreds of people to evacuate. In addition to the high tides, the storm produced strong winds; Chatham recorded a gust of 78 mph. Damage was worst from Cape Ann in northeastern Massachusetts to Nantucket, with over 100 homes destroyed or severely damaged at Marshfield, North Beach, and Brant Point. There were two injuries in the state, although there were no fatalities. Across Massachusetts, damage totaled in the hundreds of millions of dollars. This event resulted in a federal disaster declaration (FEMA-DR-920).

Winter Coastal Storm (FEMA-DR-975)—December 1992

During the 11th to 13th of December 1992, a strong nor'easter affected the Bay State. Impacts included deep and intense snowfall, freezing rain, heavy rainfall near the coast, coastal flooding, and damaging winds.

Storm total snowfall in MA 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 MA, with 6 to 20" over interior eastern MA. 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 during the 11th to 13th, the most damaging storm tide occurring early afternoon on the 12th. The Boston tide gage recorded a peak elevation of 14.21 feet above Mean Lower Low Water, 1 foot below 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 federal disaster declaration (FEMA-DR-975).

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 and 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 river at 53.10 feet with a discharge of 48,600 cubic feet per second. Major roadways were flooded. Many basements of homes were flooded and homes were severely damaged. This flooding event resulted in a federal disaster declaration (FEMA-DR-1142). Damage was estimated at over $60 million.

Heavy Rain and Flooding (FEMA-DR-1224)—June-July 1998

On June 12 through the 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. Another storm on June 30 brought heavy rain and continued the flooding from the previous events. This series of storms resulted in a federal disaster declaration (FEMA-DR-1224).

Severe Storms and Flooding (FEMA-DR-1364)—March-April 2001

A series of storm events occurred in Massachusetts between March 5 and April 16. These events included a major winter storm, heavy rainfall, and melting snow. 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. This series of flooding events resulted in a federal disaster declaration (FEMA-DR-1364).

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. This series of flooding events resulted in a federal disaster declaration (FEMA-DR-1512) and Massachusetts received over $2.7 million in individual assistance.

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 federal disaster declaration (FEMA-DR-1614) and Massachusetts received over $13 million in individual and public assistance.

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, with some areas receiving over 12 inches of rain. Small streams and main stem rivers flooded, some experienced major flooding. Some areas experienced the worst flooding since the 1938 hurricane and the floods of March 1936. There was also paralyzing urban/poor drainage flooding in portions of the northeast, especially in the Peabody area. A state of emergency was declared by the governor and this event resulted in a FEMA disaster declaration (FEMA-DR-1642). This severe storm and flooding event caused two fatalities and the state received over $56 million in individual and public assistance.

Severe Storms and Inland and Coastal 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 main stem and tributaries. This event resulted in a federal disaster declaration (FEMA-DR-1701). Those counties included in this disaster received over $8 million in public assistance from FEMA.

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 (December 11 through 12). 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 ice of ice accreted 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 to 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. This event resulted in a federal disaster declaration (FEMA-DR-1813). Those counties included in the disaster received over $51 million in public assistance from FEMA.

Severe Storm and Flooding Event (FEMA-DR-1895) - March-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 resulted in a federal disaster declaration (FEMA-DR-1895). This series of storms and flooding caused three injuries and over $85 million was received in individual and public assistance.

Tropical Storm 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). These heavy rains caused flooding throughout the Commonwealth and a presidential disaster was declared (FEMA-DR-4028). Tropical Storm Irene was closely followed by the remnants of Tropical Storm Lee, which brought additional heavy rain to Massachusetts and extended flooding. Severe river erosion occurred in northwestern Massachusetts, closing state Route 2 for (how long?). Landslides were also triggered by the heavy rain and wet soil in this area of steep slopes containing layers of glacial lake clay. The Commonwealth received over $31 million in individual and public assistance from FEMA.

Hurricane Sandy (FEMA-DR-4097)—October-November 2012

Hurricane Sandy was the largest Atlantic hurricane on record, with winds spanning 1,100 miles in diameter, reaching sustained forces of 110 mph. Estimated losses due to damage and business interruption are still being calculated, but are estimated to exceed $65 billion. At present count (December 2012), at least 253 people were killed along the path of the storm, with 131 of those deaths occurring within the U.S. although no deaths occurred in Massachusetts.

Ice Jams

According to the CRREL database, ice jams have formed at points along the following water bodies.

- Aberjona River
- Bassett Brook
- Buck River
- Caldwell Creek
- Charles River
- Maple Meadow Brook
- Marsh Brook
- Merrimack River
- Middle Branch Westfield River
- Mill River
- Priest Brook
- Quaboag River
- Quinebaug River
- Rocky Brook
- Saugus River

- Connecticut River
- Deerfield River
- Dorcester Brook
- Dry Brook
- East Meadow River
- Farmington River
- Green River
- Hoosic River
- Hop Brook
- Housatonic River
- Ipswich River
- Kearny Brook
- Millers River
- Moose Brook
- Moss Brook
- Nashoba Brook
- Nashua River
- North Nashua River
- North River
- Old Swamp River
- Otter River
- Parker River
- Schenob Brook
- Sevenmile River
- Swift River
- Sykes Brook
- Taunton River
- Wading River
- Ware River
- West Branch Farmington River
- West Branch Westfield River
- Westfield River

Locations of historical ice jam events are indicated in Figure 10-4. According to the U.S. Army CRREL database, North Central Massachusetts averages at least one ice jam per year for almost the last decade. Only Buck River, Millers River, Nashua River, Westfield River, Nashoba Brook, Otter River, Farmington River, and Westfield River-Middle Branch have seen jams since 1990. The two most recent occurrences were on the Miller's River in February 2008 and the Farmington River in March 2010.

The February 2008 event was reported as chunks of ice 1-2 feet thick, which was released due to runoff from snowmelt, rain, and spring-like conditions in the region. While no flooding was observed, the jam was approximately 1,500 feet long. The March 2010 jam was as a result of high precipitation levels across the Berkshires from March 12 - 13 ranging from 1 1/2 to 3 1/2 inches combining with snowmelt, which caused minor flooding in urban areas and small streams. Route 8 in North Otis was reported closed due to ice chunks in the road left over from an ice jam that broke on the West Branch of the Farmington River. The road was reopened after the ice chunks were cleared.

The CRREL database was queried for all ice jam events that occurred in Massachusetts from 1913 through 2012. Based on review of the CRREL database, 226 ice jam events have occurred in the Commonwealth and took place between 1913 and 2010. These events are listed in Appendix J and summarized by county in Table 10-2. Information regarding losses associated with these reported ice jams was limited.

TABLE 10-2.
NUMBER OF ICE EVENTS BY COUNTY

County	Number of Ice Events, 1913-2012
Worcester	55
Hampshire	55
Franklin	32
Berkshire	24
Barnstable	18
Hampden	14
Middlesex	11
Bristol	6

TABLE 10-2.
NUMBER OF ICE EVENTS BY COUNTY

County	Number of Ice Events, 1913-2012
Essex	5
Norfolk	3
Plymouth	3
Suffolk	0
Dukes	0
Nantucket	0

Source: CRREL

10.2.3 Probability of Future Occurrences

For the purposes of this plan, the frequency of hazard events of disaster declaration proportions is defined by the number of declared disaster events for the Commonwealth over a specified period of time. The historical record indicates the Commonwealth has experienced 20 flood-related disaster declaration occurrences from 1954 to 2012. Table 10-1 summarizes these disasters. Therefore, based on these statistics, the Commonwealth may experience a flood event of disaster declaration proportions once every 3 (2.95) years. It is noted, however, that some areas of the Commonwealth are more flood-prone than others therefore the frequency of flood events, of all sizes, varies based on watershed, riverine reach, and location along each reach.

10.2.4 Severity

As indicated, the principal factors affecting flood damage are flood depth and velocity. The deeper and faster flood flows become, the more damage they can cause. Shallow flooding with high velocities can cause as much damage as deep flooding with slow velocity. This is especially true when a channel migrates over a broad floodplain, redirecting high velocity flows and transporting debris and sediment. Flood severity can also be evaluated by examining peak discharges.

10.2.5 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. Warning times for floods can be between 24 and 48 hours. Flash flooding can be less predictable, but potential hazard areas can be warned in advanced of potential flash flooding danger. Flooding is more likely to occur due to a rain storm when the soil is already wet and/or streams are already running high from recent previous rains (conditions already in place when a storm begins are called “antecedent conditions”). NOAA’s Northeast River Forecast Center provides flood warning for Massachusetts, relying on monitoring data from the USGS stream gage network. Notice of potential flood conditions is generally available five days in advance. State agency staff 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 and the Office of Dam Safety. The National Weather Service provides briefings to state and local emergency managers, as well as notifications to the public via the media and social networking. MEMA also distributes information regarding potential flooding to local Emergency Managers, the press, and the public.

10.3 SECONDARY HAZARDS

The most problematic secondary hazards for flooding are fluvial erosion hazards, river bank erosion, and landslides, which can be more harmful than actual flooding. For instance, fluvial erosion attributed to

Hurricane Irene caused an excess of $23 Million in damage along Route 2. The impacts from these secondary hazards are especially prevalent in the upper courses of rivers with steep gradients, where floodwaters may pass quickly and without much damage, but scour the banks, edging properties closer to the floodplain or causing them to fall in. Flooding is also responsible for hazards such as landslides when high flows over-saturate soils on steep slopes, causing them to fail. The secondary hazards of flooding also affect roadways and bridges by undermining and completely washing out supporting structures. Secondary impacts also include urban flooding with respect to culverts and the associated increased water volume. Dam failures during flood events are of concern in Massachusetts, given the high density of dams constructed in the 19th century. Failure of wastewater treatment plants can occur during floods as well, releasing untreated wastewater directly into rivers and the ocean. Coastal erosion has been a significant hazard on Massachusetts' highly developed shores. In recent years, accelerated erosion has caused the collapse of buildings into the ocean or demolition of buildings at risk of collapse. Hazardous materials spills are also a secondary hazard of flooding if storage tanks rupture and spill into streams, rivers, or storm sewers.

10.4 CLIMATE CHANGE IMPACTS

"Climate change" refers to changes over a long period of time in patterns of temperature, precipitation, humidity, wind, and seasons. Climate change is forecast by some to have significant impacts on the Eastern Seaboard of the United States by mid-21st century. While it is not known if the number of storms will increase in the future as the result of climate changes, it is anticipated that the intensity of tropical and extra-tropical storms may increase as the storm intensity is a function of sea surface temperature, which continue to rise. Thus, we may experience more intense storms with greater rainfall in the future. In addition, recent work by Rawlins et al. (2012) shows that our winter weather will become warmer and wetter with 6% to 14% more precipitation than we receive currently.

Climate plays a fundamental role in shaping ecosystems and the human economies and cultures that depend on them. It is generally perceived that climate change will have a measurable impact on the occurrence and severity of flooding. As hydrology changes, what has historically been considered a 100-year flood may strike more often, leaving many communities at greater risk. Planners and engineers will need to factor a new level of safety into the design, operation, and regulation of flood protection facilities such as dams, floodways, bypass channels, and levees, as well as the design of local roads, sewers, and storm drains.

The amount of snow is critical for water supply and environmental needs, but so is the timing of snowmelt runoff into rivers and streams. Rising snowlines caused by climate change will allow more mountain area to contribute to peak storm runoff during winter months, although spring snowmelt floods may diminish under these conditions. High frequency flood events in particular (e.g. 10-year floods) may increase with a changing climate. Along with reductions in the amount of the snowpack and accelerated snowmelt, scientists project greater storm intensity, resulting in more direct runoff and flooding.

Changes in watershed vegetation and soil moisture conditions will likewise change runoff and recharge patterns. As stream flows and velocities change, erosion patterns will also change, altering channel shapes and depths, possibly increasing sedimentation behind dams, and affecting habitat and water quality. With potential increases in the frequency and intensity of wildfires due to climate change, there is potential for more floods following fire, which increase sediment loads and water quality impacts.

For the State of Massachusetts planning area, climate change is anticipated to impact flood conditions on three fronts—hydrology, sea level rise, and change in coastal landforms—as described in the following hydrology section and in the separate coastal erosion and sea level rise profiles. While many models are currently being developed to assess the potential impacts of climate change, there are currently none available to support flood hazard mitigation planning. As these models are developed in the future, this risk assessment may be enhanced to better measure these impacts.

1.4.1 Hydrology

Temperature changes are an obvious and easily measured change in climate, but atmospheric moisture, precipitation, and atmospheric circulation also change, as the whole system is affected. Radiative forcing alters heating, and at the Earth's surface this directly affects evaporation as well as sensible heating. Further, increases in temperature lead to increases in the moisture-holding capacity of the atmosphere at a rate of about 7% per °C. Together these effects alter the hydrological cycle, especially characteristics of precipitation (amount, frequency, intensity, duration, type) and extremes. In weather systems, convergence of increased water vapor leads to more intense precipitation, but reductions in duration and/or frequency, given that total amounts do not change much. This increase in precipitation has been experienced 5-10% over a 105-year period (1901-2005) studied by the IPCC in the Northeast United States. (IPCC, 2007).

In the last 20 years, the power of tropical storms has doubled (Emanuel, 2013). The increasing intensity of tropical storms is likely to continue in the coming century as ocean waters continue to warm. Additionally, it is thought that rainfall intensity of storms is likely to increase thus causing more inland flooding at both the large watershed level (riverine flooding) and smaller creek level (flash flooding).Overall, the amount of precipitation throughout the Northeast is projected to increase, with winter precipitation increasing 6 to 14% (Rawlins, 2012).

Use of historical hydrologic data has long been the standard of practice for designing and operating water supply and flood protection projects. For example, historical data are used for flood forecasting models and to forecast snowmelt runoff for water supply. This method of forecasting assumes that the climate of the future will be similar to that of the period of historical record. However, the hydrologic record cannot be used to predict changes in frequency and severity of extreme climate events such as floods. Going forward, model calibration or statistical relation development must happen more frequently, new forecast-based tools must be developed, and a standard of practice that explicitly considers climate change must be adopted. Climate change is already affecting water resources, and resource managers have observed the following:

- Historical hydrologic patterns can no longer be solely relied upon to forecast the water future.
- Precipitation and runoff patterns are changing, increasing the uncertainty for water supply and quality, flood management and ecosystem functions.
- Extreme climatic events will become more frequent, necessitating improvement in flood protection and emergency response.

10.5 EXPOSURE

To understand risk, the assets exposed to the hazard areas are identified. For the flood hazard, areas identified as hazard areas include the 1-percent and 0.2-percent (100- and 500-year) floodplains. The following discusses the Commonwealth of Massachusetts exposure to the flood hazard including:

- Population
- State facilities
- Critical facilities and infrastructure
- Economy

To assess the Commonwealth's exposure to the flood hazard, an analysis was conducted with the most current floodplain boundaries. These data include the locations of the FEMA flood zones: the 100-year flood zones or 1-percent annual chance event (including both A zones and V zones) and the 500-year flood zones or 0.2-percent annual chance event. Using ArcMap GIS software, these data were overlaid with the population, general building stock, state facility data (owned and leased), and critical facilities; and the appropriate flood zone determination was assigned.

The newest FEMA FIRM or DFIRMs were used in this analysis, including preliminary DFIRMs provided by the Department of Conservation and Recreation (DCR). Where DFIRMs were not available, Quality 3 (Q3) data were used. Franklin County does not have DFIRMs or Q3 data; however, a digital floodplain layer that had been developed by the Franklin Regional Council of Governments, which only includes the floodplain in those communities along the Connecticut River, was used for this analysis. Table 10-3 and Figure 10-6 summarize the data used for this risk assessment. Figure 10-7 displays the 1- and 0.2-percent flood hazard areas across the Commonwealth.

TABLE 10-3.
DATA USED FOR RISK ASSESSMENT

County	Data Used for 2013 Plan Update	Source
Barnstable	Q3	MassGIS—August 2012
Berkshire	Q3	MassGIS—August 2012
Bristol	DFIRM (July 7, 2009)	DCR - September 2012
Dukes	DFIRM (July 6, 2010)	DCR - September 2012
Essex	DFIRM (July 3, 2012)	DCR - September 2012
Franklin	Digital floodplain layer (1-percent flood event only) for Connecticut River (and some of the tributaries) only (there are no Q3 data for the rest of Franklin County)	DCR - September 2012
Hampden	Revised Preliminary July 13, 2012 DFIRM	DCR - September 2012
Hampshire	Q3	MassGIS—August 2012
Middlesex	DFIRM (June 4, 2010) *Shawsheen Watershed is located partially within Middlesex County The preliminary Risk MAP deliverable for Shawsheen Watershed (2011) was used in place of the data in the 2010 DFIRM database for this area.	DCR - September 2012
Nantucket	Preliminary DFIRM (July 26, 2012)	DCR - September 2012
Norfolk	DFIRM (July 17, 2012) The Town of Canton was not included in the July 17, 2012 Norfolk Countywide Flood Insurance Study or DFIRMs. The Q3 for the Town of Canton was used.	DCR - January 2013
Plymouth	Physical Map Revision to Preliminary DFIRM DB on August 16, 2012 for Marion, Mattapoisett, and Wareham. Remainder of the county has DFIRMs from July 17, 2012.	DCR - September 2012
Suffolk	DFIRM (September 25, 2009)	DCR - September 2012
Worcester	DFIRM (July 4, 2011) The DFIRM is only available for a portion of the County (Auburn, Berlin, Blackstone, Bolton, Boylston, Charlton, Clinton, Douglas, Dudley, Grafton, Harvard, Hopedale, Lancaster, Leicester, Mendon, Milford, Millbury, Millville, Northborough, Northbridge, Oxford, Paxton, Shrewsbury, Southborough, Southbridge, Spencer, Sturbridge, Sutton, Upton, Uxbridge, Webster, West Boylston, Westborough, and Worcester); the Q3 used for the remainder of the County	DCR - September 2012

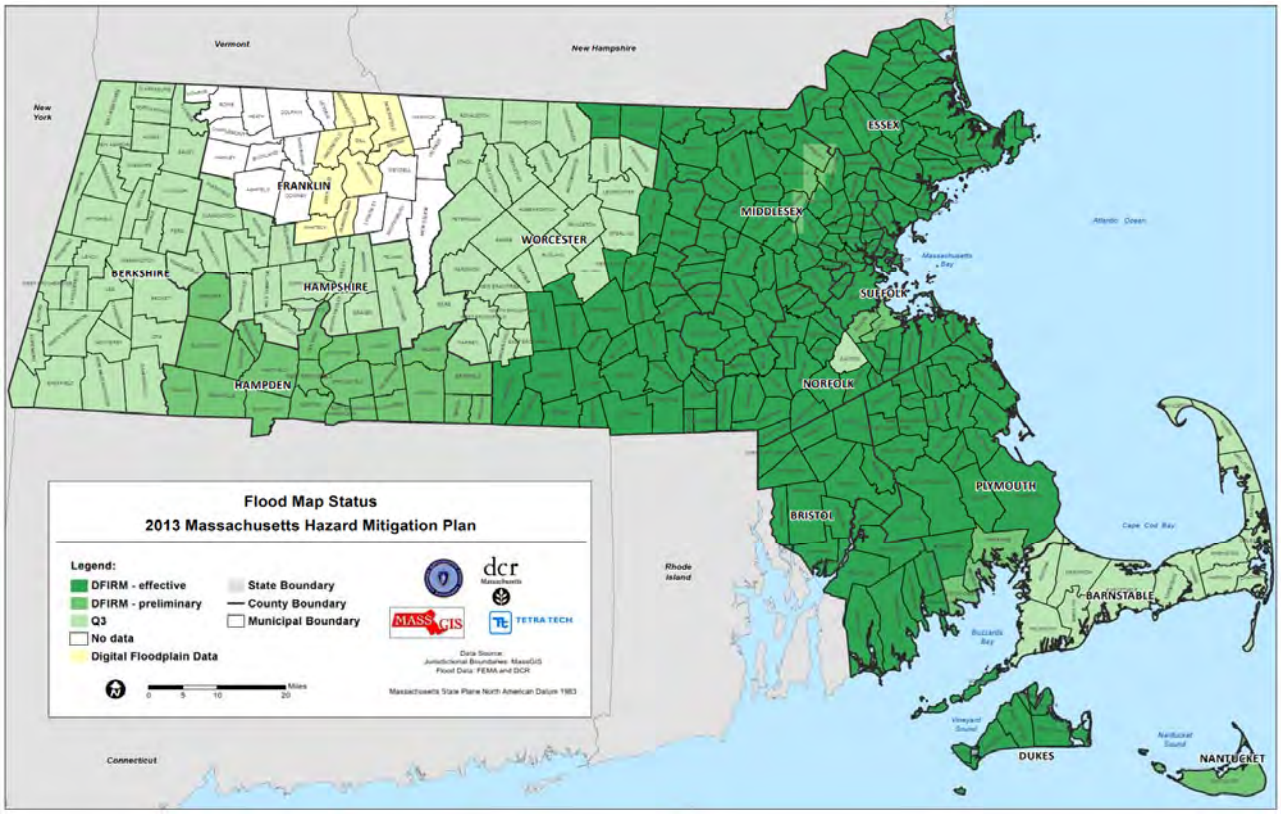


Figure 10-6. FEMA Flood Map Status for the Commonwealth of Massachusetts

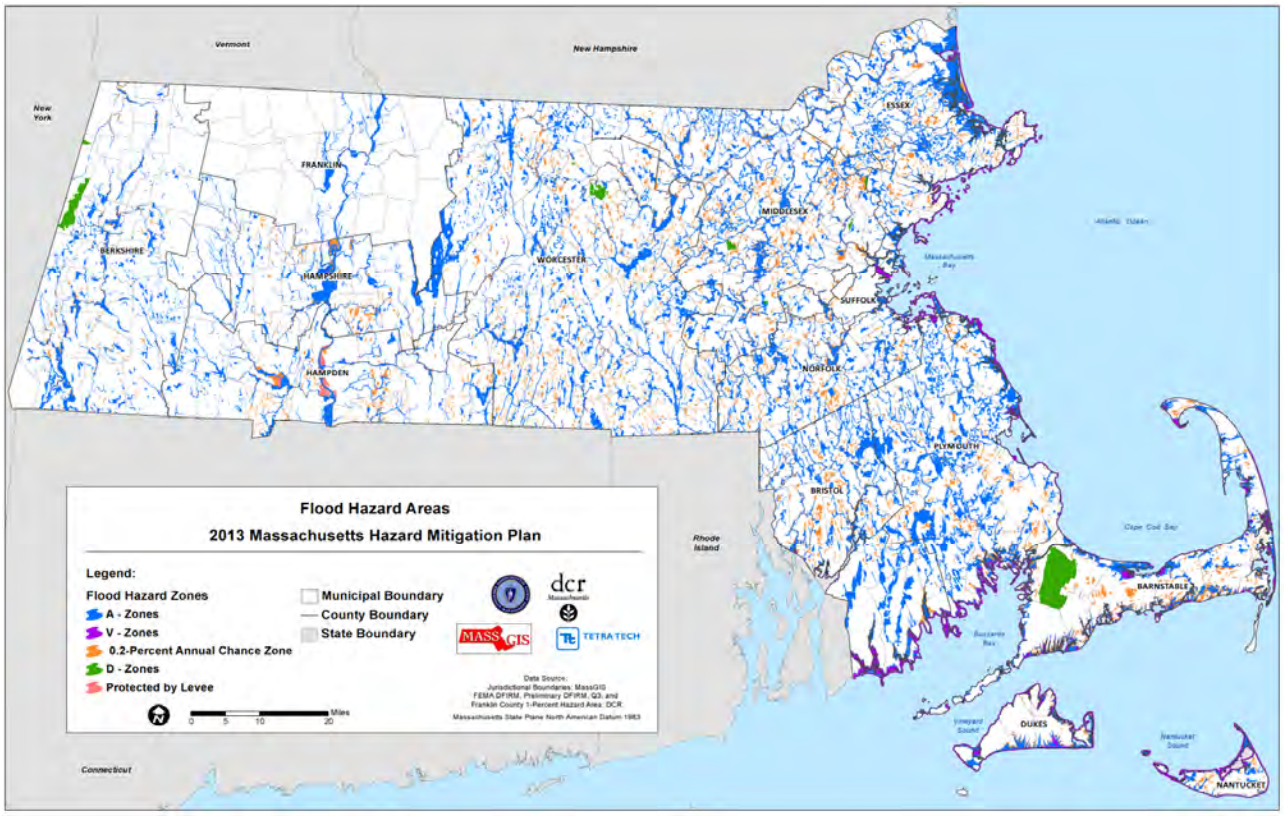


Figure 10-7. FEMA Flood Hazard Areas in the Commonwealth of Massachusetts

10.5.1 Population

The impact of flooding on life, health, and safety is dependent upon several factors including the severity of the event and whether or not adequate warning time is provided to residents. Exposure represents the population living in or near floodplain areas that could be impacted should a flood event occur. Additionally, exposure should not be limited to only those who reside in a defined hazard zone, but everyone who may be affected by the effects of a hazard event (e.g., people are at risk while traveling in flooded areas, or their access to emergency services is compromised during an event). The degree of that impact will vary and is not strictly measurable.

To estimate the population exposed to the 1-percent and 0.2-percent annual chance flood events, the flood hazard boundaries were overlaid upon the 2010 Census block population data in GIS (U.S. Census 2010). Census blocks do not follow the boundaries of the floodplain. The Census blocks with their centroid in the flood boundaries were used to calculate the estimated population exposed to this hazard. Table 10-4 lists the estimated population located within the 1-percent and 0.2-percent flood zones by County. The limitations of this analysis are recognized, and this methodology may over- or underestimate the population exposed.

TABLE 10-4.
ESTIMATED POPULATION EXPOSED TO THE 1-PERCENT AND 0.2-PERCENT ANNUAL CHANCE FLOOD EVENTS

		1-Percent Chance Flood Event						0.2-Percent Chance Flood Event	
		A-Zone		V-Zone		SFHA		X500-Zone	
County	Total 2010 Population	Population	% of Total	Population	% of Total	Population	% of Total	Population	% of Total
Barnstable	215,888	16,335	7.6	1,695	0.8	18,030	8.4	13,283	6.2
Berkshire	131,219	11,064	8.4	0	0.0	11,064	8.4	1,742	1.3
Bristol	548,285	31,059	5.7	2,316	0.4	33,375	6.1	20,178	3.7
Dukes	16,535	511	3.1	68	0.4	579	3.5	377	2.3
Essex	743,159	48,482	6.5	2,799	0.4	51,281	6.9	20,894	2.8
Franklin	71,372	1,270	1.8	0	0.0	1,270	1.8	NA	NA
Hampden	463,490	13,025	2.8	0	0.0	13,025	2.8	13,689	3.0
Hampshire	158,080	6,360	4.0	0	0.0	6,360	4.0	2,436	1.5
Middlesex	1,503,085	56,190	3.7	0	0.0	56,190	3.7	46,520	3.1
Nantucket	10,172	200	2.0	86	0.8	286	2.8	481	4.7
Norfolk	670,850	45,185	6.7	1,236	0.2	46,421	6.9	19,807	3.0
Plymouth	494,919	59,278	12.0	3,914	0.8	63,192	12.8	12,955	2.6
Suffolk	722,023	19,201	2.7	205	0.0	19,406	2.7	7,586	1.1
Worcester	798,552	31,504	3.9	1,695	0.2	33,199	4.2	17,455	2.2
Total	**6,547,629**	**339,664**	**5.2**	**14,014**	**0.2**	**353,678**	**5.4**	**177,403**	**2.7**

10.5.2 State Facilities

To assess the exposure of the state owned and leased facilities provided by DCAMM and the Office of Leasing, an analysis was conducted with the most current floodplain boundaries. Using ArcMap, GIS

software, the flood hazard area data were overlaid with the state facility data and the appropriate flood zone determination was assigned to each facility.

This analysis is much more refined since the 2010 plan due to improved DFIRMs in a number of counties and the more complete state-owned/leased building dataset used—the DCAMM data. Table 10-5 and Table 10-6 summarize the number of state buildings located in the 1-percent and 0.2-percent annual chance flood zones by County. Table 10-7 and Table 10-8 summarize the number of state buildings located in the respective zones by agency. The DCR operates numerous flood control and water recreation areas, which accounts for a large number of the structures in the flood zone.

TABLE 10-5.
2012 STATE BUILDING EXPOSURE TO FLOOD HAZARD BY COUNTY (BUILDING COUNT)

	Number of Buildings							
	Total		In A-Zone		In V-Zone		In 500-Year Zone	
County	Owned	Leased	Owned	Leased	Owned	Leased	Owned	Leased
Barnstable	297	12	31	0	23	0	3	0
Berkshire	338	20	9	0	0	0	0	0
Bristol	431	51	22	1	37	0	5	2
Dukes	10	3	0	0	1	0	1	0
Essex	499	39	44	4	5	0	9	7
Franklin	204	7	12	0	0	0	0	0
Hampden	430	36	8	0	0	0	3	3
Hampshire	546	16	23	1	0	0	1	0
Middlesex	1,043	64	13	1	0	0	18	6
Nantucket	3	2	0	2	0	0	0	0
Norfolk	654	26	23	2	0	0	3	2
Plymouth	508	34	17	0	1	0	12	1
Suffolk	326	73	36	0	0	0	4	0
Worcester	1,044	49	18	5	0	0	7	0
Total	**6,333**	**432**	**256**	**16**	**67**	**0**	**66**	**21**

Building data are updated as agencies change or modify. State-owned building information current as of October 3, 2012. State-leased building information current as of October 10, 2010. Total of 6,765 buildings for which data are available and reported in the best available DFIRM databases.

TABLE 10-6.
2012 STATE BUILDING EXPOSURE TO FLOOD HAZARD BY COUNTY (REPLACEMENT COST VALUE)

	Replacement Cost Value							
	Total		In A-Zone		In V-Zone		In 500-Year Zone	
County	Owned	Leased	Owned	Leased	Owned	Leased	Owned	Leased
Barnstable	$1,129,133,087	$17,181,274	$117,148,240	$0	$232,605,111	$0	$1,345,758	$0
Berkshire	$1,810,562,200	$41,438,632	$2,029,700	$0	$0	$0	$0	$0
Bristol	$2,862,545,772	$149,664,578	$35,722,252	$1,779,954	$40,692,248	$0	$7,385,920	$11,816,302
Dukes	$9,965,088	$6,258,960	$0	$0	$205,534	$0	$1,171,214	$0
Essex	$4,336,334,705	$136,866,724	$168,964,271	$14,182,864	$23,577,507	$0	$156,141,552	$22,369,000
Franklin	$789,074,575	$24,162,354	$14,595,793	$0	$0	$0	$0	$0
Hampden	$4,896,066,804	$155,583,444	$46,229,452	$0	$0	$0	$9,600,319	$21,533,472
Hampshire	$4,654,345,657	$33,042,196	$40,165,436	$3,767,238	$0	$0	$1,886,302	$0
Middlesex	$9,556,026,897	$325,969,758	$88,369,664	$5,154,170	$0	$0	$74,354,460	$31,334,120
Nantucket	$30,440,058	$941,186	$0	$941,186	$0	$0	$0	$0
Norfolk	$4,994,008,904	$147,822,352	$230,333,614	$26,855,864	$0	$0	$1,015,972	$21,216,764
Plymouth	$3,089,420,567	$92,983,586	$43,224,320	$0	$179,646	$0	$12,223,798	$391,418
Suffolk	$7,795,245,796	$487,827,934	$224,491,144	$0	$0	$0	$8,254,654	$0
Worcester	$9,226,864,179	$217,834,816	$138,834,085	$11,561,146	$0	$0	$24,202,417	$0
Total	**$55,180,034,288**	**$1,837,577,794**	**$1,150,107,970**	**$64,242,422**	**$297,260,047**	**$0**	**$297,582,366**	**$108,661,076**

Replacement cost value is the sum of the replacement cost value for the building and contents.

Building data are updated as agencies change or modify. State-owned building information current as of October 3, 2012. State-leased building information current as of October 10, 2010. Total of 6,765 buildings for which data are available and reported in the best available DFIRM databases.

TABLE 10-7.
2012 STATE BUILDING EXPOSURE TO FLOOD HAZARDS BY AGENCY (BUILDING COUNT)

	Number of Buildings									
	Total		A-Zone		V-Zone		SFHA Total (A & V)		500-Year Zone	
Agency	Owned	Leased	Owned	Leased	Owned	Leased	Owned	Leased	Owned	Leased
Bridgewater State University	34	4	2	0	0	0	2	0	0	0
Department of Children and Families		34	0	1	0	0	0	1	0	2
Department of Conservation and Recreation	1,963	1	148	0	43	0	191	0	21	0
Department of Corrections	593	1	1	0	0	0	1	0	0	0
Department of Developmental Services	490	31	2	3	0	0	2	3	0	1
Department of Early Education and Care		5	0	0	0	0	0	0	0	1
Department of Environmental Protection	7	5	0	0	0	0	0	0	0	0
Department of Fish and Game	177	1	28	0	1	0	29	0	3	0
Department of Food and Agriculture	1		0	0	0	0	0	0	0	0
Department of Industrial Accidents		4	0	0	0	0	0	0	0	1
Department of Mental Health	187	11	0	2	0	0	0	2	0	0
Department of Public Health	125	11	0	1	0	0	0	1	0	0
Department of State Police	129	7	1	0	0	0	1	0	2	0
Department of Transitional Assistance		27	0	2	0	0	0	2	0	1
Department of Transportation	892	23	51	1	0	0	51	1	6	3
Department of Veterans Services	9	1	3	0	0	0	3	0	0	0
Department of Youth Services	25	1	4	0	0	0	4	0	0	0
Department of Workforce Development		7	0	0	0	0	0	0	0	1
Division of Capital Asset Management	261	1	1	0	0	0	1	0	0	0
Exec. Office of Energy & Environmental. Affairs		3	0	0	0	0	0	0	0	1
Exec. Office of Health & Human Services		7	0	1	0	0	0	1	0	0
Framingham State University	25		1	0	0	0	1	0	0	0
Greenfield Community College	9	1	1	0	0	0	1	0	0	0
Massachusetts Maritime Academy	24		0	0	23	0	23	0	0	0
Massachusetts Parole Board		6	0	1	0	0	0	1	0	0
Massachusetts Rehabilitation Commission		28	0	0	0	0	0	0	0	2
Military Division	152		3	0	0	0	3	0	11	0
North Shore Community College	10	2	0	1	0	0	0	1	0	0
Northern Essex Community College	17	1	0	0	0	0	0	0	1	1
Office of Labor and Workforce Development	5		0	0	0	0	0	0	1	0
Public Employee Retirement Admin. Comm.		1	0	0	0	0	0	0	0	1
Quinsigamond Community College	14	1	0	0	0	0	0	0	0	0
Salem State University	68	1	0	0	0	0	0	0	8	0
Secretary of State	1	5	1	1	0	0	1	1	0	1
Sheriff's Department Essex	17	4	0	0	0	0	0	0	0	1
Sheriff's Department Middlesex	16	4	0	0	0	0	0	0	0	1
Sheriff's Department Nantucket		1	0	1	0	0	0	1	0	0
Trial Court	69	35	4	1	0	0	4	1	1	2
University of Massachusetts at Amherst	372	1	1	0	0	0	1	0	12	0
University of Massachusetts at Dartmouth	37	1	2	0	0	0	2	0	0	0
University of Massachusetts at Lowell	77		2	0	0	0	2	0	0	0
Westfield State University	27	2	0	0	0	0	0	0	0	1
Total	**5,833**	**279**	**256**	**16**	**67**	**0**	**323**	**16**	**66**	**21**

Building data are updated as agencies change or modify. State-owned building information current as of October 3, 2012. State-leased building information current as of October 10, 2010. Total of 6,765 buildings for which data are available and reported in the best available DFIRM databases.
Per the data provided, state agencies listed in this table do not have any buildings located in the defined flood zones.

TABLE 10-8.
2012 STATE BUILDING EXPOSURE TO FLOOD HAZARDS BY AGENCY (REPLACEMENT COST VALUE)

	Replacement Cost Value					
	Total		In SFHA (A & V Zones)		In 500-Year Zone	
Agency	Owned	Leased	Owned	Leased	Owned	Leased
Bridgewater State University	$621,405,638	$8,144,326	$9,983,126	$0	$0	$0
Department of Children and Families	$0	$168,416,910	$0	$5,782,042	$0	$11,475,380
Department of Conservation and Recreation	$3,925,871,934	$593,140	$655,301,906	$0	$49,067,950	$0
Department of Corrections	$5,511,376,140	$2,162,554	$1,019,286	$0	$0	$0
Department of Developmental Services	$2,273,503,983	$61,275,328	$621,164	$5,214,554	$0	$1,322,542
Department of Early Education and Care	$0	$11,035,338	$0	$0	$0	$2,144,120
Department of Environmental Protection	$30,835,588	$64,020,068	$0	$0	$0	$0
Department of Fish and Game	$126,701,367	$2,409,696	$30,276,612	$0	$1,203,368	$0
Department of Food and Agriculture	$4,528,850	$0	$0	$0	$0	$0
Department of Industrial Accidents	$0	$21,884,716	$0	$0	$0	$2,127,288
Department of Mental Health	$2,505,491,673	$15,495,368	$0	$2,668,592	$0	$0
Department of Public Health	$1,716,192,441	$65,004,896	$0	$2,054,348	$0	$0
Department of State Police	$567,970,734	$61,081,512	$1,704,452	$0	$1,250,732	$0
Department of Transitional Assistance	$0	$119,954,202	$0	$8,749,076	$0	$5,387,952
Department of Transportation	$1,479,411,960	$56,547,308	$64,856,197	$126,376	$3,044,436	$21,529,364
Department of Veterans Services	$12,463,486	$1,522,124	$7,192,502	$0	$0	$0
Department of Youth Services	$466,504,706	$4,123,924	$95,984,262	$0	$0	$0
Department of Workforce Development	$0	$16,480,732	$0	$0	$0	$3,041,578
Division of Capital Asset Management	$3,071,661,624	$76,495,772	$7,686,501	$0	$0	$0
Exec. Office of Energy & Environmental. Affairs	$0	$24,156,812	$0	$0	$0	$391,418
Exec. Office of Health & Human Services	$0	$58,210,506	$0	$25,706,456	$0	$0
Framingham State University	$525,548,586	$0	$17,943,000	$0	$0	$0
Greenfield Community College	$196,362,192	$5,955,640	$187,325	$0	$0	$0
Massachusetts Maritime Academy	$232,687,325	$0	$232,605,111	$0	$0	$0
Massachusetts Parole Board	$0	$9,475,002	$0	$1,149,408	$0	$0
Massachusetts Rehabilitation Commission	$0	$61,647,774	$0	$0	$0	$2,905,048
Military Division	$1,476,931,058	$0	$34,326,892	$0	$41,271,262	$0
North Shore Community College	$236,057,960	$10,662,448	$0	$4,741,258	$0	$0
Northern Essex Community College	$320,744,766	$9,272,584	$0	$0	$48,264,364	$9,272,584
Office of Labor and Workforce Development	$38,062,268	$0	$0	$0	$6,237,764	$0
Public Employee Retirement Admin. Comm.	$0	$3,874,110	$0	$0	$0	$3,874,110
Quinsigamond Community College	$298,979,215	$2,986,432	$0	$0	$0	$0
Salem State University	$1,018,650,440	$4,126,890	$0	$0	$107,877,188	$0
Secretary of State	$62,377,670	$26,693,420	$62,377,670	$3,468,264	$0	$3,119,326
Sheriff's Department Essex	$303,181,072	$9,988,614	$0	$0	$0	$1,404,350
Sheriff's Department Middlesex	$375,809,742	$7,995,202	$0	$0	$0	$3,990,652
Sheriff's Department Nantucket	$0	$814,810	$0	$814,810	$0	$0
Trial Court	$4,924,453,586	$196,022,756	$172,207,994	$3,767,238	$27,141,504	$21,486,614
University of Massachusetts at Amherst	$4,028,521,689	$3,050,668	$2,845,772	$0	$12,223,798	$0
University of Massachusetts at Dartmouth	$735,541,470	$30,960,288	$142,500	$0	$0	$0
University of Massachusetts at Lowell	$2,527,775,117	$0	$50,105,744	$0	$0	$0
Westfield State University	$566,499,830	$15,409,090	$0	$0	$0	$15,188,750
Total	**$40,182,104,110**	**$1,237,950,960**	**$1,447,368,016**	**$64,242,422**	**$297,582,366**	**$108,661,076**

1 - Building data are updated as agencies change or modify. State-owned building information is current as of October 3, 2012, and the State-leased building information is current as of October 10, 2010 with a total of 6,765 buildings.
2 - Where data are available and reported in the best available Digital Flood Insurance Rate Map databases.
3 - Per the data provided, State agencies listed in this table do not have any buildings located in the defined flood zones.

In summary, all mainland counties have state owned or leased property in an A zone. There are five counties with at least one or more state facilities in a V-zone. Structures located within the coastal high hazard area, or V-zone, were assigned a level of high risk to reflect the high levels of damage that can be sustained due to the forces of associated waves. Structures located outside of the V-zone but within the 100-year or 1-percent annual chance flood zone (A-zone), were assigned a moderate risk. Structures located in the 500-year or 0.2-percent annual chance of occurrence zone were assigned a low risk due to the infrequent occurrence of this event. In summary, there are 67 high risk structures, 272 moderate risk structures, and 87 low risk structures. The risk level of the structures is displayed in Figure 10-8.

An assessment was made of the change in flood exposure of state-owned and leased buildings from the 2010 plan to the 2013 plan. Table 10-9 and Table 10-10 summarize the findings.

As noted earlier, the best available data were used for this analysis including effective and preliminary DFIRMs, Q3 data and the digital floodplain layer that had been developed by the Franklin Regional Council of Governments, which only includes the 1-percent floodplain in nine communities along the Connecticut River in Franklin County (see Table 10-3). Since the 2010 update, numerous Counties had updated DFIRM data released: Dukes (2010), Essex (2012), Hampden (preliminary 2012), Middlesex (2010 with Shawsheen Watershed preliminary 2011), Nantucket (preliminary 2012), Plymouth (preliminary 2012), and Worcester (2011 for portion of the County). Further, 2012 preliminary updates have been made for three communities along Buzzards Bay in Plymouth County (Marion, Mattapoisett, and Wareham). The increase/decrease in buildings exposed is due in part to the updated and more accurate flood hazard boundary data available and used for this analysis.

The comparison study shows an increase in the number of buildings exposed to the 1-percent annual chance flood event (both in A and V zones), while a decrease in the number of buildings located in the 0.2-percent flood zone. As mentioned, the new flood hazard boundary data released since 2009 could account for these changes. In general, the hydrograph is changing and the 1-percent annual chance flood hazard areas have increased which are reflected in the new DFIRM databases. This may in part account for the increased number of buildings exposed to the 1-percent annual chance flood event (i.e., located in the A and V zones). Because of the changing hydrograph, the 0.2-percent annual chance flood zones have become 1-percent annual chance flood zones and thus may in part be the reason for the decrease in the number of buildings in the 0.2-percent annual chance flood zones.

The comparison study shows a large increase in the number of state buildings exposed to the flood hazard in Barnstable County. Barnstable County had preliminary DFIRMs at the time of the 2010 plan; however, they were pulled in April 2011 due to inaccuracies and their mapping is being revised as part of the FEMA Risk MAP program. Therefore, only the Q3 data were available for Barnstable County's analysis for this plan update. The differences between the former preliminary DFIRM and Q3 may help explain the increase in number of buildings exposed.

It is important to note that even for counties that did not have new flood hazard boundary data released since 2009, there are changes in the number of buildings exposed. This is due to differences between the December 2009 and the October 2012 building datasets. According to DCAMM, the building data are always being updated, changed and corrected as agencies change or modify. The 2010 plan's building dataset was not available, and an entirely new and updated dataset was obtained from DCAMM and the Office of Leasing for the 2013 plan update.

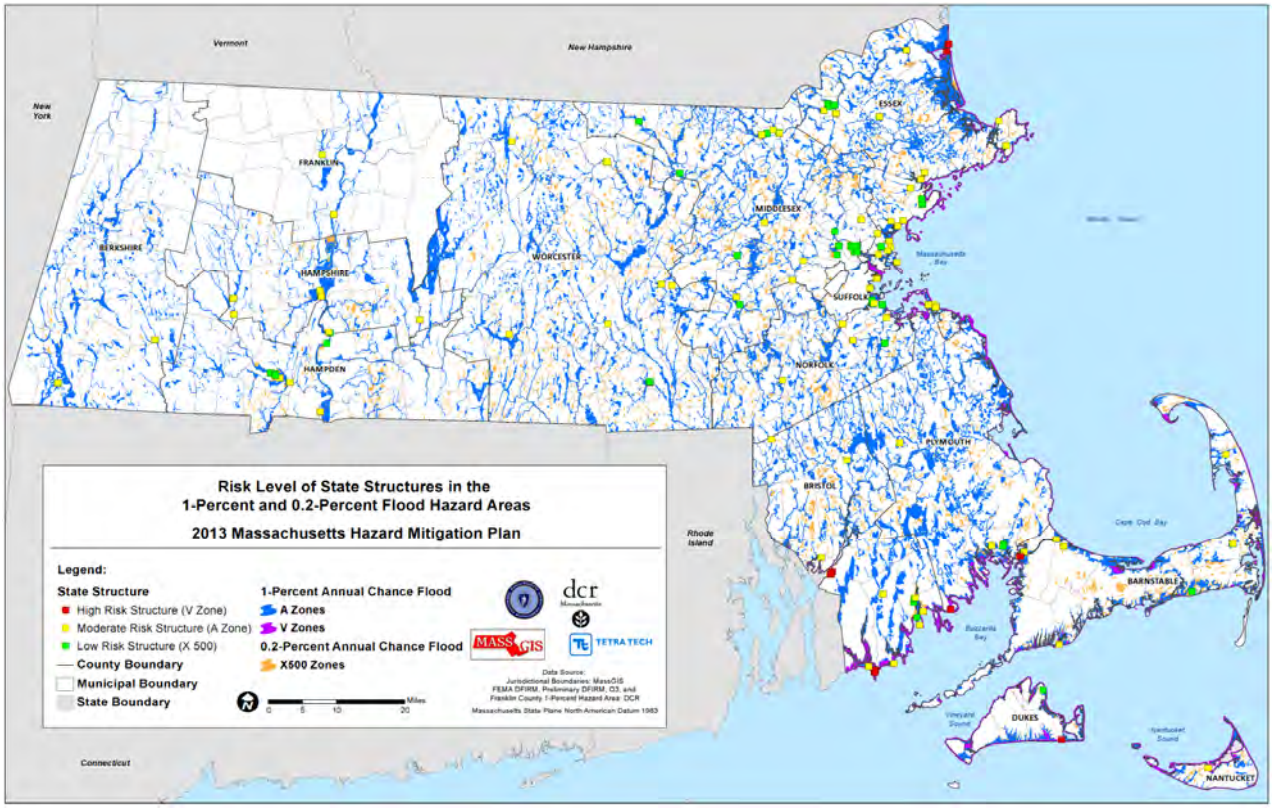


Figure 10-8. Risk Level of State Facilities in the FEMA Flood Hazard Areas

TABLE 10-9.
STATE BUILDING EXPOSURE TO FLOOD HAZARD, 2009 TO 2012 (BUILDING COUNT)

	Number of Buildings in A-Zone			Number of Buildings in V-Zone			Number of Buildings in 500-year Zone		
County	2009	2012	Change	2009	2012	Change	2009	2012	Change
Barnstable*	16	31	+15	4	23	+19	0	3	+3
Berkshire	18	9	-9	0	0	0	3	0	-3
Bristol	22	23	+1	15	37	+22	4	7	+3
Dukes*	0	0	0	1	1	0	1	1	0
Essex*	22	48	+26	1	5	+4	19	16	-3
Franklin	1	12	+11	0	0	0	-	-	-
Hampden*	12	8	-4	0	0	0	13	6	-7
Hampshire	14	24	+10	0	0	0	7	1	-6
Middlesex*	40	14	-26	0	0	0	17	24	+7
Nantucket*	0	2	2	0	0	0	3	0	-3
Norfolk*	25	25	0	0	0	0	13	5	-8
Plymouth*	12	17	+5	11	1	-10	11	13	+2
Suffolk*	28	36	+8	0	0	0	7	4	-3
Worcester*	23	23	0	0	0	0	6	7	+1
Total	**233**	**272**	**+39**	**32**	**67**	**+35**	**104**	**87**	**-17**

*New flood hazard boundary data available since 2009.

TABLE 10-10.
STATE BUILDING EXPOSURE TO FLOOD HAZARD, 2009 TO 2012 (REPLACEMENT COST VALUE)

	Building Replacement Cost Value Exposed to Flood Hazard		
County	2009 (April 2007 values)	2012	Change
Barnstable*	$64,915,500	$351,099,109	+$286,183,609
Berkshire	$7,365,485	$2,029,700	-$5,335,785
Bristol	$107,538,324	$97,396,676	-$10,141,648
Dukes*	0	$1,376,748	+$1,376,748
Essex*	$38,534,447	$385,235,194	+$346,700,747
Franklin	$10,907,370	$14,595,793	+3,688,423
Hampden*	$1,373,630	$77,363,243	+$75,989,613
Hampshire	$72,890,168	$45,818,976	-$27,071,192
Middlesex*	$166,678,526	$199,212,414	+$32,533,888
Nantucket*	0	$941,186	+$941,186
Norfolk*	$17,583,618	$279,422,214	+$261,838,596
Plymouth*	$89,963,517	$56,019,182	-$33,944,335
Suffolk*	$127,815,569	$232,745,798	+104,930,229
Worcester*	$58,515,403	$174,597,647	+$116,082,244
Total	**$764,081,557**	**$1,917,853,880**	**+$1,153,772,323**

*New flood hazard boundary data available since 2009.

The following are the key differences between the two building datasets:

- The 2010 plan used November 2009 DCAMM data with 2007 financial figures as the replacement cost values. For this analysis, replacement cost values not provided by DCAMM or the Office of Leasing were calculated based on square footage and 2011 R.S. Means values for the structure and contents.
- The exact number of buildings in the 2009 DCAMM dataset is unknown; however, the 2010 plan indicates the Commonwealth of Massachusetts owns and operates *just under 6,000 properties across the state*. However, the exact number of buildings could not be determined because the data are no longer available and could not be used or verified for this update. As discussed, for the 2013 plan update the state building data set contained both owned and leased buildings provided by both DCAMM and the Office of Leasing (a total of 6,765 buildings: 432 leased buildings and 6,333 owned buildings). The 2009 building locations were based on 'digitally enhanced and GPS corrected data.' The building data provided by DCAMM and the Office of Leasing in October 2012 were geocoded using the ArcGIS Online North America Streets 10.0 online geocoding service. This is because the data provided with the attributes needed for the risk assessment could not be joined with any existing spatial data set provided by DCAMM. A more detailed description of the methodology can be found in Appendix A.

An analysis was conducted to determine the exposure of the entire building inventory of the Commonwealth of Massachusetts to the flood hazard. To estimate the buildings exposed to the 1-percent and 0.2-percent annual chance flood events, the flood hazard boundaries were overlaid upon the Hazus-MH version 2.1 default general building stock inventory. Census blocks do not follow the boundaries of the floodplain. The Census blocks with their centroid in the flood boundaries were used to calculate the

estimated building replacement cost value exposed to this hazard by County (refer to Table 10-11 and Table 10-12.)

TABLE 10-11.
2012 ESTIMATED GENERAL BUILDING STOCK EXPOSURE TO THE 1-PERCENT ANNUAL CHANCE FLOOD EVENT

		A-Zone		V-Zone		SFHA	
County	Total Replacement Cost Value	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total
Barnstable	$47,450,250,000	$4,997,314,000	10.5	$885,946,000	1.9	$5,883,260,000	12.4
Berkshire	$20,566,219,000	$1,863,294,000	9.1	$0	0.0	$1,863,294,000	9.1
Bristol	$74,946,506,000	$5,043,388,000	6.7	$658,348,000	0.9	$5,701,736,000	7.6
Dukes	$4,894,499,000	$341,598,000	7.0	$69,885,000	1.4	$411,483,000	8.4
Essex	$100,099,771,000	$8,798,859,000	8.8	$675,898,000	0.7	$9,474,757,000	9.5
Franklin	$10,130,548,000	$339,747,000	3.4	$0	0.0	$339,747,000	3.4
Hampden	$67,212,508,000	$2,183,975,000	3.2	$0	0.0	$2,183,975,000	3.2
Hampshire	$20,961,384,000	$1,286,170,000	6.1	$0	0.0	$1,286,170,000	6.1
Middlesex	$244,161,008,000	$12,573,322,000	5.1	$0	0.0	$12,573,322,000	5.1
Nantucket	$3,610,072,000	$387,236,000	10.7	$108,214,000	3.0	$495,450,000	13.7
Norfolk	$111,344,832,000	$9,681,951,000	8.7	$212,539,000	0.2	$9,894,490,000	8.9
Plymouth	$70,614,087,000	$9,447,746,000	13.4	$1,162,525,000	1.6	$10,610,271,000	15.0
Suffolk	$115,439,212,000	$2,764,314,000	2.4	$76,732,000	0.1	$2,841,046,000	2.5
Worcester	$112,858,251,000	$7,134,892,000	6.3	$0	0.0	$7,134,892,000	6.3
Total	**$1,004,289,147,000**	**$66,843,806,000**	**6.7**	**$3,850,087,000**	**0.4**	**$70,693,893,000**	**7.0**

TABLE 10-12.
2012 ESTIMATED GENERAL BUILDING STOCK EXPOSURE TO THE 0.2-PERCENT ANNUAL CHANCE FLOOD EVENT

		X500-Zone	
County	Total Replacement Cost Value	Replacement Cost Value	% of Total
Barnstable	$47,450,250,000	$3,776,587,000	8.0
Berkshire	$20,566,219,000	$352,331,000	1.7
Bristol	$74,946,506,000	$3,444,025,000	4.6
Dukes	$4,894,499,000	$252,480,000	5.2
Essex	$100,099,771,000	$4,013,636,000	4.0
Franklin	$10,130,548,000	NA	NA
Hampden	$67,212,508,000	$2,438,523,000	3.6
Hampshire	$20,961,384,000	$352,804,000	1.7
Middlesex	$244,161,008,000	$9,199,293,000	3.8
Nantucket	$3,610,072,000	$210,985,000	5.8
Norfolk	$111,344,832,000	$2,657,019,000	2.4
Plymouth	$70,614,087,000	$2,088,030,000	3.0
Suffolk	$115,439,212,000	$828,568,000	0.7
Worcester	$112,858,251,000	$2,584,991,000	2.3

Total	**$1,004,289,147,000**	**$32,199,272,000**	**3.2**

10.5.3 Critical Facilities

To estimate the critical facilities exposed to the flood hazard, the flood hazard boundaries were overlaid upon the police stations, fire stations, hospitals, schools (pre-K through grade 12), colleges, and state emergency operation centers. Table 10-13 summarizes the number of facilities in each zone. Critical facilities exposed to the flood hazard are summarized by County in Table 10-14 through Table 10-19.

TABLE 10-13.
SUMMARY OF CRITICAL FACILITY EXPOSURE BY FLOOD HAZARD AREA

Facility Type	Total Number	A Zone	V Zone	X500 Zone	Total Exposed
Police Stations	437	13	0	12	25
Fire Stations	789	30	1	19	50
Hospitals	82	0	0	0	0
Schools (pre-K-12)	2,767	22	0	41	63
Colleges	205	3	0	2	5
Emergency Operations Centers	2	0	0	0	0
Total		**68**	**1**	**74**	**166**

Source: MassGIS, 2012

TABLE 10-14.
POLICE STATIONS EXPOSED TO THE FLOOD HAZARD BY COUNTY

County	Total	A Zone	V Zone	X500
Barnstable	20	2	—	1
Berkshire	33	1	—	1
Bristol	27	4	—	1
Dukes	10	—	—	—
Essex	39	1	—	1
Franklin	26	—	—	—
Hampden	28	—	—	2
Hampshire	23	1	—	2
Middlesex	64	1	—	4
Nantucket	3	—	—	—
Norfolk	32	—	—	—
Plymouth	31	—	—	—
Suffolk	34	1	—	—
Worcester	67	—	—	—
Total	**437**	**11**	**0**	**12**

Source: MassGIS, 2012

TABLE 10-15.
FIRE STATIONS EXPOSED TO THE FLOOD HAZARD BY COUNTY

County	Total	A Zone	V Zone	X500
Barnstable	37	3	—	1
Berkshire	46	3	—	1
Bristol	63	—	—	3
Dukes	8	—	—	1
Essex	82	4	—	1
Franklin	31	—	—	—
Hampden	51	3	—	4
Hampshire	28	1	—	3
Middlesex	164	7	—	4
Nantucket	1	—	—	—
Norfolk	59	—	1	—
Plymouth	67	5	—	—
Suffolk	47	1	—	—
Worcester	105	3	—	1
Total	**789**	**30**	**1**	**19**

Source: MassGIS, 2012

TABLE 10-16.
EMERGENCY OPERATION CENTERS EXPOSED TO THE FLOOD HAZARD BY COUNTY

County	Total	A Zone	V Zone	X500
Barnstable	—	—	—	—
Berkshire	—	—	—	—
Bristol	—	—	—	—
Dukes	—	—	—	—
Essex	—	—	—	—
Franklin	—	—	—	—
Hampden	1	—	—	—
Hampshire	—	—	—	—
Middlesex	1	—	—	—
Nantucket	—	—	—	—
Norfolk	—	—	—	—
Plymouth	—	—	—	—
Suffolk	—	—	—	—
Worcester	—	—	—	—
Total	2	0	0	0

Source: MassGIS, 2012

TABLE 10-17.
HOSPITALS EXPOSED TO THE FLOOD HAZARD BY COUNTY

County	Total	A Zone	V Zone	X500
Barnstable	2	—	—	—
Berkshire	4	—	—	—
Bristol	5	—	—	—
Dukes	1	—	—	—
Essex	10	—	—	—
Franklin	1	—	—	—
Hampden	6	—	—	—
Hampshire	2	—	—	—
Middlesex	16	—	—	—
Nantucket	1	—	—	—
Norfolk	5	—	—	—
Plymouth	4	—	—	—
Suffolk	15	—	—	—
Worcester	10	—	—	—
Total	**82**	**0**	**0**	**0**

Source: MassGIS, 2012

TABLE 10-18.
SCHOOLS EXPOSED TO THE FLOOD HAZARD BY COUNTY

County	Total	A Zone	V Zone	X500
Barnstable	82	2	—	—
Berkshire	76	—	—	—
Bristol	243	—	—	5
Dukes	10	—	—	—
Essex	309	2	—	8
Franklin	53	—	—	—
Hampden	217	—	—	6
Hampshire	113	1	—	4
Middlesex	576	4	—	9
Nantucket	4	—	—	—
Norfolk	286	4	—	1
Plymouth	197	4	—	2
Suffolk	244	3	—	5
Worcester	357	2	—	1
Total	**2,767**	**22**	**0**	**41**

Source: MassGIS, 2012

TABLE 10-19.
COLLEGES EXPOSED TO THE FLOOD HAZARD BY COUNTY

County	Total	A Zone	V Zone	X500
Barnstable	6	1	—	—
Berkshire	6	1	—	—
Bristol	12	—	—	—
Dukes	0	—	—	—
Essex	13	1	—	1
Franklin	3	—	—	—
Hampden	16	—	—	—
Hampshire	5	—	—	—
Middlesex	47	—	—	1
Nantucket	1	—	—	—
Norfolk	21	—	—	—
Plymouth	6	—	—	—
Suffolk	48	—	—	—
Worcester	21	—	—	—
Total	**205**	**3**	**0**	**2**

Source: MassGIS, 2012

To estimate the highway bridges exposed to the flood hazard, the flood hazard boundaries were overlaid upon the major bridge inventory (4,832 total bridges) provided in Hazus-MH 2.1. There are 1,210 bridges with their center within the A zone, 25 bridges in the V zone, and an additional 180 bridges in the X500 zone. Further, there are 9 bridges located in the 'protected by a levee' zone, all of which are located in Hampden County. This listing does not convey whether or not the bridge is designed and built above the base flood elevation. Table 10-20 summarizes these results.

TABLE 10-20.
NUMBER OF BRIDGES IN THE FLOOD HAZARD AREAS BY COUNTY

	Total	A Zone			V Zone			X500 Zone		
County	Exposed	Federal	State	Local	Federal	State	Local	Federal	State	Local
Barnstable	35	1	7	15	—	1	8	—	1	2
Berkshire	169	—	51	104	—	—	—	—	6	8
Bristol	109	—	38	52	—	4	4	—	4	7
Dukes	5	—	3	1	—	1	—	—	—	—
Essex	115	—	53	46	—	—	—	—	14	2
Franklin	27	—	11	16	—	—	—	—	—	—
Hampden	100	2	38	42	—	—	—	—	11	7
Hampshire	118	1	39	70	—	—	—	—	6	2
Middlesex	216	—	81	95	—	—	—	—	32	8

TABLE 10-20.
NUMBER OF BRIDGES IN THE FLOOD HAZARD AREAS BY COUNTY

County	Total Exposed	A Zone			V Zone			X500 Zone		
		Federal	State	Local	Federal	State	Local	Federal	State	Local
Nantucket	—	—	—	—	—	—	—	—	—	—
Norfolk	83	—	33	38	—	1	1	—	8	2
Plymouth	99	—	37	51	—	3	2	—	5	1
Suffolk	47	—	32	15	—	—	—	—	—	—
Worcester	292	5	99	134	—	—	—	—	25	29
Total	**1,415**	**9**	**522**	**679**	**—**	**10**	**15**	**—**	**112**	**68**

Source: Hazus-MH v. 2.1 default highway bridge inventory
Notes: The following owners were listed in the Hazus-MH v. 2.1 default highway bridge inventory (total of 4,832 bridges) and summarized into the federal, state, and local categories. The total number of bridges for each category is noted in parentheses:
Federal (22): National Park Service, Corps of Engineers (CIV)
State (3,344): State Highway Agency; State Park Reservation Agency; Bureau of Fish & Wildlife; Other State Agencies
Local (1,466): Town Highway Agency; City Highway Agency; Local Park Reservation Agency; Local Toll Authority

10.5.4 Economy

Damage to buildings can affect a community's economy and tax base. The area of each County (square miles including water bodies) exposed to the flood hazard was determined. Ten of the 14 Counties have greater than 10-percent of their area in the SFHA (A and V zones). Table 10-21 summarizes these findings.

TABLE 10-21.
2012 AREA LOCATED IN THE FLOOD HAZARD BOUNDARIES

		Area in SFHA (square miles)						Area in 0.2-Percent Flood (X500) Zone (square miles)	
		A-Zones		V-Zones		Total SFHA			
County	Total Area	Area	% of Total	Area	% of Total	Area	% of Total	Area	% of Total
Barnstable	412.48	60.29	14.62	15.27	3.70	75.56	18.32	21.72	5.27
Berkshire	946.39	65.84	6.96	0.00	0.00	65.84	6.96	6.76	0.71
Bristol	571.86	88.94	15.55	24.05	4.21	112.99	19.76	18.7	3.27
Dukes	109.90	11.28	10.26	6.80	6.19	18.08	16.45	3.13	2.85
Essex	514.90	90.36	17.55	4.32	0.84	94.68	18.39	18.89	3.67
Franklin	724.58	17.79	2.46	0.00	0.00	17.79	2.46	NA	NA
Hampden	634.06	46.63	7.35	0.00	0.00	46.63	7.35	13.8	2.18
Hampshire	545.27	51.62	9.47	0.00	0.00	51.62	9.47	10.49	1.92
Middlesex	846.59	99.34	11.73	0.00	0.00	99.34	11.73	34.94	4.13
Nantucket	49.03	7.23	14.75	3.69	7.53	10.92	22.27	2.02	4.12
Norfolk	408.54	56.38	13.80	0.79	0.19	57.17	13.99	15.47	3.79
Plymouth	689.77	129.62	18.79	10.40	1.51	140.02	20.30	18.68	2.71
Suffolk	59.74	10.11	16.92	0.30	0.50	10.41	17.43	1.62	2.71
Worcester	1,579.21	165.01	10.45	0.00	0.00	165.01	10.45	39.51	2.50
Total	**8,092.30**	**900.44**	**11.13**	**65.62**	**0.81**	**966.06**	**11.94**	**205.73**	**2.54**

Note: Franklin County does not have DFIRMs or Q3 data; however, a digital floodplain layer that had been developed by the Franklin Regional Council of Governments, which only includes the floodplain in the nine communities along the Connecticut River, was used for this analysis.

10.6 VULNERABILITY

To assess the Commonwealth's vulnerability to the flood hazard, potential losses were determined for the 1-percent and 0.2-percent annual chance flood events. The methodology used to assess vulnerability and the results are summarized within each subsection below.

10.6.1 Population

Of the population exposed, the most vulnerable include the economically disadvantaged and the population over the age of 65. Economically disadvantaged populations are more vulnerable because they are likely to evaluate their risk and make decisions to evacuate based on the net economic impact to their family. The population over the age of 65 is also more vulnerable because they are more likely to seek or need medical attention, which may not be available due to isolation during a flood event, and they may have more difficulty evacuating (see Section 4)

The total number of injuries and casualties resulting from typical riverine flooding is generally limited based on advance weather forecasting, blockades, and warnings. This historical record from 1993 to 2011 indicates there have only been two fatalities associated with a flood event (May 2006) and five injuries associated with two flood events (events occurred within two weeks of each other in March 2010). Injuries and deaths generally are not anticipated if proper warning and precautions are in place.

Ongoing mitigation efforts should help to avoid the most likely cause of injury, which results from persons trying to cross flooded roadways or channels during a flood.

Similar to riverine flooding, of the population exposed to flash flooding, the most vulnerable include the economically disadvantaged and the population over the age of 65. There is often limited warning time for flash flooding. These events are frequently associated with other natural hazard events such as earthquakes, landslides, or severe weather, which limits their predictability and compounds the hazard. Populations without adequate warning of the event are highly vulnerable to this hazard.

10.6.2 State Facilities

To estimate the potential losses to state-owned and leased structures, the exposure analysis methodology was used. As discussed, there are 6,765 state-owned/leased structures in the Commonwealth. Table 10-8 identifies a total risk exposure of greater than $1.5 billion for state-owned and leased buildings in areas potentially subject to the 1-percent annual chance flood event (A- and V-zones). For the 0.2-percent annual chance event, an additional $406 million is exposed and potentially at risk. These figures assume 100-percent loss to each structure and its contents. This estimate is considered high because flood events are generally centered within a region or watershed and do not typically occur across the entire Commonwealth at the same time. In addition, structure and content losses generally do not occur to the entire inventory exposed.

We acknowledge this methodology's limitations and have identified activities in our mitigation strategy that will advance the accuracy of the flood potential loss estimates. This includes the state agency review and validation of the owned and leased structure data in terms of location, replacement cost value of structure and contents and all relevant attributes for analysis. In addition, performing further GIS analysis in the Hazus-MH flood model by incorporating the flood-depth grids that will be available through FEMA's Risk MAP in the future.

10.6.3 Critical Facilities

Similar to the state facilities, to estimate potential losses to critical facilities and infrastructure, the exposure analysis methodology was used. The replacement cost values for critical facilities were not available for this planning effort. A total risk exposure would equal to the full replacement value of each critical facility exposed. As these data become available, the Commonwealth will update this section of the plan with new information.

In terms of highway bridges, the Hazus-MH v. 2.1 default replacement cost value for the bridges located in the 1-percent hazard area (A and V zones) is greater than $18 Billion (of the greater than $68 Billion total); an additional $2.6 Billion located in the 0.2-percent annual chance hazard area.

10.6.4 Severe Repetitive Loss Data

The NFIP data are a useful tool to determine the location of areas vulnerable to flood and severe storm hazards. Table 10-22 summarizes the NFIP policies, claims, repetitive loss, and severe repetitive loss properties in each county. Appendix I provides a detailed list of NFIP flood claims by county and municipality. As a method to examine the percentage of policies, repetitive loss and severe repetitive loss properties to the total number of housing units in each County, the 2011 total number of housing units was used.

TABLE 10-22.
NFIP POLICIES, CLAIMS, AND REPETITIVE LOSS STATISTICS

County	Number of Housing Units (2011)	Policies	% of Housing Units	Claims	Total Loss Payment	Repetitive Losses	% of Housing Units	Severe Repetitive Losses	% of Housing Units
Barnstable	161,001	10,567	6.6	1,523	$13,145,429	149	0.09	4	< 1
Berkshire	68,497	1,160	1.7	372	$2,811,377	31	0.05		
Bristol	231,083	4,067	1.8	3,296	$26,044,259	70	0.03		
Dukes	17,385	894	5.1	162	$1,605,265	17	0.10		
Essex	307,559	8,483	2.8	4,518	$68,578,887	500	0.16	17	< 1
Franklin	33,806	219	< 1	99	$3,713,435	3	0.01		
Hampden	192,197	1,185	< 1	237	$2,341,848	9	0.00		
Hampshire	62,766	555	< 1	184	$1,647,256	21	0.03	1	< 1
Middlesex	614,036	7,453	1.2	3,165	$30,069,052	365	0.06	13	< 1
Nantucket	11,776	896	7.6	414	$12,222,739	49	0.42		
Norfolk	271,502	6,401	2.4	2,612	$27,370,558	265	0.10	12	< 1
Plymouth	201,419	10,564	5.2	8,979	$104,700,955	1,060	0.53	107	< 1
Suffolk	317,327	4,158	1.3	3,914	$21,570,064	457	0.14	22	< 1
Worcester	328,586	2,071	< 1	648	$9,041,964	66	0.02	1	< 1
Total	**2,818,940**	**58,673**	**2.1**	**30,123**	**$324,863,088**	**3,062**	**0.11**	**177**	**< 1**

Sources:
Number of policies (as of November 30, 2012) is from http://bsa.nfipstat.fema.gov/reports/1011.htm#MAT
Number of claims, total loss payments, and number of repetitive loss and severe repetitive loss properties is from FEMA Region 1 as of November 30, 2012.

Barnstable, Nantucket, and Dukes Counties have the highest percentage of policies. The majority of the repetitive loss and severe repetitive loss properties are located in eastern Massachusetts, with the largest number along the coast in the Counties of Barnstable, Essex, Middlesex, Norfolk, Plymouth, and Suffolk.

Figure 10-9 and Figure 10-10 show the number of repetitive loss and severe repetitive loss properties in each municipality.

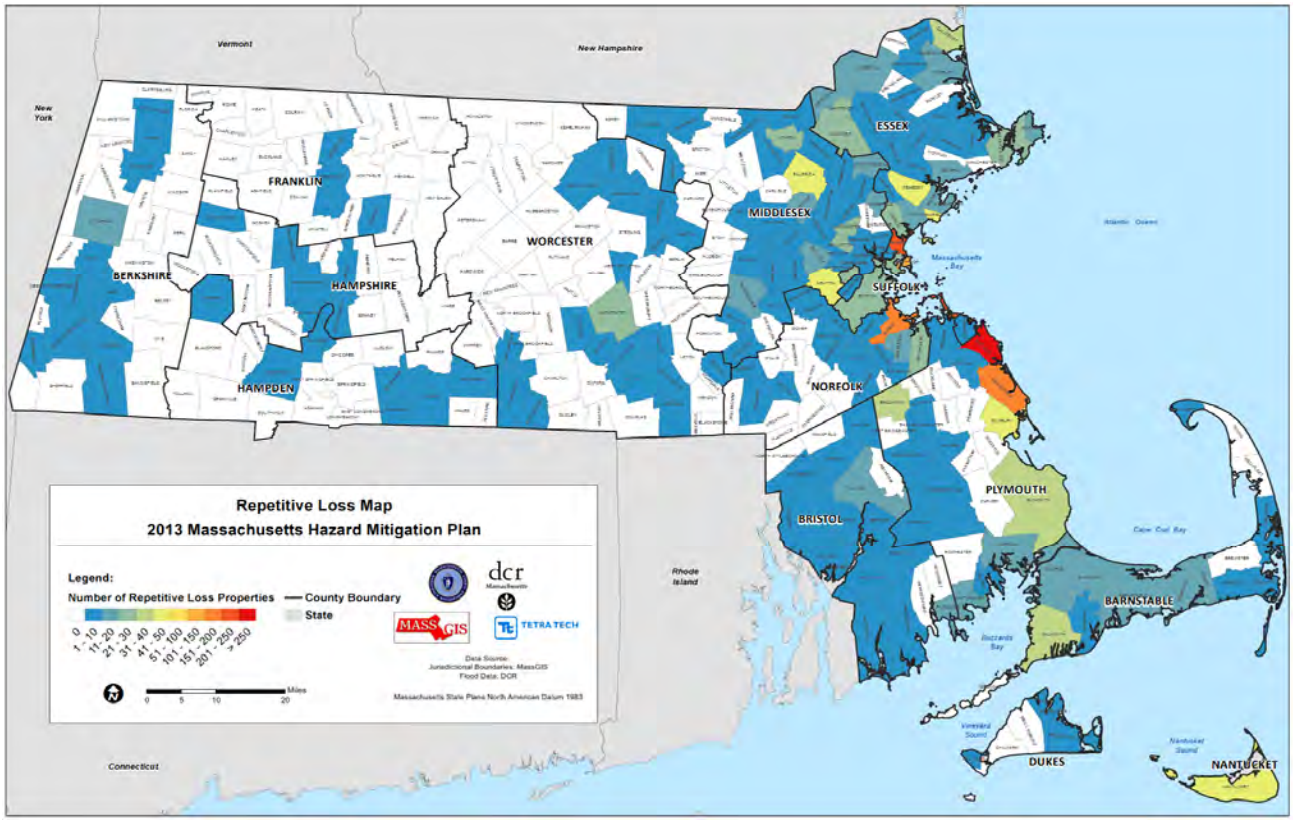


Figure 10-9. NFIP Repetitive Loss Areas

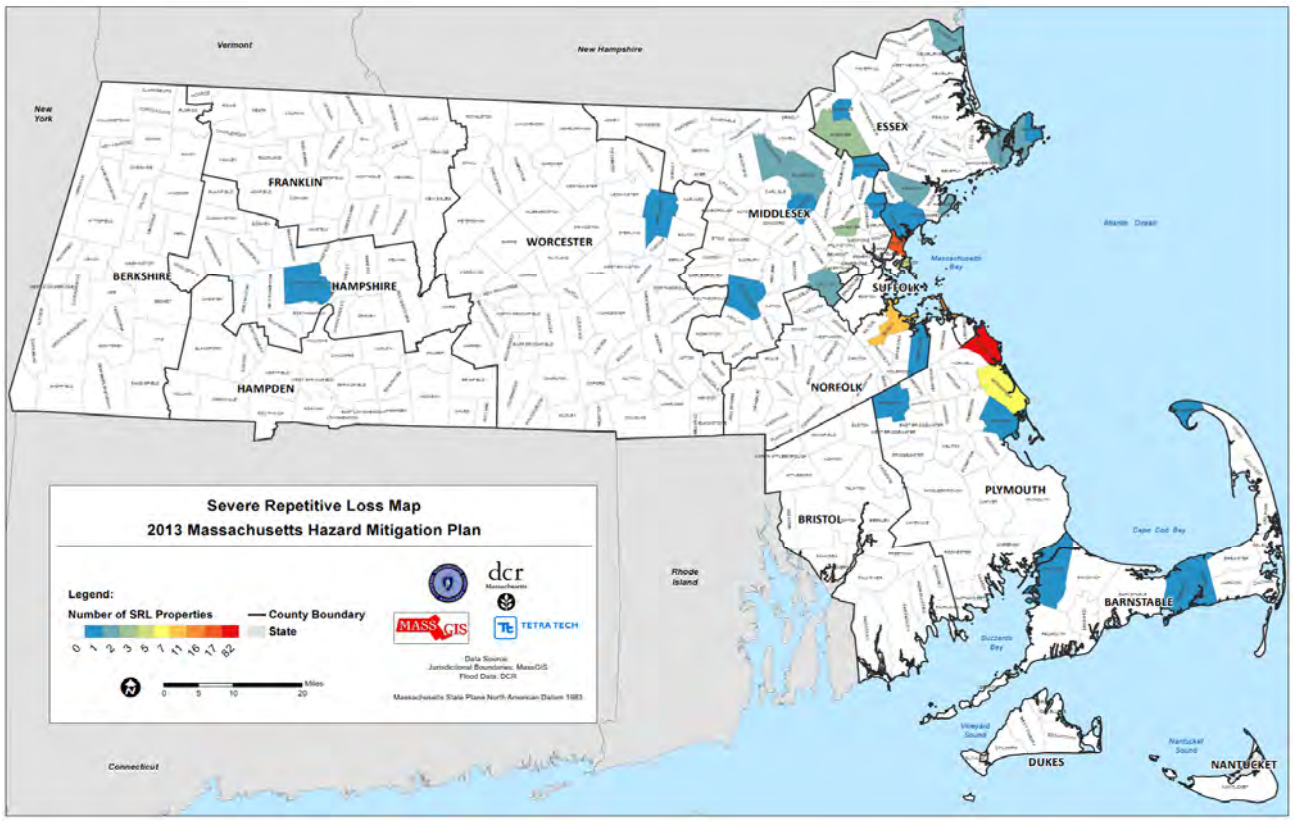


Figure 10-10. NFIP Severe Repetitive Loss Areas

Updated data for Repetitive Loss and Severe Repetitive Loss properties are identified for the years 2006-2012 in Table 10-23. In the 2010 Plan, the top 15 municipalities with the highest number of repetitive loss properties were examined. The same municipalities appear in the top 15 again, with the exception of Brockton, which is new to the list. To include all 15 municipalities previously included in the 2006 and 2010 analysis, the top 20 municipalities are reported. These municipalities are all located in eastern Massachusetts with the exception of Worcester in Worcester County.

TABLE 10-23.
NFIP REPETITIVE LOSS AND SEVERE REPETITIVE LOSS DATA

	2006			2009			2012		
Community	SRL Properties	RL Properties	RL Claims	SRL Properties	RL Properties	RL Claims	SRL Properties	RL Properties	RL Claims
Scituate	50	502	1,504	52	503	1,551	82	490	1,708
Revere	16	274	873	16	288	935	17	293	962
Hull	6	230	680	7	235	713	16	238	778
Quincy	1	131	364	1	144	408	11	169	513
Marshfield	3	155	419	3	156	442	7	158	474
Winthrop	1	139	386	5	136	396	5	140	411
Billerica	1	38	104	1	41	110	2	50	151
Nantucket	1	45	106	1	47	113	0	49	122
Nahant	1	45	123	1	46	133	2	46	136
Peabody	0	30	105	1	37	131	2	44	179
Swampscott	1	37	107	1	37	108	0	44	128
Duxbury	1	39	107	1	42	121	1	42	126
Newton	2	29	77	2	30	81	2	42	109
Brockton	*	*	*	*	*	*	1	38	100
Plymouth	2	33	86	2	34	91	0	37	100
Salisbury	*	*	*	*	*	*	2	34	100
Falmouth	0	32	72	0	34	76	0	33	74
Saugus	*	*	*	*	*	*	1	30	77
Worcester	*	*	*	*	*	*	0	29	81
Arlington	*	*	*	*	*	*	0	29	66

Source: FEMA Region 1
Notes: Top 20 repetitive loss communities for 2012, ordered by number of repetitive loss properties are provided in the table. Data listed for 2009 are through December 2009. Data listed for 2012 are through November 30, 2012. RL = Repetitive Loss; SRL = Severe Repetitive Loss. Asterisk (*) = data not available.

10.6.5 Economy

Economic losses due to a flood include, but are not limited to damage to buildings and infrastructure, agricultural losses, business interruption, impacts on tourism, and tax base. Damage to buildings can be estimated using the exposure analysis above. Other economic components such as loss of facility use, functional downtime, and social economic factors are less measurable with a high degree of certainty.

Flooding can cause extensive damage to public utilities and disruptions to the delivery of services. Loss of power and communications may occur, and drinking water and wastewater treatment facilities may be temporarily out of operation. Flooded streets and roadblocks make it difficult for emergency vehicles to respond to calls for service. Floodwaters can wash out sections of roadway and bridges, and the removal and disposal of debris can also be an enormous cost during the recovery phase of a flood event.

Direct building losses are the estimated costs to repair or replace the damage caused to the building. As discussed, the potential damage estimated to the state facilities associated with the 1-percent annual chance flood is greater than $1.5 billion.

SECTION 11. HURRICANES AND TROPICAL STORMS

11.1 GENERAL BACKGROUND

11.1.1 Tropical Storms

A tropical storm system is characterized by a low-pressure center and numerous thunderstorms that produce strong winds and heavy rain (winds are at a lower speed than hurricane-force winds, thus gaining its status as tropical storm versus hurricane). Tropical storms strengthen when water evaporated from the ocean is released as the saturated air rises, resulting in condensation of water vapor contained in the moist air. They 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.

The term "tropical" refers both to the geographical origin of these systems, which usually form in tropical regions of the globe, and to 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. The opposite direction of the wind flow is a result of the Coriolis force.

Tropical storms and tropical depressions, while generally less dangerous than hurricanes, can be deadly. The winds of tropical depressions/storms are usually not the greatest threat; rather, the rains, flooding, and severe weather associated with the tropical storms are what customarily cause more significant problems. Serious power outages can also be associated with these types of events. After the passing of Hurricane Irene through the region as a tropical storm in late August 2011, many areas of the Commonwealth were without power for in excess of 5 days.

While tropical storms can produce extremely powerful winds and torrential rain, they are also able to produce high waves, damaging storm surge, and tornadoes. They develop over large bodies of warm water, and lose their strength if they move over land due to increased surface friction and loss of the warm ocean as an energy source. This is why coastal regions can receive significant damage from a tropical cyclone. Similar impacts can be sustained from winds associated with a storm of this nature progressing far inland. Heavy rains, however, can produce significant flooding inland, and storm surges can produce extensive coastal flooding up to 25 miles from the coastline.

One measure of the size of a tropical cyclone is determined by measuring the distance from its center of circulation to its outermost closed isobar. If the radius is less than 2 degrees of latitude, or 138 miles, then the cyclone is "very small" or a "midget." A radius between 3 and 6 latitude degrees, or 207 to 420 miles, is considered "average-sized." "Very large" tropical cyclones have a radius of greater than 8 degrees or 552 miles.

11.1.2 Hurricanes

Hurricanes begin as tropical storms over the warm moist waters of the Atlantic, off the coast of West Africa, and Pacific Oceans near the equator. As the moisture evaporates, it rises until enormous amounts of heated, moist 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. Figure 11-1 shows the progressive development of hurricanes.

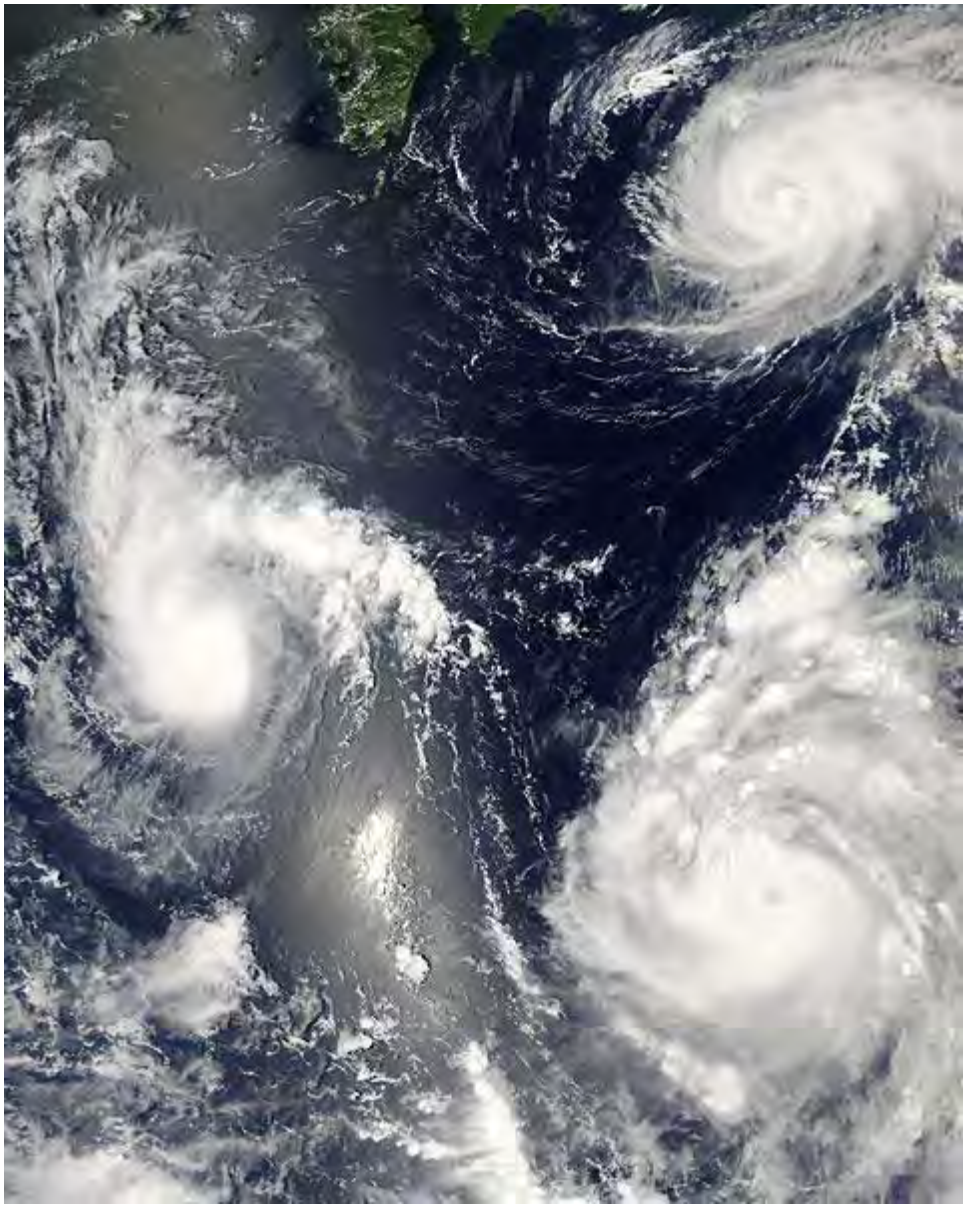


Figure 11-1. Tropical Storm Stages of Development: Weakest (left), with Only Basic Circular Shape; Stronger (top right) with Spiral Banding and Increased Centralization; Strongest (lower right) with an Eye

Tropical cyclones (tropical depressions, tropical storms, and hurricanes) form over the warm, moist waters of the Atlantic, Caribbean, and Gulf of Mexico.

- A tropical depression is declared when there is a low-pressure center in the tropics with sustained winds of 25 to 33 mph.
- A tropical storm is a named event, defined as having sustained winds from 34 to 73 mph.
- If sustained winds reach 74 mph or greater, it becomes a hurricane. The Saffir-Simpson scale ranks hurricanes based on sustained wind speeds—from Category 1 (74 to 95 mph) to Category 5 (156 mph or more). Category 3, 4, and 5 hurricanes are considered "Major" hurricanes. Hurricanes are categorized based on sustained winds; wind gusts associated with hurricanes may exceed the sustained winds and cause more severe localized damage.

When water temperatures are at least 80° F, hurricanes can grow and thrive, generating enormous amounts of energy, which is released in the form of numerous thunderstorms, flooding rainfall, and, very damaging winds. The damaging winds help create a dangerous storm surge (rise in the water above the normal astronomical tide). While 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 some of the strongest hurricanes of record have reached New England.

Hurricanes can range from as small as 50 miles across to as much as 500 miles wide; Hurricane Allen in 1980 took up the entire Gulf of Mexico. There generally are two source regions for the 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 storms tend to be very large in diameter, since they have a week or more to traverse the Atlantic Ocean and grow. Bahamas storms tend to be smaller, but they can also be just as powerful, and their effects can reach New England in only a day or two.

The eye of a hurricane is a relatively calm center, where extremely low barometric pressure exists. The location of the eye is not that important for New Englanders because the average forward speed of the entire storm averages 33 mph at the latitude of the Commonwealth. Customarily, an eye that is 15 miles wide will last for 30 minutes or less at any one location.

As our tropical systems customarily come from a southerly direction and accelerate up the east coast of the U.S., most take on a distinct appearance that is different from the classic hurricanes. Instead of having a perfectly concentric storm with heavy rain blowing from one direction, then the calm eye, then the heavy rain blowing from the opposite direction, our storms (as viewed from satellite and radar) take on an almost winter storm-like appearance. To the south and east of the track of the storm, there often are only a few showers and in fact, the sky may be sunny. But, this is normally where the worst winds and storm surge are located. To the north and west of the track of the storm is customarily where dangerous flooding rains most often occur. An additional threat associated with a tropical system from a landfall perspective is the isolated Tornados which may occur. These generally would occur in the outer bands to the north and east of the storm, a few hours to as much as 15 hours prior to landfall or near land events.

The official hurricane season runs from June 1 to November 30. However, from 1950-2012, there are no records of a land-falling hurricane in New England during June or July. August, September, and the first half of October are when the storms most frequently occur for New England. This is due, in large part, to the fact that it takes a considerable amount of time for the waters south of Long Island to warm to the temperature necessary to sustain the storms this far north. Also, 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 would be conducive for capturing a tropical system over the Bahamas and accelerating it northward.

11.1.3 Saffir/Simpson Hurricane Scale

The Saffir/Simpson scale categorizes or rates hurricanes from 1 (Minimal) to 5 (Catastrophic) based on their intensity. This is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on the slope of the continental shelf and the shape of the coastline, in the landfall region. All winds are using the U.S. 1-minute average, meaning the highest wind that is sustained for 1-minute. The Saffir/Simpson Scale described in Table 11-1 gives an overview of the wind speeds and range of damage caused by different hurricane categories.

TABLE 11-1.
SAFFIR/SIMPSON SCALE (NOAA)

Scale No. (Category)	Winds (mph)	Potential Damage
1	74 – 95	Minimal: Damage is primarily to shrubbery and trees, mobile homes, and some signs. No real damage is done to structures.
2	96 – 110	Moderate: Some trees topple, some roof coverings are damaged, and major damage is done to mobile homes.
3	111 – 130	Extensive: Large trees topple, some structural damage is done to roofs, mobile homes are destroyed, and structural damage is done to small homes and utility buildings.
4	131 – 155	Extreme: Extensive damage is done to roofs, windows, and doors; roof systems on small buildings completely fail; and some curtain walls fail.
5	> 155	Catastrophic: Roof damage is considerable and widespread, window and door damage is severe, there are extensive glass failures, and entire buildings could fail.
Additional Classifications		
Tropical Storm	39-73	NA
Tropical Depression	< 38	NA

mph = Miles per hour; NA = not applicable

11.1.4 SLOSH Mapping

The U.S. Army Corps of Engineers New England Division, in cooperation with FEMA, prepared Sea, Lake and Overland Surge from Hurricanes (SLOSH) inundation maps. SLOSH mapping represents potential flooding from worst-case combinations of hurricane direction, forward speed, landfall point, and high astronomical tide. It does not include riverine flooding caused by hurricane surge or inland freshwater flooding. The model, developed by the National Weather Service to forecast surges that occur from wind and pressure forces of hurricanes, considers only storm surge height and does not consider the effects of waves. The mapping was developed for New England coastal communities using the computer model, Long Island Sound bathymetry, and New England coastline topography.

In Massachusetts, hurricane category is the predominant factor in “worst case” hurricane surges. The resulting inundation areas are grouped into Category 1 and 2, Category 3, and Category 4. The hurricane category refers to the Saffir/Simpson Hurricane Intensity Scale. The Corps of Engineers considered the highest wind speed for each category, the highest surge level, combined with worst-case forward motion and developed a model to depict areas that would be inundated under those combined conditions. For New England, only Categories 1-3 were used.

For the 2013 SHMP, updated SLOSH maps split eastern Massachusetts into several sections and overlay the SLOSH inundation zones on base layers provided by FEMA Region IV Coastal Flood Loss Atlas team. These maps were developed for all Massachusetts’ coastal counties. Refer Figure 11-2 through Figure 11-8. The SLOSH maps do not account for future sea-level rise scenarios.

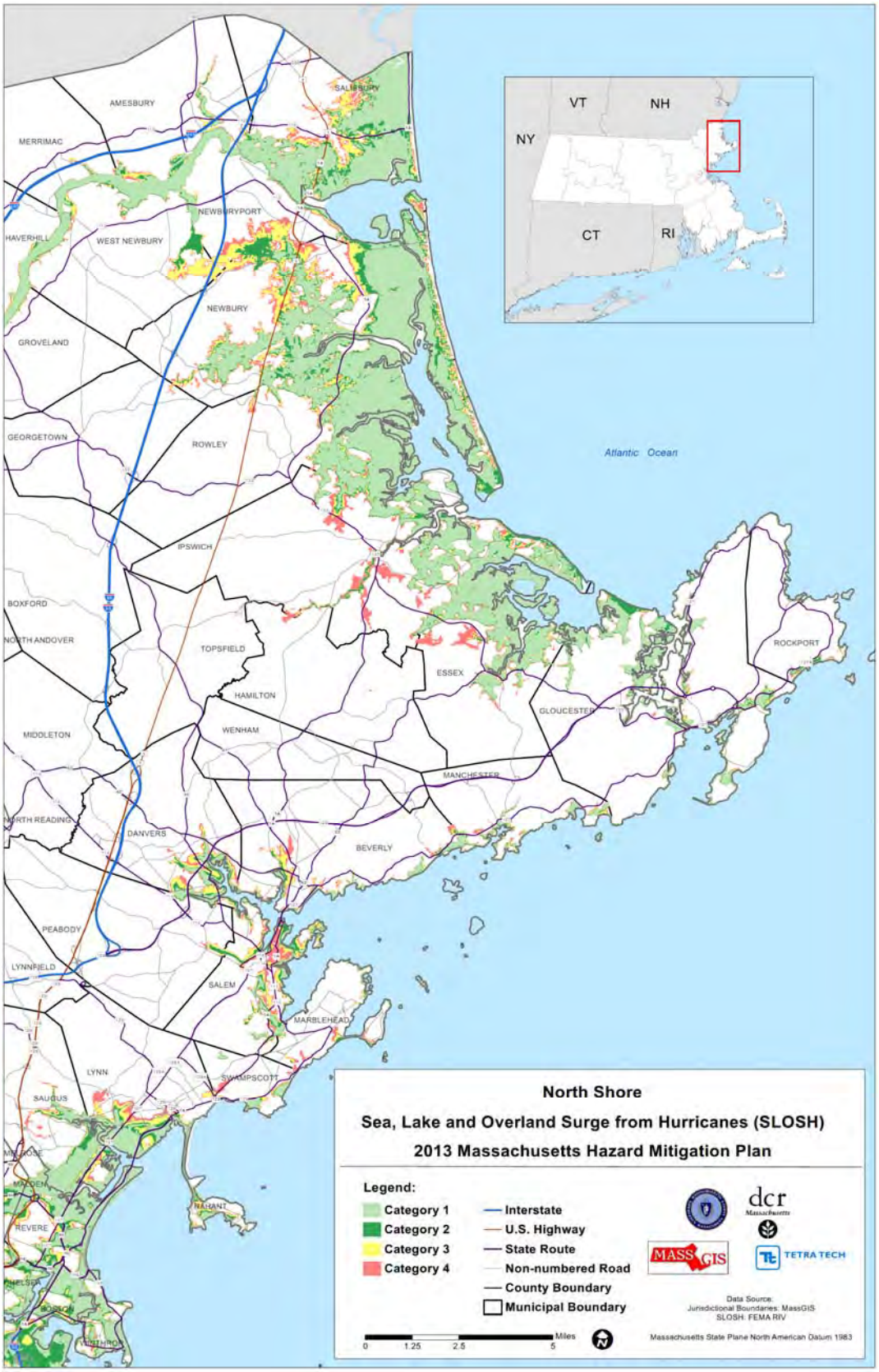


Figure 11-2. North Shore SLOSH Inundation Areas

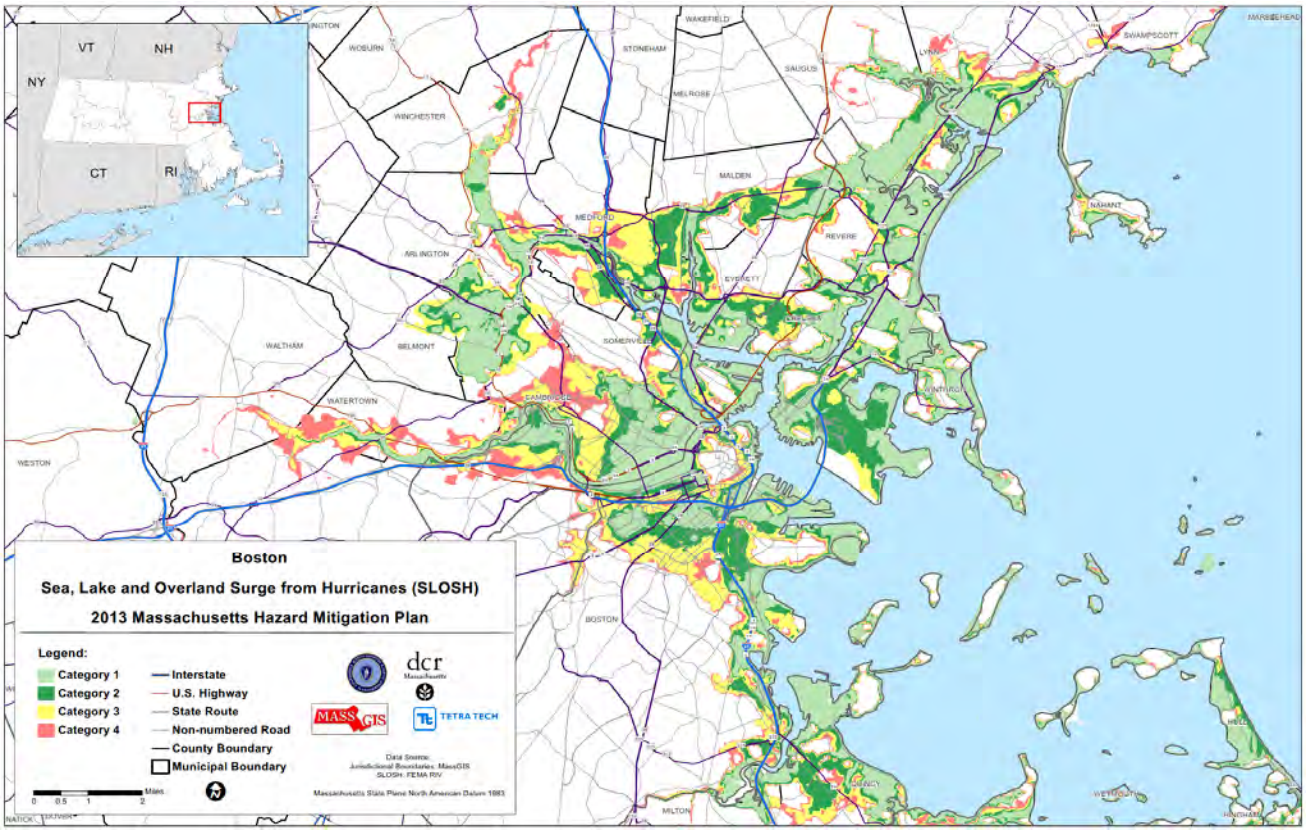


Figure 11-3. Boston SLOSH Inundation Areas

Figure 11-4. South Shore SLOSH Inundation Areas

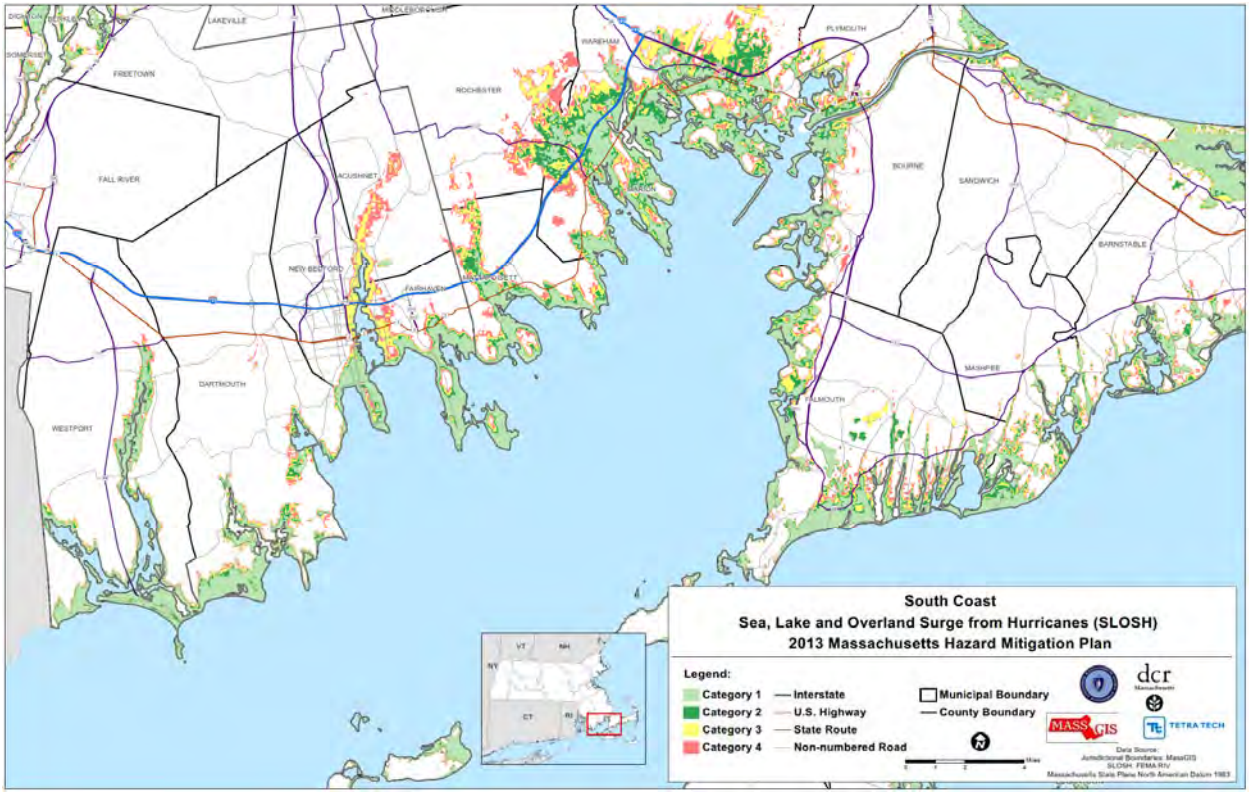


Figure 11-5. South Coastal SLOSH Inundation Areas

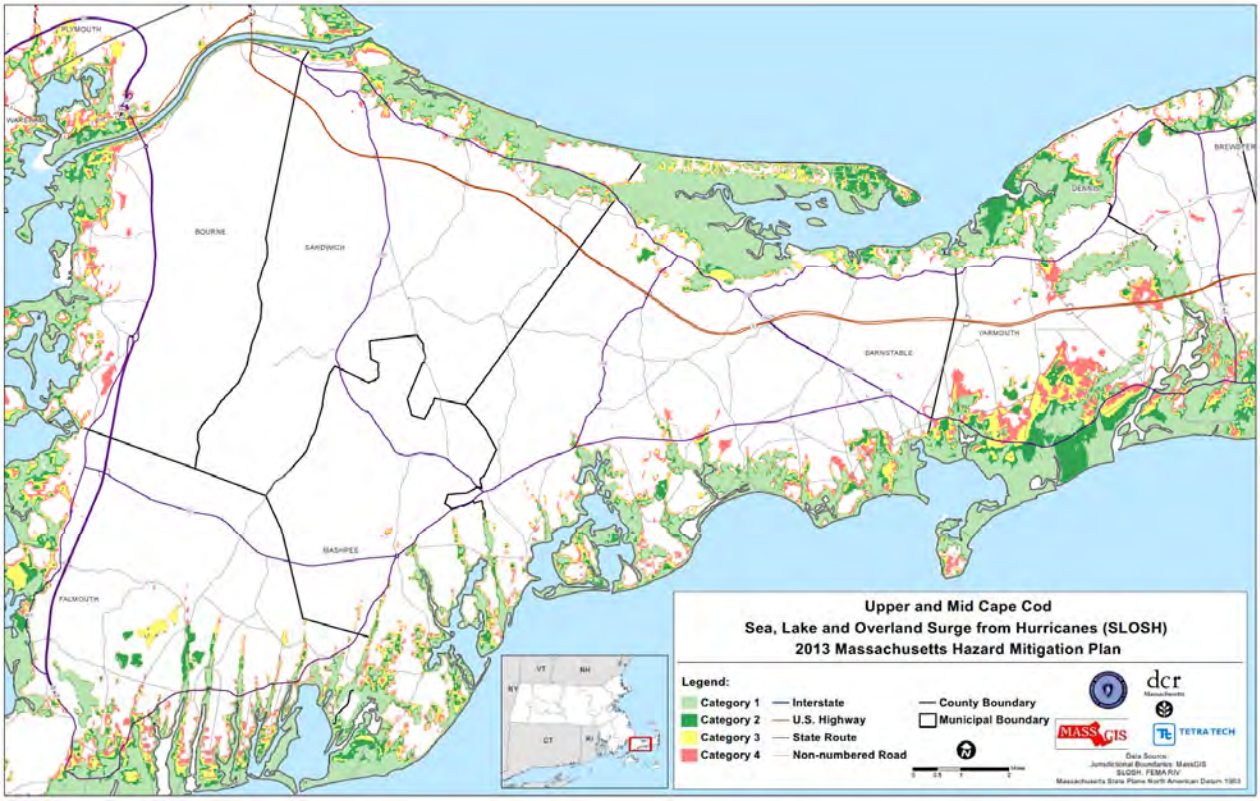


Figure 11-6. Upper and Mid Cape Cod SLOSH Inundation Areas

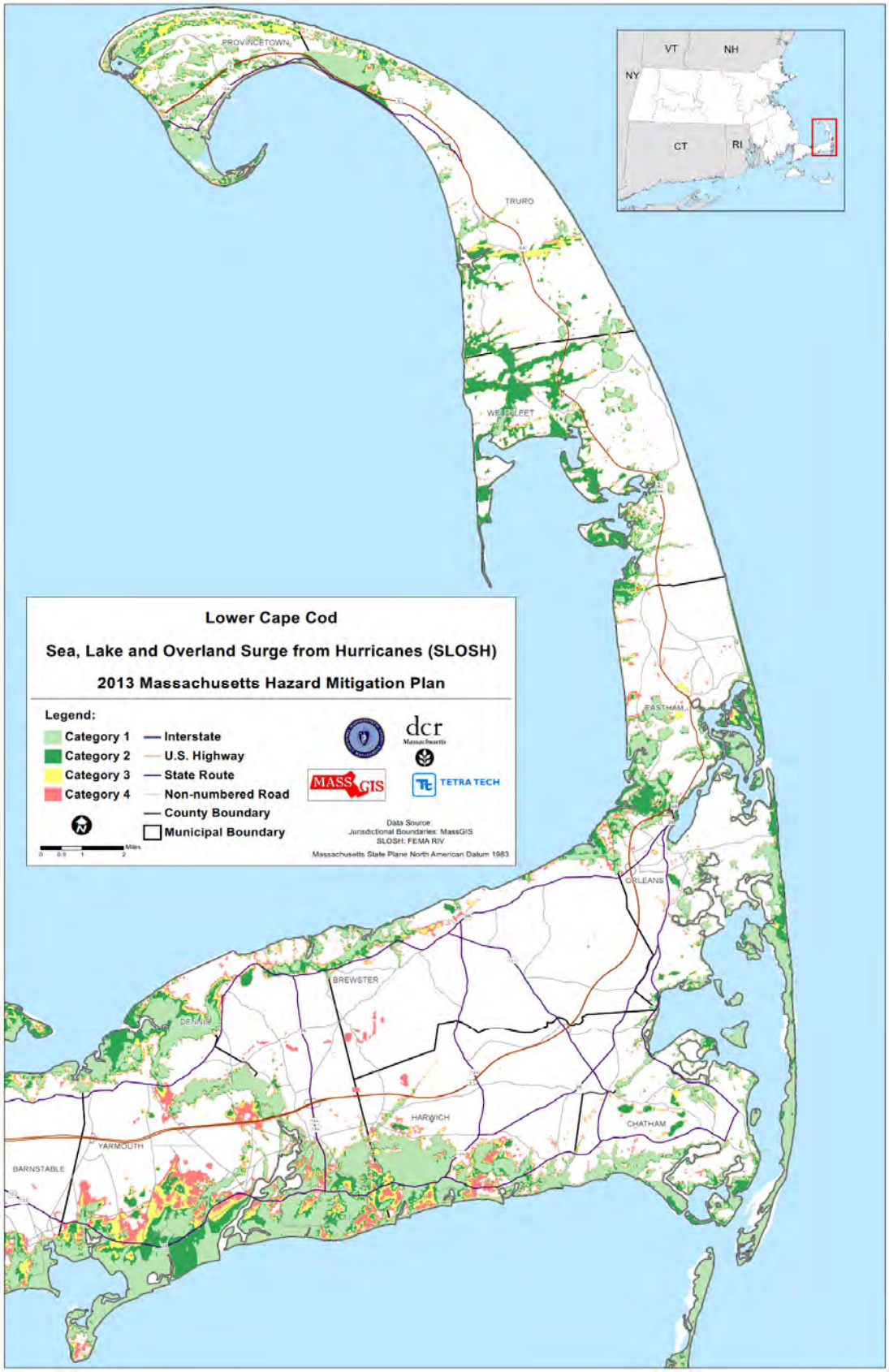


Figure 11-7. Lower Cape Cod SLOSH Inundation Areas

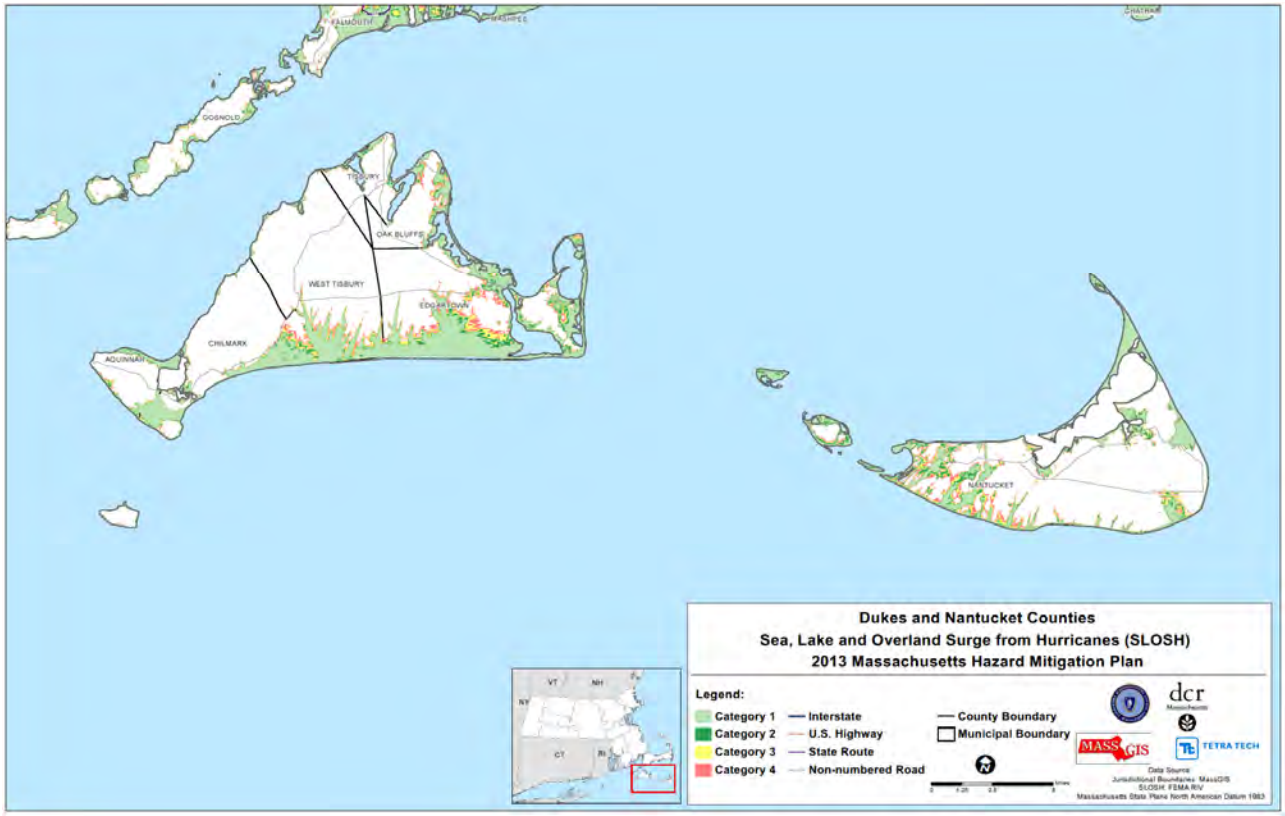


Figure 11-8. Dukes and Nantucket Counties SLOSH Inundation Areas

11.2 HAZARD PROFILE

11.2.1 Location

The Commonwealth of Massachusetts and its 78 coastal communities are vulnerable to the damaging impacts of major storms along its more than 1,500 miles of varied coastline. As development and re-development increases, less-intense storms that occur more regularly and sea-level rise will also lead to costly storm damage. The entire Commonwealth is vulnerable to hurricanes and tropical storms, dependent on the storm's track. The coastal areas are more susceptible to damage due to the combination of both high winds and tidal surge, as depicted on the SLOSH maps. Inland areas, especially those in floodplains, are also at risk for flooding, due to heavy rain, and wind damage. The majority of damage following hurricanes and tropical storms often results from residual wind damage and inland flooding, as was demonstrated during recent tropical storms.

NOAA's Historical Hurricane Tracks tool is a public interactive mapping application that displays Atlantic Basin and East-Central Pacific Basin tropical cyclone data. This interactive tool tracks tropical cyclones from 1842 to 2011 (latest date available from data source). Figure 11-9 and Figure 11-10 display tropical cyclone tracks for the Commonwealth; however, the associated names for some of these events are unknown. Between 1851 and 2011, Massachusetts has experienced in excess of 70 tropical cyclone events. These events occurred within 65 nautical miles of the Commonwealth. Abbreviations used on these figures denote tropical storms/subtropical storms as TS/SS, tropical depressions/subtropical depressions as TD/SD, and extra-tropical storms as ET.

Source: http://csc.noaa.gov/hurricanes/#

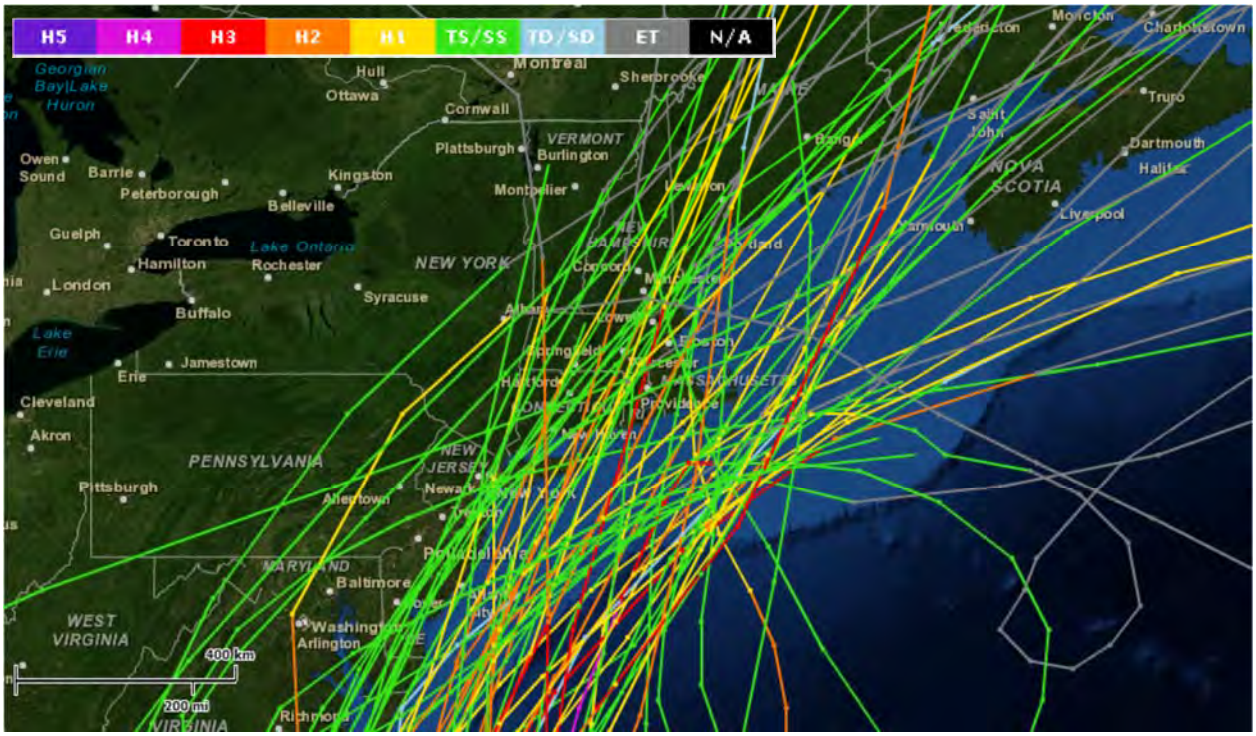


Figure 11-9 Historical North Atlantic Tropical Cyclone Tracks (1851-2011), Northeastern U.S.

Source: http://csc.noaa.gov/hurricanes/#

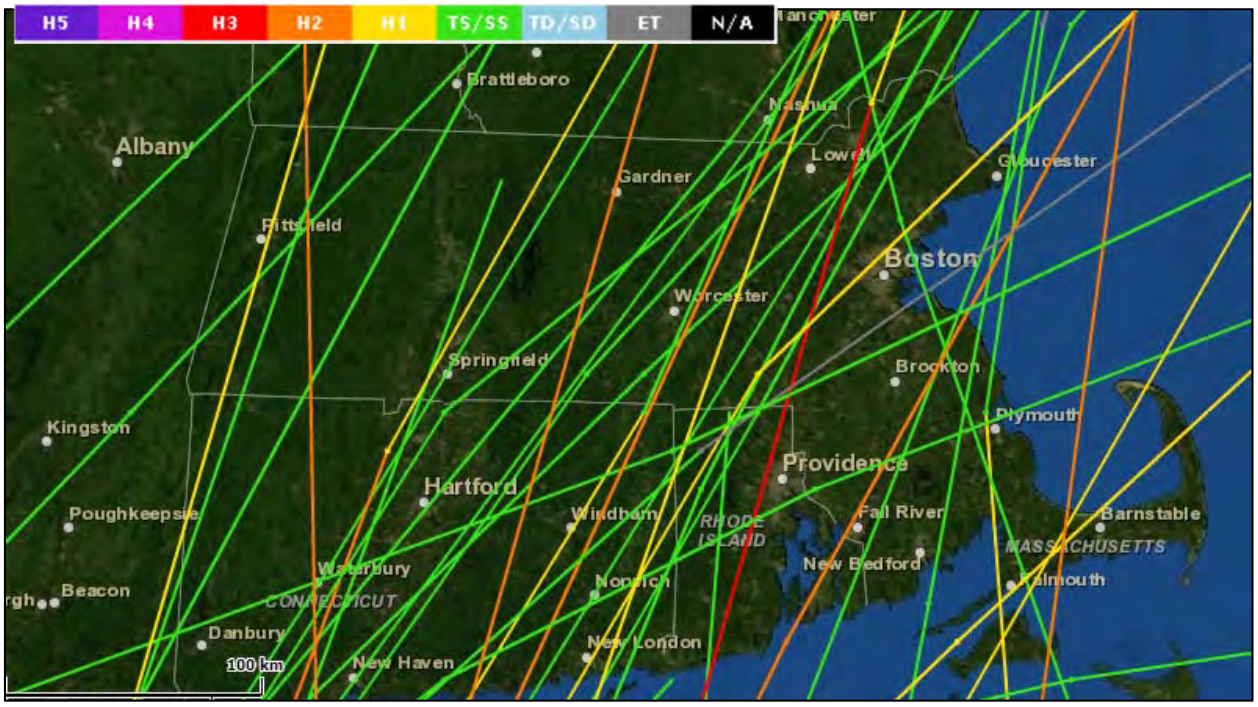


Figure 11-10. Historical North Atlantic Tropical Cyclone Tracks (1851-2011), Massachusetts Vicinity

11.2.2 Previous Occurrences

Since the destructive hurricane of 1938, several hurricanes have struck the Massachusetts coast as listed in Table 11-2. The last 10 years' worth of hurricanes to impact in Massachusetts was Hurricane Sandy (2012), the impact data for which are still being gathered as of the writing of this update. Prior hurricanes include Irene (2011), Earl (2010), Tropical Storm Bill (2009), Tropical Storm Hanna (2008), and Tropical Storm Beryl (2006). As demonstrated in the above NOAA graphics, many more tropical storms occur that do not make landfall. A hurricane or tropical storm need not make landfall to cause major damage, as the outer bands of the storm event can carry significant moisture and winds.

Based on past hurricane and tropical storms, the number of tropical systems impacting the Massachusetts coastline has increased over the course of the last six years, with six events occurring since 2006, including Hurricane Sandy. Prior to 2006, seven years had passed since the last tropical event. Utilizing simple averaging calculations, the Commonwealth averages a tropical storm event approximately every 1.75 years. It should be noted that this is not the recurrence interval, which requires a much more detailed analysis based on event type, category, and time.

The Commonwealth historically has not been impacted by a large number of Category 4 or 5 hurricanes, while Category 3 storms have caused widespread flooding. Winds have caused damage to power lines, impairing the ability of individuals to remain in their homes.

TABLE 11-2.
HISTORY OF HURRICANES AND TROPICAL STORMS

Date	Name	Category	Landfall
August 1635	Great Colonial Hurricane of 1635	3	
September 1815	Great September Gale of 1815	3	
September 1869	September Gale of 1869	3	
September 1938	New England Hurricane of 1938	3	Yes
September 1944	Great Atlantic Hurricane	4	Yes
1945	Unnamed		
1949	Unnamed		
September 1954	Edna	3	Yes
October 1954	Hazel	3	
August 1954	Carol	2-3	
August 1955	Diane	3	
September 1959	Gracie	3	
September 1960	Donna	5	Yes
September 1985	Gloria	4	
August 1991	Bob	3	Yes
July 1996	Bertha	3	
September 1999	Floyd	4	Yes
July 2006	Beryl	Tropical Storm	
September 2008	Hanna	1	
August 2009	Bill	Tropical Storm	

TABLE 11-2.
HISTORY OF HURRICANES AND TROPICAL STORMS

Date	Name	Category	Landfall
September 2010	Earl	4	
August 2011	Irene	2	
October 2012	Sandy	Tropical Storm	Yes

Table 11-2 summarizes historical hurricanes, also indicating those making landfall. Based on all sources researched, known hurricane and tropical storm events that have affected Massachusetts, and were declared a FEMA disaster, are identified in Table 11-3. This table provides detailed information concerning the FEMA declarations for the Commonwealth.

The entire Commonwealth is susceptible to hurricanes and tropical storms, in all sizes. It should be noted that it is not necessarily the strongest category storm that causes the most damage, as smaller events which stall and bring more precipitation and wind can bring greater damage than a faster moving event. Some of the hurricane events to have occurred within the region include the following:

TABLE 11-3.
FEMA HURRICANE-RELATED DISASTER DECLARATIONS (1954 TO 2012)

	DR-4097	DR-4028	EM-3315	DR-914	DR-751	DR-43	DR-22	**Total Events**
Disaster Name or Type	T Storm Sandy	Tropical Storm Irene	Hurricane Earl	Hurricane Bob	Hurricane Gloria	Hurricane/ Floods	Hurricane	
Declaration Date	12/19/2012	9/3/2011	9/2/2010	8/26/1991	10/28/1985	8/20/1955	9/2/1954	
Incident Period	10/27/12 - 11/8/12	8/27/11 - 8/29/11	9/1/10 - 9/4/10	8/19/1991	9/27/1985	8/20/1955	9/2/1954	
Affected Counties								
Barnstable	X	X	X	X	X			**5**
Berkshire		X			X			**2**
Bristol	X	X	X	X	X			**5**
Dukes	X	X	X	X	X			**5**
Essex			X	X	X			**3**
Franklin		X			X			**2**
Hampden		X		X	X			**3**
Hampshire		X			X			**2**
Middlesex			X	X	X			**3**
Nantucket	X		X	X				**3**
Norfolk		X	X	X	X			**4**
Plymouth	X	X	X	X	X			**5**
Suffolk	X		X	X	X			**4**
Worcester			X	X	X			**3**
Total	**6**	**9**	**10**	**11**	**13**	**N/A**	**N/A**	**49**

TABLE 11-3.
FEMA HURRICANE-RELATED DISASTER DECLARATIONS (1954 TO 2012)

	DR-4097	DR-4028	EM-3315	DR-914	DR-751	DR-43	DR-22	**Total Events**

Source: Sterner & Babin, Johns Hopkins University Applied Physics Laboratory, 2006

Great New England Hurricane—1938

The New England Hurricane of 1938 (or Great New England Hurricane or Long Island Express or simply The Great Hurricane of 1938) was the first major hurricane to strike New England since 1869. The storm formed near the coast of Africa in September of the 1938 Atlantic hurricane season, becoming a Category 5 hurricane on the Saffir-Simpson Hurricane Scale before making landfall as a Category 3 hurricane on Long Island on September 21. To date it remains the most powerful, costliest, and deadliest hurricane in New England history. Figure 11-11 depicts the track of this storm event. When it reached Massachusetts, it was tropical storm status. Initially, the hurricane was forecast by the U.S. National Weather Service to curve out into the Atlantic Ocean. Because the official forecasts expected mere overcast conditions, residents were unaware of the impending storm. The cyclone made landfall on Long Island, New York on September 21, 1938 as a strong Category 3 hurricane on the present-day Saffir-Simpson Hurricane Scale with a central pressure of 946 millibars. It then traveled across Long Island Sound into Connecticut, Rhode Island, Massachusetts, New Hampshire, Vermont, and finally into Canada while moving at an unusually high speed.

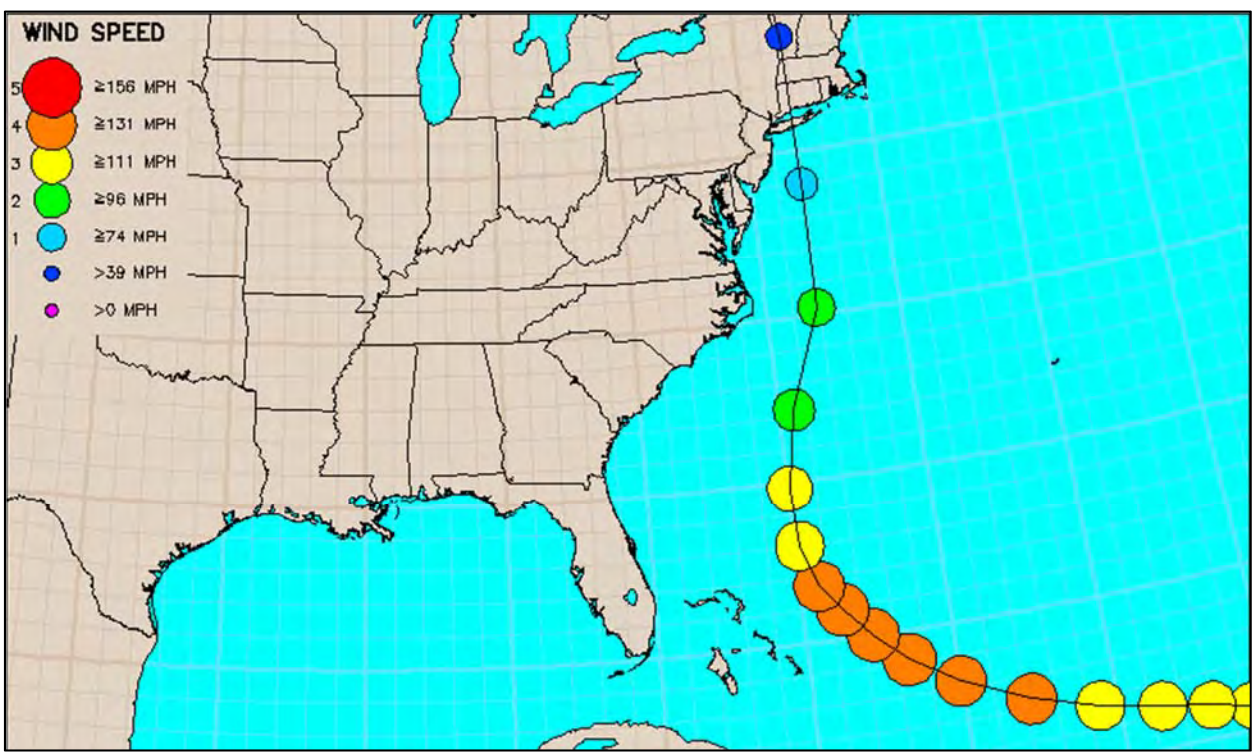


Figure 11-11. 1938 Hurricane Track, September 10 – September 22

The majority of the storm damage was from storm surge and wind. Damage is estimated at $6 billion (2004 USD), making it among the most costly hurricanes to strike the U.S. mainland. It is estimated that if an identical hurricane struck today it would cause $39.2 billion (2005 USD) in damage. Approximately

600 people died in the storm in New England, most in Rhode Island, and up to 100 people elsewhere in the path of the storm. An additional 708 people were reported injured. The hurricane also devastated the forests of the Northeast, knocking down an estimated 2 billion trees in New York and New England. The hurricane produced 18- to 25-foot tides from New London, CT east to Cape Cod in Massachusetts.

The eye of the storm followed the Connecticut River north into Massachusetts, where the winds and flooding killed 99 people. In Springfield, the river rose to 6 to 10 feet above flood stage, causing significant damage. Up to six inches of rain fell across western Massachusetts, which combined with over four inches that had fallen a few days earlier produced widespread flooding. Residents of Ware were stranded for days and relied on air-dropped food and medicine. After the flood receded, the town's Main Street was a chasm in which sewer pipes could be seen.

To the east, the surge left Falmouth and New Bedford under eight feet of water. Two-thirds of all the boats in New Bedford harbor sank. The Blue Hills Observatory registered sustained winds of 121 mph and a peak gust of 186 mph.

Hurricane Carol—August 1954

Hurricane Carol was a Category 3 hurricane with wind gusts of Category 4 strength along southern coastal Massachusetts in the Buzzards Bay area west of Cape Cod. Hurricane Carol, the most destructive hurricane to strike Southern New England since the Great New England Hurricane of 1938, made landfall on the morning of August 31, 1954 near Old Saybrook, Connecticut. During this event, 65 individuals were killed; nearly 4,000 homes, 3.500 automobiles, and over 3,000 boats were destroyed; and scores of trees and miles of power lines were blown down leaving all of Rhode Island, much of eastern Connecticut, and eastern Massachusetts without electrical power.

Hurricane Carol made landfall shortly after high-tide, causing widespread tidal flooding. Narragansett Bay and New Bedford Harbor received the largest surge value of over 14 feet in the upper reaches of both waterways. On Narragansett Bay, just north of the South Street Station site, the surge was recorded at 14.4 feet, surpassing that of the 1938 Hurricane. The heaviest amounts of rainfall, up to 6 inches, occurred in the New London, Connecticut area and across extreme north central Massachusetts (NWS, 2005).

Hurricane Edna (FEMA DR-22)—September 1954

Hurricane Edna, a Category 3 Hurricane, made landfall on September 11, 1954, passing over Martha's Vineyard and Nantucket before crossing the eastern tip of Cape Cod. Hurricane force winds of 75 to 95 mph buffeted all of eastern Massachusetts and coastal Rhode Island. Peak winds included 120 mph on Martha's Vineyard, 110 mph on Block Island, and 100 mph at Hyannis, Massachusetts. The strong winds knocked out electrical power across sections of Rhode Island, eastern Massachusetts, and nearly all of Cape Cod and the islands.

Edna arrived during a rising tide and resulted in severe flooding across Martha's Vineyard, Nantucket, and Cape Cod, where storm surges of over 6 feet were common. Farther west, storm surge values were 4 feet or less, resulting in storm tides that remained below flood stage. Damage to the boating community was severe across Cape Cod, but was much less across the remainder of Massachusetts and Rhode Island. Rainfall amounts of 3 to 6 inches were common, with over seven inches across northeastern Massachusetts. The rainfall aggravated the already saturated conditions caused by Hurricane Carol ten days earlier. The total combined rainfall for Carol and Edna ranged from 5 to 7 inches along and west of the Connecticut River and over Cape Cod, to as much as 11 inches from southeast Connecticut, across most of Rhode Island, to northeast Massachusetts. Edna was responsible for 21 deaths across the region (NWS, 2005).

Hurricane Diane and Flooding (FEMA DR-43)—August 1955

Hurricane Diane, a Category 3 event, was one of the costliest hurricanes in U.S. history, with estimated total damage exceeding $831 million. The storm brought strong winds (sustained winds of 120 mph) and

approximately 16 inches of rain in many areas, which lead to extensive flooding in much of the New England region. Throughout the impacted areas, the hurricane caused between 184 and 200 deaths. In Massachusetts, this event resulted in a FEMA disaster declaration (FEMA DR-43).

Hurricane Gloria (FEMA DR-751)—September 1985

Hurricane Gloria caused extensive damage along the east coast of the U.S. This event was responsible for eight fatalities and approximately $1.94 billion in damage. Wind gusts were sustained at 145 mph, causing Gloria to reach a Category 4 status. Historical tide data included 3.20 feet at Woods Hole, 4.42 feet at Plymouth, 2.92 feet at Chatham, and 5.04 feet at Boston. This event resulted in a federal disaster declaration (FEMA DR-751). Figure 11-12 depicts the track of Hurricane Gloria. When it reached Massachusetts, it was considered a Category 1 storm, with wind speeds of up to 74 mph.

Source: Sterner & Babin, Johns Hopkins University Applied Physics Laboratory, 2008

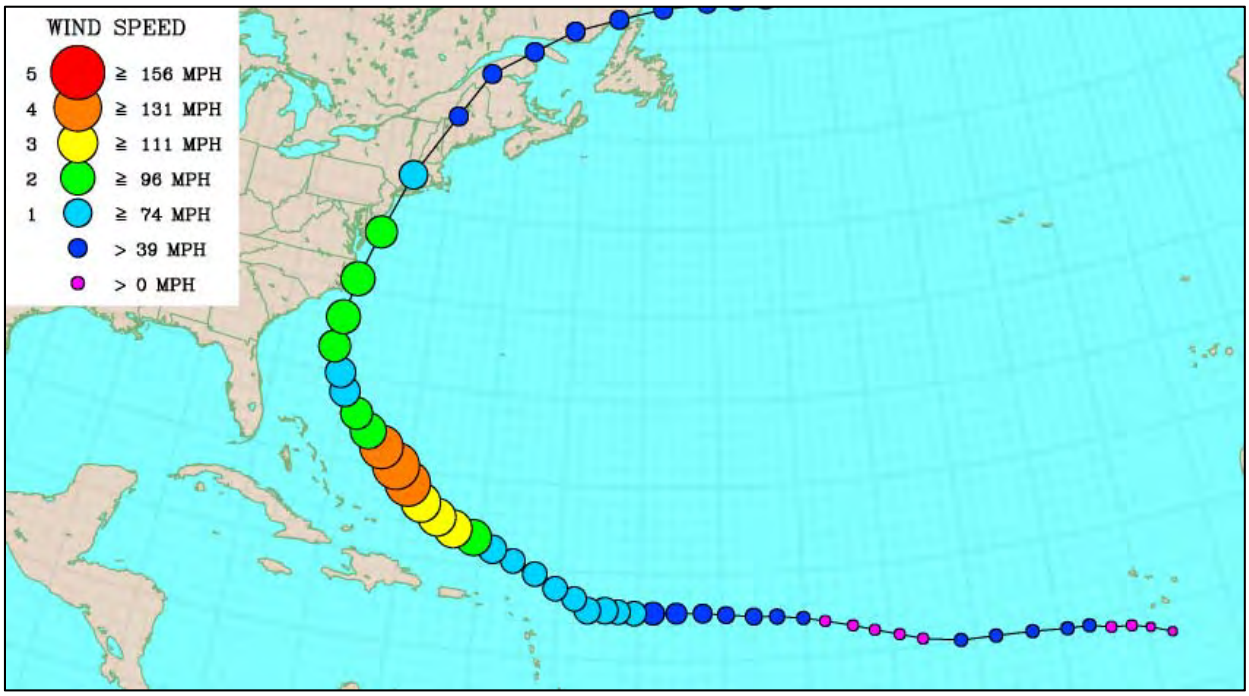


Figure 11-12. Hurricane Gloria Track, September 16 – October 2, 1985

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 were sustained at 115 mph, impacting North Carolina, 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 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 through Bristol and Plymouth Counties, traveling at a speed of 40 mph. Over 500 boats broke away from their moorings, sank, or were driven ashore. Many boats were either heavily damaged or destroyed. 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. Rainfall totals ranged between two and seven inches in the Commonwealth. This event resulted in a federal disaster declaration (FEMA DR-914).

Severe Storms and Flooding (FEMA DR-1614)—October 2005

On October 9th, 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 15th, 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 federal disaster declaration (FEMA DR-1614) and Massachusetts received over $13 million in individual and public assistance.

Tropical Storm Beryl—July 2006

One of the strongest off-season Atlantic storms to make landfall in the U.S., Beryl moved up the eastern seaboard from its initial landfall in Florida, ultimately combining with another cold-weather system as it approached Massachusetts, producing winds and heavy rain.

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 was suffered in Massachusetts, three in Florida, and two in New Jersey.

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 in Massachusetts ranged between 46 and 67 mph. Tide data included: 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. These heavy rains caused flooding throughout the Commonwealth and a presidential disaster was declared (FEMA DR-4028). The Commonwealth received over $31 million in individual and public assistance from FEMA. Figure 11-13 depicts the storm track of Hurricane Irene.

Figure 11-13. Hurricane Irene Storm Track

Hurricane Sandy (FEMA DR-4097)—October-November 2012

Hurricane Sandy was the largest Atlantic hurricane on record, with winds spanning 1,100 miles in diameter, reaching sustained forces of 110 mph. Estimated losses due to damage and business interruption are still being calculated, but are estimated to exceed $65 billion. At present count (December 2012), at least 253 people were killed along the path of the storm, with 131 of those deaths in the U.S.

11.2.3 Frequency

Storms are often categorized by return frequencies (e.g. this was a 100 year storm, etc.). There are several shortcomings related to trying to categorize storms by return frequencies. First, the historical record of storms is relatively short to accurately assess the true long-term frequency of long period events. Most records only go back about 100 years. It is a little like sampling 20 ocean waves and making a conclusion of the full range of wave amplitudes in that part of the ocean. Second, when it comes to coastal flood impacts, it is not a level playing field. Sea level rise changes the vulnerability such that storms of an average 100-year frequency will occur considerably more often. Determining how well that can be quantified is dependent on the accuracy of sea level rise predictions. Third, coastal flood impacts can vary significantly from one locality to another depending upon such factors as onshore wind component and incidence of wave activity to the coastline. Fourth, a storm may have been a once in a hundred year storm for coastal flooding but a once in 10-year storm for wind or snowfall or rainfall, etc. Also, the impact of a storm can be compounded if it has multiple severe dimensions (e.g. major coastal flooding in addition to very heavy snow and extreme winds) or if it impacts such a large area that mutual aid cannot be exercised. Fifth, development along the coastline or in other vulnerable areas can significantly increase

the impact of a storm. Thus, the same storm in 1950 might not have garnered as much attention then as it would now with the increased coastal development.

In addition, there is a great deal of misunderstanding surrounding the reference to a “100 year storm” or a return frequency of 100 years. Similar to the flood events, a 100 year storm event does not mean that one should expect such a storm (or a storm of greater intensity) once every 100 years. Rather, a 100-year storm, to use that frequency as an example, is best described as a 1% chance of occurring in any given year. There might be two or three such storms in one hundred year period and then no more for the next 200 or 300 years. Figure 11-14 shows the number of hurricanes expected to occur during a 100-year period. According to this map, all of Massachusetts can expect between 20 and 40 hurricanes during a 100-year return period.

11.2.4 Probability of Future Occurrences

The National Oceanic and Atmospheric Administration Hurricane Research Division published a map (refer to Figure 11-15) showing the chance that a tropical storm or hurricane (of any intensity) will affect a given area during the hurricane season (June to November). This analysis was based on historical data from 1944 to 1999. Based on this analysis, the Commonwealth has a six- to 30-percent chance of a tropical storm or hurricane affecting the area each year. The probability increases as you move from the northwest portion of the Commonwealth to the southeast, with the highest probability along the coast, more specifically the Islands and Cape Cod.

Source: http://pubs.usgs.gov/fs/2005/3121/2005-3121.pdf

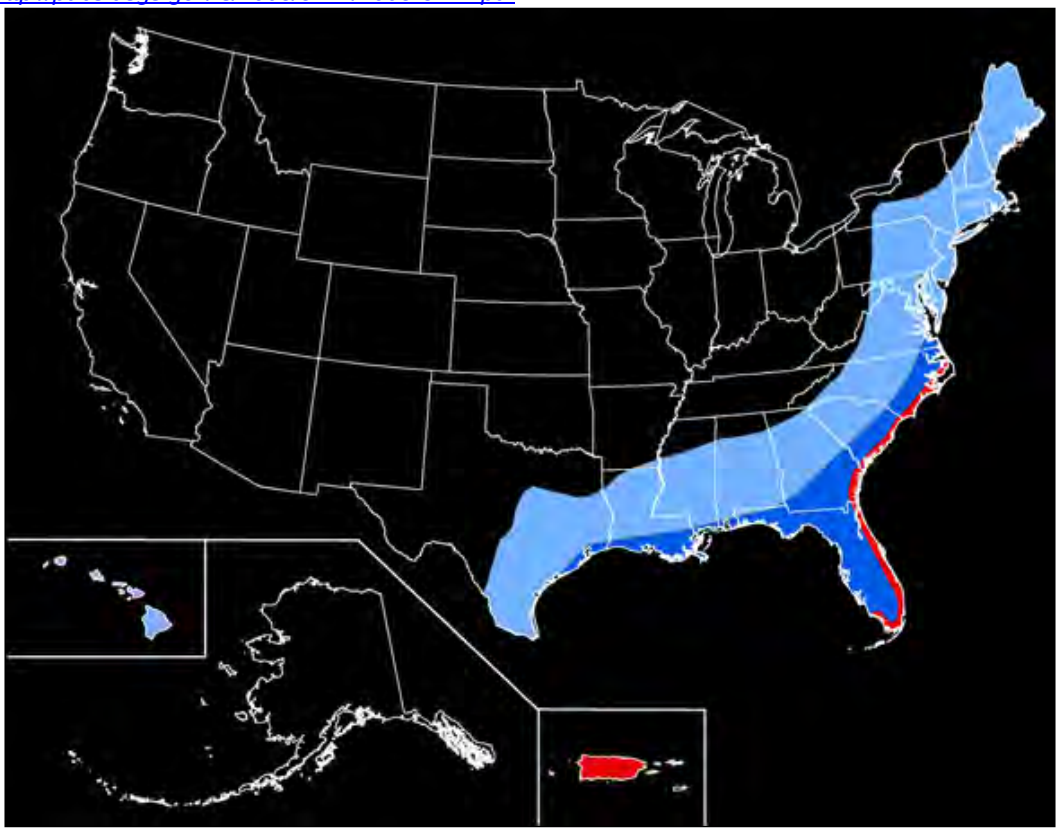


Figure 11-14. Number of Hurricanes for a 100-year Return Period: Light Blue Area, 20 to 40; Dark Blue Area, 40 to 60; Red Area, More Than 60

Source: http://www.aoml.noaa.gov/hrd/tcfag/G11.html

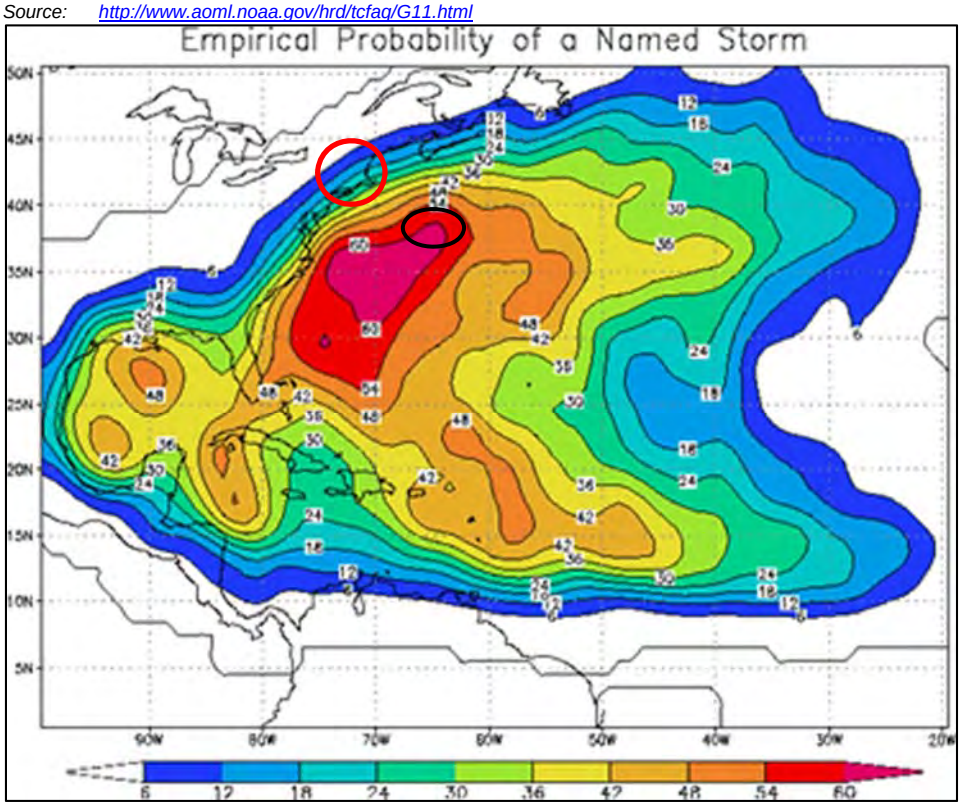


Figure 11-15. Probability of a Hurricane or Tropical Storm across Massachusetts (Circled)

A similar analysis was conducted to determine the probability that a major hurricane (Category 3, 4, or 5) will directly affect the area during hurricane season (June through November). The analysis was based on historical data from 1944 to 1999 for hurricanes within approximately 30

miles. Refer to

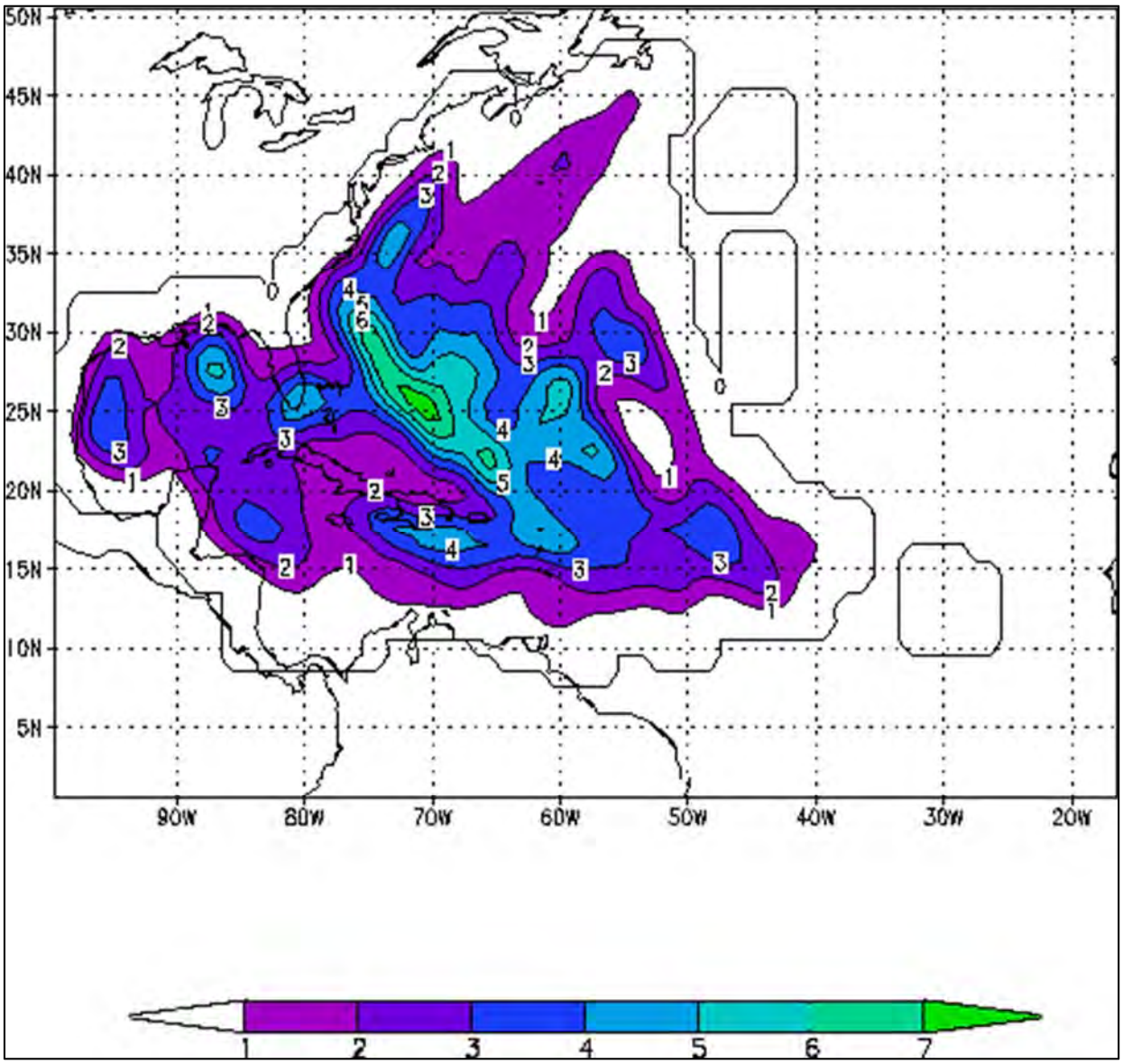


Figure 11-16. This analysis indicates that the Commonwealth has a one- to two-percent chance per year of a Category 3, 4 or 5 hurricane approaching the southern portion of the Commonwealth, but remaining off-shore to the east/southeast. This is not to say that a Category 3 through 5 hurricane could not come on-shore or that the Commonwealth could not be impacted by an event of this magnitude; but this does indicate the Commonwealth has a low probability of future occurrence for these category hurricanes.

Source: http://www.aoml.noaa.gov/hrd/tcfaq/ih_prob.gif

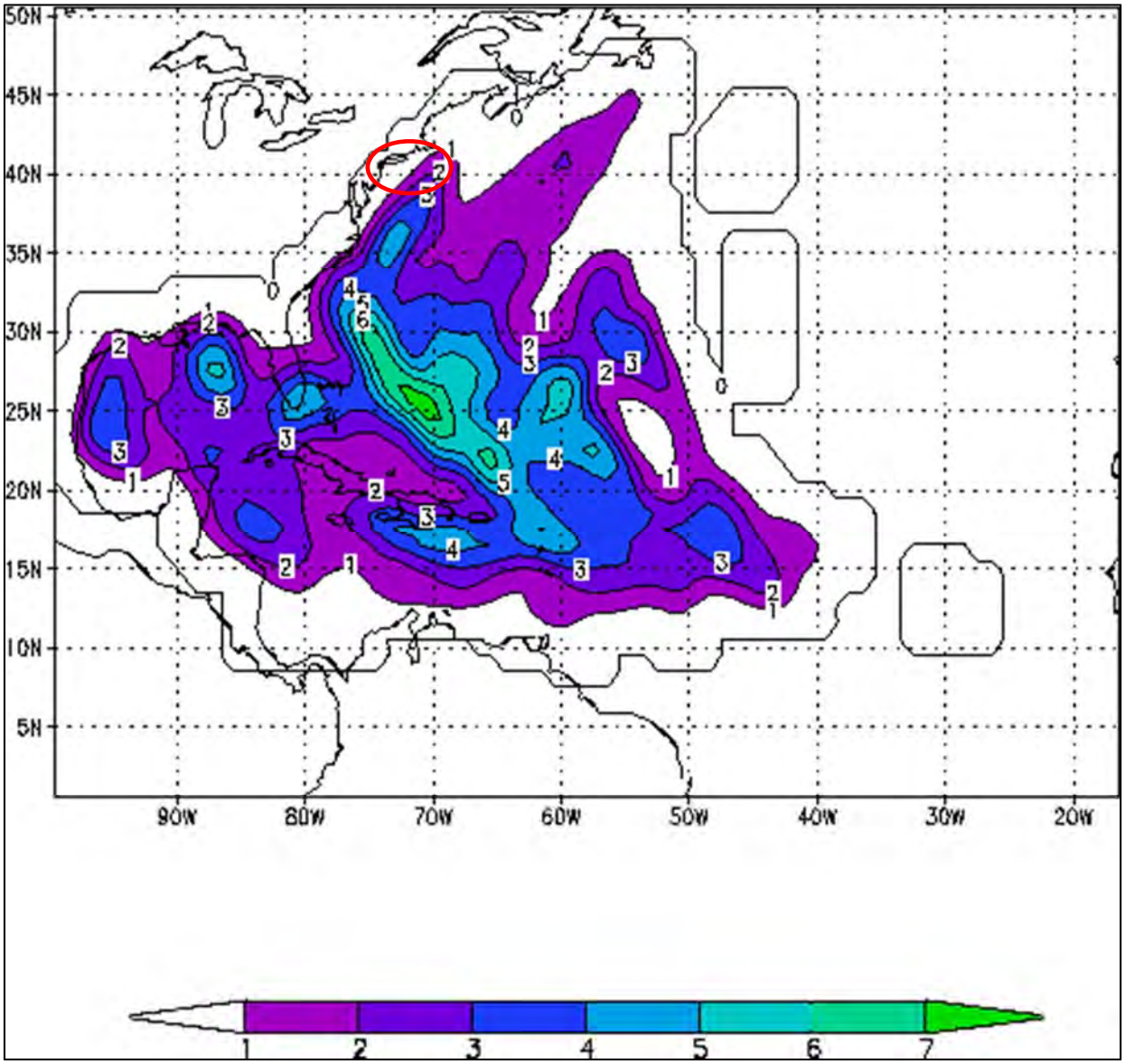


Figure 11-16. Probability of a Category 3, 4, or 5 Hurricane (Massachusetts Circled)

11.2.5 Severity

The extent of a hurricane is categorized by the Saffir-Simpson Hurricane Scale (Table 11-1). This scale categorizes or rates hurricanes from 1 (Minimal) to 5 (Catastrophic) based on their intensity. This is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale.

Location and track of a system can also be a major factor to indicate severity of storm impacts, especially when it comes to 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 effect creates the largest storm surge in the right-front quadrant of the storm. The winds are strongest there due to the combination of a storm's counter-clockwise rotation and forward motion (NOAA, date unknown). For Massachusetts, a serious scenario would be for the eye of a major hurricane to track west of Buzzards Bay. This would direct the strongest winds to push large quantities of water towards the shore, producing potential storm

surge of 25 feet or more at the upper part of Buzzards Bay. According to a SHMIC subject-matter expert and National Weather Service Meteorologist, this was most likely the scenario when the Colonial Hurricane of 1635 produced storm surge of 20 feet at the upper part of Buzzards Bay; this surge was 5 feet higher than what was recorded during the 1938 hurricane.

11.2.6 Warning Time

The National Weather Service issues a hurricane warning when sustained winds of 74 mph or higher are *expected* in a specified area in association with a tropical, subtropical, or post-tropical cyclone. A warning is issued 36 hours in advance of the anticipated onset of tropical-storm-force winds. A hurricane watch is announced when sustained winds of 74 mph or higher are *possible* within the specified area in association with a tropical, subtropical, or post-tropical cyclone. A watch is issued 48 hours in advance of the anticipated onset of tropical storm force winds (NWS, 2013). One should always prepare for a storm that is one category higher than expected because the fast forward speed of the storm means that wind gusts will be much higher, especially to the east of the track. Preparations should be complete by the time the storm is at the latitude of North Carolina. Outer bands containing squalls with heavy showers and wind gusts to tropical storm force can occur as much as 12-14 hours in advance of the eye, which can cause coastal flooding and may cut off exposed coastal roadways. The 1938 hurricane raced from Cape Hatteras to the Connecticut coast in 8 hours.

11.3 SECONDARY HAZARDS

Precursor events or hazards that may exacerbate hurricane damage include heavy rains, winds, tornadoes, storm surge, insufficient flood preparedness, sub-sea level infrastructure, and levee or dam breach or failure. Potential cascading events include health issues (mold, mildew); increased risk of fire hazards; hazardous materials, including waste byproducts; coastal erosion; compromise of levee or dam; isolated islands of humanity; increased risk of landslides or other types of land movement; disruption to transportation; disruption of power transmission and infrastructure; structural and property damage; debris distribution; and environmental impact.

11.4 CLIMATE CHANGE IMPACTS

Climate is defined not simply as average temperature and precipitation, but also by the type, frequency, and intensity of weather events. Both globally and at the local scale, climate change has the potential to alter the prevalence and severity of extremes such as storms, including those which may bring precipitation, high winds, and tornado events. While predicting changes of storm events under a changing climate is difficult, understanding vulnerabilities to potential changes is a critical part of estimating future climate change impacts on human health, society, and the environment (U.S. Environmental Protection Agency (EPA), 2006).

The Northeast has been experiencing more frequent days with temperatures above 90°F, increasing sea surface temperatures and sea levels, changes in precipitation patterns and amounts, and alterations in hydrological patterns. According to the Massachusetts Climate Change Adaptation Report, large storm events are becoming more frequent. Although there is still some level of uncertainty, research indicates the warming climate may double the frequency of Category 4 and 5 hurricanes by the end of the century, and decrease the frequency of less severe hurricane events. More frequent and intense storm events will cause an increase in damage to the built environment and have devastating effects on the economy and environment (EOEEA, 2011).

Massachusetts is committed to adapting to climate change as it continues to occur. More detailed information on climate change and its potential impact on the Commonwealth can be found in the 2011 *Massachusetts Climate Change Adaptation Report*.

11.5 EXPOSURE

To understand risk, the assets exposed to the hazard areas are identified. For the hurricane and tropical storm hazard the entire Commonwealth of Massachusetts is exposed; more specifically the wind and rains associated with these events. However, certain areas, types of building, and infrastructure are at greater risk than others, due to proximity to the coast and/or their manner of construction. Storm surge from a hurricane/tropical storm poses one of the greatest risks to residents and property.

The following discusses the Commonwealth of Massachusetts' exposure to the hurricane/tropical storm hazard including:

- Population
- State facilities
- Critical facilities and infrastructure
- Economy

FEMA Region IV Risk Analysis Team developed storm surge inundation grids for the Commonwealth in GIS format from the "maximum of maximums" outputs from the SLOSH model. These represent the worst-case storm surge scenarios for each hurricane category (1 through 4). To assess the Commonwealth's exposure to the hurricane/tropical surge, a spatial analysis was conducted using the SLOSH model. The SLOSH boundaries do not account for any inland flash flooding.

Using ArcMap, GIS software, the SLOSH zones were overlaid with the population, general building stock, state facility data (owned and leased) and critical facilities, and the appropriate SLOSH zone determination (categories one through four) was assigned.

11.5.1 Population

The impact of a hurricane or tropical storm on life, health, and safety is dependent upon several factors including the severity of the event and whether or not adequate warning time was provided to residents. It is assumed that the entire Commonwealth's population is exposed to this hazard.

To estimate the population exposed to the surge inundation areas, the SLOSH category one through four zones were overlaid on the 2010 Census block population data in GIS (U.S. Census 2010). Census blocks do not follow the boundaries of the floodplain. The Census blocks with their centroid in the SLOSH boundaries were used to calculate the estimated population exposed to the hurricane surge hazard. Table 11-4 summarizes the 2010 Census population in the Category 1 through 4 SLOSH zones by county.

TABLE 11-4.
ESTIMATED POPULATION EXPOSURE TO THE HURRICANE HAZARD

		Category 1		Category 2		Category 3		Category 4	
County	Total Population	Population	% of Total	Population	% of Total	Population	% of Total	Population	% of Total
Barnstable	215,888	21,546	10.0	31,949	14.8	43,048	19.9	53,893	25.0
Berkshire	131,219	—	—	—	—	—	—	—	—
Bristol	548,285	18,618	3.4	25,101	4.6	41,747	7.6	53,284	9.7
Dukes	16,535	1,029	6.2	1,706	10.3	2,185	13.2	2,847	17.2
Essex	743,159	21,409	2.9	30,029	4.0	48,321	6.5	68,055	9.2
Franklin	71,372	—	—	—	—	—	—	—	—

TABLE 11-4.
ESTIMATED POPULATION EXPOSURE TO THE HURRICANE HAZARD

		Category 1		Category 2		Category 3		Category 4	
County	Total Population	Population	% of Total	Population	% of Total	Population	% of Total	Population	% of Total
Hampden	463,490	—	—	—	—	—	—	—	—
Hampshire	158,080	—	—	—	—	—	—	—	—
Middlesex	1,503,085	35,539	2.4	75,501	5.0	152,071	10.1	186,568	12.4
Nantucket	10,172	71	0.7	181	1.8	474	4.7	723	7.1
Norfolk	670,850	12,503	1.9	25,095	3.7	40,360	6.0	53,743	8.0
Plymouth	494,919	19,694	4.0	30,931	6.2	38,313	7.7	46,308	9.4
Suffolk	722,023	84,728	11.7	161,104	22.3	243,901	33.8	269,737	37.4
Worcester	798,552	—	—	—	—	—	—	—	—
Total	**6,547,629**	**215,137**	**3.3**	**381,597**	**5.8**	**610,420**	**9.3**	**735,158**	**11.2**

Economically disadvantaged populations are more vulnerable because they are likely to evaluate their risk and make decisions based on the major economic impact to their family and may not have funds to evacuate. The population over the age of 65 is also more vulnerable and, physically, they may have more difficulty evacuating. The elderly are considered most vulnerable because they require extra time or outside assistance during evacuations and are more likely to seek or need medical attention which may not be available due to isolation during a storm event.

11.5.2 State Facilities

All Commonwealth state-owned and leased buildings are exposed to the wind and/or rain from the hurricane/tropical storm hazard. Refer to Table 11-5, which summarizes the total replacement cost value of all 6,765 state-owned and leased buildings in the Commonwealth.

To assess the exposure of the state-owned and leased facilities to the surge inundation from a hurricane event, the SLOSH boundaries provided by the FEMA Region IV Coastal Flood Loss Atlas team were used. The digital SLOSH zones were overlaid upon the state facility data and the appropriate SLOSH zone was determined. Table 11-6 and Table 11-7 summarize the results of the analysis by county and state agency, respectively.

TABLE 11-5.
TOTAL STATE BUILDING REPLACEMENT COST VALUE EXPOSED TO THE HURRICANE/TROPICAL STORM HAZARD

	Exposed Replacement Cost Value (Structure and Contents)		
County	Owned Facilities	Leased Facilities	Total
Barnstable	$1,129,133,087	$17,181,274	$1,146,314,361
Berkshire	$1,810,562,200	$41,438,632	$1,852,000,832
Bristol	$2,862,545,772	$149,664,578	$3,012,210,350
Dukes	$9,965,088	$6,258,960	$16,224,048
Essex	$4,336,334,705	$136,866,724	$4,473,201,429

TABLE 11-5.
TOTAL STATE BUILDING REPLACEMENT COST VALUE EXPOSED TO THE HURRICANE/TROPICAL STORM HAZARD

	Exposed Replacement Cost Value (Structure and Contents)		
County	Owned Facilities	Leased Facilities	Total
Franklin	$789,074,575	$24,162,354	$813,236,929
Hampden	$4,896,066,804	$155,583,444	$5,051,650,248
Hampshire	$4,654,345,657	$33,042,196	$4,687,387,853
Middlesex	$9,556,026,897	$325,969,758	$9,881,996,655
Nantucket	$30,440,058	$941,186	$31,381,244
Norfolk	$4,994,008,904	$147,822,352	$5,141,831,256
Plymouth	$3,089,420,567	$92,983,586	$3,182,404,153
Suffolk	$7,795,245,796	$487,827,934	$8,283,073,730
Worcester	$9,226,864,179	$217,834,816	$9,444,698,995
Total	**$55,180,034,288**	**$1,837,577,794**	**$57,017,612,082**

Note: Building data are always being updated as agencies change or modify. The state-owned building information is current as of October 3, 2012, and the state-leased building information is current as of October 10, 2010, with a total of 6,765 buildings.

TABLE 11-6.
STATE BUILDING EXPOSURE IN THE SLOSH ZONES (CUMULATIVE), BY COUNTY

	Number of State-Owned or Leased Buildings, by SLOSH Zone									
	Category 1		Category 2		Category 3		Category 4		Total All	Replacement
County	Owned	Leased	Owned	Leased	Owned	Leased	Owned	Leased	Categories	Cost Value
Barnstable	—		—	—	—	—	—	—	—	—
Berkshire	—	—	—	—	—	—	—	—	—	—
Bristol	54	1	56	2	59	5	62	7	69	$110,771,656
Dukes	2	—	4	—	4	1	4	1	5	$7,187,848
Essex	47	2	64	2	78	5	100	16	116	$807,906,384
Franklin	—	—	—	—	—	—	—	—	—	—
Hampden	—	—	—	—	—	—	—	—	—	—
Hampshire	—	—	—	—	—	—	—	—	—	—
Middlesex	8	2	18	5	27	8	31	14	45	$444,582,213
Nantucket	—	—	—	—	—	—	—	—	—	—
Norfolk	4	—	18	3	81	3	87	4	91	$443,072,666
Plymouth	14	—	31	1	32	1	46	1	47	$53,556,970
Suffolk	76	10	124	16	180	31	184	32	216	$4,019,078,238
Worcester	—	—	—	—	—	—	—	—	—	—
Total	**234**	**15**	**364**	**30**	**527**	**57**	**582**	**78**	**660**	**$6,188,087,060**

Note: SLOSH zones provided by FEMA Coastal Flood Loss Atlas Team.

TABLE 11-7.
STATE FACILITIES IN THE SLOSH ZONES (CUMULATIVE), BY STATE AGENCY

	Category 1		Category 2		Category 3		Category 4	
Agency	#	Replacement Cost Value	#	Replacement Cost Value	#	Replacement Cost Value	#	Replacement Cost Value
Alcoholic Beverages Control Commission	1	$1,619,110	1	$1,619,110	1	$1,619,110	1	$1,619,110
Board of Higher Education	1	$1,402,696	1	$1,402,696	1	$1,402,696	1	$1,402,696
Board of Library Commissioners	1	$1,846,748	1	$1,846,748	1	$1,846,748	1	$1,846,748
Bunker Hill Community College		—	—	—	6	$261,138,948	6	$261,138,948
Bureau of State Buildings		—	1	$166,987,500	1	$166,987,500	1	$166,987,500
Committee For Public Counsel Services		—	1	$1,867,322	4	$5,352,684	6	$9,578,134
Council of Government	1	$17,497,010	1	$17,497,010	1	$17,497,010	1	$17,497,010
Department of Business & Technology		—	—	—	1	$141,072	1	$141,072
Department of Children and Families	2	$10,495,898	3	$15,786,062	5	$27,676,908	9	$46,879,134
Department of Conservation and Recreation	146	$365,085,448	218	$500,827,231	322	$966,810,976	346	$1,013,824,763
Department of Corrections		—	—	—	1	$2,162,554	1	$2,162,554
Department of Developmental Services	2	$9,822,690	2	$9,822,690	5	$14,842,202	5	$14,842,202
Department of Early Education and Care	1	$4,153,848	1	$4,153,848	1	$4,153,848	1	$4,153,848
Department of Fish and Game	3	$1,537,838	19	$16,850,590	19	$16,850,590	19	$16,850,590
Department of Mental Health	1	$1,408,572	2	$132,920,922	10	$180,971,440	13	$185,037,262
Department of Public Health	2	$6,043,612	3	$9,650,542	4	$15,709,116	4	$15,709,116
Department of Public Utilities		—	1	$8,941,446	1	$8,941,446	1	$8,941,446
Department of State Police		—	7	$19,195,552	7	$19,195,552	7	$19,195,552
Department of Transitional Assistance	2	$10,638,306	3	$15,203,344	5	$25,997,950	7	$36,423,580
Department of Transportation	25	$31,343,123	37	$72,328,813	54	$113,001,267	64	$116,921,821
Department of Transportation		—	—	—	—	—	1	$1,068,720
Division of Capital Asset Management	2	$61,122,501	4	$152,585,151	4	$152,585,151	4	$152,585,151
Exec. Office of Energy & Environmental Affairs	1	$23,551,116	2	$23,942,534	2	$23,942,534	2	$23,942,534
Exec. Office of Health & Human Services	1	$4,353,698	3	$33,803,346	3	$33,803,346	3	$33,803,346
Massachusetts Department of Revenue		—	—	—	1	$8,762,970	3	$22,828,930
Massachusetts College of Art and Design		—	—	—	10	$527,402,394	10	$527,402,394
Massachusetts Cultural Council		—	—	—	1	$1,965,376	1	$1,965,376
Massachusetts Gaming Commission		—	—	—	1	$1,499,146	1	$1,499,146
Massachusetts Maritime Academy	23	$232,605,111	23	$232,605,111	23	$232,605,111	23	$232,605,111

TABLE 11-7.
STATE FACILITIES IN THE SLOSH ZONES (CUMULATIVE), BY STATE AGENCY

	Category 1		Category 2		Category 3		Category 4	
Agency	#	Replacement Cost Value	#	Replacement Cost Value	#	Replacement Cost Value	#	Replacement Cost Value
Massachusetts Rehabilitation Commission		—	1	$1,461,208	3	$16,835,012	4	$18,183,202
Massachusetts Teachers' Retirement System	1	$4,755,804	1	$4,755,804	1	$4,755,804	1	$4,755,804
Military Division	1	$19,341,560	3	$41,755,222	4	$61,096,782	8	$69,870,700
North Shore Community College		—	—	—	6	$14,810,266	6	$14,810,266
Office of Labor and Workforce Development		—	—	—	1	$6,237,764	1	$6,237,764
Office of the Chief Medical Examiner		—	—	—	1	$19,345,938	1	$19,345,938
Office of the D.A. Cape & Island		—	—	—	1	$1,595,866	1	$1,595,866
Office of the D.A. Eastern		—	—	—	—	—	2	$9,641,990
Office of the D.A. Northern		—	—	—	—	—	2	$1,961,102
Office of the State Treasurer		—	—	—	1	$2,381,108	1	$2,381,108
Public Employee Retirement Admin. Comm.		—	—	—	1	$3,874,110	1	$3,874,110
Salem State University	8	$164,933,284	15	$175,103,763	16	$183,912,917	29	$344,537,884
Secretary of State	1	$62,377,670	1	$62,377,670	1	$62,377,670	2	$72,822,538
Sex Offenders' Registry		—	—	—	—	—	1	$4,048,044
Sheriff's Department Middlesex		—	1	$3,990,652	2	$93,358,596	2	$93,358,596
Sheriff's Department Suffolk		—	—	—	8	$512,677,154	9	$874,251,452
Trial Court	1	$62,649,746	3	$79,396,854	8	$247,489,074	11	$312,342,990
University of Massachusetts at Amherst		—	13	$15,069,570	13	$15,069,570	13	$15,069,570
University of Massachusetts at Boston	20	$1,380,001,842	20	$1,380,001,842	20	$1,380,001,842	20	$1,380,001,842
University of Massachusetts at Dartmouth	2	$142,500	2	$142,500	2	$142,500	2	$142,500
Total	**249**	**$2,478,729,732**	**394**	**$3,203,892,653**	**584**	**$5,460,827,619**	**660**	**$6,188,087,060**

Note: SLOSH zones provided by FEMA Coastal Flood Loss Atlas Team.

A total of 660 structures, or nearly 10-percent of state-owned and leased facilities, are located within the SLOSH inundation zones. The Category 1 zone has 249 state structures located within and thus exposed to a Category 1 hurricane's storm surge. Category 1 storms occur more frequently than higher category storms, and structures located in this zone are the most vulnerable because they tend to be in the low lying areas very close to the coastline. Category 2 zone has 150 structures, Category 3 zone has 185 structures, and Category 4 has 76 structures. The total number of buildings exposed to each category noted in Table 11-6 and Table 11-7 are cumulative. For example, the total number of state buildings exposed to a Category 3 zone includes the buildings in Categories 1 and 2 zones as well. All other state structures that are not presented in the tables are not located in a defined SLOSH zone.

A comparison analysis was conducted to understand the changes in hurricane surge exposure to state-owned and leased buildings from the 2010 plan to the 2013 plan. Table 11-8 and Table 11-9 summarize these findings. The analysis shows an increase in the number of state buildings exposed to the Category 1 surge inundation. As noted earlier, the best available data were used for this analysis including the FEMA Region IV Coastal Flood Loss Atlas team SLOSH data. The differences between the SLOSH data and the state building database used for both plan updates may help explain the changes in the number of buildings exposed.

TABLE 11-8.
CHANGE IN NUMBER OF STATE BUILDINGS IN SLOSH ZONES BY COUNTY, 2009 TO 2012

	Category 1			Category 2			Category 3			Category 4		
County	2009	2012	Change	2009	2012	Change	2009	2012	Change	2009	2012	Change
Barnstable	10	29	19	7	21	14	9	19	10	2	2	0
Berkshire	0	0	0	0	0	0	0	0	0	0	0	0
Bristol	3	55	52	8	3	-5	13	6	-7	9	5	-4
Dukes	0	2	2	2	2	0	0	1	1	0	0	0
Essex	4	49	45	22	21	-1	10	13	3	12	33	21
Franklin	0	0	0	0	0	0	0	0	0	0	0	0
Hampden	0	0	0	0	0	0	0	0	0	0	0	0
Hampshire	0	0	0	0	0	0	0	0	0	0	0	0
Middlesex	7	10	3	12	13	1	0	12	12	5	10	5
Nantucket	0	0	0	0	0	0	0	0	0	1	0	-1
Norfolk	2	4	2	5	18	13	0	62	62	2	7	5
Plymouth	2	14	12	18	18	0	10	1	-9	6	14	8
Suffolk	29	86	57	54	54	0	7	71	64	6	5	-1
Worcester	0	0	0	0	0	0	0	0	0	0	0	0
Total	**57**	**249**	**192**	**128**	**150**	**22**	**49**	**185**	**136**	**43**	**76**	**33**

Note: To be consistent with the 2010 SHMP methodology and compare the data, the number of buildings is not cumulative in this table per zone as presented in other tables in this section.

TABLE 11-9.
CHANGE IN VALUE OF STATE BUILDINGS IN ALL SLOSH ZONES BY COUNTY, 2009 TO 2012

	Replacement Cost Value of State Buildings in All SLOSH Zones		
County	2009 (using April 2007 values)	2012	Change, 2009 - 2012
Barnstable	$93,758,283.00	$301,931,085	$208,172,802
Berkshire	0	$0	$0
Bristol	$21,709,222.00	$110,771,656	$89,062,434
Dukes	$1,528,329.00	$7,187,848	$5,659,519
Essex	$162,042,865.00	$807,906,384	$645,863,519
Franklin	0	$0	$0
Hampden	0	$0	$0
Hampshire	0	$0	$0
Middlesex	$43,190,889.00	$444,582,213	$401,391,324
Nantucket	$492,212.00	$0	-$492,212
Norfolk	$13,840,070.00	$443,072,666	$429,232,596
Plymouth	$20,833,937.00	$53,556,970	$32,723,033
Suffolk	$1,807,055,620.00	$4,019,078,238	$2,212,022,618
Worcester	0	$0	$0
Total	**$2,164,451,427.00**	**$6,188,087,060**	**$4,023,635,633**

According to DCAMM, the building data are always being updated, changed, and corrected as agencies change or modify. The 2010 plan's building dataset was not available and an entirely new and updated data set was obtained from DCAMM and the Office of Leasing for the 2013 plan update. The following are key differences between the two building data sets:

- The 2010 plan used November 2009 DCAMM data with 2007 financial figures as the replacement cost values. For this analysis, replacement cost values not provided by DCAMM or the Office of Leasing were calculated based on square footage and 2011 R.S. Means values for the structure and contents.
- The exact number of buildings in the 2009 DCAMM data set is unknown; however, the 2010 plan indicates the Commonwealth of Massachusetts owns and operates more than 6,000 properties across the Commonwealth. As discussed, for the 2013 plan update the state building data set contained both owned and leased buildings provided by both DCAMM and the Office of Leasing (a total of 6,765 buildings: 432 leased buildings and 6,333 owned buildings).
- The 2009 building locations were based on 'digitally enhanced and GPS corrected data.' The building data provided by DCAMM and the Office of Leasing in October 2012 were geocoded using the ArcGIS Online North America Streets 10.0 online geocoding service. This is because the data provided with the attributes needed for the risk assessment could not be joined with any existing spatial data set provided by DCAMM.

11.5.3 Critical Facilities

An exposure analysis was completed using the police stations, fire stations, medical facilities, and schools (pre-K through grade 12 and colleges), emergency operation centers (state only) provided by MassGIS. Table 11-10 and Table 11-11 summarize critical facility exposure to the SLOSH Category 1 through 4 storm surge inundation summarized by facility type and county, respectively.

TABLE 11-10.
CRITICAL FACILITY EXPOSURE TO SURGE INUNDATION SLOSH ZONES

County	Total	Category 1	Category 2	Category 3	Category 4
Police Stations	437	13	29	45	53
Fire Stations	789	18	32	57	79
Hospitals	82	1	3	8	11
Schools (pre-K-12)	2,767	42	96	166	208
Colleges	205	12	24	46	57
Emergency Operation Centers	2	0	0	0	0

Source: Facilities provided by MassGIS (provided September 2012)

TABLE 11-11.
CRITICAL FACILITY EXPOSURE TO SURGE INUNDATION SLOSH ZONES, BY COUNTY

County	Police Stations	Fire Stations	Hospitals	Schools (pre-K-12)	Colleges	Emergency Operation Centers
Barnstable	6	14	1	10	1	—
Berkshire	—	—	—	—	—	—
Bristol	5	8	—	13	—	—
Dukes	5	2	1	2	—	—
Essex	4	5	—	22	3	—
Franklin	—	—	—	—	—	—
Hampden	—	—	—	—	—	—
Hampshire	—	—	—	—	—	—
Middlesex	11	17	2	49	15	—
Nantucket	—	—	—	—	1	—
Norfolk	1	3	—	18	2	—
Plymouth	2	8	1	14	—	—
Suffolk	19	22	6	80	35	—
Worcester	—	—	—	—	—	—
Total	**53**	**79**	**11**	**208**	**57**	**0**

Source: Facilities provided by MassGIS (provided September 2012)

Some roads and bridges are also considered critical infrastructure, particularly those providing ingress and egress and allow emergency vehicles access to those in need. Refer to Figure 11-2 through Figure 11-8, which illustrate the major Massachusetts Department of Transportation roads layer to determine which segments are located in the SLOSH inundation areas and vulnerable to surge.

The default Hazus-MH highway bridge inventory developed from the 2001 National Bridge Inventory database was used to conduct an exposure analysis for the bridges in the Commonwealth. Table 11-12 identifies the number of highway bridges in the Hazus-MH default highway bridge inventory exposed to the SLOSH Category 1 through 4 zones summarized by county. The exposure analysis indicates 558 highway bridges are located within the Category 1 through 4 SLOSH zones of the total inventory in Hazus-MH (4,832 bridges).

TABLE 11-12.
NUMBER OF BRIDGES IN THE SLOSH HAZARD ZONES BY COUNTY

	Category 1			Category 2			Category 3			Category 4		
County	Federal	State	Local	Federal	State	Local	Federal	State	Local	Federal	State	Local
Barnstable	1	8	19	1	9	21	1	12	20	1	14	21
Berkshire	—	—	—	—	—	—	—	—	—	—	—	—
Bristol	—	13	17	—	15	23	—	24	27	—	26	29
Dukes	—	—	—	—	—	—	—	—	—	—	—	—
Essex	—	23	14	—	28	18	—	31	20	—	40	25
Franklin	—	—	—	—	—	—	—	—	—	—	—	—
Hampden	—	—	—	—	—	—	—	—	—	—	—	—
Hampshire	—	—	—	—	—	—	—	—	—	—	—	—
Middlesex	—	29	1	—	44	2	—	59	6	—	68	9
Nantucket	—	—	2	—	—	2	—	—	2	—	—	2
Norfolk	—	1	2	—	—	3	—	12	4	—	16	5
Plymouth	—	19	12	—	26	13	—	31	14	—	36	15
Suffolk	—	100	11	—	142	13	—	209	20	—	230	21
Worcester	—	—	—	—	—	—	—	—	—	—	—	—
Total	**1**	**193**	**78**	**1**	**264**	**95**	**1**	**378**	**113**	**1**	**430**	**127**

Source: Hazus-MH v 2.1; FEMA Region IV Coastal Flood Loss Atlas SLOSH Boundaries

11.5.4 Economy

Damage to buildings can impact a community's economy and tax base. In determining this level of impact, the area of each county (square miles) exposed to the Category 1 through 4 SLOSH inundation was determined. Of the nine counties with area in the SLOSH inundation zones, four counties have greater than 10-percent of their area within the Category 1 boundary. Suffolk County has the greatest percent of their area in the inundation zones from 21.5-percent (Category 1) to greater than 42-percent (Category 4). The Islands (Dukes and Nantucket Counties) and Barnstable County also have a large percentage of their total area exposed to storm surge inundation. Table 11-13 summarizes these findings.

TABLE 11-13.
AREA LOCATED IN THE SLOSH ZONES (SQUARE MILES)

		Category 1		Category 2		Category 3		Category 4	
County	Total Area	Area	% of Total	Area	% of Total	Area	% of Total	Area	% of Total
Barnstable	412.48	59.3	14.4	82.9	20.1	98.0	23.8	111.8	27.1
Berkshire	946.39	—	—	—	—	—	—	—	—
Bristol	571.86	24.4	4.3	30.9	5.4	40.7	7.1	49.7	8.7
Dukes	109.90	22.4	20.4	26.1	23.7	29.5	26.8	33.1	30.1
Essex	514.90	47.3	9.2	55.6	10.8	64.3	12.5	74.0	14.4
Franklin	724.58	—	—	—	—	—	—	—	—
Hampden	634.06	—	—	—	—	—	—	—	—
Hampshire	545.27	—	—	—	—	—	—	—	—
Middlesex	846.59	6.5	0.8	10.4	1.2	16.1	1.9	19.0	2.2
Nantucket	49.03	8.3	16.9	10.6	21.7	12.6	25.8	14.9	30.5
Norfolk	408.54	5.1	1.2	7.0	1.7	8.6	2.1	10.2	2.5
Plymouth	689.77	34.6	5.0	48.4	7.0	60.4	8.8	71.7	10.4
Suffolk	59.74	12.9	21.5	18.4	30.8	23.4	39.1	25.4	42.5
Worcester	1,579.21	—	—	—	—	—	—	—	—
Total	**8,092.30**	**220.8**	**2.7**	**290.3**	**3.6**	**353.6**	**4.4**	**409.8**	**5.1**

Source: FEMA Region IV Coastal Flood Loss Atlas SLOSH boundaries

11.6 VULNERABILITY

To assess the Commonwealth's vulnerability to the hurricane and tropical storm hazard, potential losses were determined for historical events selected by the SHMT and the THIRA Workgroup: Tropical Storm Irene (2011), Category 1 Hurricane Gloria (1985), Category 2 Hurricane Bob (1991), and Category 3 Unnamed Hurricane (1938). The Hazus-MH model and the SLOSH data were used to estimate potential losses to these events.

11.6.1 Population

Residents may be displaced or require temporary to long-term sheltering. In addition, downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life. Socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing.

The historical events were run in Hazus-MH to estimate the sheltering needs (U.S. Census 2000) should this event occur today. It should be noted that Hazus-MH utilizes 2000 Census data, and therefore, the totals will vary slightly. The estimated shelter needs are summarized in Table 11-14. All counties, with the exception of Barnstable and Berkshire Counties, have experienced an increase in population growth since the 2000 Census (see Section 5); therefore, the numbers in Table 11-14 are conservative.

TABLE 11-14.
ESTIMATED SHELTER NEEDS - WIND ONLY ANALYSIS

	Tropical Storm		Category 1 - Hurricane		Category 2 - Hurricane		Category 3 - Hurricane	
County	Displaced Households	Short Term Shelter Needs	Displaced Households	Short Term Shelter Needs	Displaced Households	Short Term Shelter Needs	Displaced Households	Short Term Shelter Needs
Barnstable	0	0	0	0	486	112	4	1
Berkshire	0	0	0	0	0	0	69	15
Bristol	0	0	0	0	1,203	344	732	201
Dukes	0	0	0	0	57	13	1	0
Essex	0	0	0	0	15	1	143	35
Franklin	0	0	0	0	0	0	180	44
Hampden	0	0	9	2	0	0	2,211	611
Hampshire	0	0	3	1	0	0	524	129
Middlesex	0	0	25	4	23	1	971	216
Nantucket	0	0	0	0	2	0	0	0
Norfolk	0	0	0	0	94	15	349	72
Plymouth	0	0	0	0	408	90	104	27
Suffolk	0	0	2	0	160	43	860	248
Worcester	0	0	263	68	0	0	2,230	591
Total	**0**	**0**	**302**	**75**	**2,448**	**619**	**8,378**	**2,190**

Source: Hazus-MH v. 2.1 (U.S. Census 2000)

11.6.2 State Facilities

To estimate the potential losses to state-owned and leased structures, the SLOSH data were used. There are 6,765 state-owned/leased structures in the Commonwealth; all of which are exposed to the hurricane/tropical storm hazard. Table 11-5 summarizes the total replacement cost value of these structures.

Structures located in the storm surge inundation areas are at greatest risk to surge-related damage. The SLOSH inundation area for a Category 4 event and the estimated depth of flooding per FEMA Region IV are shown in Figure 11-17 through Figure 11-23 for the coastal regions. A total risk exposure of nearly $6.2 billion is estimated for state-owned and leased buildings located in the Category 1 through 4 SLOSH zones. The Hurricane Category 4 SLOSH depth grids provided by FEMA Region IV were imported into the Hazus-MH flood model, and the potential losses were estimated for the state-owned and leased facilities. Table 11-15 and Table 11-16 summarize the potential losses by county and agency, respectively.

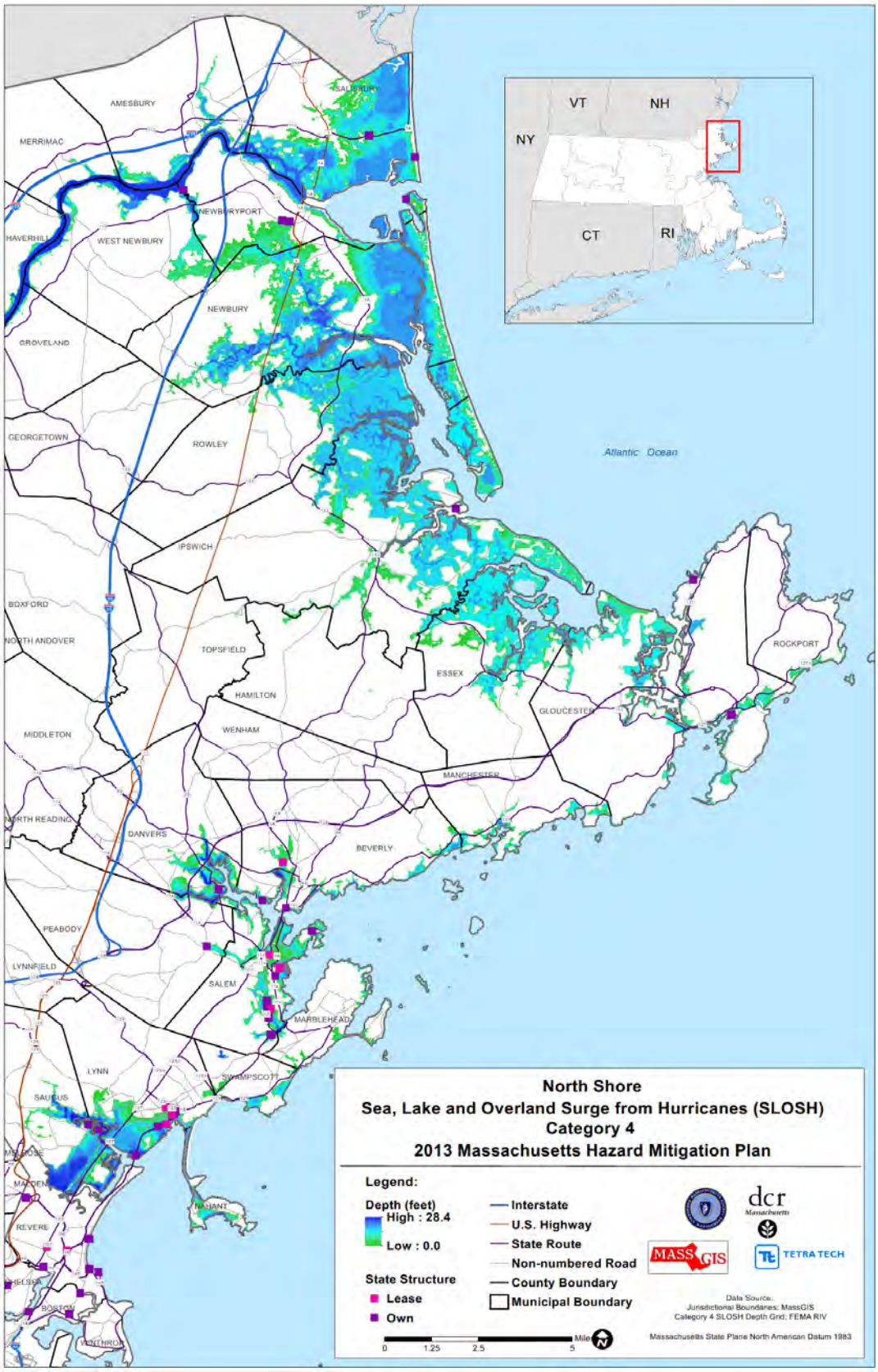


Figure 11-17. North Shore SLOSH Inundation for a Category 4 Event

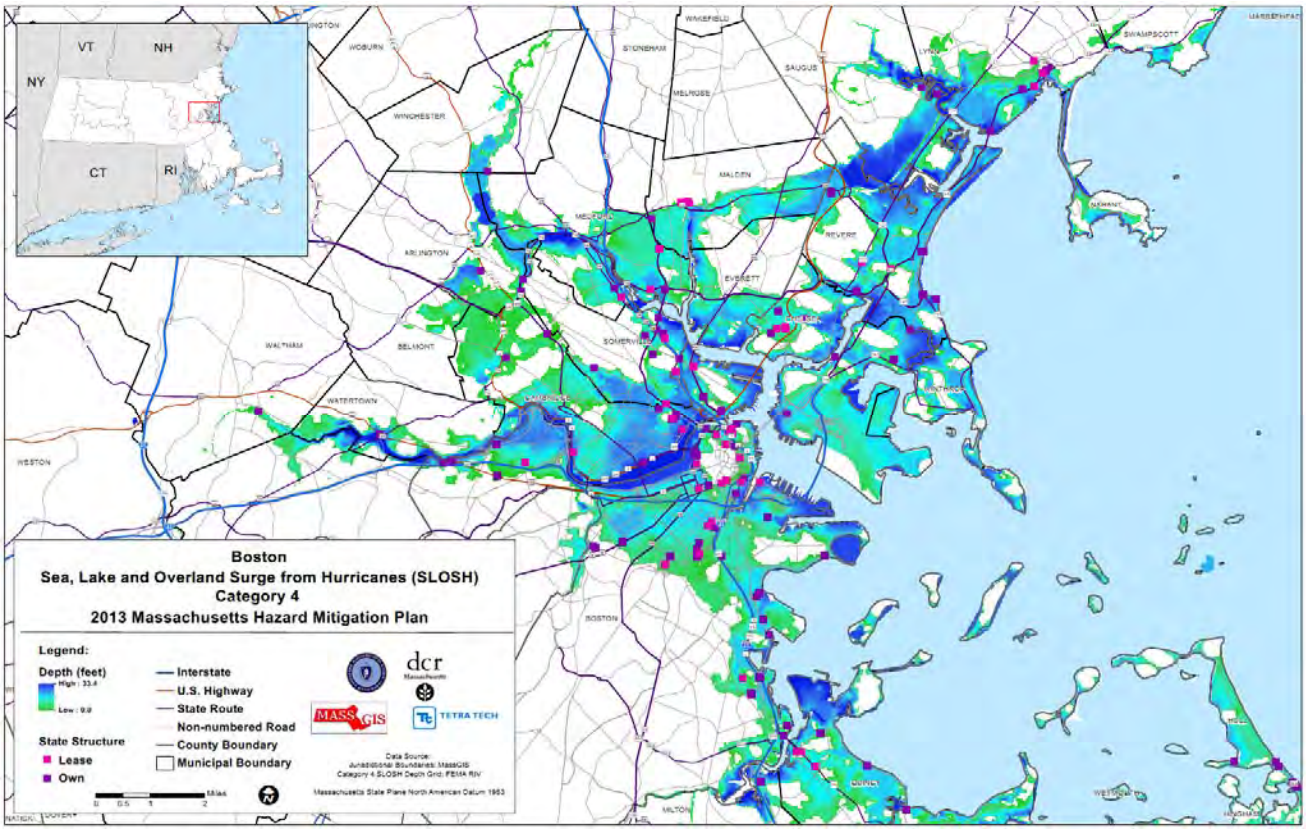


Figure 11-18. Boston SLOSH Inundation for a Category 4 Event

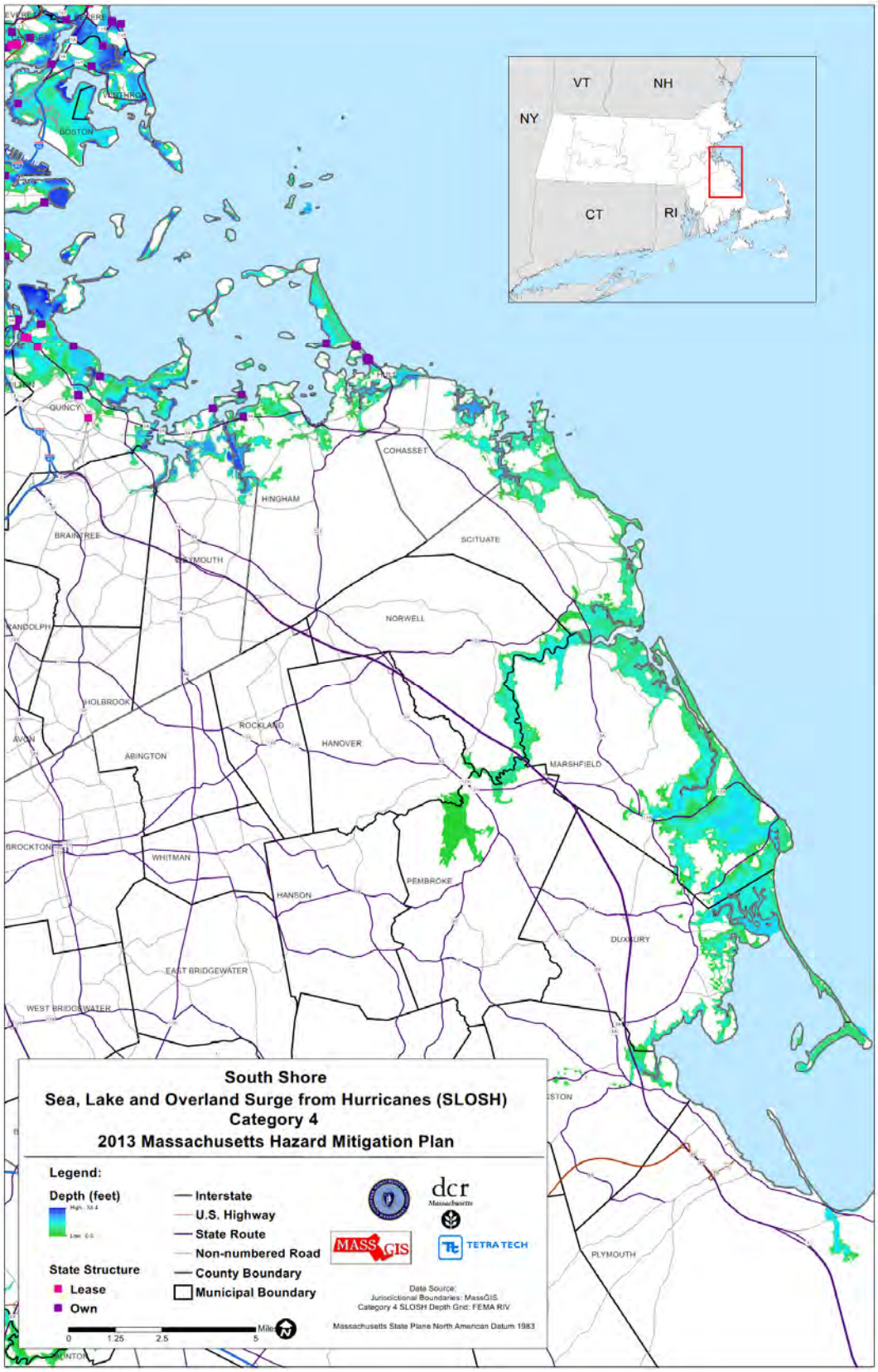


Figure 11-19. South Shore SLOSH Inundation for a Category 4 Event

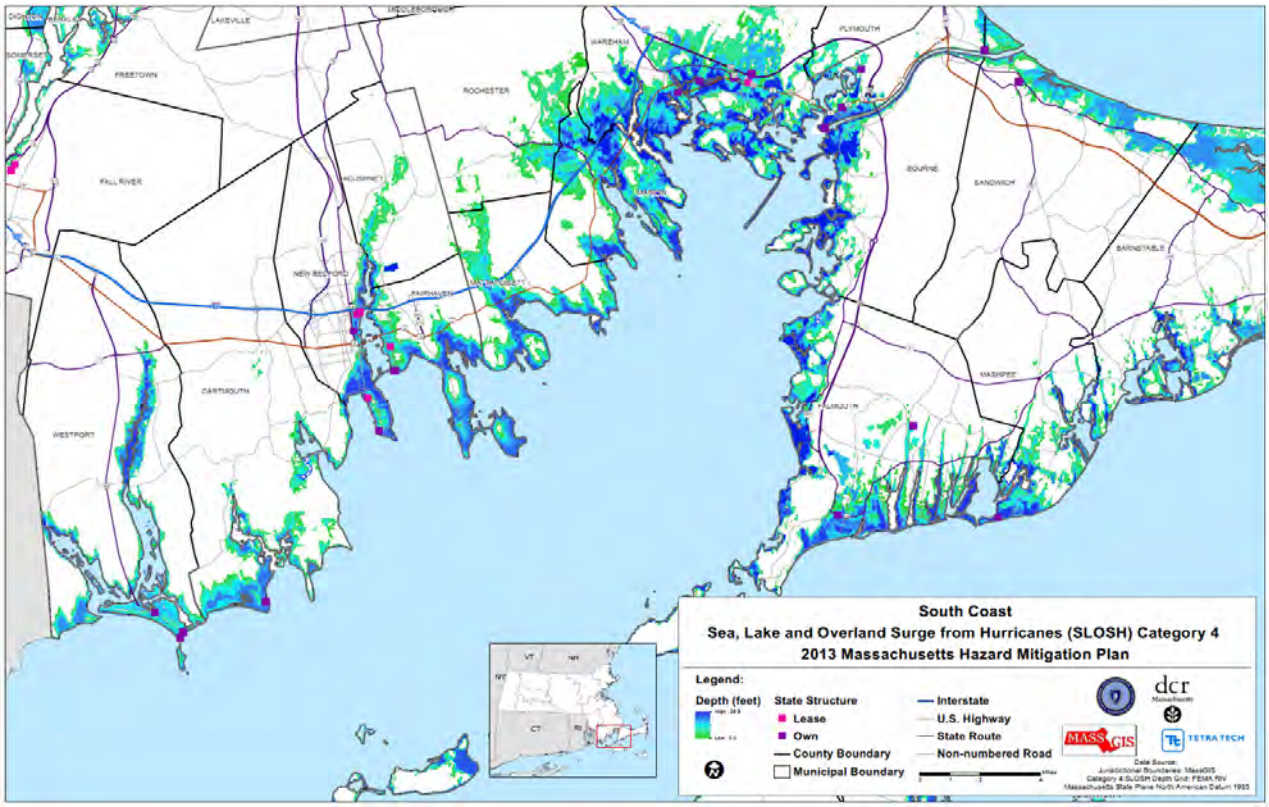


Figure 11-20. South Coastal SLOSH Inundation for a Category 4 Event

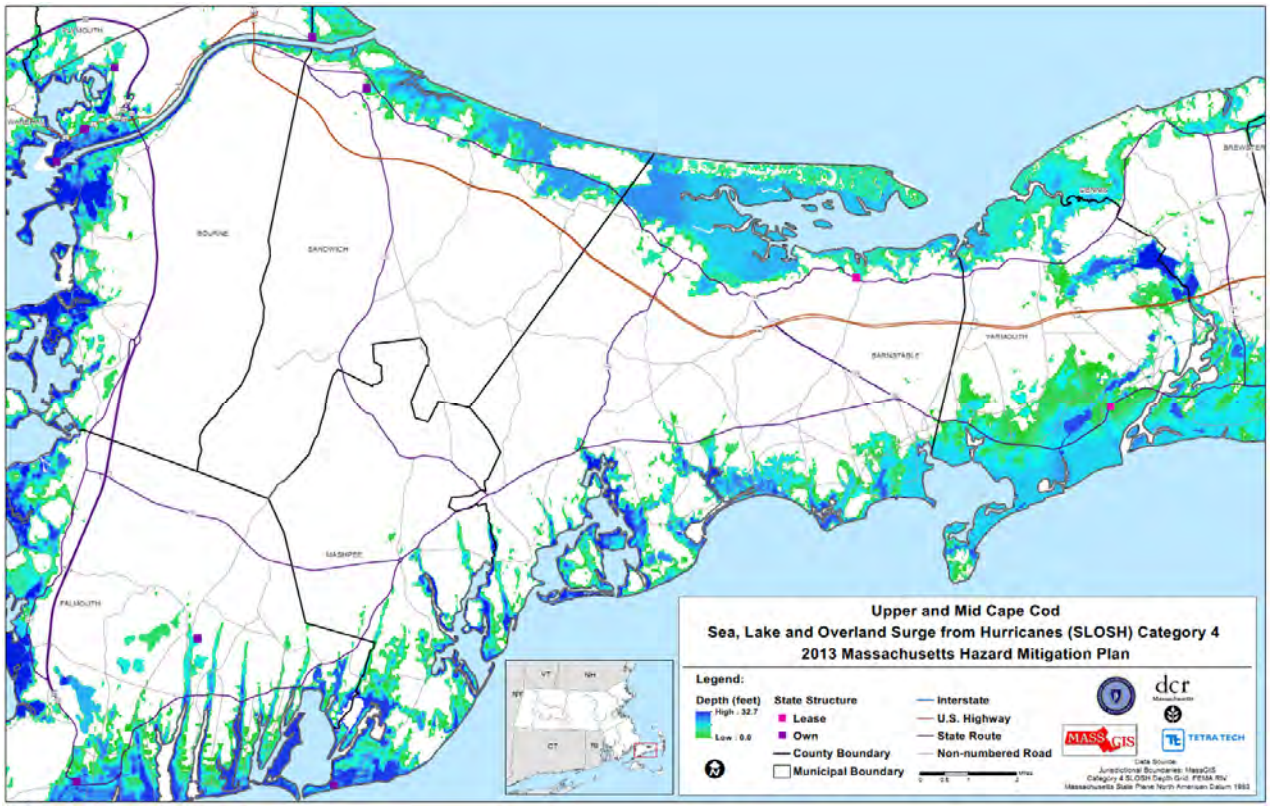


Figure 11-21. Upper and Mid Cape Cod SLOSH Inundation for a Category 4 Event

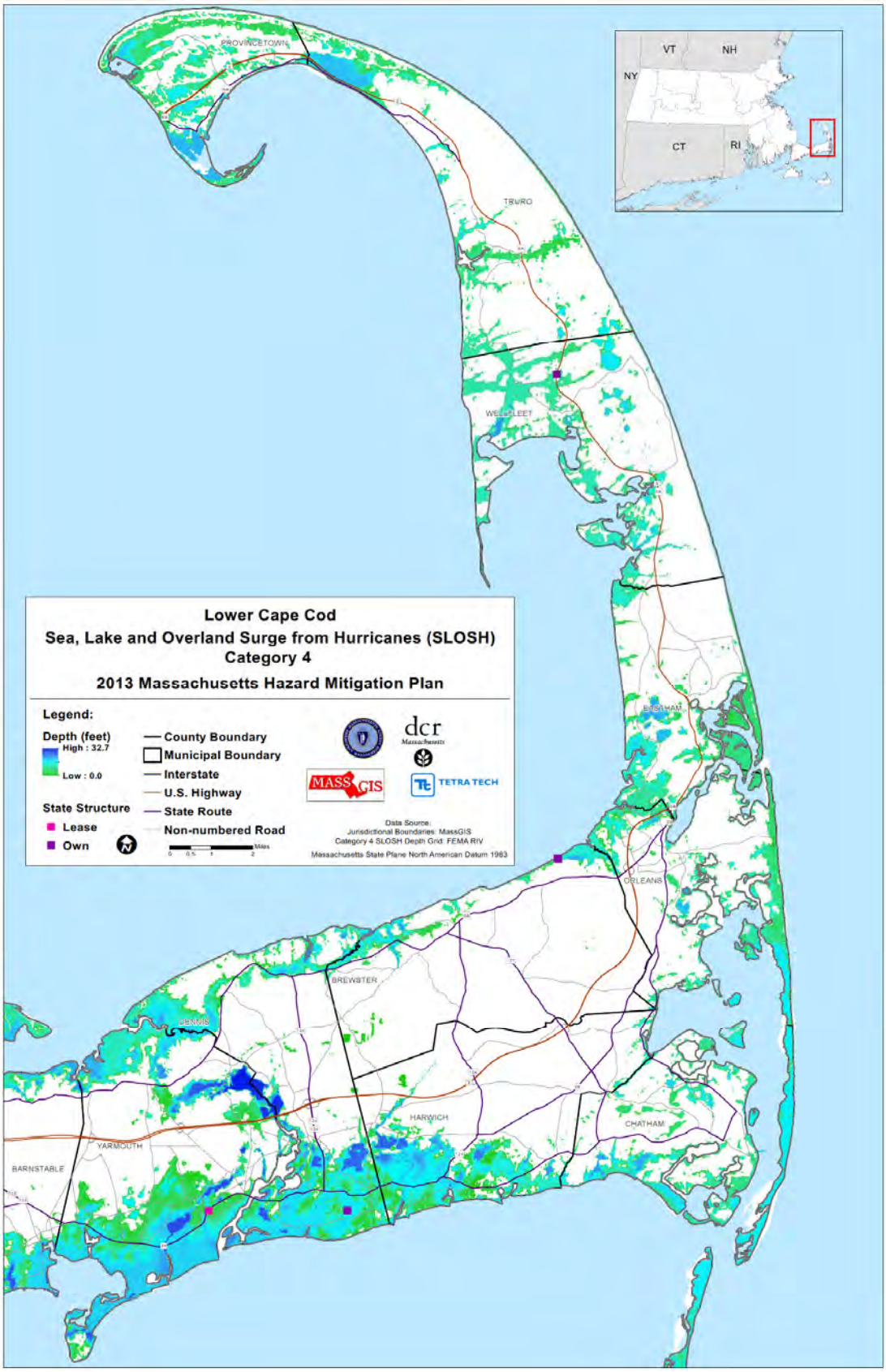


Figure 11-22. Lower Cape Cod SLOSH Inundation for a Category 4 Event

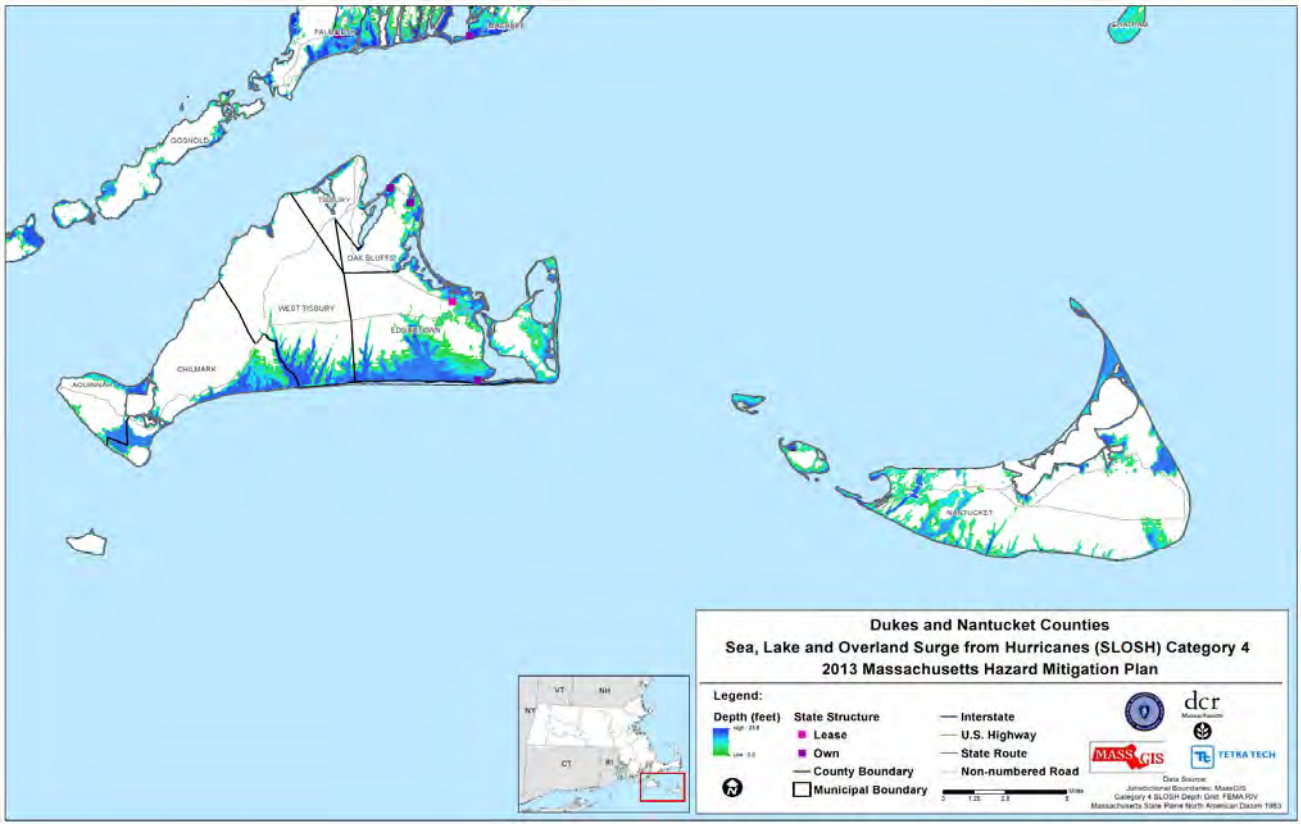


Figure 11-23. Dukes and Nantucket Counties SLOSH Inundation for a Category 4 Event

TABLE 11-15.
ESTIMATED POTENTIAL STATE-OWNED AND LEASED BUILDING LOSS FROM HURRICANE CATEGORY 4 STORM SURGE BY COUNTY

	State-Owned Structures		State-Leased Structures		Total Loss		Loss as Percent of Total Exposed[a]	
County	Number	Loss (Structure and Contents)	Number	Loss (Structure and Contents)	Number	Loss (Structure and Contents)	Number	Value
Barnstable	50	$249,484,117	3	$1,062,726	53	$250,546,843	75%	83.0%
Berkshire	—	—	—	—	—	—	—	—
Bristol	56	$53,412,358	6	$14,537,016	62	$67,949,374	90%	61.3%
Dukes	4	$1,271,978	1	$1,400,697	5	$2,672,675	100%	37.2%
Essex	71	$340,393,691	9	$11,552,589	80	$351,946,280	69%	43.6%
Franklin	—	—	—	—	—	—	—	—
Hampden	—	—	—	—	—	—	—	—
Hampshire	—	—	—	—	—	—	—	—
Middlesex	28	$199,025,028	11	$27,205,515	39	$226,230,543	87%	50.9%
Nantucket	—	—	—	—	—	—	—	—
Norfolk	80	$157,365,033	3	$25,365,895	83	$182,730,928	91%	41.2%
Plymouth	36	$35,535,485	1	$313,831	37	$35,849,316	79%	66.9%

TABLE 11-15.
ESTIMATED POTENTIAL STATE-OWNED AND LEASED BUILDING LOSS FROM HURRICANE CATEGORY 4 STORM SURGE BY COUNTY

	State-Owned Structures		State-Leased Structures		Total Loss		Loss as Percent of Total Exposed[a]	
County	Number	Loss (Structure and Contents)	Number	Loss (Structure and Contents)	Number	Loss (Structure and Contents)	Number	Value
Suffolk	181	$2,211,450,558	32	$130,170,940	213	$2,341,621,497	99%	58.3%
Worcester	—	—	—	—	—	—	—	—
Total	**506**	**3247938248**	**66**	**211609209.8**	**572**	**$3,459,547,458**	**87%**	**55.9%**

a. Percentage of number of exposed buildings based on 2012 building count from Table 11-8. Percentage of building value based on 2012 value listed in Table 11-9

Source: (SLOSH and Hazus-MH v. 2.1)

TABLE 11-16.
ESTIMATED POTENTIAL STATE-OWNED AND LEASED BUILDING LOSS FROM HURRICANE CATEGORY 4 STORM SURGE BY STATE AGENCY

	State-Owned Structures		State-Leased Structures		Total Loss		Loss as Percent of Total Exposed[a]	
Agency	Number	Loss (Structure and Contents)	Number	Loss (Structure and Contents)	Number	Loss (Structure and Contents)	Number	Value
Alcoholic Beverages Control Commission	—	—	1	$1,363,246	1	$1,363,246	100	84.2
Board of Higher Education	—	—	1	$1,048,449	1	$1,048,449	100	74.7
Board of Library Commissioners	—	—	1	$1,244,432	1	$1,244,432	100	67.4
Bunker Hill Community College	6	$126,040,875	—	—	6	$126,040,875	100	48.3
Bureau of State Buildings	1	$100,549,460	—	—	1	$100,549,460	100	60.2
Committee For Public Counsel Services	—	—	5	$3,107,376	5	$3,107,376	83.3	32.4
Council of Government	1	$13,624,281	—	—	1	$13,624,281	100	77.9
Department of Business & Technology	—	—	1	$83,761	1	$83,761	100	59.4
Department of Children and Families	—	—	8	$19,577,794	8	$19,577,794	88.9	41.8
Department of Conservation and Recreation	312	$543,824,436	—	—	312	$543,824,436	90.2	53.6
Department of Corrections	—	—	1	$1,279,438	1	$1,279,438	100	59.2
Department of Developmental Services	2	$571,427	3	$8,930,011	5	$9,501,438	100	64.0
Department of Early Education and Care	—	—	1	$3,828,847	1	$3,828,847	100	92.2
Department of Fish and Game	19	$9,726,114	—	—	19	$9,726,114	100	57.7

TABLE 11-16.
ESTIMATED POTENTIAL STATE-OWNED AND LEASED BUILDING LOSS FROM HURRICANE CATEGORY 4 STORM SURGE BY STATE AGENCY

	State-Owned Structures		State-Leased Structures		Total Loss		Loss as Percent of Total Exposed[a]	
Agency	Number	Loss (Structure and Contents)	Number	Loss (Structure and Contents)	Number	Loss (Structure and Contents)	Number	Value
Department of Mental Health	9	$106,129,240	2	$1,628,207	11	$107,757,447	84.6	58.2
Department of Public Health	—	—	4	$8,504,461	4	$8,504,461	100	54.1
Department of Public Utilities	—	—	1	$5,511,256	1	$5,511,256	100	61.6
Department of State Police	7	$11,303,854	—	—	7	$11,303,854	100	58.9
Department of Transitional Assistance	—	—	5	$15,106,162	5	$15,106,162	71.4	41.5
Department of Transportation	39	$34,897,699	4	$17,027,396	43	$51,925,095	67.2	44.4
Department of Workforce Development	—	—	1	$172,142	1	$172,142	100	16.1
Division of Capital Asset Management	3	$40,637,218	1	$46,060,984	4	$86,698,202	100	56.8
Exec. Office of Energy & Environmental Affairs	—	—	2	$18,720,345	2	$18,720,345	100	78.2
Exec. Office of Health & Human Services	—	—	3	$18,947,403	3	$18,947,403	100	56.1
Massachusetts Department of Revenue	—	—	2	$5,631,121	2	$5,631,121	66.7	24.7
Massachusetts College of Art and Design	10	$320,596,092	—	—	10	$320,596,092	100	60.8
Massachusetts Cultural Council	—	—	1	$1,089,452	1	$1,089,452	100	55.4
Massachusetts Gaming Commission	—	—	1	$134,326	1	$134,326	100	9.0
Massachusetts Maritime Academy	23	$217,485,779	—	—	23	$217,485,779	100	93.5
Massachusetts Rehabilitation Commission	—	—	3	$4,870,086	3	$4,870,086	75.0	26.8
Massachusetts Teachers' Retirement System	—	—	1	$4,195,897	1	$4,195,897	100	88.2
Military Division	3	$23,827,749	—	—	3	$23,827,749	37.5	34.1
North Shore Community College	4	$1,829,596	2	$4,640,883	6	$6,470,479	100	43.7
Office of Labor and Workforce Development	1	$4,527,536	—	—	1	$4,527,536	100	72.6
Office of the Chief Medical Examiner	1	$8,594,737	—	—	1	$8,594,737	100	44.4
Office of the D.A. Cape & Island	—	—	1	$78,651	1	$78,651	100	4.9
Office of the State Treasurer	—	—	1	$213,352	1	$213,352	100	9.0
Public Employee Retirement Admin. Comm.	—	—	1	$2,175,170	1	$2,175,170	100	56.1

TABLE 11-16.
ESTIMATED POTENTIAL STATE-OWNED AND LEASED BUILDING LOSS FROM HURRICANE CATEGORY 4 STORM SURGE BY STATE AGENCY

	State-Owned Structures		State-Leased Structures		Total Loss		Loss as Percent of Total Exposed[a]	
Agency	Number	Loss (Structure and Contents)	Number	Loss (Structure and Contents)	Number	Loss (Structure and Contents)	Number	Value
Salem State University	17	$144,094,487	—	—	17	$144,094,487	58.6	41.8
Secretary of State	1	$48,812,498	1	$534,067	2	$49,346,565	100	67.8
Sex Offenders' Registry	—	—	1	$206,985	1	$206,985	100	5.1
Sheriff's Department Middlesex	1	$45,731,190	1	$3,391,395	2	$49,122,585	100	52.6
Sheriff's Department Suffolk	9	$369,589,776	—	—	9	$369,589,776	100	42.3
Trial Court	4	$127,745,589	5	$12,306,116	9	$140,051,705	81.8	44.8
University of Massachusetts at Amherst	13	$9,318,753	—	—	13	$9,318,753	100	61.8
University of Massachusetts at Boston	20	$938,479,861	—	—	20	$938,479,861	100	68.0
Total	**506**	**$3,247,938,248**	**66**	**$211,609,210**	**572**	**$3,459,547,458**	**86.7**	**55.9**

a. Percentages based on Category 4 building count and value listed in Table 11-7.
Source: (SLOSH and Hazus-MH v. 2.1)

An analysis was conducted to determine the wind-only impacts from hurricane/tropical storm events for four categories (Tropical Storm and Categories 1 through 3) for the entire general building stock of the Commonwealth. Figure 11-24 through Figure 11-27 display the modeled wind speeds for the four events analyzed. Because of differences in building construction, residential structures are generally more susceptible to wind 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.

Historical hurricanes selected by the SHMT and THIRA workgroup were runs in Hazus-MH version 2.1 to estimate the potential losses to the Commonwealth's general building stock inventory. Table 11-17 summarizes the estimated building loss (structure only) from the wind from these historical events. Total dollar damage reflects the overall impact to buildings at an aggregate level.

TABLE 11-17.
ESTIMATED BUILDING LOSS—WIND ONLY

	Estimated Building Loss (Structure Replacement Cost Value) - Wind Only			
County	Tropical Storm	Category 1 - Hurricane	Category 2 - Hurricane	Category 3 - Hurricane
Barnstable	$550,164	$8,338,069	$499,560,100	$71,830,501
Berkshire	$1,063,884	$611,203	$0	$90,154,567
Bristol	$3,783,342	$41,697,917	$475,212,659	$365,998,827

TABLE 11-17.
ESTIMATED BUILDING LOSS—WIND ONLY

	Estimated Building Loss (Structure Replacement Cost Value) - Wind Only			
County	Tropical Storm	Category 1 - Hurricane	Category 2 - Hurricane	Category 3 - Hurricane
Dukes	$29,543	$1,022,482	$86,437,805	$13,002,014
Essex	$3,814,974	$81,159,400	$76,981,069	$198,751,407
Franklin	$2,459,610	$2,838,860	$0	$107,144,442
Hampden	$18,712,164	$80,678,760	$1,033,838	$1,039,617,581
Hampshire	$5,497,184	$14,274,115	$431,019	$279,193,870
Middlesex	$16,152,101	$281,451,429	$159,437,291	$839,387,681
Nantucket	$0	$307,560	$13,942,210	$5,666,945
Norfolk	$5,168,628	$83,316,231	$199,960,533	$389,425,228
Plymouth	$3,003,919	$33,991,768	$430,676,992	$203,313,119
Suffolk	$4,150,185	$63,563,158	$138,425,859	$339,014,544
Worcester	$19,933,588	$282,271,445	$26,583,708	$986,287,259
Total	**$84,319,286**	**$975,522,397**	**$2,108,683,082**	**$4,928,787,985**

Note: Default Hazus-MH v. 2.1 general building stock inventory based on 2000 Census and 2006 R.S. Means replacement cost values. The general building stock inventory includes all occupancy classes no matter type of ownership (private, state, etc.)

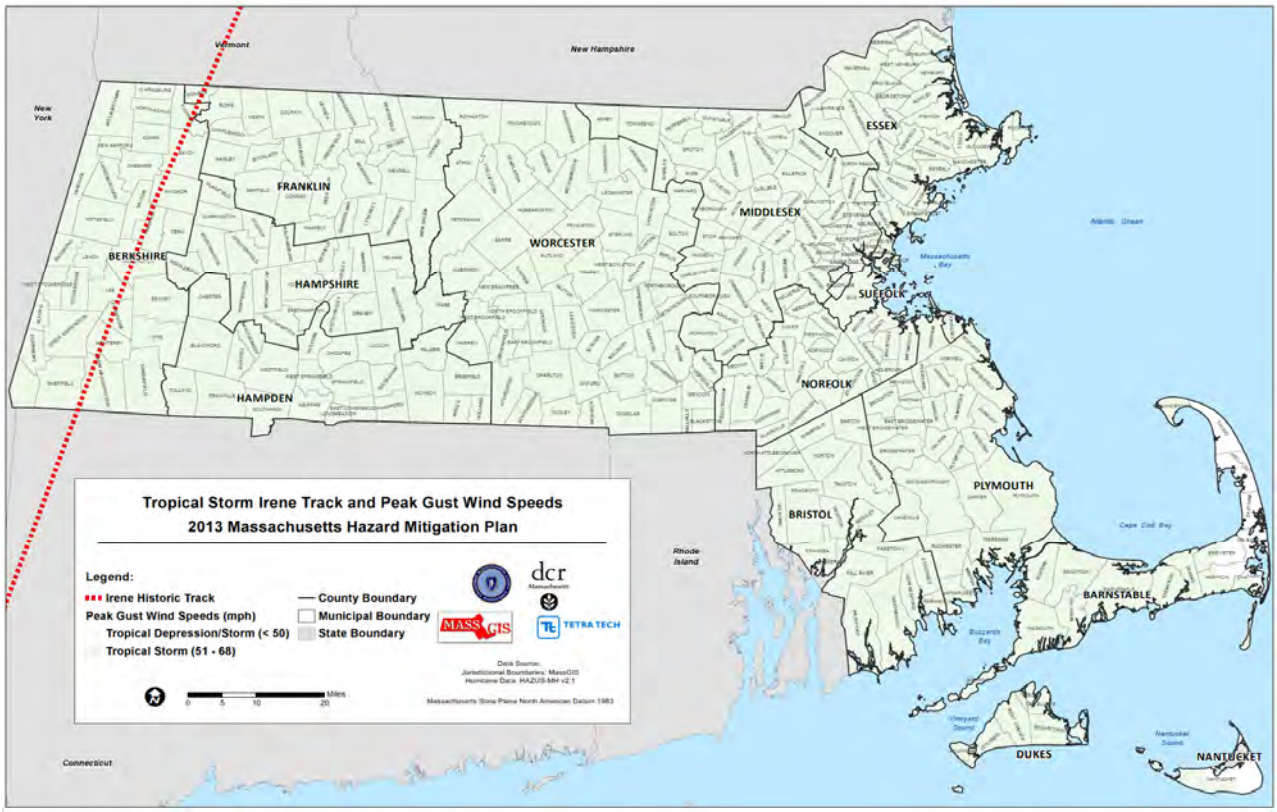


Figure 11-24. Tropical Storm Irene Track and Peak Gust Wind Speeds in Massachusetts

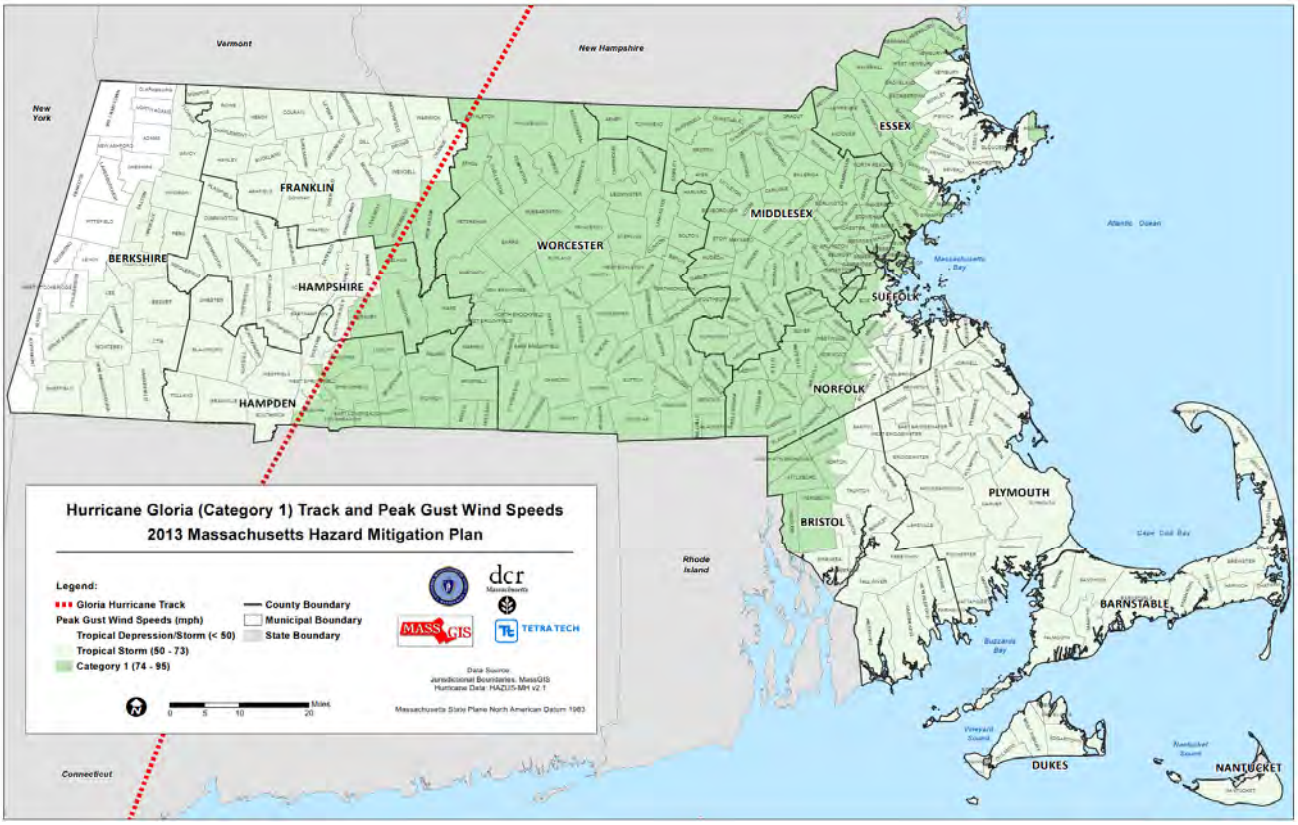


Figure 11-25. Hurricane Gloria (Category 1) Track and Peak Gust Wind Speeds in Massachusetts

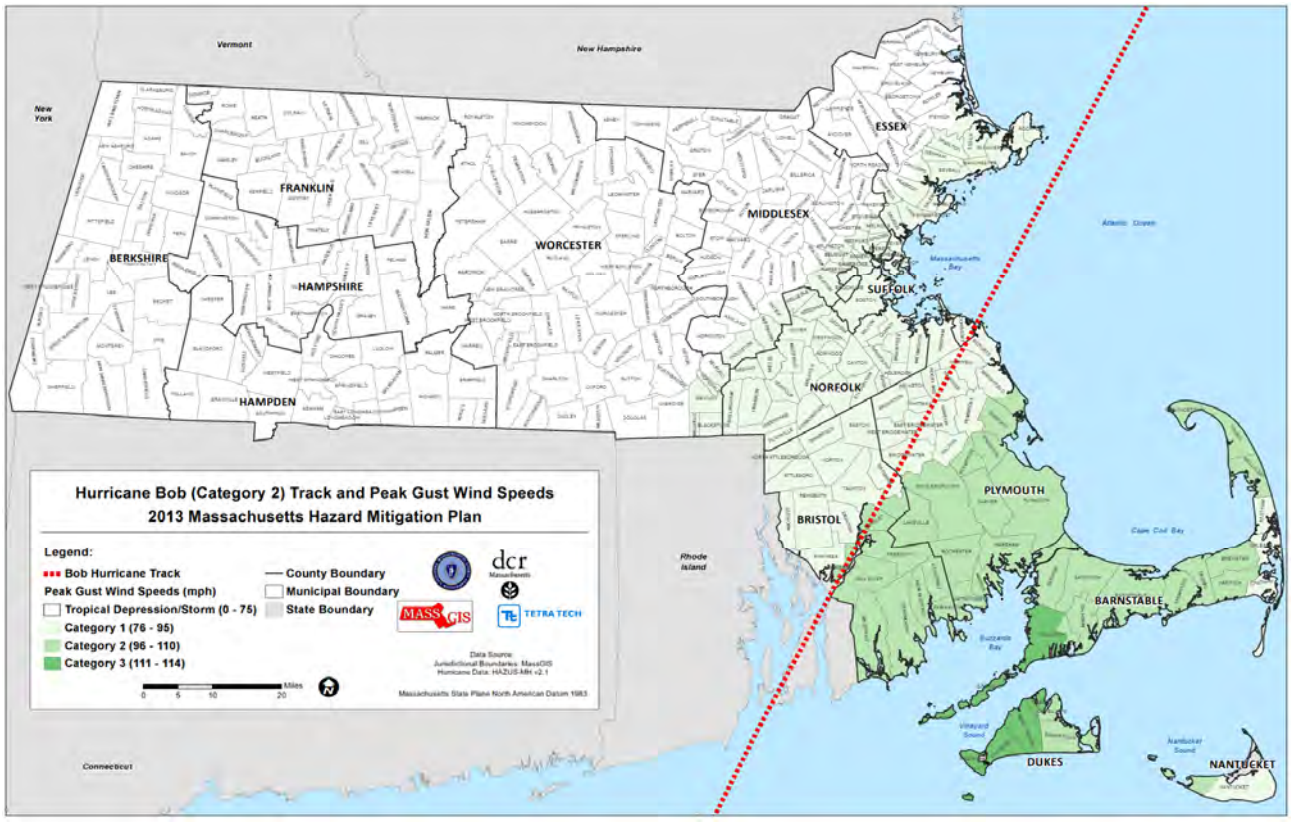


Figure 11-26. Hurricane Bob (Category 2) Track and Peak Gust Wind Speeds in Massachusetts

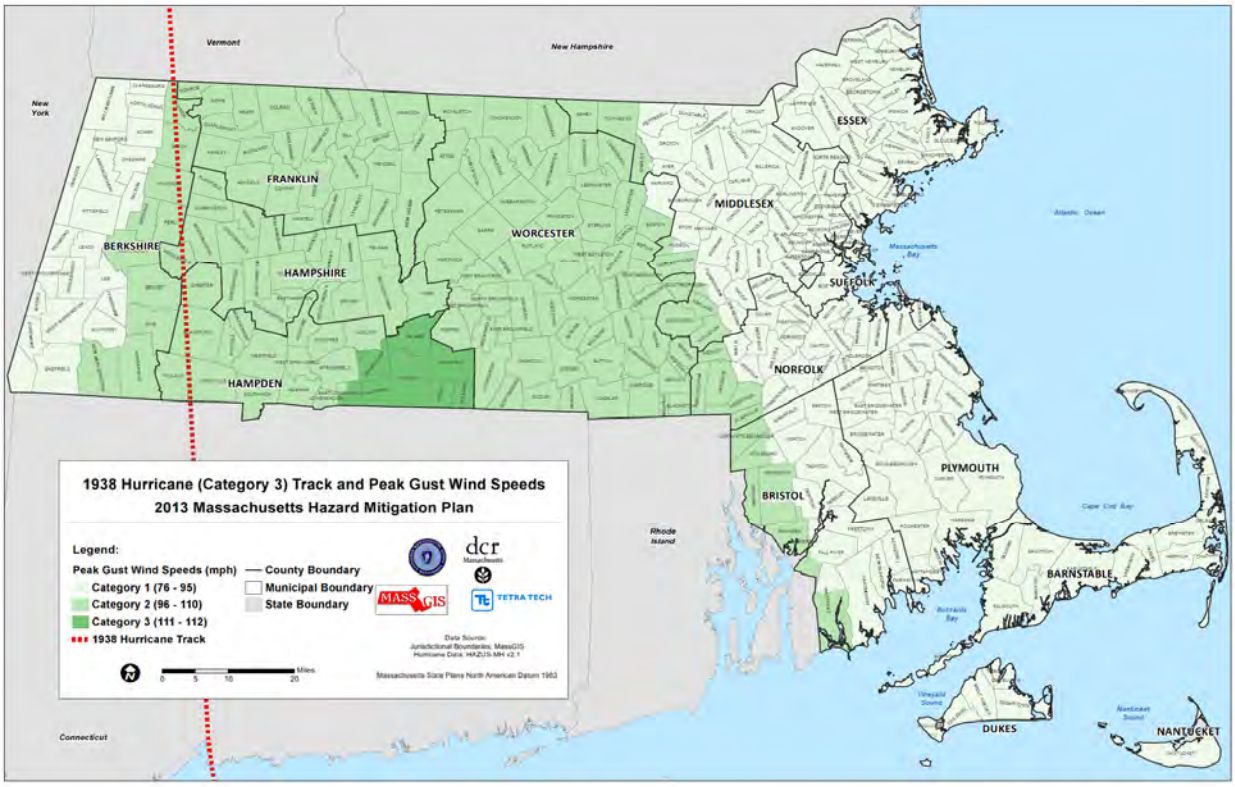


Figure 11-27. 1938 Unnamed Hurricane (Category 3) Track and Peak Gust Wind Speeds in Massachusetts

11.6.3 Critical Facilities

Hazus-MH does not estimate potential dollar losses to critical facilities at this time. When this capability is available, the Commonwealth can enhance this section of the plan. For the purposes of this plan update, to estimate potential losses to critical facilities and infrastructure, the exposure analysis methodology was used. As mentioned earlier, all critical facilities and infrastructure are exposed to hurricane and tropical storm winds and rain; however, those located within the surge inundation zones are at greater risk. The replacement cost values for critical facilities were not available for this planning effort. A total risk exposure would equal to the full replacement value of each critical facility exposed.

At this time, Hazus-MH v. 2.1 does not estimate losses to transportation lifelines and utilities as part of the hurricane model. Transportation lifelines are not considered particularly vulnerable to the wind hazard; they are more vulnerable to cascading effects such as flooding, falling debris etc. Impacts to transportation lifelines affect both short-term (e.g., evacuation activities) and long-term (e.g., day-to-day commuting) transportation needs. In terms of highway bridges, the Hazus-MH v. 2.1 default replacement cost value for the bridges located in the SLOSH Category 1 through 4 hazard areas is $17 billion (of the greater than $68 billion total).

11.6.4 Economy

Hurricane/tropical storm events can greatly impact the economy, including loss of business function (e.g., tourism, recreation), damage to inventory, relocation costs, wage loss, and rental loss due to the repair/replacement of buildings. Hazus-MH estimates the total economic loss associated with each storm scenario (direct building losses and business interruption losses). Direct building losses are the estimated costs to repair or replace the damage caused to the building. This is discussed earlier in this section. Business interruption losses are the losses associated with the inability to operate a business because of the wind damage sustained during the storm or the temporary living expenses for those displaced from their home because of the event. The economic losses generated by Hazus-MH for each of the deterministic scenarios are summarized in Table 11-18 through Table 11-21.

Hazus-MH v 2.1 also estimates the amount of debris that may be produced a result of wind events. The debris produced is summarized in Table 11-22 through Table 11-25. Because the estimated debris production does not include flooding, this is likely a conservative estimate and may be higher if multiple impacts occur. Please note the following as documented in the Hazus-MH Hurricane User Manual:

> *'The Eligible Tree Debris columns provide estimates of the weight and volume of downed trees that would likely be collected and disposed at public expense. As discussed in Chapter 12 of the Hazus-MH Hurricane Model Technical Manual, the eligible tree debris estimates produced by the Hurricane Model tend to underestimate reported volumes of debris brought to landfills for a number of events that have occurred over the past several years. This indicates that that there may be other sources of vegetative and non-vegetative debris that are not currently being modeled in Hazus. For landfill estimation purposes, it is recommended that the Hazus debris volume estimate be treated as an approximate lower bound. Based on actual reported debris volumes, it is recommended that the Hazus results be multiplied by three to obtain an approximate upper bound estimate. It is also important to note that the Hurricane Model assumes a bulking factor of 10 cubic yards per ton of tree debris. If the debris is chipped prior to transport or disposal, a bulking factor of 4 is recommended. Thus, for chipped debris, the eligible tree debris volume should be multiplied by 0.4'.*

TABLE 11-18.
ESTIMATED ECONOMIC LOSS - WIND ONLY ANALYSIS—TROPICAL STORM

County	Inventory	Relocation	Income	Rental	Wage
Barnstable	$0	$2,027	$0	$0	$0
Berkshire	$0	$1,401	$0	$0	$0
Bristol	$0	$11,110	$0	$0	$0
Dukes	$0	$147	$0	$0	$0
Essex	$0	$14,592	$0	$0	$0
Franklin	$0	$1,151	$0	$0	$0
Hampden	$0	$39,056	$0	$32,509	$0
Hampshire	$0	$3,709	$0	$0	$0
Middlesex	$0	$29,791	$0	$0	$0
Nantucket	$0	$90	$0	$0	$0
Norfolk	$0	$9,400	$0	$0	$0
Plymouth	$0	$4,380	$0	$0	$0
Suffolk	$0	$28,381	$0	$0	$0
Worcester	$0	$34,613	$0	$20,764	$0
Total	**$0**	**$179,850**	**$0**	**$53,273**	**$0**

TABLE 11-19.
ESTIMATED ECONOMIC LOSS - WIND ONLY ANALYSIS— CATEGORY 1 HURRICANE

County	Inventory	Relocation	Income	Rental	Wage
Barnstable	$0	$24,092	$0	$34,383	$0
Berkshire	$0	$246	$0	$0	$0
Bristol	$0	$343,640	$0	$475,695	$0
Dukes	$0	$1,476	$0	$1,853	$0
Essex	$3,101	$1,198,574	$0	$1,687,150	$0
Franklin	$0	$1,428	$0	$224	$0
Hampden	$27,622	$1,922,278	$0	$1,233,825	$0
Hampshire	$9,605	$189,336	$0	$134,777	$0
Middlesex	$34,332	$3,926,543	$12,942	$3,849,975	$12,354
Nantucket	$0	$226	$0	$69	$0
Norfolk	$0	$482,274	$0	$589,650	$0
Plymouth	$0	$118,150	$0	$156,308	$0
Suffolk	$7	$1,683,517	$0	$2,440,722	$0
Worcester	$234,153	$9,729,543	$942,587	$9,161,341	$965,280
Total	**$308,820**	**$19,621,322**	**$955,528**	**$19,765,972**	**$977,635**

TABLE 11-20.
ESTIMATED ECONOMIC LOSS - WIND ONLY ANALYSIS—CATEGORY 2 HURRICANE

County	Inventory	Relocation	Income	Rental	Wage
Barnstable	$914,358	$43,621,607	$4,887,287	$20,277,628	$7,437,197
Berkshire	$0	$0	$0	$0	$0
Bristol	$1,567,800	$27,212,483	$3,951,471	$23,409,079	$5,686,125
Dukes	$261,260	$10,156,843	$685,006	$4,345,912	$1,431,531
Essex	$5,040	$1,732,128	$9,121	$1,914,259	$3,241
Franklin	$0	$0	$0	$0	$0
Hampden	$0	$2,654	$0	$0	$0
Hampshire	$0	$179	$0	$0	$0
Middlesex	$3,728	$2,013,132	$0	$2,660,773	$0
Nantucket	$8,579	$728,688	$164,458	$451,192	$230,201
Norfolk	$47,407	$5,255,841	$187,454	$4,497,384	$93,549
Plymouth	$613,285	$20,416,867	$2,722,476	$10,672,014	$4,196,047
Suffolk	$16,711	$5,200,997	$38,584	$7,022,634	$33,489
Worcester	$0	$114,170	$0	$127,700	$0
Total	**$3,438,169**	**$116,455,589**	**$12,645,857**	**$75,378,575**	**$19,111,380**

TABLE 11-21.
ESTIMATED ECONOMIC LOSS - WIND ONLY ANALYSIS— CATEGORY 3 HURRICANE

County	Inventory	Relocation	Income	Rental	Wage
Barnstable	$14,495	$2,490,381	$154,868	$1,451,431	$128,893
Berkshire	$125,457	$2,938,005	$170,025	$2,304,071	$188,577
Bristol	$729,256	$16,173,442	$2,314,907	$16,058,167	$3,111,610
Dukes	$9,271	$481,145	$77,366	$341,198	$96,707
Essex	$66,328	$7,354,357	$366,031	$6,988,385	$130,057
Franklin	$387,305	$6,543,605	$1,075,793	$3,554,837	$2,195,021
Hampden	$6,895,455	$98,936,571	$12,794,122	$49,021,751	$20,790,666
Hampshire	$948,277	$21,614,918	$3,072,611	$10,856,486	$6,476,624
Middlesex	$673,522	$29,352,528	$4,824,120	$27,993,029	$4,454,761
Nantucket	$1,115	$239,681	$28,854	$144,911	$10,251
Norfolk	$329,542	$12,632,902	$1,987,433	$10,348,853	$1,849,797
Plymouth	$91,639	$5,826,556	$474,344	$4,183,729	$320,450
Suffolk	$133,387	$17,537,733	$3,528,169	$21,561,065	$3,069,888
Worcester	$3,811,338	$57,308,453	$11,360,720	$42,243,231	$18,430,050
Total	**$14,216,387**	**$279,430,278**	**$42,229,364**	**$197,051,144**	**$61,253,352**

TABLE 11-22.
ESTIMATED DEBRIS - WIND ONLY ANALYSIS— TROPICAL STORM

County	Brick/Wood (tons)	Concrete (tons)	Trees (tons)	Tree Volume (cubic yards)
Barnstable	0	0	0	0
Berkshire	0	0	22,729	227,295
Bristol	179	0	11,008	110,083
Dukes	0	0	0	0
Essex	325	0	6,355	63,558
Franklin	58	0	33,908	339,094
Hampden	1,463	0	27,529	275,313
Hampshire	205	0	24,675	246,709
Middlesex	1,004	0	23,066	230,567
Nantucket	0	0	0	0
Norfolk	218	0	9,484	94,849
Plymouth	25	0	12,696	126,943
Suffolk	933	0	609	6,147
Worcester	1,227	0	49,510	495,117
Total	**5,637**	**0**	**221,569**	**2,215,675**

TABLE 11-23.
ESTIMATED DEBRIS - WIND ONLY ANALYSIS— CATEGORY 1 HURRICANE

County	Brick/Wood (tons)	Concrete (tons)	Trees (tons)	Tree Volume (cubic yards)
Barnstable	390	0	10,941	109,405
Berkshire	0	0	17,824	178,251
Bristol	4,801	0	39,135	391,373
Dukes	46	0	1,376	13,750
Essex	10,213	0	46,418	464,224
Franklin	103	0	43,162	431,628
Hampden	8,644	0	135,626	1,356,271
Hampshire	1,161	0	67,290	672,890
Middlesex	28,705	0	184,036	1,840,306
Nantucket	13	0	0	0
Norfolk	6,902	0	36,138	361,379
Plymouth	2,105	0	40,546	405,423
Suffolk	12,800	0	3,185	31,824
Worcester	38,571	0	634,560	6,345,566
Total	**114,454**	**0**	**1,260,237**	**12,602,289**

TABLE 11-24.
ESTIMATED DEBRIS - WIND ONLY ANALYSIS— CATEGORY 2 HURRICANE

County	Brick/Wood (tons)	Concrete (tons)	Trees (tons)	Tree Volume (cubic yards)
Barnstable	78,229	334	217,535	2,175,341
Berkshire	0	0	0	0
Bristol	82,800	94	282,486	2,824,789
Dukes	13,994	102	99,627	996,267
Essex	10,068	0	39,437	394,364
Franklin	0	0	0	0
Hampden	0	0	5,849	58,501
Hampshire	1	0	4,787	47,871
Middlesex	19,541	0	49,041	490,358
Nantucket	2,112	2	5,171	51,706
Norfolk	21,920	0	85,963	859,612
Plymouth	49,705	111	427,102	4,271,032
Suffolk	29,373	0	5,862	58,622
Worcester	2,357	0	42,115	421,146
Total	**310,100**	**643**	**1,264,975**	**12,649,608**

TABLE 11-25.
ESTIMATED DEBRIS - WIND ONLY ANALYSIS— CATEGORY 3 HURRICANE

County	Brick/Wood (tons)	Concrete (tons)	Trees (tons)	Tree Volume (cubic yards)
Barnstable	7,929	0	56,764	567,643
Berkshire	12,966	3	642,976	6,429,759
Bristol	60,938	16	261,013	2,610,177
Dukes	1,687	0	26,769	267,697
Essex	28,838	0	114,722	1,147,180
Franklin	15,503	37	735,129	7,351,280
Hampden	163,750	713	734,365	7,343,637
Hampshire	41,320	125	641,215	6,412,152
Middlesex	112,133	9	401,286	4,012,869
Nantucket	673	0	2,894	28,942
Norfolk	46,464	6	167,894	1,678,960
Plymouth	20,478	0	252,527	2,525,272
Suffolk	70,185	0	10,819	108,175
Worcester	155,732	178	1,415,750	14,157,481
Total	**738,596**	**1,087**	**5,464,123**	**54,641,226**

SECTION 12. LANDSLIDE

12.1 GENERAL BACKGROUND

The term landslide includes a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. Although gravity acting on an over steepened slope is the primary reason for a landslide, there are other contributing factors (USGS, 2013). According to the state geologist, Steve Mabee, slope saturation by water is a primary cause of landslides in the Commonwealth. This effect can be in the form of intense rainfall, snowmelt, changes in groundwater level, and water level changes along coastlines, earth dams, and the banks of lakes, rivers, and reservoirs. Water added to a slope can not only add weight to the slope, which increases the driving force, but can increase the pore pressure in fractures and soil pores, which decreases the internal strength of the earth materials needed to resist the driving forces.

Landslides in Massachusetts can be divided into four general groups, construction related, over steepened slopes caused by undercutting due to flooding or wave action, adverse geologic conditions, and slope saturation. Construction related failures occur predominantly in road cuts excavated into glacial till where topsoil has been placed on top of the till. This juxtaposition of materials with different permeability often causes a failure plane to develop along the interface between the two materials resulting in sliding following heavy rains. Examples can be found along the Massachusetts Turnpike. Other construction related failures occur in utility trenches excavated in materials that have very low cohesive strength and associated high water table (usually within a few feet of the surface). This occurs in sandy deposits with very few fine sediments to give the material cohesive strength and can occur in any part of the state.

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 covers the majority of the state. Areas where this type of failure is occurring include Cape Cod, Nantucket, Martha's Vineyard, Scituate, Newbury, and along some of the major river valleys. Adverse geologic conditions exist anywhere there are lacustrine or marine clays. Clays have relatively low strength. When over steepened or exposed in excavations these areas often produce classic rotational landslides. The clays often formed in the deepest parts of many of the glacial lakes that existed in Massachusetts following the last glaciation. Some of the major glacial lakes are Bascom, Hitchcock, Nashua, Sudbury, Concord, and Merrimack. The greater Boston area is also underlain by the Boston Blue Clay, a glacio-marine clay.

Another occurrence of landslides in Massachusetts results from slope saturation. This occurs following heavy rains and dominantly in areas with steep slopes underlain by glacial till or bedrock. Bedrock is relatively 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, and less permeable, unweathered till and/or bedrock. Water accumulates on this less permeable layer increasing the pore pressure at the interface. This interface becomes a plane of weakness. If conditions are favorable failure will occur" (Mabee, 2010).

12.2 HAZARD PROFILE

12.2.1 Location

The entire U.S. experiences landslides, with 36 states having moderate to highly severe landslide hazards. Expansion of urban and recreational developments into hillside areas leads to more people being threatened by landslides each year. Figure 12-1 shows landslide potential mapped by the USGS for the eastern U.S. Landslides are common throughout the Appalachian region and New England. The greatest eastern hazard is from sliding of clay-rich soils. Based on the U.S. data set for landslides, it appears that

areas along the Connecticut River in western Massachusetts, and the greater Boston area have the highest risk to landslide. Figure 12-2 illustrates the landslide incidence and susceptibility zones in Massachusetts.

Source: http://pubs.usgs.gov/fs/2005/3156/2005-3156.pdf

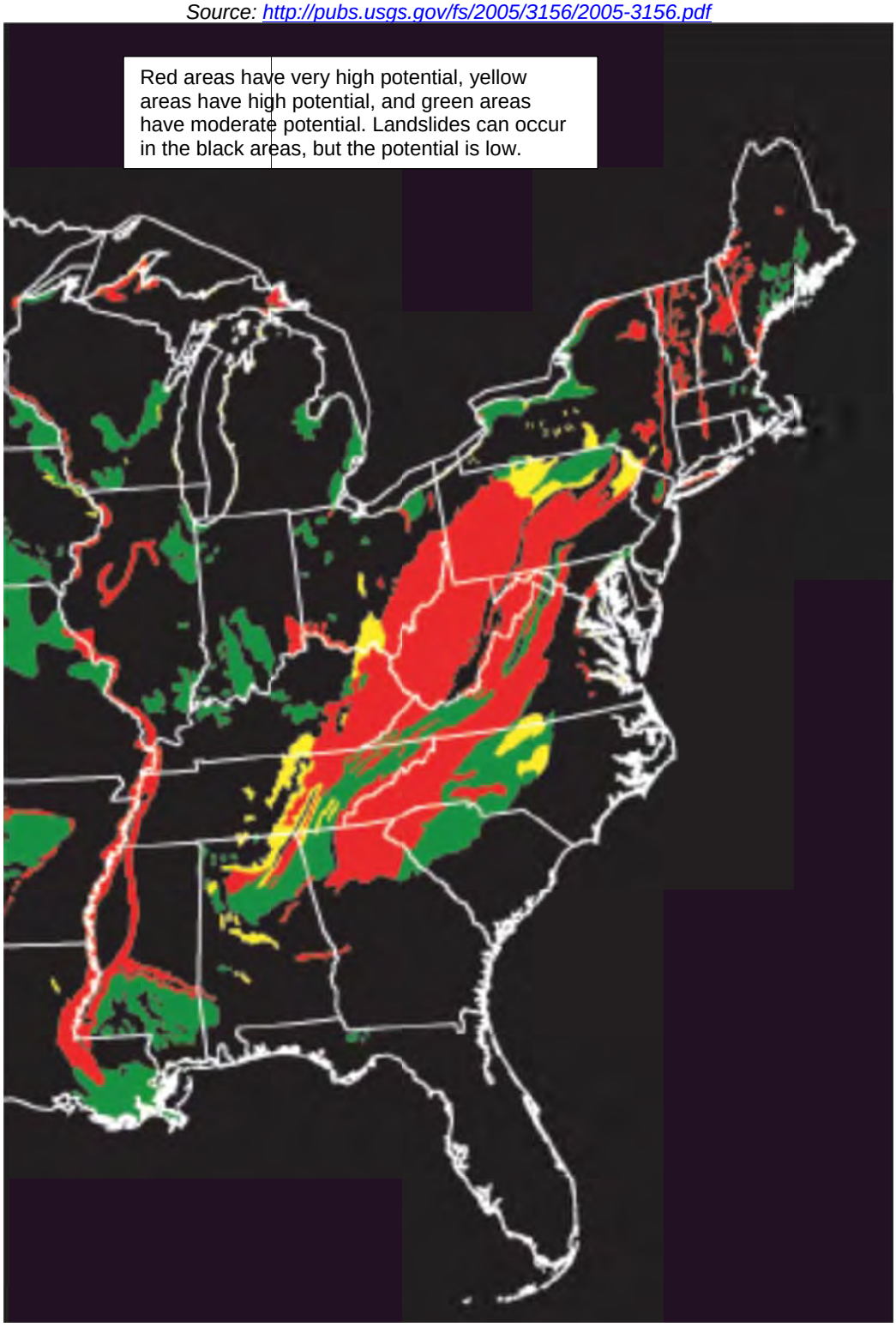


Figure 12-1. Landslide Potential of the Eastern U.S.

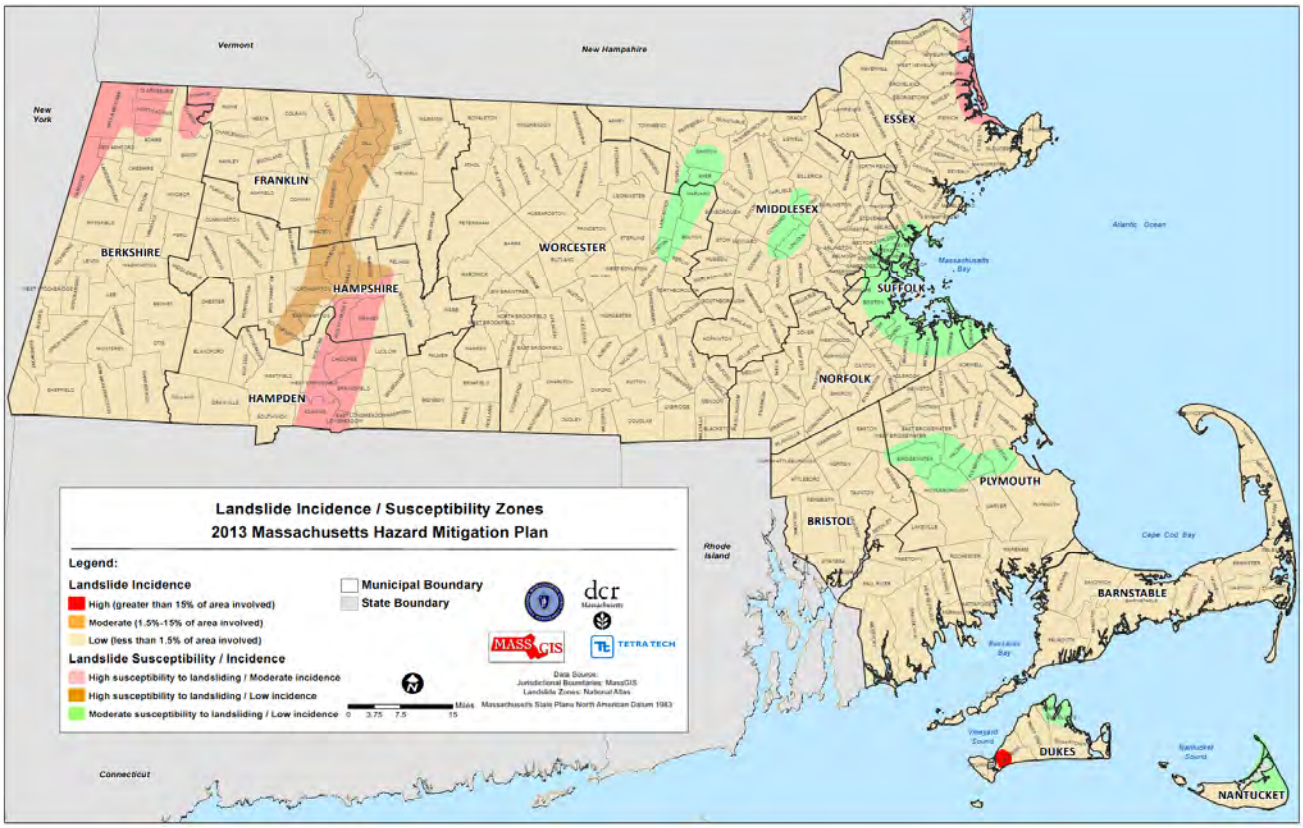


Figure 12-2. Landslide Incidence/Susceptibility Zones

12.2.2 Previous Occurrences

Nationwide landslides constitute a major geologic hazard as they are widespread, occurring in all 50 states, and cause approximately $1-2 billion in damage and more than 25 fatalities on average each year. In Massachusetts, landslides tend to be more isolated in size and pose threats to highways and structures that support fisheries, tourism, timber harvesting, mining, energy production, and general transportation. Landslides commonly occur with other major natural disasters such as earthquakes and floods that exacerbate relief and reconstruction efforts.

Many landslide events may have occurred in remote areas causing their existence or impact to go unnoticed. Therefore, this hazard profile may not identify all ground failure events that have impacted the Commonwealth. Expanded development and other land use may contribute to the increased number of landslide incidences and/or increased number of reported events in the recent record.

- In 1901, 11 landslides occurred along the east face of Mount Greylock after heavy rains (Mabee, 2010).
- In 1936, one home was destroyed and six others evacuated during a slide in North Adams (Mabee, 2010).
- On 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.
- On 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.

- On 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.
- In 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.
- On 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.
- On 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 FEMA 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.
- On March 7, 2011, heavy rains fell across coastal and interior New England. The 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.
- In 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. Estimated cost of temporary repairs was $23.5 million (Mabee and Kopera, 2011). Figure 12-3 illustrates the location of this event. Figure 12-4 shows the largest of the landslides that took place during this event, which measured 900 feet long, 1.5 acres, and an estimated 4,950 cubic yards. Table 12-1 summarizes statistics on landslides that occurred.

In October 2011, additional slides also occurred in Deerfield after the October 31, 2011 snowstorm causing clogging of culverts under the railroad and Routes 5 and 10 leading to siltation of a wetland and subsequent flooding of nearby homes (Mabee, 2010).

12.2.3 Probability of Future Occurrences

Landslides are often triggered by other natural hazards such as earthquakes, heavy rain, floods, or wildfires, so landslide frequency is often related to the frequency of these other hazards. In general, landslides are most likely during periods of higher than average rainfall. The ground must be saturated prior to the onset of a major storm for significant landsliding to occur.

For the purposes of this plan, the probability of future occurrences is defined by the number of events over a specified period of time. There have been zero federally declared landslide disasters from 1954 to 2012. It is noted that the historical record may underestimate the true number of events that have taken place in the Commonwealth. Looking at the recent record, from 1996 to 2012, there were eight (8) events

that triggered one or more slides in the Commonwealth. However, according to the state geologist, there were at least 30 or more landslide related events in the last 10 to 20 years (Mabee, 2010). This roughly equates to one to three landslide events each year.

12.2.4 Severity

To determine the extent of a landslide hazard, the affected areas need to be identified and the probability of the landslide occurring within some time period needs to be assessed. Natural variables that contribute to the overall extent of potential landslide activity in any particular area include soil properties, topographic position and slope, and historical incidence. Predicting a landslide is difficult, even under ideal conditions. As a result, the landslide hazard is often represented by landslide incidence and/or susceptibility, defined below:

- Landslide incidence is the number of landslides that have occurred in a given geographic area. High incidence means greater than 15-percent of a given area has been involved in landsliding; medium incidence means that 1.5 to 15-percent of an area has been involved; and low incidence means that less than 1.5-percent of an area has been involved.

Source: Mabee, 2012 (portion of the poster entitled Geomorphic Effects of Tropical Storm Irene on Western Massachusetts: Landslides and Fluvial Erosion along the Deerfield and Cold Rivers, Charlemont and Savoy, MA)

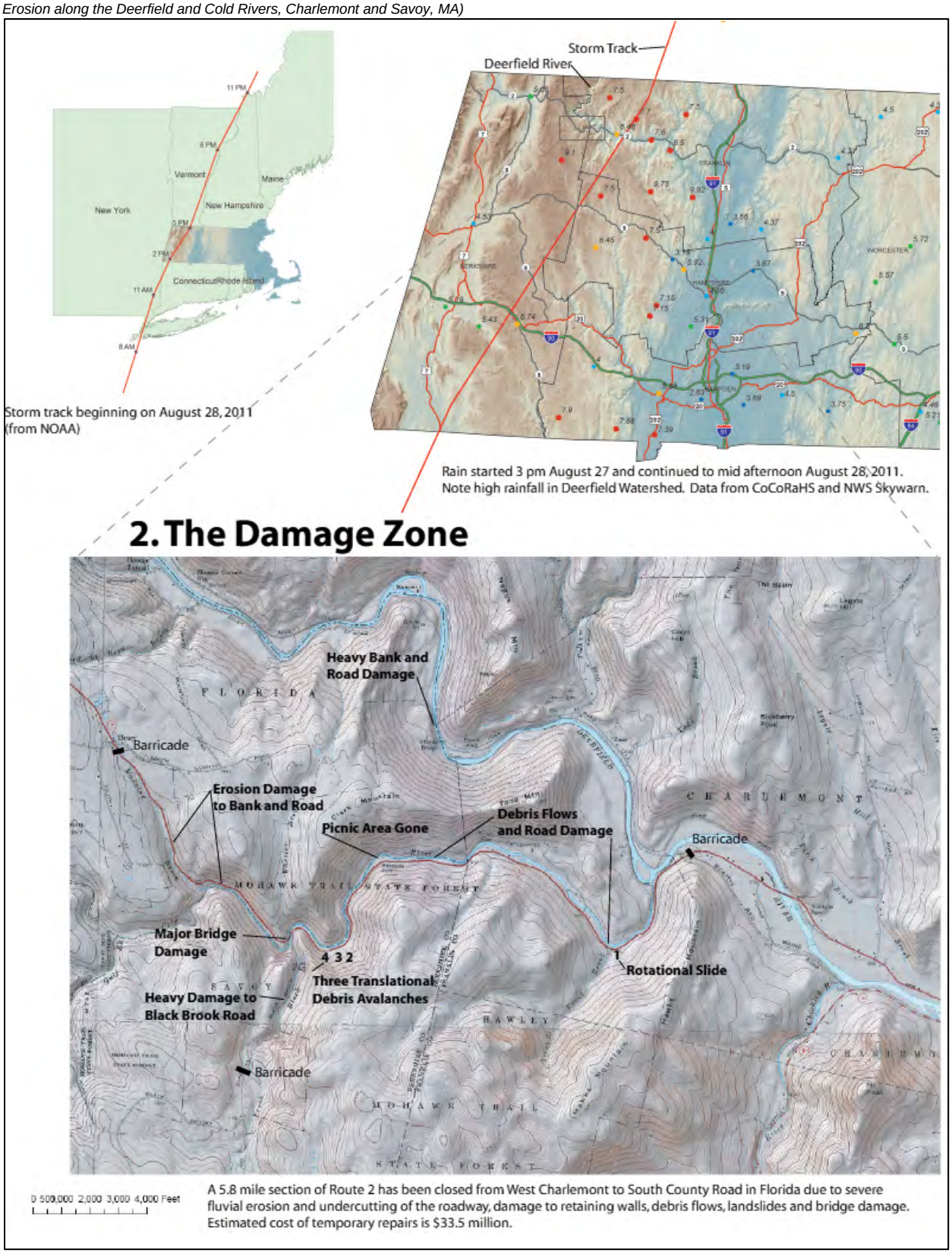


Figure 12-3. Location of August 2011 Event

Source: Mabee, 2012 (portion of the poster entitled Geomorphic Effects of Tropical Storm Irene on Western Massachusetts: Landslides and Fluvial Erosion along the Deerfield and Cold Rivers, Charlemont and Savoy, MA)

Figure 12-4. Largest August 2011 Landslide

TABLE 12-1.
STATISTICS ON THE SLIDES IN AUGUST 2011

The statistics on all the slides. Nearly 2500 feet in combined length, 3 acres of coverage and about 9800 cubic yards of material moved.

Parameter	Slide 2	Slide 3	Slide 4
Bottom Width (ft)	120	58	48
Top Width (ft)	45	42	38
Ave. 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)	3716	2214	1397
Max. Volume (CY)	6193	3690	2329
Ave. Volume (CY)	4954	2952	1863

Source: Mabee, 2012 (portion of the poster entitled Geomorphic Effects of Tropical Storm Irene on Western Massachusetts: Landslides and Fluvial Erosion Along the Deerfield and Cold Rivers, Charlemont and Savoy, MA)

- Landslide susceptibility is defined as the probable degree of response of geologic formations to natural or artificial cutting, to loading of slopes, or to unusually high precipitation. It can be assumed that unusually high precipitation or changes in existing conditions can initiate landslide movement in areas where rocks and soils have experienced numerous landslides in the past. Landslide susceptibility depends on slope angle and the geologic material underlying the slope. Landslide susceptibility only identifies areas potentially affected and does not imply a time frame when a landslide might occur. High, medium, and low susceptibility are delimited by the same percentages used for classifying the incidence of landsliding.

Landslides destroy property and infrastructure and can take the lives of people. Slope failures in the United States result in an average of 25 lives lost per year and an annual cost to society of about $1.5 billion.

12.2.5 Warning Time

Mass movements 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. Some methods used to monitor mass movements can provide an idea of the type of movement and the amount of time prior to failure. It is also possible to determine what areas are at risk during general time periods. Assessing the geology, vegetation, and amount of predicted precipitation for an area can help in these predictions. However, there is no practical warning system for individual landslides. The current standard operating procedure is to monitor situations on a case-by-case basis, and respond after the event has occurred. Generally accepted warning signs for landslide activity include the following:

- 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 house
- Tilting or cracking of concrete floors and foundations
- Broken water lines 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, possibly accompanied by increased turbidity (soil content)
- Sudden decrease in creek water levels though rain is still falling or 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.

12.3 SECONDARY HAZARDS

Landslides can cause several types of secondary effects, such as blocking access to roads, which can isolate residents and businesses and delay commercial, public, and private transportation. This could result in economic losses for businesses. Other potential problems resulting from landslides are power and communication failures. Vegetation or poles on slopes can be knocked over, resulting in possible losses to

power and communication lines. Landslides also have the potential of destabilizing the foundation of structures, which may result in monetary loss for residents. They also can damage rivers or streams, potentially harming water quality, fisheries, and spawning habitat.

12.4 CLIMATE CHANGE IMPACTS

With the latest regional models showing warmer and wetter winters for New England (Rawlins et al., 2012), Climate change may impact storm patterns, increasing the probability of more frequent, intense storms with varying duration. Increase in global temperature could affect the snowpack and its ability to hold and store water. Warming temperatures also could increase the occurrence and duration of droughts, which would increase the probability of wildfire, reducing the vegetation that helps to support steep slopes. All of these factors would increase the probability for landslide occurrences.

12.5 EXPOSURE

To understand risk, the assets exposed to the hazard areas are identified within the known landslide areas. The following discusses the Commonwealth of Massachusetts' exposure to the landslide hazard including:

- Population
- State facilities
- Critical facilities
- Economy

In an attempt to estimate the Commonwealth's vulnerability to the landslide hazard, the Geology - Landslide Incidence and Susceptibility GIS layer from National Atlas was used to coarsely define the general landslide susceptible area (herein "approximate hazard area") (Figure 12-2) (Godt, 2001). According to Radbruch-Hall et al. (1982), the Landslide Incidence and Susceptibility GIS layer from National Atlas

> '…was prepared by evaluating formations or groups of formations shown on the geologic map of the United States (King and Beikman, 1974) and classifying them as having high, medium, or low landslide incidence (number of landslides) and being of high, medium, or low susceptibility to landsliding. Thus, those map units or parts of units with more than 15 percent of their area involved in landsliding were classified as having high incidence; those with 1.5 to 15 percent of their area involved in landsliding, as having medium incidence; and those with less than 1.5 percent of their area involved, as having low incidence. This classification scheme was modified where particular lithofacies are known to have variable landslide incidence or susceptibility. In continental glaciated areas, additional data were used to identify surficial deposits that are susceptible to slope movement. Susceptibility to landsliding was defined as the probable degree of response of the areal rocks and soils to natural or artificial cutting or loading of slopes or to anomalously high precipitation. High, medium, and low susceptibility are delimited by the same percentages used in classifying the incidence of landsliding. For example, it was estimated that a rock or soil unit characterized by high landslide susceptibility would respond to widespread artificial cutting by some movement in 15 percent or more of the affected area. We did not evaluate the effect of earthquakes on slope stability, although many catastrophic landslides have been generated by ground shaking during earthquakes. Areas susceptible to ground failure under static conditions would probably also be susceptible to failure during earthquakes.'

The limitations of this data set and analysis are recognized and are only used to provide a general estimate until higher resolution data are available Commonwealth-wide.

In an effort to address the limitations of the datasets associated with the ability to determine risk associated with landslides, the Massachusetts Geological Survey and University of Massachusetts - Amherst applied for and were awarded a FEMA Hazard Mitigation Grant Program grant to conduct statewide mapping and identification of landslide hazards that can be used for community level planning as well as prioritizing high risk areas for mitigation. This project is currently underway and results will be available for future updates of this plan to allow for better analysis of this hazard. Further, rapid fluvial geomorphological assessment and fluvial erosion hazard mapping for stream corridor planning and mitigation is also being conducted to better characterize this hazard in the Commonwealth.

12.5.1 Population

Due to the nature of census block data, it is difficult to determine demographics of populations vulnerable to mass movements. To estimate the population vulnerable to the landslide hazard, the Landslide Incidence and Susceptibility approximate hazard areas were overlaid upon the 2010 Census population data (U.S. Census, 2010). Please note the Census blocks do not align exactly with the hazard areas and, therefore, these estimates should be considered for planning purposes only. Further, some areas did not have a defined landslide hazard category assigned due to the differences in extent of the polygon datasets. In these cases, the adjacent landslide hazard area classification was assigned to the Census block. The Census blocks with their centroid located in each zone were used to calculate the estimated population exposed to the landslide hazard. In total, there are an estimated 265 people in the high landslide incidence zone, all located in Dukes County (or less than one-percent of the Commonwealth's total population). Further, there are approximately 417,688 in the high susceptibility (either moderate or low incidence) areas in the Commonwealth (or 6.4-percent of the Commonwealth's population). Table 12-2 summarizes the estimated population within the defined hazard areas by county.

12.5.2 State Facilities

To assess the exposure of the state-owned and leased facilities provided by DCAMM and the Office of Leasing, an analysis was conducted with the approximate landslide hazard areas. Using ArcMap, GIS software, the approximate hazard area data were overlaid with the state facility data to determine which facilities are within the defined hazard areas. Table 12-2 and Table 12-3 summarize the number of state-owned and leased buildings in the landslide hazard area by county. Figure 12-5 show the locations of state-owned and state-leased buildings in the high or moderate landslide hazard areas (1,439 structures).

TABLE 12-2.
2010 POPULATION IN THE LANDSLIDE HAZARD AREAS

		High Incidence		High Susceptibility, Moderate Incidence		High Susceptibility, Low Incidence		Moderate Susceptibility, Low Incidence		Low Incidence	
County	Population	Number	% Total	Number	% Total	Number	% Total	Number	% Total	Number	% Total
Barnstable	215,888	—	—	—	—	—	—	—	—	215,888	100
Berkshire	131,219	—	—	23,446	17.9	—	—	—	—	107,773	82
Bristol	548,285	—	—	—	—	—	—	352	0.1	547,933	100
Dukes	16,535	265	1.6	—	—	—	—	7,713	46.6	8,557	52
Essex	743,159	—	—	7,945	1.1	—	—	28,179	3.8	707,035	95
Franklin	71,372	—	—	123	0.2	32,919	46.1	—	—	38,330	54
Hampden	463,490	—	—	261,505	56.4	—	—	—	—	201,985	44
Hampshire	158,080	—	—	24,483	15.5	67,267	42.6	—	—	66,330	42
Middlesex	1,503,085	—	—	—	—	—	—	236,185	15.7	1,266,900	84
Nantucket	10,172	—	—	—	—	—	—	357	3.5	9,815	96
Norfolk	670,850	—	—	—	—	—	—	203,348	30.3	467,502	70
Plymouth	494,919	—	—	—	—	—	—	76,479	15.5	418,440	85
Suffolk	722,023	—	—	—	—	—	—	563,677	78.1	158,346	22
Worcester	798,552	—	—	—	—	—	—	24,713	3.1	773,839	97
Total	**6,547,629**	**265**	**<1**	**317,502**	**4.8**	**100,186**	**2**	**1,141,003**	**17**	**4,988,673**	**76**

Source: U.S. Census, 2010; Godt, 2001

TABLE 12-3.
STATE-OWNED AND LEASED FACILITIES EXPOSED TO THE LANDSLIDE HAZARD

County	High Susceptibility, Moderate Incidence	High Susceptibility, Low Incidence	Moderate Susceptibility, Low Incidence	Low Incidence
Barnstable	—	—	—	309
Berkshire	67	—	—	291
Bristol	—	—	—	482
Dukes	—	—	4	9
Essex	18	—	5	515
Franklin	—	92	—	119
Hampden	150	—	—	316
Hampshire	26	110	—	426
Middlesex	—	—	168	939
Nantucket	—	—	—	5
Norfolk	—	—	144	536
Plymouth	—	—	268	274
Suffolk	—	—	341	53
Worcester	—	—	46	1,047
Total	**261**	**202**	**976**	**5,321**

Source: DCAMM, 2012; Godt, 2001
Note: Five facilities are located in an area where the landslide hazard area is not defined.

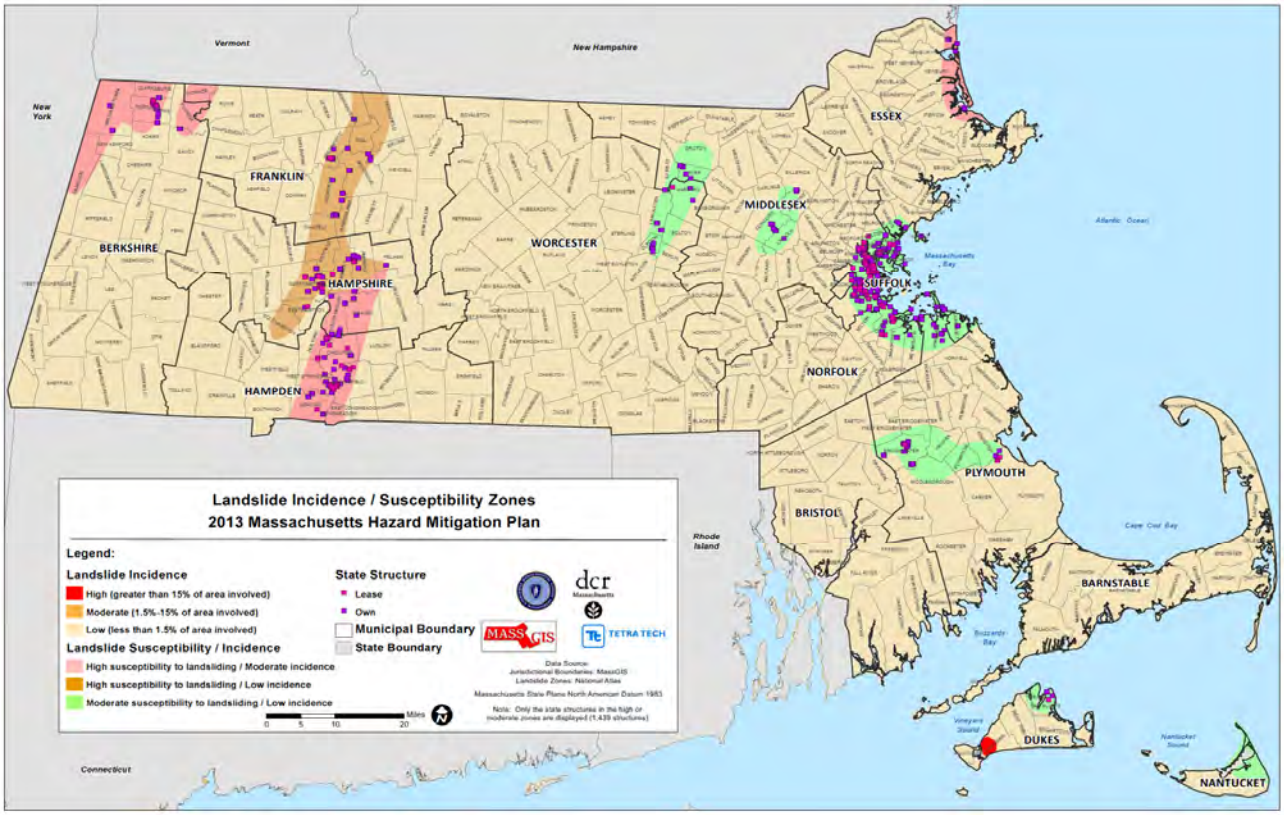


Figure 12-5. State-Owned and Leased Facilities in the High or Moderate Landslide Incidence/Susceptibility Areas

12.5.3 Critical Facilities

Critical facilities located in landslide hazard areas are exposed to the hazard. The numbers of critical facilities exposed to the landslide hazard areas are listed in Table 12-4 through Table 12-8. In addition to the facilities identified in the tables, one state emergency operations center is in a high susceptibility/moderate incidence area and one is in a low incidence area.

TABLE 12-4.
NUMBER OF POLICE EXPOSED TO THE LANDSLIDE HAZARD

County	High Susceptibility, Moderate Incidence	High Susceptibility, Low Incidence	Moderate Susceptibility, Low Incidence	Low Incidence
Barnstable	—	—	—	20
Berkshire	4	—	—	29
Bristol	—	—	—	27
Dukes	—	—	4	6
Essex	1	—	1	37
Franklin	—	8	—	18
Hampden	11	—	—	17
Hampshire	2	8	—	13
Middlesex	—	—	13	51
Nantucket	—	—	—	3
Norfolk	—	—	6	26
Plymouth	—	—	5	26

TABLE 12-4.
NUMBER OF POLICE EXPOSED TO THE LANDSLIDE HAZARD

County	High Susceptibility, Moderate Incidence	High Susceptibility, Low Incidence	Moderate Susceptibility, Low Incidence	Low Incidence
Suffolk	—	—	27	7
Worcester	—	—	3	64
Total	**18**	**16**	**59**	**344**

Source: MassGIS, 2012; Godt, 2001

TABLE 12-5
NUMBER OF FIRE DEPARTMENTS EXPOSED TO THE LANDSLIDE HAZARD

County	High Incidence	High Susceptibility, Moderate Incidence	High Susceptibility, Low Incidence	Moderate Susceptibility, Low Incidence	Low Incidence
Barnstable	—	—	—	—	37
Berkshire	—	4	—	—	42
Bristol	—	—	—	—	63
Dukes	1	—	—	2	5
Essex	—	—	—	3	79
Franklin	—	1	10	—	20
Hampden	—	23	—	—	28
Hampshire	—	3	8	—	17
Middlesex	—	—	—	18	146
Nantucket	—	—	—	—	1
Norfolk	—	—	—	19	40
Plymouth	—	—	—	10	57
Suffolk	—	—	—	39	8
Worcester	—	—	—	6	99
Total	**1**	**31**	**18**	**97**	**642**

Source: MassGIS, 2012; Godt, 2001

TABLE 12-6.
NUMBER OF HOSPITALS EXPOSED TO THE LANDSLIDE HAZARD

County	High Susceptibility, Moderate Incidence	High Susceptibility, Low Incidence	Moderate Susceptibility, Low Incidence	Low Incidence
Barnstable	—	—	—	2
Berkshire	1	—	—	3
Bristol	—	—	—	5
Dukes	—	—	1	—
Essex	—	—	—	10
Franklin	—	1	—	—
Hampden	4	—	—	2
Hampshire	—	1	—	1
Middlesex	—	—	3	13
Nantucket	—	—	—	1
Norfolk	—	—	2	3

TABLE 12-6.
NUMBER OF HOSPITALS EXPOSED TO THE LANDSLIDE HAZARD

County	High Susceptibility, Moderate Incidence	High Susceptibility, Low Incidence	Moderate Susceptibility, Low Incidence	Low Incidence
Plymouth	—	—	—	4
Suffolk	—	—	12	3
Worcester	—	—	1	9
Total	**5**	**2**	**19**	**56**

Source: MassGIS, 2012; Godt, 2001

TABLE 12-7.
NUMBER OF SCHOOLS (PRE-K – 12) EXPOSED TO THE LANDSLIDE HAZARD

County	High Incidence	High Susceptibility, Moderate Incidence	High Susceptibility, Low Incidence	Moderate Susceptibility, Low Incidence	Low Incidence
Barnstable	—	—	—	—	82
Berkshire	—	14	—	—	62
Bristol	—	—	—	—	243
Dukes	1	—	—	3	6
Essex	—	—	—	8	301
Franklin	—	—	29	—	24
Hampden	—	126	—	—	91
Hampshire	—	13	65	—	35
Middlesex	—	—	—	76	500
Nantucket	—	—	—	—	4
Norfolk	—	—	—	64	222
Plymouth	—	—	—	26	171
Suffolk	—	—	—	187	57
Worcester	—	—	—	15	342
Total	**1**	**153**	**94**	**379**	**2,140**

Source: MassGIS, 2012; Godt, 2001

TABLE 12-8.
NUMBER OF COLLEGES EXPOSED TO THE LANDSLIDE HAZARD

County	High Susceptibility, Moderate Incidence	High Susceptibility, Low Incidence	Moderate Susceptibility, Low Incidence	Low Incidence
Barnstable	—	—	—	6
Berkshire	3	—	—	3
Bristol	—	—	—	12
Dukes	—	—	—	—
Essex	—	—	1	12
Franklin	—	1	—	2
Hampden	13	—	—	3

TABLE 12-8.
NUMBER OF COLLEGES EXPOSED TO THE LANDSLIDE HAZARD

County	High Susceptibility, Moderate Incidence	High Susceptibility, Low Incidence	Moderate Susceptibility, Low Incidence	Low Incidence
Hampshire	1	3	—	1
Middlesex	—	—	9	38
Nantucket	—	—	1	—
Norfolk	—	—	6	15
Plymouth	—	—	1	5
Suffolk	—	—	43	5
Worcester	—	—	1	20
Total	**17**	**4**	**62**	**122**

Source: MassGIS, 2012; Godt, 2001

A significant amount of infrastructure can be exposed to mass movements:

- **Roads**—Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations. Landslides can block egress and ingress on roads, causing isolation for neighborhoods, traffic problems, and delays for public and private transportation. This can result in economic losses for businesses.
- **Bridges**—Landslides can significantly impact road bridges. Mass movements can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous for use. Table 12-9 summarizes the bridges located in the landslide hazard areas.
- **Power Lines**—Power lines are generally elevated above steep slopes, but the towers supporting them can be subject to landslides. A landslide could trigger failure of the soil underneath a tower, causing it to collapse and ripping down the lines. Power and communication failures due to landslides can create problems for vulnerable populations and businesses.

12.5.4 Economy

A landslide's impact on the economy and estimated dollar losses are difficult to measure. As stated earlier, landslides can impose direct and indirect impacts on society. Direct costs include the actual damage sustained by buildings, property, and infrastructure. Indirect costs, such as clean-up costs, business interruption, loss of tax revenues, reduced property values, and loss of productivity are difficult to measure. Additionally, ground failure threatens transportation corridors, fuel and energy conduits, and communication lines (USGS, 2003).

TABLE 12-9.
NUMBER OF BRIDGES EXPOSED TO THE LANDSLIDE HAZARD

County	High Susceptibility, Moderate Incidence	High Susceptibility, Low Incidence	Moderate Susceptibility, Low Incidence	Low Incidence	Outside Defined Hazard Areas
Barnstable	—	—	—	96	2
Berkshire	57	—	—	357	—
Bristol	—	—	—	348	19
Dukes	—	—	2	2	1
Essex	3	—	4	361	7
Franklin	2	65	—	212	—
Hampden	175	—	—	240	—
Hampshire	17	62	—	156	—
Middlesex	—	—	81	671	—
Nantucket	—	—	—	2	—
Norfolk	—	—	89	244	4
Plymouth	—	—	36	221	2
Suffolk	—	—	302	49	7
Worcester	—	—	24	912	—
Total	**254**	**127**	**538**	**3874**	**42**

Source: HAZUS-MH v. 2.1 default bridges; Godt, 2001
*Bridges are located outside of defined hazard areas such as over bodies of water.

For the purposes of this analysis, the replacement cost value of the general building stock located in the high incidence or high susceptibility landslide hazard areas is considered vulnerable to this hazard. Table 12-10 summarizes these values by county. Based on this approach of analysis, Franklin, Hampden, and Hampshire Counties are the most vulnerable to the landslide hazard as it relates to the building replacement cost value and the associated percentage of potential impact of approximately 50-percent of value being exposed.

12.6 VULNERABILITY

12.6.1 Population

In general, the population exposed to higher risk landslide areas is considered to be vulnerable. Further, population located downslope are vulnerable to this hazard as well. Increasing population and the fact that many homes are built on view property atop or below bluffs and on steep slopes subject to mass movement, increases the number of lives endangered by this hazard.

TABLE 12-10.
BUILDING AND CONTENT REPLACEMENT COST VALUE IN LANDSLIDE HAZARD AREAS

County	Total Replacement Cost Value	High Incidence	% Total	High Susceptibility, Moderate Incidence	% Total	High Susceptibility, Low Incidence	% Total
Barnstable	$47,450,250,000	—	—	—	—	—	—
Berkshire	$20,566,219,000	—	—	$3,609,042,000	17.5	—	—
Bristol	$74,946,506,000	—	—	—	—	—	—
Dukes	$4,894,499,000	$144,916,000	3.0	—	—	—	—
Essex	$100,099,771,000	—	—	$1,357,094,000	1.4	—	—
Franklin	$10,130,548,000	—	—	$22,597,000	0.2	$5,052,163,000	49.9
Hampden	$67,212,508,000	—	—	$39,696,615,000	59.1	—	—
Hampshire	$20,961,384,000	—	—	$2,966,193,000	14.2	$10,264,349,000	49.0
Middlesex	$244,161,008,000	—	—	—	—	—	—
Nantucket	$3,610,072,000	—	—	—	—	—	—
Norfolk	$111,344,832,000	—	—	—	—	—	—
Plymouth	$70,614,087,000	—	—	—	—	—	—
Suffolk	$115,439,212,000	—	—	—	—	—	—
Worcester	$112,858,251,000	—	—	—	—	—	—
Total	**$1,004,289,147,000**	**$144,916,000**	**< 1**	**$44,042,499,000**	**4.4**	**$15,316,512,000**	**1.5**

Source: HAZUS-MH v. 2.1; Godt, 2001

12.6.2 State Facilities

To estimate the potential losses to state-owned and leased structures, the exposure analysis methodology was used. As discussed, there are 6,765 state-owned/leased structures in the Commonwealth. Table 12-11 and Table 12-12 identify the replacement cost value of the state-owned and leased buildings located in the landslide hazard areas by county and agency, respectively. The values shown assume 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.

TABLE 12-11.
REPLACEMENT COST VALUE OF STATE-OWNED AND LEASED BUILDINGS EXPOSED TO THE LANDSLIDE HAZARD BY LANDSLIDE RISK AND COUNTY

County	High Susceptibility, Low Incidence	High Susceptibility, Moderate Incidence	Low Incidence	Moderate Susceptibility, Low Incidence	**Total**
Barnstable					**$1,146,314,361**
Lease	—	—	$17,181,274	—	
Own	—	—	$1,129,133,087	—	
Berkshire					**$1,852,000,832**
Lease	—	$14,797,914	$26,640,718	—	
Own	—	$448,678,247	$1,361,883,953	—	
Bristol					**$3,012,210,350**
Lease	—	—	$149,664,578	—	
Own	—	—	$2,862,545,772	—	
Dukes					**$16,224,048**
Lease	—	—	$6,000,330	$258,630	
Own	—	—	$8,583,402	$1,381,686	
Essex					**$4,473,201,429**
Lease	—	—	$136,866,724	—	
Own	—	$40,489,911	$4,160,832,458	$135,012,336	
Franklin					**$813,236,929**
Lease	$12,650,102	—	$11,512,252	—	
Own	$280,365,221	—	$508,709,354	—	
Hampden					**$5,051,650,248**
Lease	—	$133,102,974	$22,480,470	—	
Own	—	$1,809,364,515	$3,086,702,289	—	
Hampshire					**$4,687,387,853**
Lease	$26,043,416	—	$6,998,780	—	
Own	$1,027,877,514	$17,755,949	$3,608,712,194	—	
Middlesex					**$9,881,996,655**
Lease	—	—	$274,107,566	$51,862,192	
Own	—	—	$7,977,083,190	$1,578,943,706	
Nantucket					**$31,381,244**
Lease	—	—	$941,186	—	
Own	—	—	$30,440,058	—	
Norfolk					**$5,141,831,256**
Lease	—	—	$82,325,618	$65,496,734	
Own	—	—	$4,448,605,755	$545,403,149	
Plymouth					**$3,182,404,153**
Lease	—	—	$77,885,394	$15,098,192	
Own	—	—	$1,211,391,815	$1,878,028,752	
Suffolk					**$8,247,560,162**
Lease	—	—	$99,245,614	$388,582,320	
Own	—	—	$91,187,408	$7,668,544,820	
Worcester					**$9,444,698,995**
Lease	—	—	$205,010,236	$12,824,580	
Own	—	—	$7,971,118,166	$1,255,746,013	
Total					**$56,982,098,514**
Lease	**$38,693,518**	**$147,900,888**	**$1,116,860,740**	**$534,122,648**	
Own	**$1,308,242,736**	**$2,316,288,622**	**$38,456,928,901**	**$13,063,060,461**	

TABLE 12-12.
STATE-OWNED AND LEASED BUILDINGS EXPOSED TO THE LANDSLIDE HAZARD BY STATE AGENCY

	High Susceptibility, Low Incidence		High Susceptibility, Moderate Incidence		Low Incidence		Moderate Susceptibility, Low Incidence		
State Agency	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Total
Alcoholic Beverages Control Commission	—	—	—	—	—	—	$1,619,110	100.0	$1,619,110
Attorney General	—	—	$2,149,464	46.7	$2,451,108	53.3	—	—	$4,600,572
Berkshire Community College	—	—	—	—	$239,840,975	100	—	—	$239,840,975
Board of Higher Education	—	—	—	—	—	—	$1,402,696	100	$1,402,696
Board of Library Commissioners	—	—	—	—	—	—	$1,846,748	100	$1,846,748
Bridgewater State University	—	—	—	—	$3,760,852	0.6	$625,789,112	99.4	$629,549,964
Bristol Community College	—	—	—	—	$381,670,168	100	—	—	$381,670,168
Bunker Hill Community College	—	—	—	—	—	—	$280,704,380	100	$280,704,380
Bureau of State Buildings	—	—	$33,722,612	1.2	$512,120,650	18.7	$2,185,641,270	80	$2,731,484,532
Cape Cod Community College	—	—	—	—	$201,526,780	100	—	—	$201,526,780
Chelsea Soldiers' Home	—	—	—	—	—	—	$420,265,816	100	$420,265,816
Children's Trust Fund	—	—	—	—	—	—	$2,200,228	100	$2,200,228
Civil Defense Headquarters	—	—	—	—	$82,566,828	100	—	—	$82,566,828
Committee For Public Counsel Services	$1,063,910	2.6	$3,440,744	8.4	$19,200,888	46.8	$17,319,410	42.2	$41,024,952
Commonwealth Zoo Commission	—	—	—	—	$46,269,164	60.9	$29,707,477	39.1	$75,976,641
Council of Government	—	—	—	—	—	—	$17,497,010	100	$17,497,010
Department of Agricultural Resources	$641,232	100.0	—	—	—	—	—	—	$641,232
Department of Business and Technology	—	—	—	—	$141,072	100	—	—	$141,072
Department of Children and Families	—	—	$19,629,180	11.7	$120,480,542	71.5	$28,307,188	16.8	$168,416,910
Department of Conservation and Recreation	$11,409,166	0.3	$170,039,562	4.4	$2,517,110,340	64.5	$1,204,373,937	30.9	$3,902,933,006
Department of Corrections	—	—	—	—	$3,438,171,288	62.4	$2,075,367,406	37.6	$5,513,538,694

TABLE 12-12.
STATE-OWNED AND LEASED BUILDINGS EXPOSED TO THE LANDSLIDE HAZARD BY STATE AGENCY

	High Susceptibility, Low Incidence		High Susceptibility, Moderate Incidence		Low Incidence		Moderate Susceptibility, Low Incidence		
State Agency	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Total
Department of Developmental Services	$5,062,526	0.2	$1,711,822	0.1	$2,314,669,658	99.1	$13,335,305	0.6	$2,334,779,311
Department of Early Education and Care	—	—	—	—	$5,612,384	50.9	$5,422,954	49.1	$11,035,338
Department of Education	—	—	—	—	$130,950,398	100	—	—	$130,950,398
Department of Environmental Protection	—	—	$26,698,134	28.1	$68,157,522	71.9	—	—	$94,855,656
Department of Fire Services	—	—	—	—	$62,035,434	100	—	—	$62,035,434
Department of Fish and Game	$23,122,970	17.9	$49,636	—	$86,863,616	67.3	$19,074,841	14.8	$129,111,063
Department of Food and Agriculture	—	—	$4,528,850	100.0	—	—	—	—	$4,528,850
Department of Industrial Accidents	—	—	—	—	$7,190,884	32.9	$14,693,832	67.1	$21,884,716
Department of Mental Health	$369,879,787	14.7	$7,233,600	0.3	$1,951,204,071	77.4	$192,669,584	7.6	$2,520,987,041
Department of Public Health	$2,348,512	0.1	—	—	$1,721,263,231	96.6	$57,585,594	3.2	$1,781,197,337
Department of Public Utilities	—	—	—	—	—	—	$8,941,446	100	$8,941,446
Department of State Police	$116,500,840	18.5	$11,687,852	1.9	$481,668,002	76.6	$19,195,552	3.1	$629,052,246
Department of Telecommunications and Cab	—	—	—	—	—	—	$2,709,472	100	$2,709,472
Department of Transitional Assistance	—	—	$17,777,892	14.8	$77,859,726	64.9	$24,316,584	20.3	$119,954,202
Department of Transportation	$217,084,939	14.2	$189,413,934	12.4	$980,929,747	64.4	$136,549,148	9.0	$1,523,977,768
Department of Veterans Services	—	—	$7,192,502	51.4	$6,793,108	48.6	—	—	$13,985,610
Department of Youth Services	—	—	—	—	$470,628,630	100	—	—	$470,628,630
Department of Elementary and Secondary Education	—	—	—	—	$31,345,824	100	—	—	$31,345,824
Department of Workforce Development	—	—	$4,685,536	28.4	$8,831,102	53.6	$2,964,094	18.0	$16,480,732

TABLE 12-12.
STATE-OWNED AND LEASED BUILDINGS EXPOSED TO THE LANDSLIDE HAZARD BY STATE AGENCY

	High Susceptibility, Low Incidence		High Susceptibility, Moderate Incidence		Low Incidence		Moderate Susceptibility, Low Incidence		
State Agency	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Total
Disabled Persons Protection Commission	—	—	—	—	—	—	$2,137,440	100	$2,137,440
Div. of Health Care Finance and Policy	—	—	—	—	—	—	$10,687,200	100	$10,687,200
Division of Administrative Law Appeals	—	—	—	—	—	—	$2,514,164	100	$2,514,164
Division of Banks	—	—	—	—	$1,396,282	21	$5,258,636	79.0	$6,654,918
Division of Capital Asset Management	—	—	$1,649,468	0.1	$2,807,365,464	89.2	$339,142,464	10.8	$3,148,157,396
Division of Insurance	—	—	—	—	—	—	$9,660,694	100	$9,660,694
Division of Professional Licensure	—	—	—	—	—	—	$9,404,202	100	$9,404,202
Division of Standards	—	—	—	—	$1,517,316	100	—	—	$1,517,316
Emergency Management Agency	—	—	$3,160,504	100.0	—	—	—	—	$3,160,504
Exec. Office of Energy and Environmental Affairs	—	—	—	—	$605,696	2.5	$23,551,116	97.5	$24,156,812
Exec. Office of Health and Human Services	—	—	$3,282,306	5.6	$21,124,854	36.3	$33,803,346	58.1	$58,210,506
Fitchburg State University	—	—	—	—	$658,051,935	100	—	—	$658,051,935
Framingham State University	—	—	—	—	$525,548,586	100	—	—	$525,548,586
Greenfield Community College	$5,955,640	2.9	—	—	$196,362,192	97.1	—	—	$202,317,832
Holyoke Community College	—	—	$3,953,560	1.0	$404,228,384	99	—	—	$408,181,944
Holyoke Soldiers' Home	—	—	—	—	$210,550,728	100	—	—	$210,550,728
Information Technology Division	—	—	$21,182,030	100.0	—	—	—	—	$21,182,030
Judicial Conduct Commission	—	—	—	—	—	—	$772,150	100	$772,150
Massachusetts Bay Community College	—	—	—	—	$135,991,622	100	—	—	$135,991,622
Massachusetts Bay Community College	—	—	—	—	$46,338,516	100	—	—	$46,338,516

TABLE 12-12.
STATE-OWNED AND LEASED BUILDINGS EXPOSED TO THE LANDSLIDE HAZARD BY STATE AGENCY

	High Susceptibility, Low Incidence		High Susceptibility, Moderate Incidence		Low Incidence		Moderate Susceptibility, Low Incidence		
State Agency	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Total
Massachusetts College of Art and Design	—	—	—	—	—	—	$527,402,394	100	$527,402,394
Massachusetts College of Liberal Arts	—	—	$363,904,867	91.5	$33,748,500	8.5	—	—	$397,653,367
Massachusetts Commission Against Discrimination	—	—	—	—	$278,134	100	—	—	$278,134
Massachusetts Commission for the Blind	—	—	—	—	$7,542,492	100	—	—	$7,542,492
Massachusetts Commission for the Deaf and Hard of Hearing	—	—	—	—	$2,556,646	100	—	—	$2,556,646
Massachusetts Cultural Council	—	—	—	—	—	—	$2,749,014	100	$2,749,014
Massachusetts Department of Revenue	—	—	$3,900,828	7.9	$28,035,734	57	$17,259,562	35.1	$49,196,124
Massachusetts Developmental Disabilities Council	—	—	—	—	—	—	$1,218,074	100	$1,218,074
Massachusetts Gaming Commission	—	—	—	—	—	—	$1,499,146	100	$1,499,146
Massachusetts Maritime Academy	—	—	—	—	$232,687,325	100	—	—	$232,687,325
Massachusetts National Guard	$816,248	21.0	—	—	$3,065,126	79.0	—	—	$3,881,374
Massachusetts Parole Board	—	—	—	—	$8,325,594	87.9	$1,149,408	12.1	$9,475,002
Massachusetts Rehabilitation Commission	$1,122,156	1.8	$3,986,858	6.5	$33,630,212	54.6	$22,908,548	37.2	$61,647,774
Massachusetts Sheriff's Association	—	—	—	—	—	0.0	$567,224	100	$567,224
Massachusetts State Lottery Commission	—	—	$1,637,012	3.3	$48,255,914	96.7	—	—	$49,892,926
Massachusetts Teachers' Retirement System	—	—	$710,966	13.0	—	0.0	$4,755,804	87	$5,466,770
Massasoit Community College	—	—	—	—	$383,445,357	100	—	—	$383,445,357
Mental Health Legal Advisors	—	—	—	—	—	0.0	$677,302	100	$677,302

TABLE 12-12.
STATE-OWNED AND LEASED BUILDINGS EXPOSED TO THE LANDSLIDE HAZARD BY STATE AGENCY

	High Susceptibility, Low Incidence		High Susceptibility, Moderate Incidence		Low Incidence		Moderate Susceptibility, Low Incidence		
State Agency	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Total
Middlesex Community College	—	—	—	—	$72,531,208	19.8	$293,117,142	80.2	$365,648,350
Military Division	$412,052	0.03	$193,324,940	13.1	$1,071,151,128	72.5	$212,042,939	14.4	$1,476,931,058
Mount Wachusett Community College	—	—	—	—	$475,216,655	97.4	$12,824,580	2.6	$488,041,235
Municipal Police Training Committee	—	—	—	—	$5,829,868	100	—	—	$5,829,868
North Shore Community College	—	—	—	—	$246,720,408	100	—	—	$246,720,408
Northern Essex Community College	—	—	—	—	$330,017,350	100	—	—	$330,017,350
Office For Refugees and Immigrants	—	—	—	—	$1,199,104	100	—	—	$1,199,104
Office of Environmental Law Enforcement	—	—	—	—	$420,540	100	—	—	$420,540
Office of Labor and Workforce Development	—	—	—	—	$38,062,268	100	—	—	$38,062,268
Office of the Chief Medical Examiner	—	—	$830,130	4.1	—	—	$19,345,938	95.9	$20,176,068
Office of the D.A. Bristol	—	—	—	—	$8,113,188	100	—	—	$8,113,188
Office of the D.A. Cape and Island	—	—	—	—	$1,595,866	100	—	—	$1,595,866
Office of the D.A. Eastern	—	—	—	—	$9,641,990	100	—	—	$9,641,990
Office of the D.A. Hampden	—	—	$3,168,488	100.0	—	—	—	—	$3,168,488
Office of the D.A. Middle	—	—	—	—	$5,615,856	100	—	—	$5,615,856
Office of the D.A. Norfolk	—	—	—	—	$6,447,854	100	—	—	$6,447,854
Office of the D.A. Northern	—	—	—	—	$14,448,294	91.2	$1,400,024	8.8	$15,848,318
Office of the D.A. Northwestern	$7,491,192	100	—	—	—	—	—	—	$7,491,192
Office of the D.A. Plymouth	—	—	—	—	$5,324,630	100	—	—	$5,324,630
Office of the D.A. Suffolk	—	—	—	—	—	—	$14,452,034	100	$14,452,034
Office of the State Auditor	—	—	$648,980	10.7	$5,438,450	89.3	—	—	$6,087,430
Office of the State Treasurer	—	—	—	—	—	—	$3,825,216	100	$3,825,216

TABLE 12-12.
STATE-OWNED AND LEASED BUILDINGS EXPOSED TO THE LANDSLIDE HAZARD BY STATE AGENCY

	High Susceptibility, Low Incidence		High Susceptibility, Moderate Incidence		Low Incidence		Moderate Susceptibility, Low Incidence		
State Agency	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Total
Public Employee Retirement Admin. Comm.	—	—	—	—	—	—	$3,874,110	100	$3,874,110
Quinsigamond Community College	—	—	—	—	$301,965,647	100	—	—	$301,965,647
Registry of Motor Vehicles	—	—	—	—	$20,878,316	100	—	—	$20,878,316
Roxbury Community College	—	—	—	—	—	—	$272,730,036	100	$272,730,036
Salem State University	—	—	—	—	$1,022,777,330	100	—	—	$1,022,777,330
Secretary of State	—	—	—	—	$26,693,420	30	$62,377,670	70.0	$89,071,090
Sex Offenders' Registry	—	—	—	—	$4,048,044	100	—	—	$4,048,044
Sheriff's Department Berkshire	—	—	—	—	$222,443,410	100	—	—	$222,443,410
Sheriff's Department Bristol	—	—	—	—	$59,784,324	100	—	—	$59,784,324
Sheriff's Department Essex	—	—	—	—	$313,169,686	100	—	—	$313,169,686
Sheriff's Department Franklin	$153,896	0.1	—	—	$102,711,202	99.9	—	—	$102,865,098
Sheriff's Department Hampden	—	—	$93,329,692	13.3	$607,535,874	86.7	—	—	$700,865,566
Sheriff's Department Hampshire	$97,011,962	100	—	—	—	—	—	—	$97,011,962
Sheriff's Department Middlesex	—	—	—	—	$287,588,762	74.9	$96,216,182	25.1	$383,804,944
Sheriff's Department Nantucket	—	—	—	—	$814,810	100	—	—	$814,810
Sheriff's Department Norfolk	—	—	—	—	$7,812,590	68.5	$3,591,394	31.5	$11,403,984
Sheriff's Department Suffolk	—	—	—	—	—	—	$874,251,452	100	$874,251,452
Sheriff's Department Worcester	—	—	—	—	$8,659,992	100	—	—	$8,659,992
Springfield Technical Community College	—	—	$1,154,896,536	100.0	—	—	—	—	$1,154,896,536
State Reclamation and Mosquito Control B	—	—	—	—	$10,574,716	100	—	—	$10,574,716
Trial Court	$99,888,933	2.0	$110,661,024	2.2	$3,129,719,233	61.1	$1,780,207,152	34.8	$5,120,476,342
University of Massachusetts at Amherst	$386,970,294	9.6	—	—	$3,644,481,845	90.4	$120,218	—	$4,031,572,357

TABLE 12-12.
STATE-OWNED AND LEASED BUILDINGS EXPOSED TO THE LANDSLIDE HAZARD BY STATE AGENCY

	High Susceptibility, Low Incidence		High Susceptibility, Moderate Incidence		Low Incidence		Moderate Susceptibility, Low Incidence		
State Agency	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Replacement Cost Value	% of Total	Total
University of Massachusetts at Boston	—	—	—	—	—	—	$1,380,001,842	100	$1,380,001,842
University of Massachusetts at Dartmouth	—	—	—	—	$766,501,758	100	—	—	$766,501,758
University of Massachusetts at Lowell	—	—	—	—	$2,527,775,117	100	—	—	$2,527,775,117
University of Massachusetts Medical School	—	—	—	—	$1,475,508,795	90.2	$160,187,098	9.8	$1,635,695,893
Westfield State University	—	—	—	—	$581,908,920	100	—	—	$581,908,920
Worcester State University	—	—	—	—	$390,694,594	100	—	—	$390,694,594
Total	**$1,346,936,254**	**2.4**	**$2,464,189,510**	**4.3**	**$39,573,789,641**	**69.4**	**$13,597,183,109**	**23.9**	**$56,982,098,514**

Source: DCAMM, 2012; Godt, 2001

12.6.3 Critical Facilities

Several types of infrastructure are exposed to landslides, including transportation, water, sewer, and power. Highly susceptible areas of the Commonwealth include mountain and coastal roads and transportation infrastructure. At this time all critical facilities, infrastructure, and transportation corridors located within the high incidence and high susceptibility hazard areas are considered vulnerable until more information becomes available.

From 1986 to 1990, the estimated Massachusetts Department of Transportation's (MassDOT) average annual cost of highway contracts to address landslide problems was $1,000,000. In addition, the average annual MassDOT maintenance expense needed to keep highways safe from landslide related activities was $2,000,000. These estimates only apply to state highways. The cost associated with remediation work and cleanup of debris from only four landslide-related events during the October 2005 rain event that affected Massachusetts was $2,300,000. The recent damage to a 6-mile stretch of Route 2 caused by tropical storm Irene (2011) which included debris flows, four landslides, and fluvial erosion and undercutting of infrastructure cost $23 million just for the temporary repairs. Accordingly, landslides have a significant cost to taxpayers, yet this hazard is not well known because most earth movements occur during extreme rainstorms and it is the rain and associated flooding that receives the majority of the publicity.

12.6.4 Economy

In general, the built environment located in the high susceptibility zones and the population, structures, and infrastructure located downslope are vulnerable to this hazard. In an attempt to estimate the general

building stock vulnerable to this hazard, the associated building replacement values (buildings and contents) were determined for the identified Census blocks within the approximate hazard areas. These values estimate the costs to repair or replace the damage caused to the building. These dollar value losses to the Commonwealth's total building inventory replacement value would impact the local tax base and economy. Based on building inventory replacement, Franklin, Hampden, and Hampshire Counties, which have approximately 50-percent of their building replacement cost value in the high incidence or high susceptibility hazard areas, are the most vulnerable counties to this hazard. Table 12-10 lists the replacement value (structure and contents) of general building stock exposed to this hazard by county.

SECTION 13. NOR'EASTERS

13.1 GENERAL BACKGROUND

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. A northeast coastal storm, known as a nor'easter, is typically a large counter-clockwise wind circulation around a low-pressure center often resulting in heavy snow, high winds, and rain. The storm radius is often as much as 1000 miles. These storms occur most often in late fall and early winter. Sustained wind speeds of 20-40 mph are common during a nor'easter with short-term wind speeds gusting up to 50-60 mph. Nor'easters are among winter's most ferocious storms. These strong areas of low pressure often form either in the Gulf of Mexico or off the east coast in the Atlantic Ocean. The low will then either move up the east coast into New England and the Atlantic provinces of Canada, or out to sea. These winter weather events are notorious for producing heavy snow, rain, and oversized waves that crash onto Atlantic beaches, often causing beach erosion and structural damage. Wind gusts associated with these storms can exceed hurricane force in intensity. Nor'easters may also sit stationary for several days, affecting multiple tide cycles and extended heavy precipitation. The level of damage in a strong hurricane is often more severe than a nor'easter, but historically Massachusetts has suffered more damage from nor'easters because of the greater frequency of these coastal storms (1 or 2 per year). Nor'easters are commonly accompanied with a storm surge equal to or greater than 2.0 feet. The comparison of hurricanes to nor'easters reveals that the duration of high surge and winds in a hurricane is 6 to 12 hours while a nor'easter's duration can be from 12 hours to 3 days. Table 13-1 summarizes the similarities and differences of nor'easters and hurricanes.

TABLE 13-1.
COMPARISON CHART

	Nor'easters	Hurricanes
Similarities		
	Economic Impacts Winds Surge and Wave Action Inland Flooding potentials	
Differences		
Duration:	Lasting days on average	Lasting only hours
Season:	October-May	August-October
Evacuations:	Fewer coastal area evacuations, off season	Very populated coastal areas
Debris impacts:	Less foliage	Full foliage

Nor'easters are a common winter occurrence in New England and repeatedly result in flooding, various degrees of wave and erosion damage to structures, and erosion of natural resources, such as beaches, dunes, and coastal bluffs. The erosion of coastal features commonly results in greater potential for damage to shoreline development from future storms.

Detailed studies of satellite images and other readings suggest that some low pressure systems associated with nor'easters may develop tropical storm characteristics such as an eye in the center of the low.

13.1.1 Rating Scales

Northeast Snowfall Impact Scale

There is no widely used scale to classify snowstorms. The Northeast Snowfall Impact Scale (NESIS) developed by Paul Kocin of The Weather Channel and Louis Uccellini of the National Weather Service (Kocin and Uccellini, 2004) characterizes and ranks high-impact northeast snowstorms. These storms have large areas of 10-inch snowfall accumulations and greater. NESIS has five categories, as shown in Table 13-2.

TABLE 13-2.
NESIS CATEGORIES, CORRESPONDING NESIS VALUES, AND DESCRIPTION

Category	NESIS	Value Description
1	1—2.499	Notable
2	2.5—3.99	Significant
3	4—5.99	Major
4	6—9.99	Crippling
5	10.0+	Extreme

See Squires and Lawrimore for details on how NESIS scores are calculated at the National Climatic Data Center.

The index differs from other meteorological indices in that it uses population information in addition to meteorological measurements. Thus, NESIS gives an indication of a storm's societal impacts. This scale was developed because of the impact northeast snowstorms can have on the rest of the country in terms of transportation and economics. NESIS scores are a function of the area affected by the snowstorm, the amount of snow, and the number of people living in the path of the storm. The aerial distribution of snowfall and population information are combined in an equation that calculates a NESIS score, which varies from 1 for smaller storms to over 10 for extreme storms. The raw score is converted into one of the five NESIS categories. The largest NESIS values result from storms producing heavy snowfall over large areas that include major metropolitan centers. NOAA began using the NESIS in 2005 to determine impact from snow events.

Regional Snowfall Index

Since completion of the 2010 SHMP, NOAA has enhanced NESIS to a new tool, the Regional Snowfall Index (RSI), which differs from other indices as it includes societal impacts. As many of the local jurisdictional plans are still current, the Commonwealth has determined that it is in the best interest to include information on both the NESIS scale and the RSI scale. The RSI determines significance factors for snowstorms impacting the eastern two-thirds of the U.S. The Commonwealth of Massachusetts falls within the Northeast Region. The RSI ranks snowstorm impacts on a scale system from 1 to 5 as depicted in Table 13-3.

Based on established indices, the RSI is a regional index; a separate index is produced for each of the six NCDC climate regions in the eastern two-thirds of the nation. The indices are calculated in a similar fashion to NESIS, but the new indices require region-specific parameters and thresholds for the calculations.

TABLE 13-3.
REGIONAL SNOWFALL INDEX (RSI)

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

For further details on how RSI scores are calculated at the National Climatic Data Center, see Squires, et al. (2011). NOAA, http://www.ncdc.noaa.gov/snow-and-ice/rsi/

The RSI is important because of the need to place snowstorms and their societal impacts into a historical perspective on a regional scale. For example in February 1973, a major snowstorm hit the Southeast affecting areas not prone to snow. The storm stretched from the Louisiana and Mississippi Gulf coasts northeastward to the Carolinas. Over 11 million people received more than 5 inches of snow and three quarters of a million people in Georgia and South Carolina experienced over 15 inches of snow. This is currently the 10th highest ranked storm for the Southeast region. This storm would not even be ranked in NESIS. This example illustrates why it is important to discriminate impacts between the established six regions. For clarification purposes, thresholds are established for each of the six regions. Snowfall thresholds for the Northeast are 4, 10, 20, and 30 inches of snowfall amounts.

13.1.2 Coastal Storm Frequency Caveats

Similar to flood and hurricanes, storms are often categorized by return frequencies (e.g. this was a 100-year storm, etc.). As previously discussed within other hazard profiles, there are several shortcomings related to trying to categorize storms by return frequencies:

- First, the historical record of storms is relatively short to accurately assess the true long-term frequency of long period events. Most records only go back about 100 years. It is a little like sampling 20 ocean waves and making a conclusion of the full range of wave amplitudes in that part of the ocean.
- Second, when it comes to coastal flood impacts, it is not a level playing field. Sea level rise changes the vulnerability such that storms of an average 100-year frequency will occur considerably more often. Determining how well that can be quantified is dependent on the accuracy of sea level rise predictions.
- Third, coastal flood impacts can vary significantly from one locality to another depending upon such factors as onshore wind component and incidence of wave activity to the coastline.
- Fourth, a storm may have been a once in a hundred year storm for coastal flooding but a once in 10-year storm for wind or snowfall or rainfall, etc. Also, the impact of a storm can be compounded if it has multiple severe dimensions (e.g. major coastal flooding in addition to very heavy snow and extreme winds) or if it impacts such a large area that mutual aid cannot be exercised.
- Fifth, development along the coastline or in other vulnerable areas can significantly increase the impact of a storm. Thus, the same storm in 1950 might not have garnered as much attention then as it would now with the increased coastal development.

In addition, there is a great deal of misunderstanding surrounding the reference to a 100-year storm or a return frequency of 100 years. Similar to the flood events, a 100 year storm event does not mean that one should expect such a storm (or a storm of greater intensity) once every 100 years. Rather, a 100-year storm, to use that frequency as an example, is best described as a 1-percent chance of occurring in any given year. There might be two or three such storms in one hundred year period and then no more for the next 200 or 300 years

13.2 HAZARD PROFILE

13.2.1 Location

Massachusetts and its 78 coastal communities are all vulnerable to the damaging impacts of major storms, such as nor'easters, along more than 1,500 miles of varied coastline. As development and re-development increases, less-intense storms that occur more regularly and sea-level rise will also lead to costly storm damage. Similar to hurricane events, the coastal areas are more susceptible to damage due to the combination of high winds, waves, and tidal surge. However, nor'easters can also bring heavy snow which can paralyze a city to the entire New England region. Inland areas, especially those in floodplains, are also at risk for flooding, due to heavy rain or snow, and wind damage.

13.2.2 Previous Occurrences

Table 13-4 depicts the top 40 major winter storms in the Northeast and ranks them based on the NESIS scale. Based on all sources researched, known nor'easter events that have affected Massachusetts, and were declared a FEMA disaster, are identified in Table 13-5. This table provides detailed information concerning the FEMA declarations for the Commonwealth. The following sections provide descriptions of major events.

Coastal Storms, Flood, Ice, Snow (DR-546)—February 1978

The February 1978 Blizzard remains as the benchmark storm for comparison by all subsequent nor'easters. This life-threatening nor'easter crippled most of the Commonwealth with blizzard conditions, extraordinarily heavy snow, high winds, and devastating coastal flooding. The storm claimed 73 lives in Massachusetts and 26 in neighboring Rhode Island. Over 10,000 people had to be sheltered. An unprecedented ban on non-emergency vehicle traffic lasted for a week in much of eastern Massachusetts.

The timing of the storm exacerbated its impact. This blizzard grew to its full fury during the Monday evening rush hour and caused over 3500 vehicles to be stranded on route 128 alone in eastern Massachusetts with snowfall rates of at least 3 inches per hour and visibility near zero. Boston recorded a wind gust of 79 mph, and the wind peaked out at 93 mph in Chatham. Snowfall generally ranged from 1 to 3 feet with a large swath of 30+ inch amounts in the southwest suburbs of Boston. Snowfall reports included 32.5 inches in Rockport, 27.1 inches in Boston, 20.2 inches in Worcester, and 38.0 inches in Woonsocket, RI.

Major coastal flooding occurred over multiple high tide cycles and destroyed or severely damaged over 2000 homes. This storm set the all-time high water mark (to date) of 15.25 feet above Mean Lower Low Water at the Boston Harbor National Ocean Service tide gage. Mariner accounts refer to waves in excess of 30 feet just offshore. The storm triggered many harrowing evacuations and rescues along both the North and South Shores. This event did result in a federal disaster declaration (FEMA DR-546) (Strauss, date unknown).

TABLE 13-4.
NESIS STORMS DATA FOR MASSACHUSETTS 1953-2012

Rank	Year	Date	NESIS	Category	Description
1	1993	Mar 12 - 14	13.20	5	Extreme
2	1996	Jan 06 - 08	11.78	5	Extreme
3	2003	Feb 15 - 18	8.91	4	Crippling
4	1960	Mar 02 - 05	8.77	4	Crippling
5	1961	Feb 02 - 05	7.06	4	Crippling
6	1964	Jan 11 - 14	6.91	4	Crippling
7	2005	Jan 21 - 24	6.80	4	Crippling
8	1978	Jan 19 - 21	6.53	4	Crippling
9	1969	Dec 25 - 28	6.29	4	Crippling
10	1958	Feb 14 - 17	6.25	4	Crippling
11	1983	Feb 10 - 12	6.25	4	Crippling
12	1966	Jan 29 - 31	5.93	3	Major
13	1978	Feb 05 - 07	5.78	3	Major
14	2007	Feb 12-15	5.63	3	Major
15*	2010	Feb 23-28	5.46	3	Major
16	1987	Jan 21 - 23	5.40	3	Major
17	1994	Feb 08 - 12	5.39	3	Major
18*	2011	Jan 9-13	5.31	3	Major
19*	2011	Feb 1-3	5.30	3	Major
20*	2010	Dec 24-28	4.92	3	Major
21	1972	Feb 18 - 20	4.77	3	Major
22	1979	Feb 17 - 19	4.77	3	Major
23	1960	Dec 11 - 13	4.53	3	Major
24*	2010	Feb 22-28	4.38	3	Major
25	1969	Feb 22 - 28	4.29	3	Major
26*	2010	Feb 9-11	4.10	3	Major
27	2006	Feb 12 - 13	4.10	3	Major
28	1961	Jan 18 - 21	4.04	3	Major
29	2009	Dec 18-21	4.03	3	Major
30	1966	Dec 23 - 25	3.81	2	Significant
31	1958	Mar 18 - 21	3.51	2	Significant
32	1969	Feb 08 - 10	3.51	2	Significant
33	1967	Feb 05 - 07	3.50	2	Significant
34	1982	Apr 06 - 07	3.35	2	Significant
35	2007	Mar 15-18	2.55	2	Significant
36	2000	Jan 24 - 26	2.52	2	Significant
37	2000	Dec 30-31	2.37	1	Notable
38	1997	Mar 31-Apr 1	2.29	1	Notable
39*	2011	Jan 26-27	2.17	1	Notable
40	1956	Mar 18-19	1.87	1	Notable

* Storm is a new event added since the last plan update. Data as of Jan 2013.

TABLE 13-5.
FEMA NOR'EASTER-RELATED DISASTER DECLARATIONS (1954 TO 2012)

Disaster #	Disaster Type	Declaration Date	Incident Period	Barnstable	Berkshire	Bristol	Dukes	Essex	Franklin	Hampden	Hampshire	Middlesex	Nantucket	Norfolk	Plymouth	Suffolk	Worcester	Number of Counties Impacted
EM-3343	Severe Storm	11/1/11	10/29/11 – 10/30/11		X			X	X	X	X	X		X			X	8
DR-1959	Severe Winter Storm and Snowstorm	03/07/11	1/11/11 - 1/12/11		X			X		X	X	X		X		X		7
DR-1701	Severe Storms and Inland and Coastal Flooding	05/16/07	4/15/07 - 4/25/07	X	X		X	X	X	X	X				X			8
DR-1614	Severe Storms and Flooding	11/10/05	10/7/05 - 10/16/05		X	X		X	X	X	X	X		X	X		X	10
DR-975	Winter Coastal Storm	12/21/92	12/11/92 - 12/13/92	X			X	X				X	X	X	X	X	X	9
DR-920	Severe Coastal Storm	11/04/91	10/30/91 - 11/2/91	X			X	X					X	X	X	X		7
DR-546	Coastal Storms, Flood, Ice, Snow	02/10/78	2/6/78 - 2/8/78	X		X	X	X					X	X	X	X		8
Total				**4**	**4**	**2**	**4**	**7**	**3**	**4**	**4**	**4**	**3**	**6**	**5**	**4**	**3**	

Severe Coastal Storm (DR-920)—October-November 1991

This storm was 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. Winds from this event were measured over 80 MPH, with waves over 30 feet in some parts of the coastline. This storm caused flooding and wind damage in several counties. This event resulted in a federal disaster declaration (FEMA DR-920).

Great Nor'easter of 1992 (DR-975)—December 1992

A strong nor'easter affected the Commonwealth from December 11 to 13, 1992. Impacts included deep and intense snowfall, freezing rain, heavy rainfall near the coast, coastal flooding, and damaging winds. Total snowfall in Massachusetts was as high as 4 feet over the higher elevations of the Berkshires, with 48 inches reported in Beckett, Savoy, and Peru. Drifts were as high as 12 feet in the Berkshires. Snowfall of 18 inches to 32 inches was common over central Massachusetts, with 6 to 20 inches over interior eastern Massachusetts. Some locations 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 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 during the 11th to 13th, the most damaging storm tide occurring early afternoon on the 12th. 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 '78. 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 (Marine, 1994).

Heavy Snow / Nor'easter—March 1994

A strong nor'easter passed to the southeast of Cape Cod, resulting in heavy snow and blowing and drifting snow. Snowfall totals ranged between six and 15 inches from the Boston metro area west and north. Over southeast Massachusetts, between three and six inches of snow fell before it changed to rain. Wind gusts of up to 40 and 60 mph resulted from this event and created snow drifts of up to three feet. Buildings were damaged, businesses and schools were closed, and highway travel was disrupted. The Commonwealth had approximately $5 million in property damage.

Blizzard/Nor'easter (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 FEMA emergency declaration (FEMA EM-3201). Those counties included in the disaster received over $49 million in public assistance from FEMA.

Coastal Storm / Nor'easter—October 2005 (DR-1614)

A strong nor'easter, combined with the remnants of Tropical Storm Wilma, brought heavy rainfall, damaging winds, and coastal flooding to the eastern portion of Massachusetts (see Figure 13-1). Rainfall totals ranged between two and 2.5 inches. The high winds brought down limbs, trees, and wires, resulting in power outages to thousands of people. This event caused approximately $733,000 in property damage.

Severe Storms and Inland and Coastal Flooding (Nor'easter) (DR-1701)—April 2007 (Patriot's Day Event)

> "I have never seen anything like this in 30 years where the entire town is without power."
>
> *Townsend Board of Selectmen*
> *Quote from Worcester Telegram & Gazette*

An intense coastal storm (April 15-16, 2007) brought wet snow, sleet and rain to parts of western Massachusetts. Snowmelt and heavy rain between 3 and 6 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. During the peak of the storm, approximately 90,000 customers were without power statewide. This event resulted in a federal disaster declaration (FEMA DR-1701). 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.

Figure 13-1. Coastal Storm Surge During October 2005 Storm

Winter Storm/Nor'easter (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 federal 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.

Severe Storm/Nor'easter (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 federal emergency declaration (FEMA EM-3343) for the following counties: Berkshire, Essex, Franklin, Hampden, Hampshire, Middlesex, Norfolk, and Worcester.

13.2.3 Probability of Future Occurrences

Nor'easters may occur at any time of the year; however, they are most common from September through April. Nor'easters are a major concern for Massachusetts' residents not only because of the damage potential in any given storm, but because of their frequent rate of occurrence.

For the purposes of this plan, the probability of future occurrences is defined by the number of events for over a specified period of time. The historical record indicates the Commonwealth has only experienced three nor'easter-related federally declared from 1954 to 2012. This figure greatly underestimates how often nor'easters occur in the Northeast and impact Massachusetts. Based on the historical record of the top 40 events from 1953 to 2011, nor'easters have an average frequency of 1 or 2 per year. While in a typical year it is unlikely to have multiple nor'easter events, some years, such as 2010, experienced four (4) events.

13.2.4 Severity

The magnitude or severity of a nor'easter depends on several factors including a region's climatological susceptibility to snowstorms, snowfall amounts, snowfall rates, wind speeds, temperatures, visibility, storm duration, topography, and time of occurrence during the day (e.g., weekday versus weekend), and time of season. The severity of a nor'easter also depends on the time of occurrence relative to the lunar tide cycles (spring or neap tides) and during what tide stage the maximum storm surge occurs at (high tide or low tide).

13.2.5 Warning Time

Meteorologists can often predict the likelihood of a nor'easter event. NOAA's National Weather Service monitors potential nor'easter events, and provides forecasts and information several days in advance of the storm in order to help prepare for the incident.

Nor'easters are a common winter occurrence in the Commonwealth of Massachusetts and New England and repeatedly result in flooding, various degrees of wave and erosion damage to structures, and erosion of natural resources, such as beaches, dunes, and coastal bluffs. The erosion of coastal features commonly results in greater potential for damage to shoreline development from future storms.

13.3 CLIMATE CHANGE IMPACTS

Climate change refers to unstable weather patterns caused by increases in the average global temperature. Greenhouse gases form a blanket of pollution that stays in the atmosphere and may be the ultimate cause of climate change instability characterized by severe weather events such as storms, droughts, floods, head waves, and sea level rise.

Weather extremes are likely to become more frequent and cause more damage under a changing climate. Although no specific storm is directly linked to climate change, an increasing number of events could become more common. These storms could cause downed power lines, overburdened septic systems, and travel delays.

Climate change may also lead to coastal impacts. Massachusetts may lose beachfront in the coming years as climate change may cause rising sea levels and stronger coastal storms, including nor'easters. In addition, climate change will result in significant impacts on the coast and ocean waters of Massachusetts. On the coast, changes in temperature can have major impacts on sensitive ecosystems.

Sea level rise will exacerbate impacts on development, infrastructure, and natural systems from erosion and storm damage. Impacts may include loss of life; extensive property damage; destruction of public infrastructure; release of sewage, oil, debris, and other contaminants; and loss of commercial and marine-related businesses critical to local, regional, and state economies.

New England is expected to experience changes in the amount, frequency, and timing of precipitation.

13.4 EXPOSURE

To understand risk, the assets exposed to the hazard areas are identified. For the nor'easter hazard the entire Commonwealth of Massachusetts is exposed, more specifically the wind and rain/snow associated with these events. However, certain areas, types of building and infrastructure are at greater risk than others due to proximity to the coast and/or their manner of construction. Storm surge from a nor'easter poses one of the greatest risks to residents and property.

The following discusses the Commonwealth of Massachusetts exposure to the nor'easter hazard including:

- Population
- State facilities
- Critical facilities
- Economy

There are similarities and differences between nor'easters and hurricane events, as shown earlier in Table 13-1. Both types of events can bring high winds and surge inundation resulting in similar impacts on the population, structures, and the economy. For the purposes of this plan, the Hazus-MH wind/surge model was used to estimate potential losses to the February 1978 nor'easter with current (2010) population and built environment.

13.4.1 Population

The impact of a nor'easter on life, health, and safety is dependent upon several factors including the severity of the event and whether or not adequate warning time was provided to residents. It is assumed that the entire Commonwealth's population is exposed to this hazard (wind and rain/snow). Figure 13-3 displays the peak gust wind speeds of the 1978 nor'easter modeled in Hazus-MH.

Of the population exposed, the most vulnerable include the economically disadvantaged and population over the age of 65. Economically disadvantaged populations are more vulnerable because they are likely to evaluate their risk and make decisions to evacuate based on the net economic impact on their families. The population over the age of 65 is also more vulnerable because they are more likely to seek or need medical attention which may not be available due to isolation during a flood event, and they may have more difficulty evacuating. Section 4 summarizes the Commonwealth's demographics.

A nor'easter surge inundation zone does not exist to estimate the population exposed. To estimate the population exposed to storm surge, the SLOSH Category 1 through 4 zones were overlaid upon the 2010 Census block population data in GIS (U.S. Census 2010). Census blocks do not follow the boundaries of the floodplain. The Census blocks with their centroid in the SLOSH boundaries were used to calculate the estimated population exposed to the hurricane surge hazard. Table 11-4 summarizes the 2010 Census population in the Category 1 through 4 SLOSH zones by County.

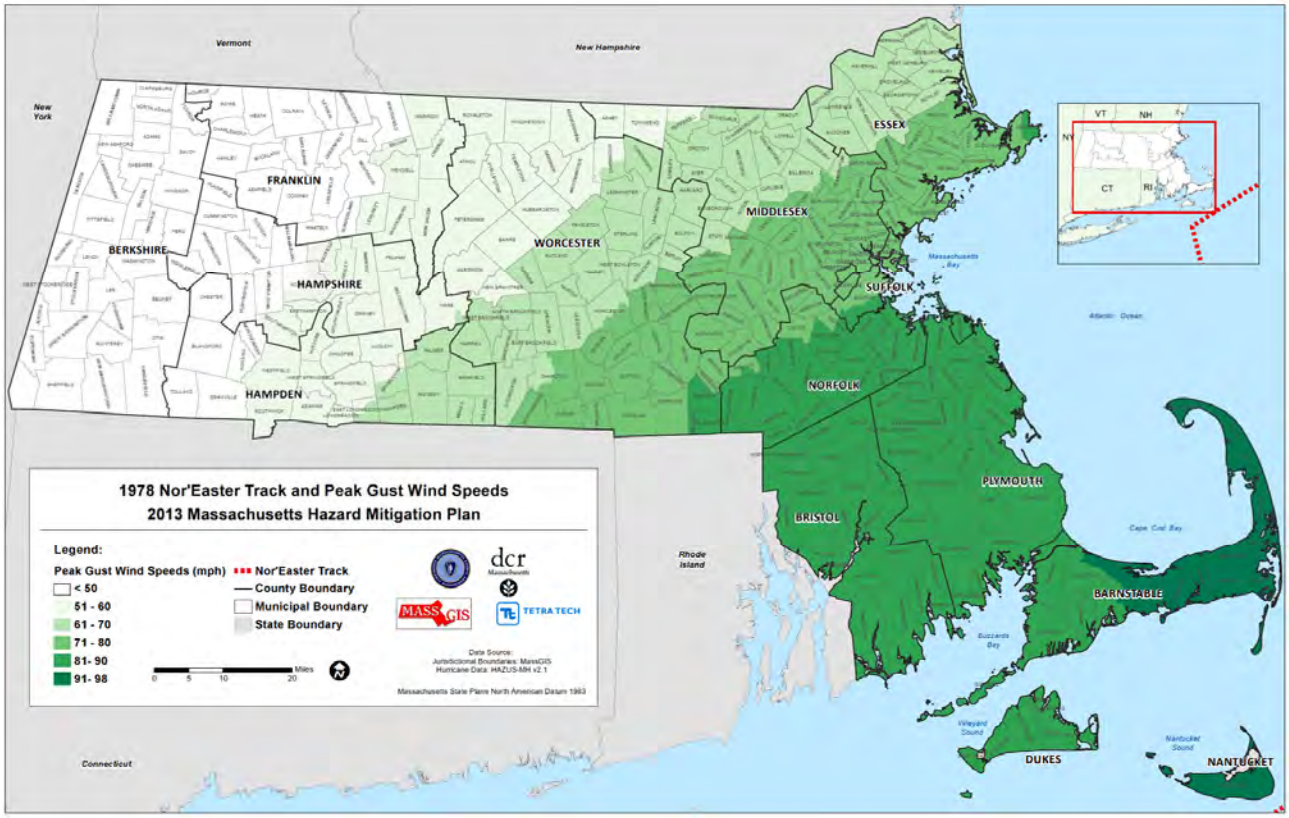


Figure 13-2. Peak Gust Wind Speeds for the 1978 Nor'easter Event in Massachusetts

13.4.2 State Facilities

All Commonwealth state-owned and leased buildings are exposed to the wind and/or rain/snow from the nor'easter hazard. Table 11-5 summarizes the total replacement cost value of all 6,765 state-owned and leased buildings in the Commonwealth. Table 11-6 summarizes the buildings located in the SLOSH zones as a general indication of buildings at risk to storm surge.

13.4.3 Critical Facilities

A nor'easter event may happen and impact anywhere in the Commonwealth; therefore, all critical facilities are exposed to this hazard. Critical facilities and infrastructure at greatest risk are those that may be impacted by storm surge. Tables 11-10 through 11-12 provide a complete listing of the critical facilities, highway bridges, and roadways exposed to the SLOSH model's inundation zones.

13.4.4 Economy

Nor'easter events can greatly impact the economy, including loss of business function, damage to inventory (utility outages), relocation costs, wage loss, and rental loss due to the repair/replacement of buildings. The entire Commonwealth is exposed to a nor'easter event.

Damage to buildings can impact a community's economy and tax base. The area of each County (square miles) exposed to the SLOSH inundation zones is listed by County in Table 11-13. Of the nine Counties with area in the SLOSH inundation zones, four have more than 10 percent of their area in the Category 1 boundary. Suffolk County has the greatest percent of its area in the inundation zones, from 21.5 percent in Category 1 to 42.5 percent in Category 4. The Islands (Dukes and Nantucket Counties) and Barnstable County also have a large percentage of their total area exposed to storm surge inundation.

13.5 VULNERABILITY

To assess the Commonwealth's vulnerability to the nor'easter hazard, potential losses were determined for an historical event selected by the SHMT and the THIRA workgroup: February 1978 nor'easter.

13.5.1 Population

Residents may be displaced or require temporary to long-term sheltering. In addition, downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life. Socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing.

The 1978 historical event was run in Hazus-MH to estimate the sheltering needs should this event occur today. The estimated shelter needs due to wind-only impacts are summarized in Table 13-6. All counties, with the exception of Barnstable and Berkshire Counties, have experienced an increase in population growth since the 2000 Census (see Section 4). Therefore, the numbers in Table 13-6 are conservative.

13.5.2 State Facilities

Hazus-MH does not estimate potential dollar losses to critical facilities at this time. When this capability is available, the Commonwealth can enhance this section of the plan. Due to the similarities in impacts from a hurricane and nor'easter, the potential losses to state-owned and leased structures due to storm surge calculated using the SLOSH data can be used. All 6,765 state-owned/leased structures in the Commonwealth are exposed to the nor'easter hazard. Table 11-5 summarizes their total replacement cost value.

TABLE 13-6.
ESTIMATED SHELTER NEEDS FOR 1978 NOR'EASTER;
WIND-ONLY ANALYSIS (U.S. CENSUS 2000)

County	Displaced Households	Short Term Shelter Needs
Barnstable	68	12
Berkshire	0	0
Bristol	107	31
Dukes	1	0
Essex	4	1
Franklin	0	0
Hampden	0	0
Hampshire	0	0
Middlesex	22	1
Nantucket	2	0
Norfolk	65	10
Plymouth	51	11
Suffolk	99	22
Worcester	1	0
Total	**420**	**88**

Source: Hazus-MH v. 2.1

Structures located in the storm surge inundation areas are at greatest risk to surge-related damage. A total risk exposure of nearly $6.2 billion is estimated for state-owned and leased buildings located in the

Category 1 through 4 SLOSH zones. The Hurricane Category 4 SLOSH depth grids provided by FEMA Region IV were imported into the Hazus-MH flood model and the potential losses were estimated for the state-owned and leased facilities. Tables 11-15 and 11-16 summarize the potential losses by County and agency, respectively.

13.5.3 Critical Facilities

Hazus-MH does not estimate potential dollar losses to critical facilities at this time. When this capability is available, the Commonwealth can enhance this section of the plan. For the purposes of this plan update, to estimate potential losses to critical facilities and infrastructure, the exposure analysis methodology was used. As mentioned earlier, all critical facilities and infrastructure are exposed to nor'easter winds and rain/snow (see Tables 11-10 through 11-12); however, those located within the surge inundation zones are at greater risk. The replacement cost values for critical facilities were not available for this planning effort. A total risk exposure would be equal to the full replacement value of each critical facility exposed.

At this time, Hazus-MH 2.1 does not estimate losses to transportation lifelines and utilities as part of the hurricane model. Transportation lifelines are not considered particularly vulnerable to the wind hazard; they are more vulnerable to cascading effects such as flooding, falling debris etc. Impacts to transportation lifelines affect both short-term (e.g., evacuation activities) and long-term (e.g., day-to-day commuting) transportation needs. In terms of highway bridges, the Hazus-MH v. 2.1 default replacement cost value for the bridges located in the SLOSH Category 1 through 4 hazard areas is $17 billion (of the greater than $68 billion total).

13.5.4 Economy

Nor'easter events, similar to hurricanes and tropical storms, can greatly impact the economy, including loss of business function (e.g., tourism, recreation), damage to inventory, relocation costs, wage loss, and rental loss due to the repair/replacement of buildings. Hazus-MH estimates the total economic loss associated with each storm scenario (direct building losses and business interruption losses). Direct building losses are the estimated costs to repair or replace the damage caused to the building.

A Hazus-MH analysis was conducted to determine the combination wind and surge impacts from the 1978 nor'easter event for the entire Commonwealth building stock. Because of differences in building construction, residential structures are generally more susceptible to wind damage than commercial and industrial structures. Wood and masonry buildings in general, regardless of their occupancy class, tend to experience more wind damage than concrete or steel buildings. Table 13-7 summarizes the estimated building loss (structure and contents). Total damage reflects the overall impact at an aggregate level.

TABLE 13-7.
ESTIMATED BUILDING LOSS FROM HAZUS WIND AND STORM SURGE ANALYSIS (STRUCTURE AND CONTENTS REPLACEMENT COST VALUE) 1978 NOR'EASTER

County	Total (Wind and Surge)	Total Wind Only	Total Surge Only
Barnstable	$590,093,258	$194,949,258	$395,144,000
Berkshire	$0	$0	$0
Bristol	$204,625,675	$176,935,675	$27,690,000
Dukes	$53,040,437	$13,157,437	$39,883,000
Essex	$732,222,926	$64,446,927	$667,775,999
Franklin	$484,957	$484,957	$0
Hampden	$5,963,018	$5,963,018	$0
Hampshire	$1,897,908	$1,897,908	$0

TABLE 13-7.
ESTIMATED BUILDING LOSS FROM HAZUS WIND AND STORM SURGE ANALYSIS (STRUCTURE AND CONTENTS REPLACEMENT COST VALUE) 1978 NOR'EASTER

County	Total (Wind and Surge)	Total Wind Only	Total Surge Only
Middlesex	$462,591,150	$221,504,150	$241,087,000
Nantucket	$24,544,131	$17,829,131	$6,715,000
Norfolk	$427,367,579	$231,024,579	$196,343,000
Plymouth	$555,012,866	$242,940,866	$312,072,000
Suffolk	$1,317,085,107	$134,302,106	$1,182,783,001
Worcester	$60,441,016	$60,441,016	$0
Total	**$4,435,370,029**	**$1,365,877,029**	**$3,069,493,001**

Source: Hazus-MH v. 2.1

Business interruption losses are the losses associated with the inability to operate a business because of the wind damage sustained during the storm or the temporary living expenses for those displaced from their home because of the event. Table 13-8 summarizes the economic losses generated by Hazus-MH's wind model for the 1978 nor'easter event.

TABLE 13-8.
ESTIMATED ECONOMIC LOSS - WIND ONLY HAZUS ANALYSIS HAZUS (U.S. CENSUS 2000)

	1978 Nor'easter				
County	Inventory	Relocation	Income	Rental	Wage
Barnstable	$103,177	$7,139,400	$1,175,329	$4,902,295	$1,481,350
Berkshire	$0	$0	$0	$0	$0
Bristol	$82,310	$5,691,937	$249,251	$5,351,144	$88,553
Dukes	$7,098	$459,138	$69,722	$328,793	$92,091
Essex	$2,463	$1,054,740	$0	$1,136,239	$0
Franklin	$0	$84	$0	$0	$0
Hampden	$0	$3,980	$0	$0	$0
Hampshire	$0	$917	$0	$0	$0
Middlesex	$3,187	$2,017,793	$0	$2,638,504	$0
Nantucket	$10,385	$782,505	$194,022	$486,607	$266,986
Norfolk	$36,595	$4,638,261	$94,102	$3,866,167	$33,432
Plymouth	$52,313	$5,003,665	$235,416	$3,302,624	$201,368
Suffolk	$14,660	$4,656,222	$2,646	$6,328,687	$946
Worcester	$101	$407,748	$0	$562,705	$0
Total	**$312,289**	**$31,856,390**	**$2,020,489**	**$28,903,765**	**$2,164,726**

Source: Hazus-MH v. 2.1

Hazus-MH 2.1 also estimates the amount of debris that may be produced a result of wind events. Table 13-9 summarizes the debris produced from the wind only aspect of the storm hazard. Because the

estimated debris production does not include flooding, this is likely a conservative estimate and may be higher if multiple impacts occur. Note the following from the Hazus-MH Hurricane User Manual:

> The Eligible Tree Debris columns provide estimates of the weight and volume of downed trees that would likely be collected and disposed at public expense. As discussed in Chapter 12 of the Hazus-MH Hurricane Model Technical Manual, the eligible tree debris estimates produced by the Hurricane Model tend to underestimate reported volumes of debris brought to landfills for a number of events that have occurred over the past several years. This indicates that that there may be other sources of vegetative and non-vegetative debris that are not currently being modeled in Hazus. For landfill estimation purposes, it is recommended that the Hazus debris volume estimate be treated as an approximate lower bound. Based on actual reported debris volumes, it is recommended that the Hazus results be multiplied by three to obtain an approximate upper bound estimate. It is also important to note that the Hurricane Model assumes a bulking factor of 10 cubic yards per ton of tree debris. If the debris is chipped prior to transport or disposal, a bulking factor of 4 is recommended. Thus, for chipped debris, the eligible tree debris volume should be multiplied by 0.4.

TABLE 13-9.
ESTIMATED DEBRIS - 1978 NOR'EASTER WIND ONLY ANALYSIS (U.S. CENSUS 2000)

County	Brick/Wood (tons)	Concrete (tons)	Trees (tons)	Tree Volume (cubic yards)
Barnstable	24,660	9	117,205	1,172,065
Berkshire	0	0	0	0
Bristol	21,168	0	148,211	1,482,129
Dukes	1,501	0	20,208	202,087
Essex	7,521	0	30,721	307,241
Franklin	0	0	7,316	73,159
Hampden	54	0	8,360	83,580
Hampshire	6	0	6,361	63,607
Middlesex	20,497	0	55,718	557,140
Nantucket	2,321	2	5,969	59,686
Norfolk	19,269	0	81,312	813,137
Plymouth	16,779	0	237,870	2,378,770
Suffolk	26,011	0	5,458	54,584
Worcester	5,091	0	62,853	628,508
Total	**144,878**	**11**	**787,562**	**7,875,693**

Source: Hazus-MH v. 2.1

SECTION 14. SEVERE WEATHER

14.1 GENERAL BACKGROUND

14.1.1 High Winds

Wind is air in motion relative to surface of the earth. For non-tropical events over land, the NWS issues a Wind Advisory (sustained winds of 31 to 39 mph for at least 1 hour or any gusts 46 to 57 mph) or a High Wind Warning (sustained winds 40+ mph or any gusts 58+ mph). For non-tropical events over water, the NWS issues a small craft advisory (sustained winds 25-33 knots), a gale warning (sustained winds 34-47 knots), a storm warning (sustained winds 48 to 63 knots), or a hurricane force wind warning (sustained winds 64+ knots). For tropical systems, the NWS issues a tropical storm warning for any areas (inland or coastal) that are expecting sustained winds from 39 to 73 mph. A hurricane warning is issued for any areas (inland or coastal) that are expecting sustained winds of 74 mph.

Effects from high winds can include downed trees and/or power lines and damage to roofs, windows, etc. High winds can cause scattered power outages. High winds are also a hazard for the boating, shipping, and aviation industry sectors.

Massachusetts is susceptible to high wind from several types of weather events: before and after frontal systems, hurricanes and tropical storms, severe thunderstorms and tornadoes, and Nor'easters. Sometimes, wind gusts of only 40 to 45 mph can cause scattered power outages from trees and wires being downed. This is especially true after periods of prolonged drought or excessive rainfall, since both are situations which can weaken the root systems and make them more susceptible to the winds' effects. Winds measuring less than 30 mph are not considered to be hazardous under most circumstances.

14.1.2 Thunderstorms

A thunderstorm is a storm with lightning and thunder produced by a cumulonimbus cloud, usually producing gusty winds, heavy rain, and sometimes hail. Effective January 5, 2010, the NWS modified the hail size criterion to classify a thunderstorm as 'severe' when it produces damaging wind gusts in excess of 58 mph (50 knots), hail that is 1 inch in diameter or larger (quarter size), or a tornado (NWS, 2013).

Cumulonimbus clouds produce lightning, which locally heats the air to 50,000 degrees Celsius, which in turn produces an audible shock wave, known as thunder. Frequently during thunderstorm events, heavy rain and gusty winds are present. Less frequently, hail is present, which can become very large. Tornadoes can also be generated during these events.

Three basic ingredients are required for a thunderstorm to form: moisture, rising unstable air (air that keeps rising when given a nudge), and a lifting mechanism. The sun heats the surface of the earth, which warms the air above it. If this warm surface air is forced to rise—by hills or mountains, or areas where warm/cold or wet/dry air bump together can cause rising motion—it will continue to rise as long as it weighs less and stays warmer than the air around it. As the air rises, it transfers heat from the surface of the earth to the upper levels of the atmosphere (the process of convection). The water vapor it contains begins to cool, releasing the heat; and it 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. Ice particles usually have positive charges, and rain droplets usually have negative charges. When the charges build up enough, they are 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 (< 2.5 mile path) downburst is known as a "microburst" and a larger downburst is called a "macro-burst." An organized, fast-moving line of microbursts traveling across large areas is known as a "derecho." These occasionally occur in Massachusetts. The strongest downburst recorded was 175 mph, in North Carolina. Winds exceeding 100 mph have been measured from downbursts in Massachusetts.

14.1.3 Tornadoes

A tornado is a narrow, violently rotating column of air that extends from the base of a cumulonimbus cloud to the ground. The visible sign of a tornado is the dust and debris that are caught in the rotating column made up of water droplets. Tornadoes are the most violent of all atmospheric storms. The following are common ingredients for tornado formation:

- Very strong winds in the mid 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 mph at the surface and 50 mph at 7,000 feet.)
- Very warm, moist air near the ground with unusually cooler air aloft
- A forcing mechanism such as a cold front or leftover weather boundary from previous shower or thunderstorm activity

Tornadoes can form from individual cells within severe thunderstorm squall lines. They can form from an isolated super-cell thunderstorm. They can be spawned by tropical cyclones or even their remnants that are passing through. And, weak tornadoes can even sometimes occur from air that is converging and spinning upward, with little more than a rain shower occurring in the vicinity.

Typically, there are 1 to 3 tornadoes somewhere in southern New England per year. Most occur in the late afternoon and evening hours, when the heating is the greatest. The most common months are June, July, and August, but the Great Barrington, MA tornado (1995) occurred in May and the Windsor Locks, CT tornado (1979) occurred in October.

Tornado damage severity is measured by the Fujita Tornado Scale, in which wind speed is not measured directly but rather estimated from the amount of damage. As of February 01, 2007, the National Weather Service began rating tornadoes using the Enhanced Fujita-scale (EF-scale). It is considerably more complicated than the original F-scale, and it allows surveyors to create more precise assessments of tornado severity. Table 14-1 and Table 14-2 illustrate the EF-scale and the damage indicators.

A 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. There are two methods of formation:

- Waterspouts can form on a clear day with the right amount of instability and wind shear. These can have wind speeds of 60 to 100 mph, but since they do not move very far, they can often be navigated around. They can become a threat to land if they drift onshore.
- A tornadic waterspout is a true tornado that is moving over water at the time that it forms. These form from the same processes that cause tornadoes (see section above).

TABLE 14-1.
THE ENHANCED F-SCALE

Fujita Scale			Derived		Operational EF Scale	
F Number	Fastest ¼ mile (mph)	3-second gust (mph)	EF Number	3-second gust (mph)	EF Number	3-second gusts (mph)
0	40-72	45-78	0	65-85	0	65-85
1	73-112	79-117	1	86-109	1	86-110
2	113-157	118-161	2	110-137	2	111-135
3	158-207	162-209	3	138-167	3	136-165
4	208-260	210-261	4	168-199	4	166-200
5	261-318	262-317	5	200-234	5	Over -200

TABLE 14-2.
ENHANCED FUJITA SCALE DAMAGE INDICATORS

No.	Damage Indicator	No.	Damage Indicator
1	Small barns, frames outbuildings	15	School – 1-story elementary (interior or exterior halls)
2	One or two-family residences	16	School – junior or senior high school
3	Single-wide mobile home	17	Low-rise (1-4 story) building
4	Double-wide mobile home	18	Mid-rise (5-20) building
5	Apt, Condo, townhouse (3 stories or less)	19	High-rise (over 20 stories
6	Motel	20	Institutional bldg. (hospital, govt. or university)
7	Masonry Apt. or motel	21	Metal building system
8	Small retail building (fast food)	22	Service station canopy
9	Small professional (Doctor office, Bank)	23	Warehouse (tilt-up walls or heavy timber)
10	Strip Mall	24	Transmission line tower
11	Large shopping mall	25	Free-standing tower
12	Large, isolated (big box) retail building	26	Free standing pole (light, flag, luminary)
13	Automobile showroom	27	Tree – hardwood
14	Automobile service building	28	Tree – softwood

The National Weather Service issues a Special Marine Warning for waterspouts over the coastal waters. The Service issues a Tornado Warning if a waterspout shows signs of moving toward land.

14.1.4 Extreme Temperatures

There is no universal definition for extreme temperatures. The term is relative to the usual weather in the region based on climatic averages. Extreme heat, for this climatic region, is usually defined as a period of three or more consecutive days above 90°F, but more generally a prolonged period of excessively hot weather, which may be accompanied by high humidity. Extreme cold, again, is relative to the normal climatic lows in a region. Temperatures that drop decidedly below normal and wind speeds that increase can cause harmful wind-chill factors. The wind chill is the apparent temperature felt on exposed skin due to the combination of air temperature and wind speed.

Massachusetts has four well-defined seasons. The seasons have several defining factors, with temperature one of the most significant. Extreme temperatures can be defined as those that are far outside the normal ranges. The average temperatures for Massachusetts are:

- Winter (Dec-Feb) Average = 27.51ºF
- Summer (Jun-Aug) Average = 68.15ºF

Criteria for issuing alerts for Massachusetts are provided on National Weather Service web pages: http://www.erh.noaa.gov/box/warningcriteria.shtml.

Extreme Cold

Extreme cold is a dangerous situation that can result in health emergencies for susceptible people, such as those without shelter or who are stranded or who live in homes that are poorly insulated or without heat. The following are some of the lowest temperatures recorded in Massachusetts for the period from 1895 to present (Source: NOAA, www.ncdc.noaa.gov.):

- Blue Hills, MA –21°F
- Boston, MA –12°F
- Worcester, MA –19°F

Extreme cold events are when temperatures drop well below normal in an area. In regions relatively unaccustomed to winter weather, near freezing temperatures are considered "extreme cold." Extreme cold temperatures are characterized by the ambient air temperature dropping to approximately 0 degrees Fahrenheit (ºF) or below.

When winter temperatures drop significantly below normal, staying warm and safe can become a challenge. Extremely cold temperatures often accompany a winter storm, which may also cause power failures and icy roads. Staying indoors as much as possible can help reduce the risk of car crashes and falls on the ice, but cold weather also can present hazards indoors. Many homes will be too cold, either due to a power failure or because the heating system is not adequate for the weather. The use of space heaters and fireplaces to stay warm, and/or generators and candles in power outages increases the risks of residential fires and carbon monoxide poisoning. Exposure to cold temperatures, whether indoors or outside, can cause other serious or life-threatening health problems. Infants and the elderly are particularly at risk, but anyone can be affected.

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. Carbon monoxide levels are typically higher during cold weather because the cold temperatures make combustion less complete and cause inversions that trap pollutants close to the ground.

Another hazard of extended cold temperatures in Massachusetts is saltwater freezing in coastal bays and harbors. Coastal freezing can interfere with transportation of goods and people, plus inhibit fishing and other industries reliant on boats.

The extent (severity or magnitude) of extreme cold temperatures are generally measured through the Wind Chill Temperature Index. Wind Chill Temperature is the temperature that people and animals feel when outside and it is based on the rate of heat loss from exposed skin by the effects of wind and cold. As the wind increases, the body is cooled at a faster rate causing the skin's temperature to drop.

The NWS issues a Wind Chill Advisory if the Wind Chill Index is forecast to dip to –15ºF to –24ºF for at least 3 hours, using only the sustained winds (not gusts). The NWS issues a Wind Chill Warning if the Wind Chill Index is forecast to fall to –25ºF or colder for at least 3 hours using only the sustained wind.

On November 1, 2001, the NWS implemented a new Wind Chill Temperature Index. It was designed to more accurately calculate how cold air feels on human skin. Figure 14-1 shows the new Wind Chill

Temperature Index. The Index includes a frostbite indicator, showing points where temperature, wind speed, and exposure time will produce frostbite to humans. The chart shows three shaded areas of frostbite danger. Each shaded area shows how long a person can be exposed before frostbite develops. In Massachusetts, a wind chill warning is issued by the NWS Taunton Forecast Office when the Wind Chill Temperature Index, based on sustained wind, is –25ºF or lower for at least three hours.

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

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

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

Where, T= Air Temperature (ºF) V= Wind Speed (mph) Effective 11/01/01

Figure 14-1. Wind Chill Temperature Index and Frostbit Risk

Extreme Heat

The NWS issues a Heat Advisory when the Heat Index is forecast to reach 100-104 degrees F for 2 or more hours. The NWS issues an Excessive Heat Warning if the Heat Index is forecast to reach 105+ degrees F for 2 or more hours. The following are some of the highest temperatures recorded for the period from 1895 to present (Source: NOAA, www.ncdc.noaa.gov.):

- Blue Hills, MA 101°F
- Boston, MA 102°F
- Worcester, MA 96°F

Heat waves cause more fatalities in the U.S. than the total of all other meteorological events combined. In Boston, over 50 people die each year due to heat-related illnesses. From 1979-2012, excessive heat exposure caused in excess of 8,000 deaths in the United States. During this period, more people in this country died from extreme heat than from hurricanes, lightning, tornadoes, floods, and earthquakes combined. Because most heat-related deaths occur during the summer, people should be aware of who is at greatest risk and what actions can be taken to prevent a heat-related illness or death. At greater risk are the elderly, children, and people with certain medical conditions, such as heart disease. However, even young and healthy individuals can succumb to heat if they participate in strenuous physical activities during hot weather. Some behaviors also put people at greater risk: drinking alcohol, taking part in strenuous outdoor physical activities in hot weather, and taking medications that impair the body's ability to regulate its temperature or that inhibit perspiration.

In Massachusetts, heat warnings are issued by the NWS Taunton Forecast Office as follows (http://www.erh.noaa.gov/box/warningcriteria.shtml):

- Excessive Heat Warning: Daytime heat indices of 105°F or higher for 2 or more hours
- Heat Advisory: Daytime heat indices of 100ºF to 104ºF for 2 or more hours
- Heat Wave: Issued for non-criteria warning/advisory heat. A heat wave is defined as 3 or more days of temperatures 90ºF or above.

Temperatures that are 10ºF or more above the average high temperature for the region and last for several hours are defined as extreme heat. An extended period of extreme heat of three or more consecutive days is typically called a heat wave and is often accompanied by high humidity. There is no universal definition of a heat wave because the term is relative to the usual weather in a particular area. The term heat wave is applied both to routine weather variations and to extraordinary spells of heat which may occur only once a century. A basic definition of a heat wave implies that it is an extended period of unusually high atmosphere-related heat stress, which causes temporary modifications in lifestyle and which may have adverse health consequences for the affected population.

Based on the criteria for heat stress forecasts developed by the National Weather Service (NWS), watches or warnings are issued when thresholds of daytime high and nighttime low heat index (Hi) values are exceeded for at least two consecutive days. To determine the Heat Index, one needs to know the temperature and relative humidity. Once both values are known, the Heat Index will be the corresponding number with both values, as shown in Table 14-3. That number provides a temperature that the body feels. It is important to know that the Heat Index values are devised for shady, 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 be extremely hazardous.

Urbanized areas and urbanization creates an exacerbated type of risk during an extreme heat event, compared to rural and suburban areas. As defined by the U.S. Census Bureau, urban areas are classified as all territory, population, and housing units located in urbanized areas (an urban area of 50,000 or more people) and urban clusters (urban areas under 50,000 people). The U.S. Census delineates urbanized area and urban cluster boundaries to encompass densely settled territory, which generally consists of:

- A cluster of one or more block groups or census blocks each of which has a population density of at least 1,000 people per square mile at the time.
- Surrounding block groups and census blocks each of which has a population density of at least 500 people per square mile at the time.
- Less densely settled blocks that form enclaves or indentations, or are used to connect non-contiguous areas with qualifying densities (U.S. Census Bureau, 2003).

TABLE 14-3.
HEAT INDEX CHART

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

Category	Heat Index	Health Hazards
Extreme Danger	130 °F – Higher	Heat Stroke or Sunstroke is likely with continued exposure.
Danger	105 °F – 129 °F	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Extreme Caution	90 °F – 105 °F	Sunstroke, muscle cramps, and/or heat exhaustions possible with prolonged exposure and/or physical activity.
Caution	80 °F – 90 °F	Fatigue possible with prolonged exposure and/or physical activity.

Approximately 47-percent of the world's population lives in urban areas. This number is expected to increase by two-percent each year between 2000 and 2015. As these urban areas develop and change, so does the landscape. Buildings, roads, and other infrastructure replace open land and vegetation. Surfaces that were once permeable and moist are now impermeable and dry. These changes cause urban areas to become warmer than the surrounding areas. This forms an 'island' of higher temperatures – often referred to as 'heat islands'.

The term 'heat island' describes built up areas that are hotter than nearby rural areas. The annual mean air temperature of a city with more than one million people can be between 1.8 and 5.4ºF warmer than its surrounding areas. In the evening, the difference in air temperatures can be as high as 22ºF. Heat islands occur on the surface and in the atmosphere. On a hot, sunny day, the sun can heat dry, exposed urban surfaces to temperatures 50ºF to 90ºF hotter than the air. Heat islands can affect communities by increasing peak energy demand during the summer, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and death, and water quality degradation.

Air quality is also susceptible to impacts of extreme heat events. The Air Quality Index (AQI) is an index for reporting daily air quality that indicates how clean or polluted the air is and what associated health effects might be a concern. The AQI focuses on health effects that may be experienced within a few hours or days after breathing polluted air. The U.S. Environmental Protection Agency (EPA) calculates the AQI for five major air pollutants regulated by the Clean Air Act: ground-level ozone, particle pollution (also known as particulate matter), carbon monoxide, sulfur dioxide, and nitrogen dioxide. For each of these pollutants, EPA has established national air quality standards to protect public health .Ground-level ozone and airborne particles are the two pollutants that pose the greatest threat to human health in this country and typically trigger air quality alerts in Massachusetts during periods of extreme heat. Daily AQI values

range from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 represents good air quality with little potential to affect public health, while an AQI value over 300 represents hazardous air quality. An AQI value of 100 generally corresponds to the national air quality standard for the pollutant, which is the level EPA has set to protect public health. AQI values below 100 are generally thought of as satisfactory. When AQI values exceed 100, air quality is considered to be unhealthy, first for sensitive groups of people then for everyone as values get higher. National Weather Service Forecast Offices issue air quality alerts for public notification and provide recommendations for reducing risks associated with poor air quality as needed. (http://www.airnow.gov/?action=aqibasics.aqi) Daily values for AQI are posted at: http://www.epa.gov/region1/airquality/today.html.

In 2011, nationally 206 people died as a result of extreme heat, up significantly from 138 fatalities in 2010. This number is well above the 10-year average for heat related fatalities, 119. There were no heat related deaths occurring in Massachusetts during 2011. In 2011, the most dangerous place to be was in a permanent home, likely with little or no air conditioning, where a reported 119 deaths (58%) occurred. The next most dangerous identified locations were outside or in an open area, where 31 people (15%) succumbed to heat. Texas numbered the most heat victims, 46, followed by Pennsylvania, 36, and Illinois, 33. Extreme heat most strongly affected older adults aged 50+, with 170 deaths (58%). Typically, older adults are the group most affected by heat. Many more males, 133 (64%), than females, 73 (35%), were killed by heat. Those susceptible to extreme heat may suffer from dehydration, heat exhaustion, heat cramps, heat stokes or even death. Air-conditioning is the number one protective factor against heat-related illness and death.

14.1.5 Drought

Drought is a temporary irregularity and differs from aridity since the latter is restricted to low rainfall regions and is a permanent feature of climate. Drought is a period characterized by long durations of below normal precipitation. Drought occurs in virtually all climatic zones yet its characteristics vary significantly from one region to another, since it is relative to the normal precipitation in that region. Drought can affect agriculture, water supply, aquatic ecology, wildlife, and plant life. There are four ways that drought can be defined or grouped:

- Meteorological drought is a measure of departure of precipitation from normal. It is defined solely on the degree of dryness. Due to climatic differences, what might be considered a drought in one location of the country may not be a drought in another location.
- Agricultural drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced ground water or reservoir levels, etc. It 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 water demands of plant life, primarily crops.
- Hydrological drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply and occurs when these water supplies are below normal. It is related to the effects of precipitation shortfalls on stream flows and reservoir, lake, and groundwater levels.
- Socioeconomic drought is associated with the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought. This differs from the aforementioned types of drought because its occurrence depends on the time and space processes of supply and demand to identify or classify droughts. The supply of many economic goods depends on weather (e.g., water, forage, food grains, fish, and hydroelectric power). Socioeconomic drought occurs when the demand for an economic good exceeds

supply as a result of a weather-related shortfall in water supply (National Drought Mitigation Center, 2012).

Drought can produce a range of impacts that span many sectors of an economy and can reach beyond an area experiencing physical drought. This exists because water is integral to our ability to produce goods and provide services. Direct impacts of drought include reduced crop yield, increased fire hazard, reduced water levels, and damage to wildlife and fish habitat. The consequences of these impacts illustrate indirect impacts that include: reduction in crop, rangeland, and forest productivity may result in reduced income for farmers and agribusiness, increased prices for food and timber, unemployment, reduced tax revenues due to reduced expenditures, increased crime, foreclosures, migration, and disaster relief programs. The many impacts of drought can be listed as economic, environmental, or social.

Economic impacts occur in agriculture and related sectors because of the reliance of these sectors on surface and subsurface water supplies. Environmental impacts are the result of damage to plant and animal species, wildlife habitat, and air and water quality; forest and grass fires; degradation of landscape quality; loss of biodiversity; and soil erosion. Social impacts involve public safety, health, conflicts between water users, reduced quality of life, and inequities in the distribution of impacts and disaster relief. A summary of potential impacts associated with drought are identified in Table 14-4. This table includes only some of the potential impacts of drought.

TABLE 14-4.
ECONOMIC, ENVIRONMENTAL AND SOCIAL IMPACTS OF DROUGHT

Economical	Environmental	Social
• Loss of national economic growth, slowing down of economic development • Damage to crop quality, less food production • Increase in food prices • Increased importation of food (higher costs) • Insect infestation • Plant disease • Loss from dairy and livestock production • Unavailability of water and feed for livestock which leads to high livestock mortality rates • Disruption of reproduction cycles (breeding delays or unfilled pregnancies) • Increased predation • Increased fire hazard - Range fires and Wildland fires • Damage to fish habitat, loss from fishery production • Income loss for farmers and others affected • Unemployment from production declines • Loss to recreational and tourism industry • Loss of hydroelectric power • Loss of navigability of rivers and canals	• Increased desertification - Damage to animal species • Reduction and degradation of fish and wildlife habitat • Lack of feed and drinking water • Disease • Increased vulnerability to predation. • Loss of wildlife in some areas and too many in others • Increased stress to endangered species • Damage to plant species, loss of biodiversity • Increased number and severity of fires • Wind and water erosion of soils • Loss of wetlands • Increased groundwater depletion • Water quality effects • Increased number and severity of fires • Air quality effects	• Food shortages • Loss of human life from food shortages, heat, suicides, violence • Mental and physical stress • Water user conflicts • Political conflicts • Social unrest • Public dissatisfaction with government regarding drought response • Inequity in the distribution of drought relief • Loss of cultural sites • Reduced quality of life which leads to changes in lifestyle • Increased poverty • Population migrations

The Commonwealth of Massachusetts is often considered a ‘water-rich’ state. Abundant precipitation results from frontal systems or storms that move across the continent and exit through the Northeast.

Under normal conditions, regions across the state annually receive between 44 and 47 inches of precipitation.

The Drought Management Plan was developed in 2001 as a working document and has been activated several times. This plan has been updated in consultation with the Drought Management Task Force (agencies and organizations providing technical advice on drought conditions) to reflect the lessons of past experience and to ensure a thorough and responsive approach to managing drought conditions in the future.

As part of this statewide drought management plan, data provided by the respective agencies are compiled into the "Current Water Conditions Report," a report summarizing current water resource conditions, in the Commonwealth that is prepared on a monthly basis by the Department of Conservation and Recreation (DCR) for the Water Resources Commission.

Unlike many other emergency situations, the severity of droughts develops over time allowing the opportunity to develop and implement appropriate measures as the situation worsens. Therefore, the Massachusetts Drought Management Plan defines action levels that trigger general levels of response given the severity of the situation.

Although Massachusetts is relatively small, it has a number of distinct regions that experience significantly different weather patterns and react differently to the amounts of precipitation they receive. Therefore, the Drought Management Task Force assesses drought conditions on a regional basis, rather than using a single, statewide assessment.

Because drought conditions vary due to precipitation patterns, these regions may be adjusted based on the conditions in any particular drought situation. At times, the Task Force may advise that a drought be defined on a watershed basis, if drought indices indicate that an entire watershed is affected but that watershed straddles a region that would otherwise not be considered to be affected by drought. In addition, areas served by water supplies outside of their regions have their drought conditions, as applied to their water supplies only, assessed by the capacities of their systems, rather than by the regional indices. Regional indices are used to assess drought conditions in areas served by water supplies outside of these regions. A regional approach allows customization of drought actions and conservation measures to address particular situation in each region. Because regions differ in population, density, water demand, topography, and runoff characteristics, different responses may be needed.

Drought Levels

In the Commonwealth, five levels of drought have been developed to characterize drought severity:

- Normal
- Advisory
- Watch
- Warning
- Emergency

These drought levels are based on the conditions of natural resources and are intended to provide information on the current status of water resources. The levels provide a basic framework from which to take actions to assess, communicate, and respond to drought conditions. They begin with a normal situation where date are routinely collected and distributed, move to heightened caution with increased data collection during an advisory, to increased assessment and proactive education during a watch. Water restrictions might be appropriate at the watch or warning stage, depending on the capacity of each individual water supply system. A warning level indicates a severe situation and the possibility that a

drought emergency may be necessary. A drought emergency is when a mandatory water restriction or use of emergency supplies is necessary.

The action levels specified are a general plan of action to coordinate statewide response to drought situations. However, numerous individual agencies have particular responsibilities that they are responsible for implementing on an ongoing basis. In addition, individual communities have a range of actions they can take to manage their systems during droughts.

Drought Indices

A number of drought indices are available to assess the various impacts of dry conditions. The Commonwealth uses a multi-index system to determine the severity of a drought or extended period of dry conditions.

A determination of drought level is based on seven indices: Standardized Precipitation Index, Crop Moisture Index, Keetch-Byram Drought Index (KBDI), Precipitation, Groundwater levels, Stream flow levels, and Index Reservoir levels. In the 2001 Drought Management Plan, the Palmer Drought Severity Index was included as an index, however it was found to be non-responsive to drought conditions in 1999 and 2001-2002. Thus, the Palmer Drought Index was replaced with the Standardized Precipitation Index. The 2001 Drought Management Plan also used a daily Fire Danger Index; this was replaced with the KBDI in 2010 on the recommendation of the DCR Bureau of Forest Fire Control. The KBDI gives a longer-term indication of drought conditions related to the severity of forest fire behavior (fuel moisture), that affect potential fire spread and the resources needed to extinguish fires. The KBDI is less subject to daily fluctuations than the daily fire danger rating. A detailed description of each index is provided below.

Drought level is determined monthly based on the number of indices which have reached a given drought level. A majority of the indices would need to be triggered in a region in order for a drought designation for the region to move to a more severe level. Drought levels are declared on a regional basis for each of the six regions in Massachusetts. Drought levels may also be made county by county or watershed-specific. Once a drought level of warning and emergency have been reached for the precipitation index, conditions must improve to those of the previous level before a determination is made to reduce the warning or emergency.

The NCDC's Crop Moisture Index reflects short-term soil moisture conditions for agriculture. It was developed to assess short-term crop water conditions and needs across major crop-producing regions (Palmer, W.C., 1968. *Keeping track of crop moisture conditions, nationwide: The new Crop Moisture Index*. Weatherwise 21:156–161). It is based on the concept of abnormal evapotranspiration deficit, calculated as the difference between computed actual evapotranspiration and computed potential evapotranspiration (i.e., expected or appropriate evapotranspiration). Actual evapotranspiration is based on the temperature and precipitation that occurs during the week and computed soil moisture in both the topsoil and subsoil layers. The maps are issued weekly and are posted on-line at: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/cmi.gif.

The Standardized Precipitation Index (SPI) is a probability index that considers only precipitation. It is based on the probability of recording a given amount of precipitation, and the probabilities are standardized so that an index of zero indicates the median precipitation amount (half of the historical precipitation amounts are below the median, and half are above the median). The index is negative for drought and positive for wet conditions. SPI reflects soil moisture and precipitation conditions and is calculated monthly using the Massachusetts Rainfall Database maintained by the DCR Office of Water Resources. SPI values are calculated for "look-back" periods of 1 month, 3 months, 6 months, and 12 months. The SPI values for the time periods are equivalent to the precipitation total's number of standard deviations from the normal for that time period. Drought thresholds for look-back periods of 3-month, 6-month, and 12-months are specified in the Massachusetts Drought Management Plan. The KBDI is a drought index designed for fire potential assessment. It is a number representing the net effect of evapotranspiration and precipitation in producing cumulative moisture deficiency in deep duff and upper

soil layers. The index increases each day without rain and decreases when it rains. The scale ranges from 0 (no moisture deficit) to 800 (maximum drought possible). The range of the index is determined by assuming that there is eight inches of moisture in a saturated soil that is readily available to the vegetation. For different soil types, the depth of soil required to hold eight inches of moisture varies. A prolonged drought influences fire intensity, largely because more fuel is available for combustion. The drying of organic material in the soil can lead to increased difficulty in fire suppression. The KBDI is reported weekly from 13 Massachusetts fire districts by the DCR Bureau of Fire Control; however, these data are not available online.

The Precipitation Index is a comparison of measured precipitation amounts (in inches) to historical normal precipitation. Cumulative amounts for 3, 6, and 12-month periods are factored into the drought determination. These data are available from the DCR Office of Water Resources.

The Groundwater Level Index is based on the number of consecutive months that groundwater levels are below normal (lowest 25th percentile of period of record for the respective months). The USGS monitors groundwater levels in a network of monitoring wells throughout Massachusetts. The USGS develops monthly groundwater condition maps showing areas as above normal, normal or below normal. DCR provides a table specifying whether each Massachusetts Drought Region experienced normal, above-normal, or below-normal groundwater levels each month and includes this information in the monthly report, *Current Water Conditions in Massachusetts*.

The Stream Flow Index is based on the number of consecutive months that stream flow levels are below normal (lowest 25th percentile of period of record for the respective months). The USGS monitors stream flow in a network of gages throughout Massachusetts. The USGS develops monthly stream flow condition maps showing areas as above normal, normal or below normal. In addition, USGS provides a table that describes cumulative monthly stream flow as normal, above normal, or below normal.

The Reservoir Index is based on the water levels of small, medium, and large index reservoirs across the Commonwealth. The reservoir level relative to normal conditions for each month of the year is considered. As part of its monthly water conditions report, the DCR Office of Water Resources maintains a list of index water supply reservoirs and the percentage at which they are at capacity as well as and non-water supply index reservoir levels, as available. Reservoir data are summarized in the DCR monthly Water Conditions Reports.

Table 14-5 displays the drought thresholds for these drought indices and includes the drought level. A drought emergency will end when the conditions that led to the specific emergency have abated. For example, a critically low reservoir will need to have made significant recovery, or groundwater wells will need to have returned to normal operating capacities. If an emergency has been declared based on environmental impacts, the emergency will end when these conditions have ended.

TABLE 14-5.
DROUGHT INDICES

SPI	Crop Moisture Index*	KBDI	Precipitation	Groundwater	Stream Flow	Reservoir
Drought Level: Normal						
3-month > -1.5 or 6-month > -1.0 or 12-month > -1.0	0.0 to -1.0 Slightly dry	<200	1 month below normal	2 consecutive months below normal**	1 month below normal**	Reservoir levels at or near normal for the time of year

TABLE 14-5.
DROUGHT INDICES

SPI	Crop Moisture Index*	KBDI	Precipitation	Groundwater	Stream Flow	Reservoir
Drought Level: Advisory						
3-month > -1.5 to -2.0 or 6-month > -1.0 to -1.5 or 12-month > -1.0 to -1.5	-1.0 to -1.9 Abnormally dry	200-400	2 month cumulative below 65% of normal	3 consecutive months below normal**	At least 2 out of 3 consecutive months below normal**	Small index Reservoirs below normal
Drought Level: Watch						
3-month > -2.0 or 6-month > -1.5 to -3.0 or 12-month > -1.5 to -2.0	-2.0 to -2.9 Excessively dry	400-600	1 of the following criteria met: 3 month cum. <65% or 6 month cum. < 70% or 12 month cum. < 70%	4-5 consecutive months below normal**	At least 4 out of 5 consecutive months below normal**	Medium Index Reservoirs below normal
Drought Level: Warning						
6-month <-3.0 or 12-month -2.0 to -2.5	<-2.9 Severely dry	600-800	1 of the following criteria met: 3 month cum. <65% and 6 month cum. <65% or 6 month cum. <65% and 12 month cum. <65% or 3 month cum. <65% and 12 month cum. <65%	6-7 consecutive months below normal**	At least 6 out of 7 consecutive months below normal**	Large index reservoirs below normal
Drought Level: Emergency						
12-month <-2.5	<-2.9 Severely dry	600-800	Same criteria as warning and previous month was warning or emergency	>8 months below normal**	>7 months below normal**	Continuation of previous month's conditions

* Crop Moisture Index is subject to frequent change; the drought level for this indicator is determined based on the repeated or extended occurrence at a given level

** Below normal for groundwater and stream flow are defined as being with the lowest 25th percentile of the period of record

Drought warnings, watches, and advisories can be reduced based normal levels of precipitation returning or groundwater levels returning to the "normal" range. In order to return to normal status, groundwater levels must be in the normal range or one of two precipitation measures must be met: three months of precipitation that is cumulatively above normal; or long-term cumulative precipitation above normal.

14.2 HAZARD PROFILE

14.2.1 Location

High Winds

The entire commonwealth is vulnerable to high winds that can cause a wide range of damage. However, the coast is most frequently impacted by damage due to high wind events. The rest of this section provides more information on wind hazards, as wind is associated with other hazard events. The State Building Code has incorporated engineering standards for wind loads. Wind loads are for buildings and their components are to be designed to withstand the code-specified wind loads. Calculating wind loads is important in design of the wind force-resisting system, including structural members, components, and cladding, against shear, sliding, overturning, and uplift actions. The wind load zones for Massachusetts are shown on the Hurricane Tracks Map in Appendix 4.

Figure 14-2 indicates how the frequency and strength of windstorms impacts the U.S. and the general location of the most wind activity. This is based on 40 years of tornado history and 100 years of hurricane history, collected by FEMA. States located in Wind Zone IV have experienced the greatest number of tornadoes and the strongest tornadoes. The Commonwealth of Massachusetts is located within Wind Zone II, with speeds up to 180 mph. The entire Commonwealth is also located within the hurricane-susceptible region. The western portion of the Commonwealth is located within the special wind region. Table 14-6 describes the areas affected by the different wind zones.

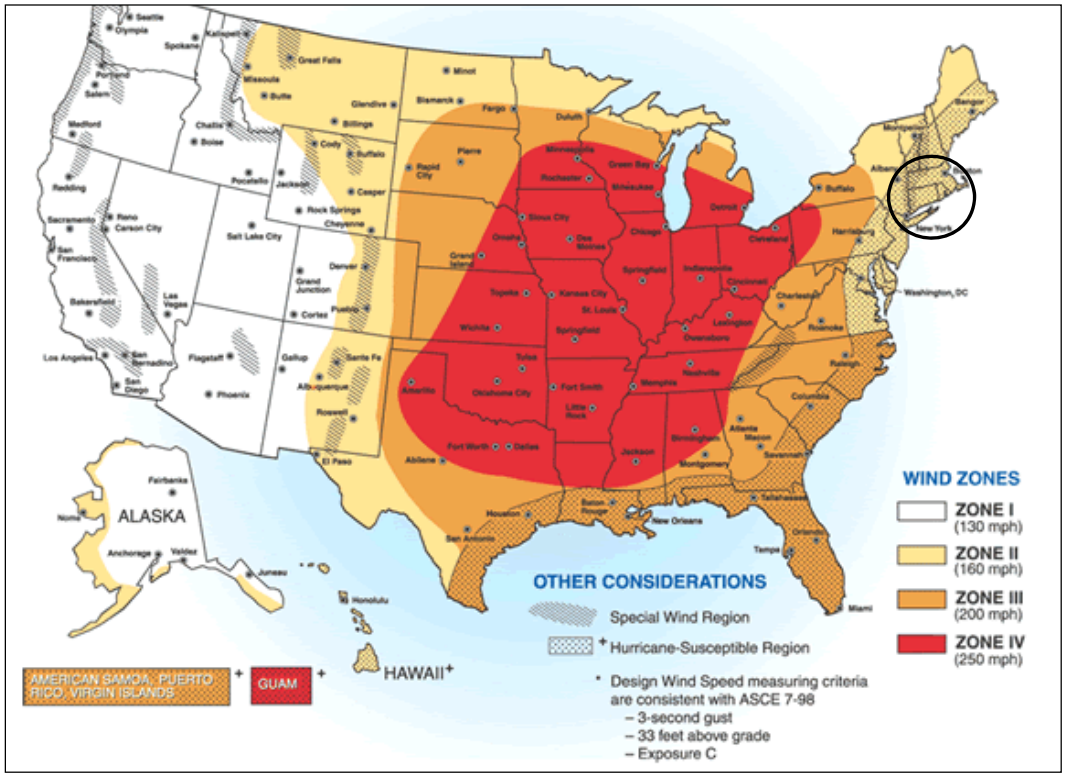


Figure 14-2. Wind Zones in the U.S.

TABLE 14-6.
WIND ZONES IN THE U.S.

Wind Zones	Areas Affected
Zone I (130 mph)	All of Washington, Oregon, California, Idaho, Utah, and Arizona. Western parts of Montana, Wyoming, Colorado, and New Mexico. Most of Alaska, except the east and south coastlines.
Zone II (160 mph)	Eastern parts of Montana, Wyoming, Colorado, and New Mexico. Most of North Dakota. Northern parts of Minnesota, Wisconsin, and Michigan. Western parts of South Dakota, Nebraska, and Texas. All New England States. Eastern parts of New York, Pennsylvania, Maryland, and Virginia. Washington, DC.
Zone III (200 mph)	Areas of Minnesota, South Dakota, Nebraska, Colorado, Kansas, Oklahoma, Texas, Louisiana, Mississippi, Alabama, Georgia, Tennessee, Kentucky, Pennsylvania, New York, Michigan, and Wisconsin. Most or all of Florida, Georgia, South Carolina, North Carolina, Virginia, West Virginia. All of American Samoa, Puerto Rico, and Virgin Islands.
Zone IV (250 mph)	Mid US including all of Iowa, Missouri, Arkansas, Illinois, Indiana, and Ohio and parts of adjoining states of Minnesota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, Louisiana, Mississippi, Alabama, Georgia, Tennessee, Kentucky, Pennsylvania, Michigan, and Wisconsin. Guam.
Special Wind Region	Isolated areas in the following states: Washington, Oregon, California, Idaho, Utah, Arizona, Montana, Wyoming, Colorado, New Mexico. The borders between Vermont and New Hampshire; between New York, Massachusetts and Connecticut; between Tennessee and North Carolina.
Hurricane Susceptible Region	Southern US coastline from Gulf Coast of Texas eastward to include entire state of Florida. East Coastline from Maine to Florida, including all of Massachusetts, Connecticut, Rhode Island, Delaware, and Washington DC. All of Hawaii, Guam, American Samoa, Puerto Rico, and Virgin Islands.

Thunderstorms

Thunderstorms affect relatively small areas, rather than large regions much like winter storms and hurricane events. Thunderstorms can strike in all regions of the U.S.; however, they are most common in the central and southern states. The atmospheric conditions in these regions of the country are most ideal for generating these powerful storms. It is estimated that there are as many as 40,000 thunderstorms each day worldwide. Figure 14-3 shows the average number of thunderstorm days throughout the U.S. The most thunderstorms are seen in the southeast states, with Florida having the highest incidences (80 to over 100 thunderstorm days each year). This figure indicates that Massachusetts experiences between 10 and 30 thunderstorm days each year. Figure 14-4 shows the average number of thunderstorm days with extreme winds throughout the U.S.

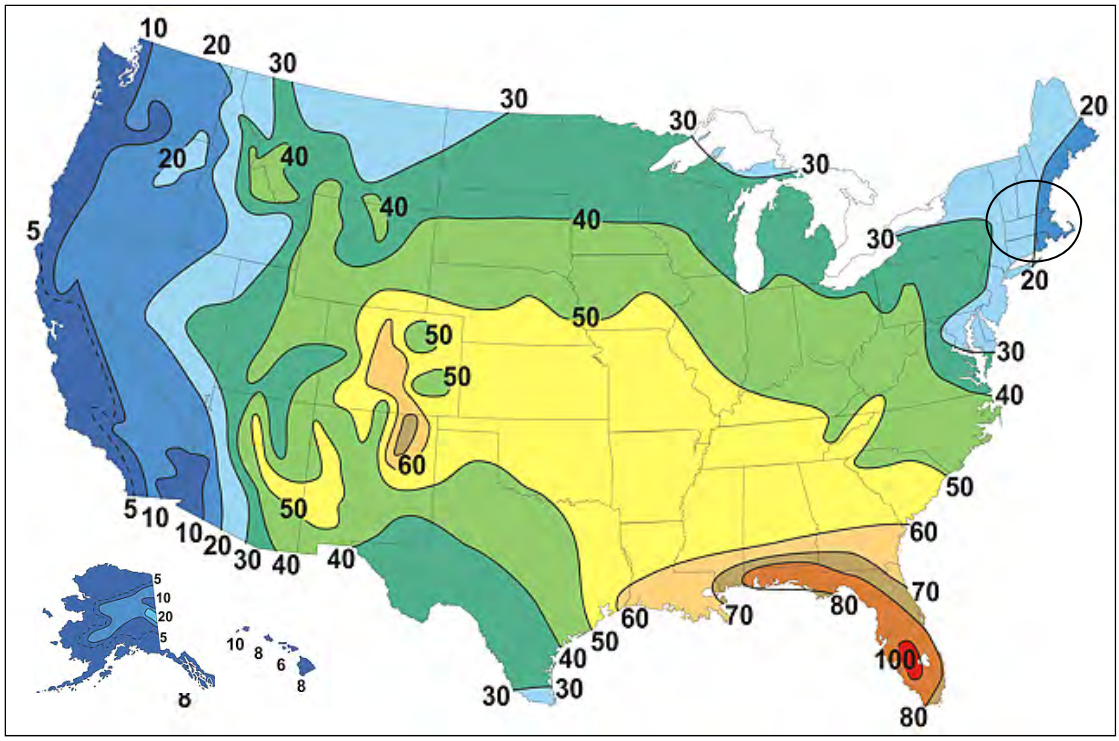


Figure 14-3. Annual Average Number of Thunderstorm Days in the U.S.

Source: MSNBC.com, 2007

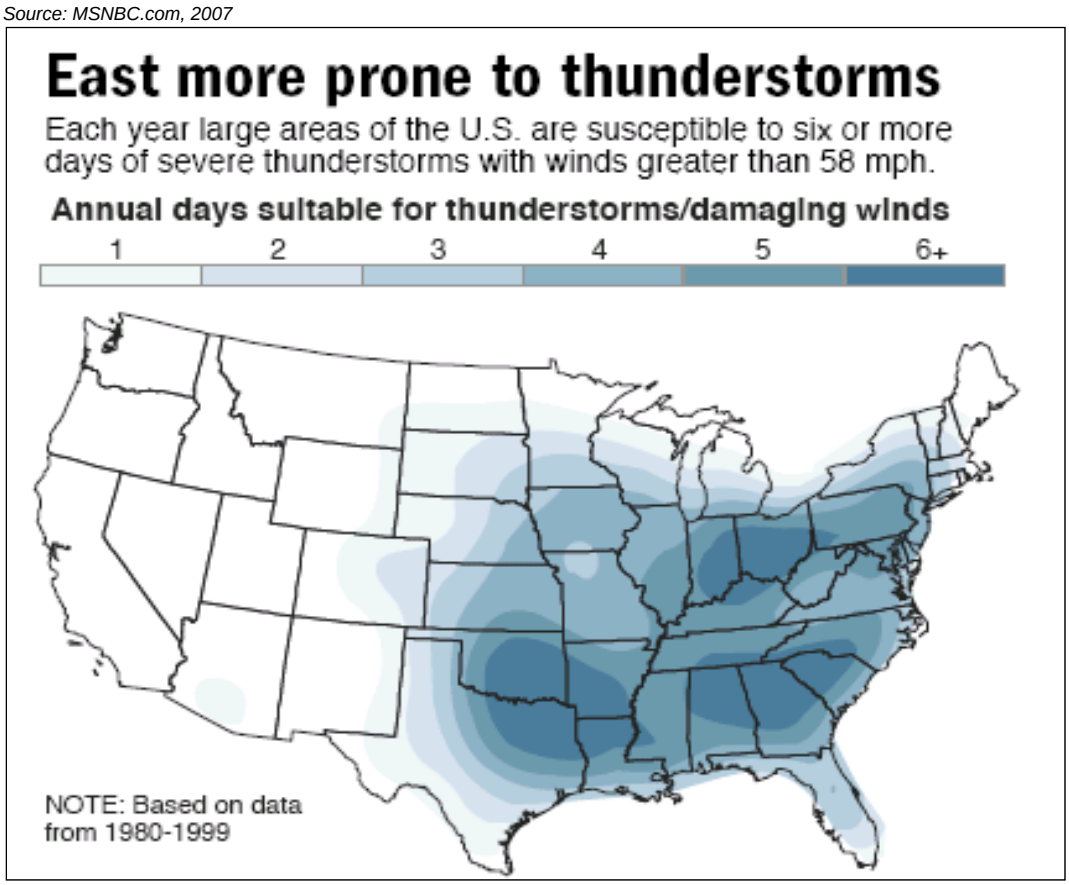


Figure 14-4. Annual Days Suitable for Thunderstorms with Extreme Winds

Tornadoes

The U.S. experiences more tornadoes than any other country. In a typical year, approximately 1,000 tornadoes affect the U.S. The peak of the tornado season is April through June, with the highest concentration of tornadoes in the central U.S. Figure 14-5 shows the annual average number of tornadoes between 1991 and 2010. Massachusetts experienced an average of one tornado event annually between 1991 and 2010.

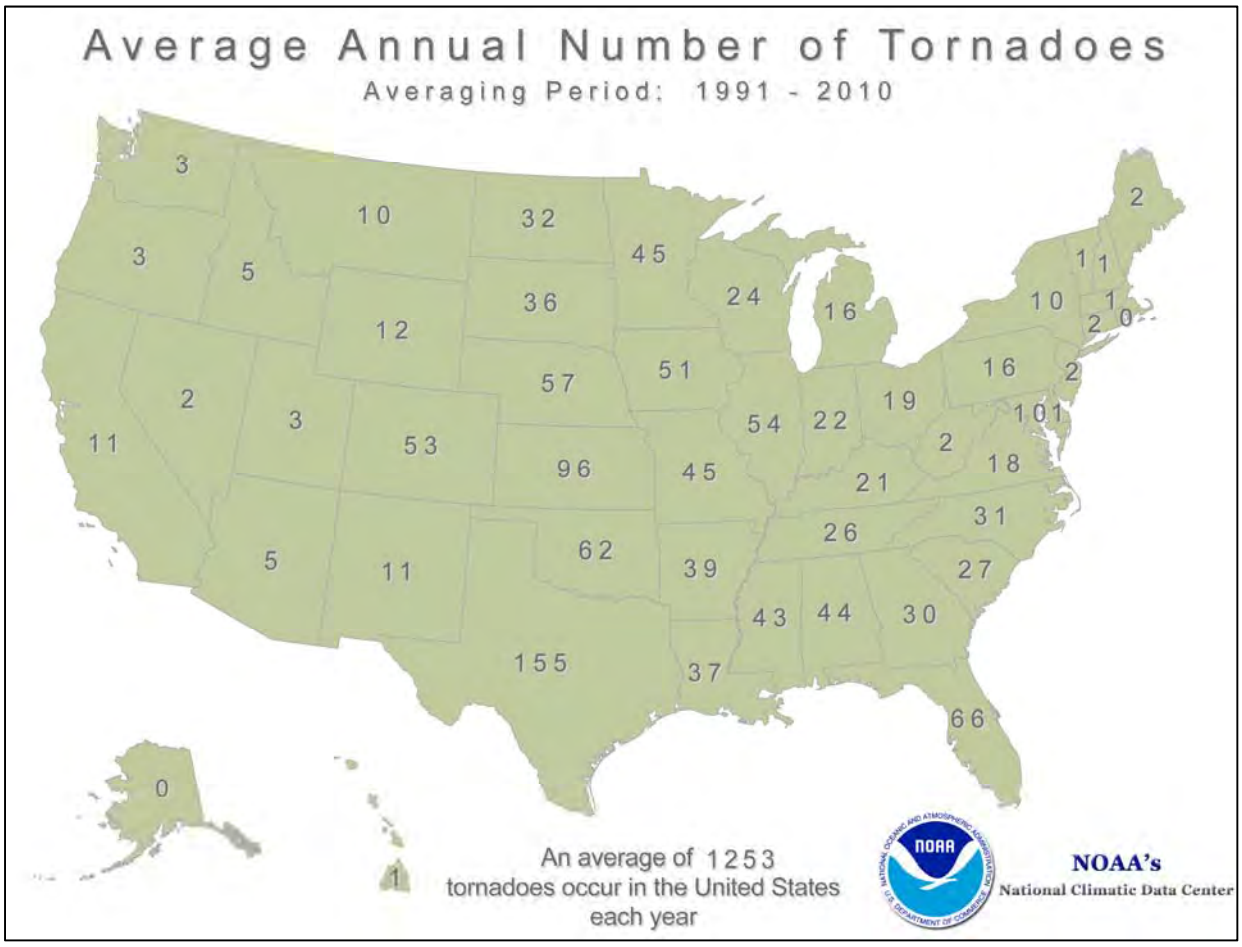


Figure 14-5. Annual Average Number of Tornadoes in the U.S., 1991 to 2010

Figure 14-6 indicates that a majority of the Commonwealth, with the exception of the southeastern section (Mid-Hudson Region), is not located within a high or highest risk tornado area. Southwest Massachusetts is located within the highest risk area of tornadoes. The remainder of the Commonwealth is not included in the high or highest risk areas. Details regarding historical tornado events are discussed in the next section (Previous Occurrences and Losses) of this profile.

Source: USGS Themes Data; information and statistical interpretations from NOAA, 2012

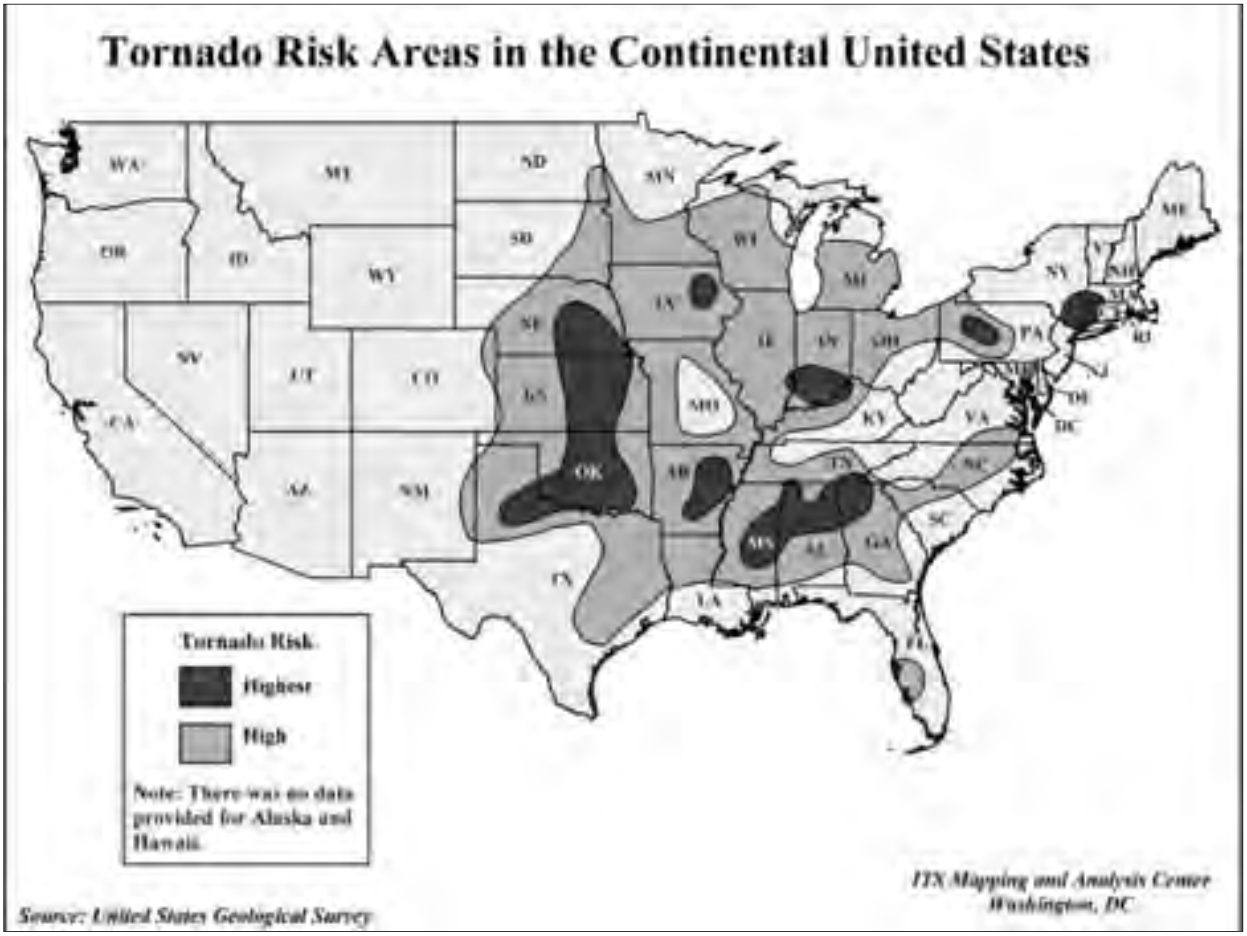


Figure 14-6. Tornado Risk in the U.S.

A study from NOAA's National Severe Storms Laboratory provided estimates of the long-term threat from tornadoes. The Laboratory used historical data to estimate the daily probability of tornado occurrences across the U.S., no matter the magnitude of the tornado. Figure 14-7 shows the estimates prepared by the Laboratory. In Massachusetts, it is estimated that the probability of a tornado occurring is 0 to 0.4 days per year. The density per 25 square miles in the map's legend indicates the probable number of tornadoes for each 25 square mile cell within the contoured zone that can be expected over a similar period of record (51 years). It should be noted that the density number does NOT indicate the number of events that can be expected across the entire zone on the map.

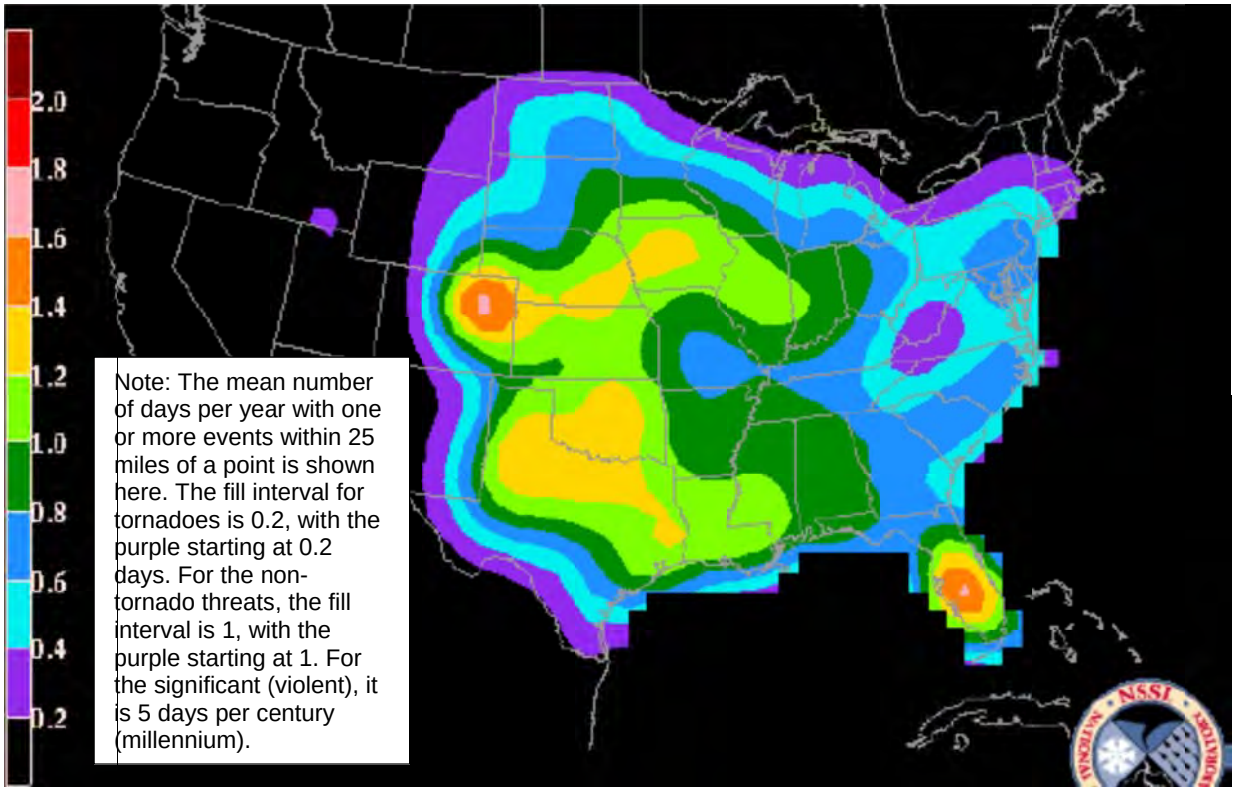


Figure 14-7. Total Annual Threat of Tornado Events in the U.S., 1980-1999

The analysis depicts point locations of initial tornado touchdown locations for the period of record using graduated symbols. These symbols depict tornado intensity based on the original Fujita Scale with thematically shaded tornado density zones derived through Arc View Spatial Analyst software and recorded tornado touchdown locations. These touchdown locations, obtained from NOAA, are based on a search radius of 50,000 square miles and the density of historical tornadoes translated to any given 20 square mile area.

The Enhanced F-scale is a set of wind estimates (not measurements) based on damage. Its uses three-second gusts estimated at the point of damage based on a judgment of 8 levels of damage to the 28 indicators listed in Table 14-2. These estimates vary with height and exposure. Important: The 3-second gust is not the same wind as in standard surface observations. Standard measurements are taken by weather stations in open exposures (http://www.spc.noaa.gov/faq/tornado/ef-scale.html, April 2007).

A tornado may happen anywhere in Massachusetts given the right atmospheric conditions. The Reported Tornado Occurrences Map depicts the tornado risk based on probability of occurrence based past events. The density per 25 square miles indicates the probable number of tornado touchdowns for each 25 square mile cell within the contoured zone that can be expected over a similar period of record (approximately 50 years). It should be noted that the density number does NOT indicate the number of events that can be expected across the entire zone, but the percent probability of occurrence in the given area. The analysis indicated that the area at greatest risk for a tornado touchdown runs from central to northeastern Massachusetts.

Massachusetts does not fall within Tornado Alley. However, tornadoes can occur at any time and in any area. Since Massachusetts experiences far fewer tornadoes than other parts of the country, residents may be less prepared to react to a tornado.

Extreme Temperatures

Climate divisions are regions within a state that are climatically homogeneous. NOAA has divided the U.S. into 359 climate divisions. The boundaries of these divisions typically coincide with the county boundaries, except in the western U.S., where they are based largely on drainage basins (U.S. Energy Information Administration, Date Unknown).

According to NOAA, Massachusetts is made up of three climate divisions: Western, Central, and Coastal (NOAA, 2012). Figure 14-8 shows the climate divisions throughout the U.S. and Figure 14-9 shows the climate divisions of Massachusetts.

Source: NOAA, 2012

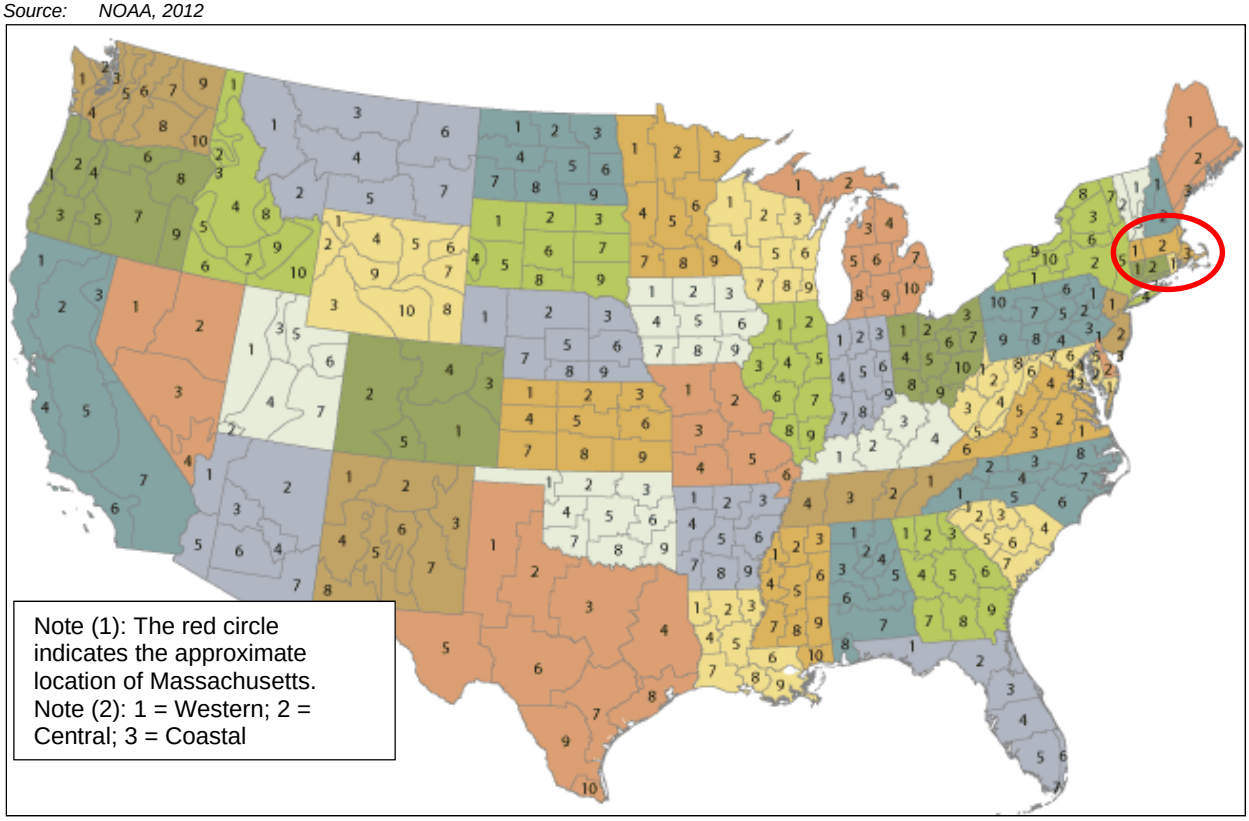


Figure 14-8. Climate Divisions of the United States

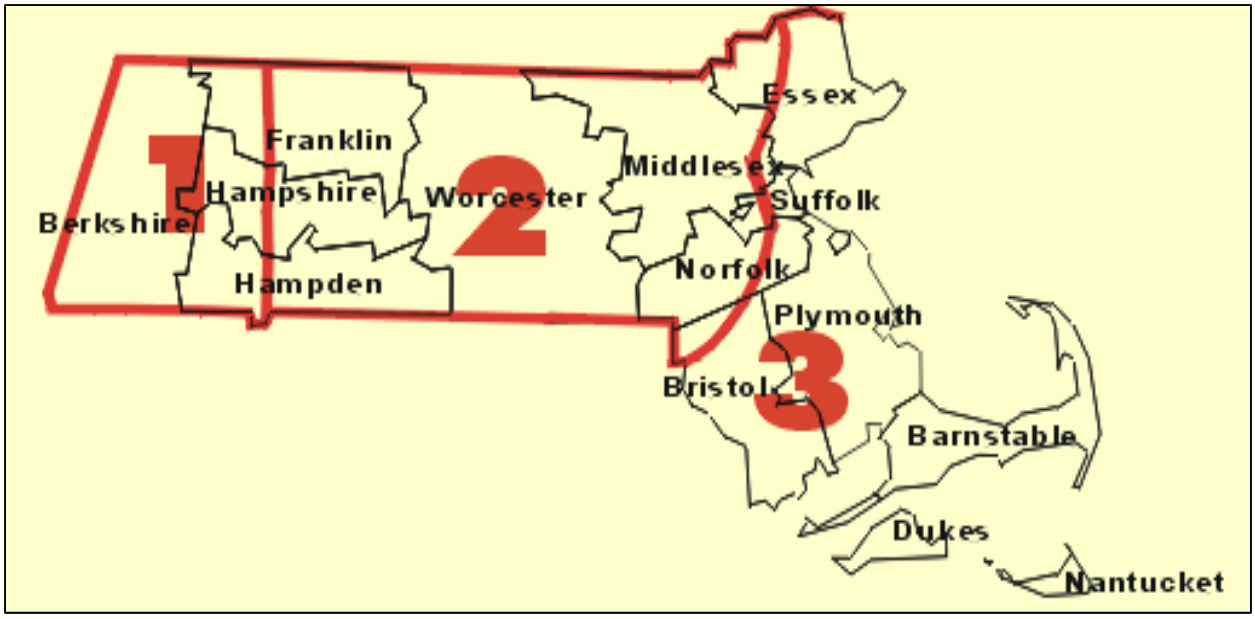


Figure 14-9. Climate Divisions of Massachusetts

Temperature extremes can occur throughout the entire Commonwealth of Massachusetts. Areas that are more prone to heat include inland urban areas. Boston is susceptible to the stresses of heat waves for two reasons. First, the City has a large population of residents considered to be vulnerable during extreme heat (elderly and low-income). Second, the City's dark colored infrastructure in combination with the lack of vegetation creates the urban heat island effect.

Colder temperatures and extremes are more common in the higher elevations. The coastal areas also have lower daily averages that the inlands parts of the Commonwealth, but do not carry the same extreme temperature records.

According to the National Weather Service and the Centers for Disease Control, extreme heat events are the most common cause of weather-related deaths in the United States, causing more deaths annually than hurricanes, lightning, tornadoes, floods, and earthquakes combined. However, in 2011, tornado was the top weather fatality event, with 553 deaths and then heat events with 206 deaths.

Drought

Based on past events and current criteria outlined in the Massachusetts Drought Management Plan, it appears that western Massachusetts may be more vulnerable than eastern Massachusetts to severe drought conditions. However, many factors, such as water supply sources, population, economic factors (i.e., agriculture based economy), and infrastructure, may affect the severity and length of a drought event. The Massachusetts Drought Management Plan takes into account regional responses to such conditions.

The DCR precipitation index divides the Commonwealth into six regions: Western, Central, Connecticut River Valley, Northeast, Southeast, and Cape and Islands (see Figure 14-10).

Figure 14-11 illustrates the watershed extents for all surface water supplies including active, inactive, emergency, sources outside of Massachusetts.

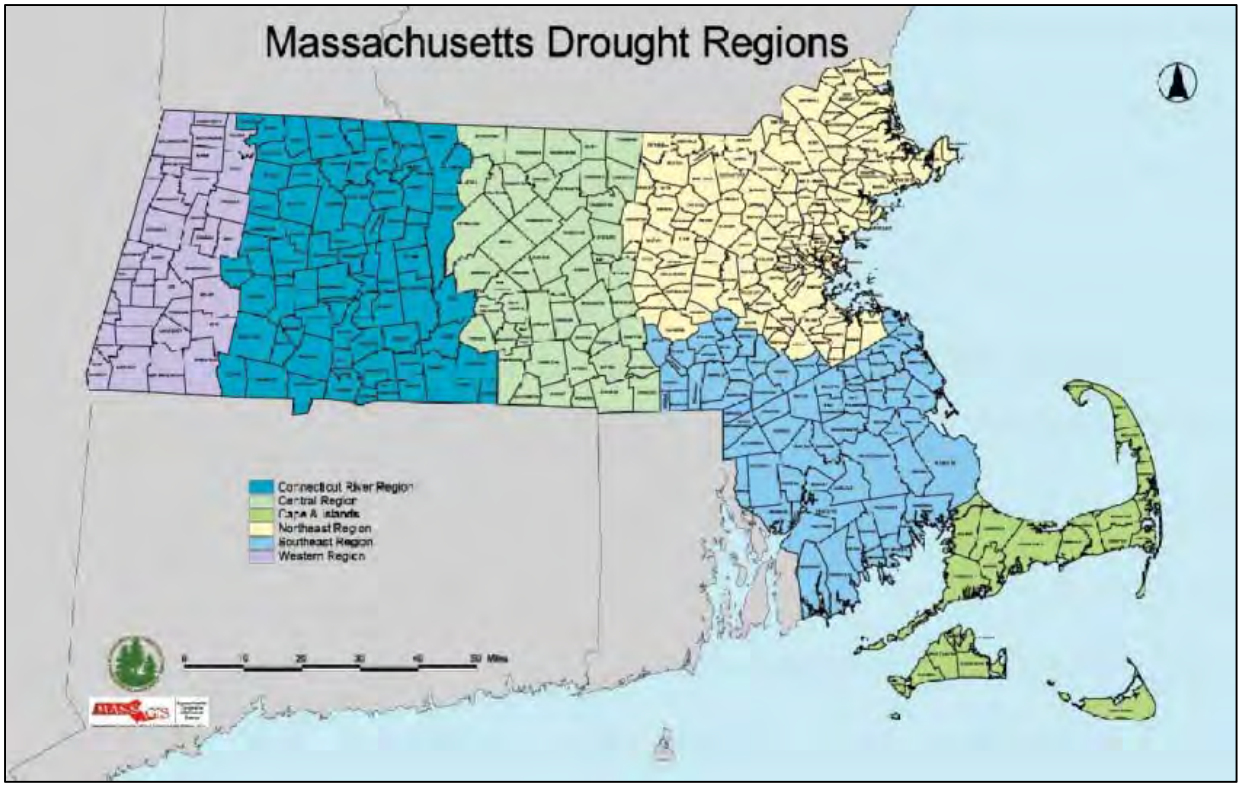


Figure 14-10. Drought Regions of Massachusetts

Source: MassGIS

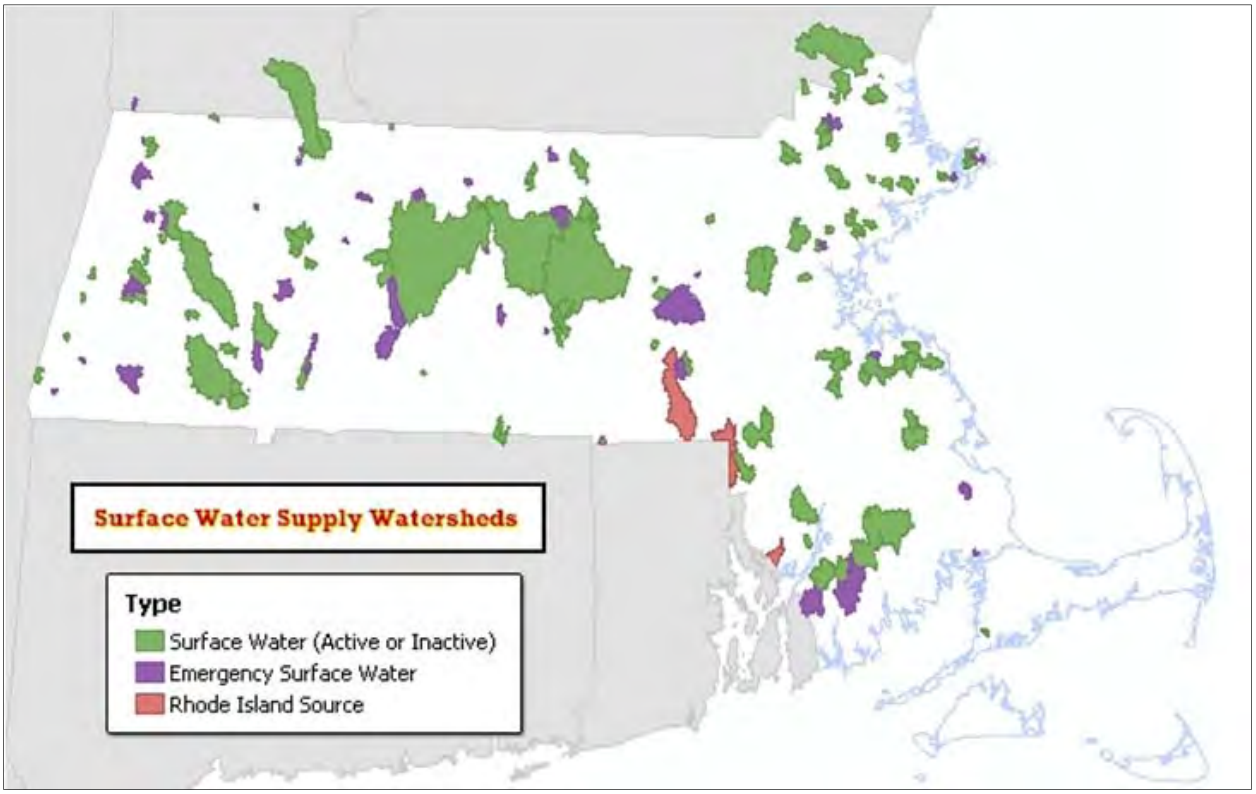


Figure 14-11. Watersheds with Surface Water Intakes for Drinking Water

14.2.2 Previous Occurrences

FEMA Declarations

Based on all sources researched, known severe weather events that have affected Massachusetts and were declared a FEMA disaster are identified in Table 14-7, which provides detailed information concerning the FEMA declarations for the Commonwealth. Figure 14-12 illustrates the number of disasters per County. Specific event types are described in the following sections.

TABLE 14-7.
FEMA SEVERE WEATHER-RELATED DISASTER DECLARATIONS (1954 TO 2012)

Disaster #	Disaster Type	Declaration Date	Incident Period	Barnstable	Berkshire	Bristol	Dukes	Essex	Franklin	Hampden	Hampshire	Middlesex	Nantucket	Norfolk	Plymouth	Suffolk	Worcester	**Number of Counties Impacted**
DR-325	Severe Storms, Flooding	03/06/72	03/06/72					X						X	X	X		**4**
DR-790	Severe Storms, Flooding	04/18/87	3/30/87 - 4/13/87		X			X	X	X	X	X		X			X	**8**
DR-1142	Severe Storms/Flooding	10/25/96	10/20/96 - 10/25/96					X				X		X	X	X		**5**
DR-1224	Heavy Rain and Flooding	06/23/98	6/13/98 - 7/6/98			X		X				X		X	X	X	X	**7**
DR-1364	Severe Storms & Flooding	04/10/01	3/5/01 - 4/16/01			X		X				X		X	X	X	X	**7**
DR-1614	Severe Storms and Flooding	11/10/05	10/7/05 - 10/16/05		X	X			X	X	X	X		X	X		X	**9**
DR-1642	Severe Storms and Flooding	05/25/06	5/12/06 - 5/23/06					X				X				X		**3**
DR-1701	Severe Storms and Inland and Coastal Flooding	05/16/07	4/15/07 - 4/25/07	X	X		X	X	X	X	X				X			**8**
DR-1895	Severe Storm and Flooding	03/29/10	3/12/10 - 4/26/10			X		X				X		X	X	X	X	**7**
DR-1994	Severe Storms and Tornadoes	06/15/11	06/01/11							X							X	**2**
DR-4051	Severe Storm and Snowstorm	01/06/12	10/29/11 - 10/30/11		X				X	X	X	X					X	**6**
Total				**1**	**4**	**4**	**1**	**8**	**4**	**5**	**4**	**8**	**0**	**7**	**7**	**6**	**7**	**66**

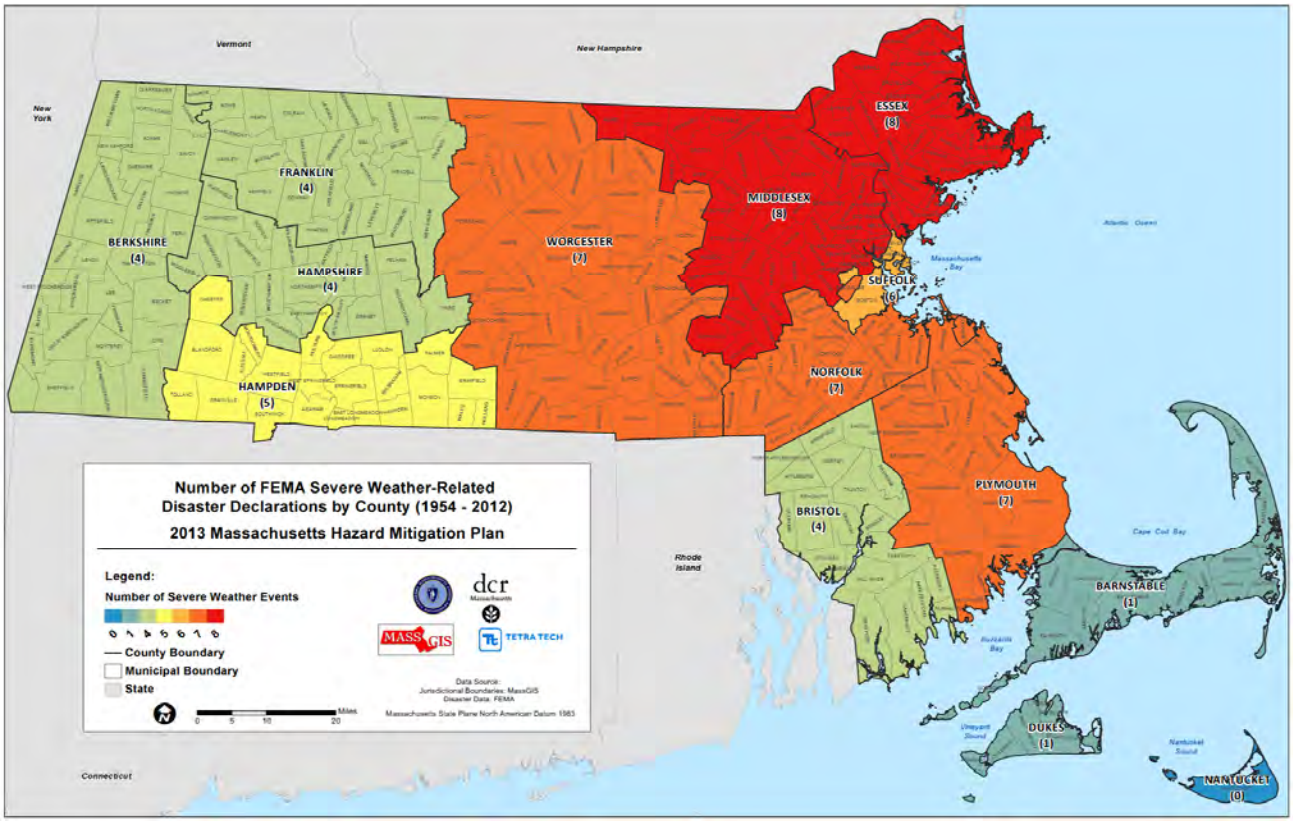


Figure 14-12. Number of FEMA Severe Weather-Related Disaster Declarations (1954 to 2012)

High Winds

The Storm Prediction Center maintains a severe weather database that contains information regarding hail, tornado, and damaging events. The damaging wind reports include data from 1955 to 2011. For the purpose of this plan, the last 20 years of data was inspected. According to the Storm Prediction Center database, over the course of the last 20 years, the Commonwealth has experienced 1,443 damaging wind events, with an annual frequency of 72.15 per year. The events from the past 20 years caused over $29.4 million in property losses and $1.25 million in crop losses. Along with the monetary losses, these damaging wind events caused 88 injuries and three fatalities.

Thunderstorms

There have been several damaging thunderstorms in Massachusetts.

- The **March 1972** storm event resulted in a federal disaster declaration (FEMA DR-325); however, detailed information regarding this event was not available.
- A pair of spring storms occurring within a few days of one another in **March and April 1987** combined with snowmelt to produce record flooding in Massachusetts, Maine, and New Hampshire. The events brought over 8 inches of rainfall to some areas of Massachusetts and combined with already high river conditions to produce major flooding in the Connecticut and Merrimack River basins. In addition, several of the Corps of Engineers dams recorded record pool levels (NOAA, date unknown). This March-April 1987 event resulted in a federal disaster declaration (FEMA DR-790).
- On **October 19 through October 20, 1996**, 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 and 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. Major roadways were flooded. Many basements of homes were flooded and homes were severely damaged. This event resulted in a federal disaster declaration (FEMA DR-1142). Damage was estimated at over $10 million.

- In **June 1998**, a very slow moving and complex storm system moved through southeast New England. The combination of its slow movement and presence of tropical moisture across the region produced rainfall of 6 to 12 inches over much of eastern Massachusetts. This led to widespread urban, small stream, and river flooding. As a result, the counties of Suffolk, Essex, Middlesex, Norfolk, and Bristol received a presidential disaster declaration for the Individual Household Program (Individual Assistance) on June 23, 1998. The counties of Plymouth and Worcester were added to the initial declaration on July 3, 1998. This 1998 storm caused more than $7 million in personal property damage (FEMA DR-1224).
- A series of storm events occurred in Massachusetts between **March 5 and April 16, 2001**. These events included a major winter storm, heavy rainfall, and melting snow. On March 5, a major winter storm impacted 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. This series of flooding events resulted in a federal disaster declaration (FEMA DR-1364).
- On **October 9, 2005**, 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 federal disaster declaration (FEMA DR-1614) and Massachusetts received over $13 million in individual and public assistance.
- Between **May 13 and 15, 2006**, heavy rain caused widespread flooding across much of eastern Massachusetts. Rainfall totals ranged between eight and 12 inches, with some areas receiving over 12 inches of rain. Small streams and main stem rivers flooded, some experienced major flooding. Some areas experienced the worst flooding since the 1938 hurricane and the floods of March 1936. A state of emergency was declared by the governor and this event resulted in a FEMA disaster declaration (FEMA DR-1642). This severe storm and flooding event caused two fatalities and the Commonwealth received over $56 million in individual and public assistance.
- 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 federal 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.

- On **May 24, 2009** Bristol, Plymouth, Norfolk, and Worcester Counties experienced an intense thunderstorm causing minor flooding, winds exceeding 70 mph, and quarter sized to golf-ball sized hail.
- A series of severe storms and flooding events occurred throughout Massachusetts between **March 10 and April 26, 2010**. These storms brought widespread rainfall, causing small streams to rise above their flood stages. River flooding, coupled with heavy rain and poor drainage flooding resulted in a federal disaster declaration (FEMA DR-1895). This series of storms and flooding caused three injuries and over $145 million was received in individual and public assistance.
- On **July 26, 2011**, a strong cold front moved across southern New England in which severe thunderstorms developed. These storms produced large hail and damaging winds. The strong winds knocked down many trees and power lines in Berkshire, Hampden, and Hampshire Counties. Hail sizes were from quarter-size to ping-pong-ball-size. A microburst occurred will Wilbraham that resulted in significant tree damage. Hundreds of trees were downed. Many roads were closed. Based on tree damage, the strongest winds were estimated to have been between 90 and 100 mph in Wilbraham. The affected areas had over $1.5 million in property damage.
- Between **August 19 and 21, 2011**, Berkshire, Hampshire, Essex, Middlesex, Suffolk, Franklin, Norfolk, and Worcester Counties experienced severe thunderstorms that produced quarter sized hail and damaging winds. The strong winds knocked down numerous trees and power lines in the affected areas, causing nearly $100,000 in property damage.
- A rare October Nor'easter brought heavy snow to portions of southern New England on **October 29, 2011**. 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, MA. 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 federal disaster declaration (FEMA DR-4051) for the following counties: Berkshire, Franklin, Hampden, Hampshire, Middlesex, and Worcester.

Tornadoes

Over the course of the last 20 years, the Commonwealth has experienced 52 tornadoes, with an annual frequency of 2.6 per year. Table 14-8 lists all recorded tornado events in the Commonwealth since 1950.

TABLE 14-8.
TORNADO EVENTS BETWEEN 1950 AND 2011

Date	F-Scale	Fatalities	Injuries	Date	F-Scale	Fatalities	Injuries
8/21/1951	2	0	0	8/17/1970	1	0	0
12/18/1951	2	0	0	8/28/1970	2	0	0
6/9/1953	4	90	1228	10/3/1970	1	0	0
6/9/1953	3	0	17	10/3/1970	3	1	0
7/14/1954	1	0	0	7/1/1971	1	0	1
8/16/1954	1	0	0	7/1/1971	1	0	2
7/5/1955	2	0	0	7/17/1971	1	0	0
7/12/1955	2	0	0	9/13/1971	3	0	0
10/24/1955	1	0	0	11/7/1971	1	0	0
10/24/1955	1	0	0	11/7/1971	1	0	0
6/1/1956	1	0	0	7/3/1972	1	0	0
6/1/1956	1	0	0	7/3/1972	1	0	0
6/1/1956	1	0	0	7/21/1972	2	0	4
6/1/1956	1	0	14	7/21/1972	1	0	0
6/13/1956	1	0	0	8/9/1972	1	0	0
9/12/1956	1	0	0	8/9/1972	2	0	1
11/21/1956	2	0	0	8/9/1972	1	1	6
11/21/1956	2	0	0	8/27/1972	2	0	0
11/21/1956	2	0	0	9/14/1972	1	0	0
12/18/1956	1	0	0	9/14/1972	0	0	0
5/10/1957	-9	0	0	8/2/1973	0	0	0
5/10/1957	1	0	0	8/28/1973	4	4	36
6/19/1957	1	0	0	9/6/1973	1	0	0
6/19/1957	1	0	0	9/29/1974	3	0	1
6/19/1957	1	0	0	7/13/1975	2	0	0
7/5/1957	1	0	0	7/24/1975	2	0	0
7/5/1957	2	0	0	5/3/1976	1	0	0
6/26/1958	1	0	0	6/29/1977	1	0	0
7/11/1958	2	0	0	8/22/1977	1	0	2
7/11/1958	1	0	0	7/27/1978	0	0	0
7/11/1958	1	0	0	8/10/1979	2	2	2
7/11/1958	2	0	0	8/10/1979	1	0	1
7/16/1958	1	0	1	6/22/1981	3	0	3
7/29/1958	1	0	0	7/18/1983	0	0	0
8/13/1958	1	0	0	8/1/1983	0	0	0
8/14/1958	2	0	0	7/5/1984	1	0	0
8/25/1958	2	0	0	7/5/1984	1	0	0
9/7/1958	0	0	0	7/11/1984	1	0	0
9/7/1958	0	1	1	9/27/1985	1	0	0
7/13/1960	0	0	0	8/7/1986	1	0	0
7/2/1961	0	0	0	8/8/1986	1	0	0

TABLE 14-8.
TORNADO EVENTS BETWEEN 1950 AND 2011

Date	F-Scale	Fatalities	Injuries	Date	F-Scale	Fatalities	Injuries
7/3/1961	0	0	0	9/16/1986	1	0	0
7/21/1961	2	0	0	7/10/1989	1	0	0
7/21/1962	1	0	3	7/10/1989	1	0	0
10/12/1962	2	0	0	7/10/1989	1	0	0
5/20/1963	2	0	0	7/10/1989	1	0	0
5/20/1963	2	0	0	7/10/1989	0	0	0
5/20/1963	2	0	0	7/10/1989	1	0	1
5/20/1963	2	0	0	7/10/1989	0	0	0
7/18/1963	1	0	0	5/18/1990	0	0	0
7/21/1963	0	0	0	5/18/1990	0	0	0
9/12/1963	1	0	0	8/10/1990	0	0	0
10/3/1963	1	0	0	8/15/1991	1	0	0
5/19/1964	0	0	0	6/24/1992	0	0	0
5/19/1964	1	0	0	6/27/1992	0	0	4
7/4/1964	1	0	0	5/29/1995	4	3	24
7/29/1964	0	0	0	7/3/1997	1	0	0
7/29/1964	1	0	0	7/3/1997	1	0	0
5/27/1965	1	0	0	7/3/1997	2	0	0
6/9/1965	0	0	0	7/3/1997	2	0	0
8/10/1965	1	0	0	7/3/1997	1	0	0
8/28/1965	2	0	0	7/3/1997	2	0	0
3/1/1966	2	0	0	8/6/1997	0	0	0
8/11/1966	2	0	0	8/20/1997	0	0	0
8/11/1966	2	0	0	6/2/2000	1	0	0
8/31/1966	2	0	0	6/17/2001	1	0	0
8/31/1966	0	0	1	6/30/2001	0	0	0
11/18/1967	2	0	0	7/23/2002	1	0	0
7/1/1968	1	0	1	8/20/2004	0	0	0
7/17/1968	1	0	0	8/21/2004	1	0	0
7/19/1968	0	0	0	6/29/2005	0	0	0
8/9/1968	1	0	4	7/11/2006	2	0	0
8/9/1968	1	0	0	7/19/2007	0	0	0
8/9/1968	1	0	0	7/23/2008	0	0	0
5/29/1969	1	0	0	6/1/2011	3	3	200
6/18/1970	1	0	0	6/1/2011	1	0	0
7/11/1970	1	0	0	6/1/2011	0	0	0
8/2/1970	1	0	0	6/1/2011	0	0	0

The most destructive tornado in New England history was the Worcester tornado of June 9, 1953. The F4 tornado hit at about 3:30 p.m. The funnel quickly intensified, carving a 46-mile path of death and destruction as it moved through seven towns. The twister tore through Barre, Rutland, Holden, Worcester,

Shrewsbury, Westborough, and Southborough. It killed 94 people and left approximately 1,300 people injured. The National Storm Prediction Center 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 and into the Atlantic Ocean. A music box and a 3-foot aluminum trap door were found about 35 miles away, according to NOAA. Further, frozen mattresses fell into Boston Harbor, after having been carried aloft by the tornado.

On August 15, 1991, an F1 tornado touched down in Georgetown (Essex County) at the north end of Rock Pond and then skipped along, moving from northwest to southeast, across Route 97. It then touched down near the south-southeast shore of Pentucket Pond where it caused the greatest damage. A number of large trees were snapped off 20 feet above the ground. A car was crushed by a falling tree and a modular home had its roof blown off. The tornado continued approximately one-quarter mile southeast and then disappeared. Width of the damage path varied from 300 yards to as narrow as 50 yards.

Based on the extent of destruction, the Worcester tornado may have been an EF5 – the most severe on the Enhanced Fujita Tornado Scale. Two other deadly tornadoes occurred later – the May 29, 1995 Great Barrington tornado, an EF4, which claimed 3 lives and injured 24; and the August 28, 1973 West Stockbridge tornado, a EF4, which killed 4 and injured 36.

A National Weather Service Damage Survey Team concluded that an EF1 Tornado and/or Waterspout occurred in a portion of Eastern Rhode Island and Southeast Massachusetts on July 23, 2008 at 4:05 PM. What began as a waterspout just off of Rumstick Point in Barrington, Rhode Island quickly moved onto land over the southern portion of Warren, Rhode Island. It then continued eastward into southeastern Massachusetts. Most of the damage had a rating of EF0 on the Enhanced Fujita Scale with wind speeds of 65 to 75 mph. However, there was one small section of Warren, RI that demonstrated EF1 damage, where wind speeds were estimated at 90 mph. The tornado path length was 4.2 miles and very narrow with a path width of only 40 yards. No injuries were reported. The majority of the damage was to trees, some of which fell onto power lines and houses.

An EF2 tornado moving north-northeast from Rockingham County New Hampshire into Merrimack County New Hampshire on July 24, 2008. Although this event did not fall within the Massachusetts borders, the touchdown occurred about 35 miles north of the state line. Homes and buildings in the Tornadoes path sustained damage along the path, which was up to a half-mile wide and 50 miles long. The tornado traveled through 5 counties, resulting in 1 fatality and damage to over 100 structures some of which were completely destroyed.

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). This event resulted in a FEMA disaster declaration (FEMA DR-1994).

Extreme Temperatures

Since 1994, there have been 19 cold weather events within the Commonwealth, ranging from Cold/Wind Chill to Extreme Cold/Wind Chill events. Since 1995, there have been 43 warm weather events, ranging from Record Warmth/Heat to Excessive Heat events. Detailed information regarding most of these extreme temperature events was not available.

In June 2008, temperatures across Massachusetts were recorded above 90 degrees for a period of four days, breaking records in some areas. The high of 94 degrees in Worcester was three degrees hotter than a

1984 record and the high of 96 degrees in Providence, two degrees above a 1974 record. As a result of days of heat public schools in Taunton and Fall River were dismissed early. While in other towns children's attendance was optional.

In 2012, Massachusetts experienced 27 broken heat records. Most of these records were broken between June 20 and June 22, 2012. June 2012 was the first major heat wave of the summer to hit the east coast, including Massachusetts.

Table 14-9 and Table 14-10 summarize historical cold-weather and warm-weather events.

TABLE 14-9.
NOTABLE COLD WEATHER EVENTS

Date	Type	Date	Type
1/15/1994	Cold	2/3/2007	Extreme Cold/Wind Chill
1/18/1994	Cold	1/1/2009	Cold/Wind Chill
1/19/1994	Cold	1/16/2009	Cold/Wind Chill
1/27/1994	Cold	4/29/2009	Frost/Freeze
1/17/2000	Extreme Cold	5/19/2009	Frost/Freeze
5/20/2002	Freeze	6/1/2009	Frost/Freeze
5/22/2002	Freeze	5/9/2010	Frost/Freeze
10/15/2002	Freeze	5/13/2010	Frost/Freeze
1/15/2004	Extreme Cold/Wind Chill	1/23/2011	Extreme Cold/Wind Chill
1/25/2007	Cold/Wind Chill		

TABLE 14-10.
NOTABLE WARM WEATHER EVENTS

Date	Type	Date	Type
1/13/1995	Record Warmth	7/16/1999	Record Warmth
7/13/1995	Record Heat	7/17/1999	Record Warmth
2/22/1997	Record Warmth	7/18/1999	Record Warmth
1/3/1998	Record Warmth	9/7/1999	Record Warmth
3/27/1998	Record Warmth	3/8/2000	Record Warmth
3/28/1998	Record Warmth	5/8/2000	Record Heat
3/31/1998	Record Warmth	5/9/2000	Record Heat
9/27/1998	Record Heat	10/14/2000	Record Warmth
12/2/1998	Record Warmth	12/17/2000	Record Warmth
12/7/1998	Record Warmth	4/24/2001	Record Heat
1/24/1999	Record Warmth	5/2/2001	Record Heat
2/12/1999	Record Warmth	5/3/2001	Record Heat
3/18/1999	Record Warmth	5/4/2001	Record Heat
6/7/1999	Excessive Heat	5/12/2001	Record Heat

TABLE 14-10.
NOTABLE WARM WEATHER EVENTS

Date	Type	Date	Type
6/7/1999	Record Heat	7/6/2010	Excessive Heat
7/4/1999	Excessive Heat	7/21/2011	Excessive Heat
7/5/1999	Record Heat		

Drought

Most droughts in Massachusetts have started with dry winters, rather than a dry summer. During the summer of 2002, one-third of the country, including Massachusetts, experienced drought conditions. Massachusetts has experienced multi-year drought periods in 1879-83, 1908-12, 1929-32, 1939-44, 1961-69, and 1980- 83. The most severe drought on record in the northeastern United States was during 1961-69. Water supplies and agriculture were affected because of the severity and long duration of the drought. Precipitation was less than average beginning in 1960 in western Massachusetts and beginning in 1962 in eastern Massachusetts. Table 14-11 summarizes estimated historical droughts in the Commonwealth based on the SPI.

TABLE 14-11.
ESTIMATED DROUGHTS BASED ON THE MASSACHUSETTS STANDARDIZED PRECIPITATION INDEX

Year(s)	Duration (months)	Lowest SPI Statistic	Lowest SPI value for Statistic	Month of Lowest SPI Statistic	Estimated Drought Level
1924-1925	13	12-month	-2.28	August-25	Warning
1930-1931	12	12-month	-2.52	September-30	Emergency
1934-1935	15	12-month	-2.10	March-35	Warning
1944	11	12-month	-1.95	October-44	Watch
1949-1950	15	12-month	-1.92	May-50	Watch
1957-1958	12	12-month	-2.23	July-57	Warning
1964-1967	36	12-month	-3.26	April-66	Emergency
1971	8	12-month	-1.90	February-72	Watch
1980-1981	13	12-month	-1.84	March-81	Watch
1985	7	12-month	-1.94	July-85	Watch
1988-1989	11	12-month	-1.73	February-89	Watch
1990-1991	9	12-month	-1.54	July-91	Watch
2001-2002	13	12-month	-1.63	August-02	Watch

The summer of 1999 was a very dry summer with high temperatures. The eastern U.S. experienced most of this drought/heat wave and had extensive agricultural losses. Overall, this event caused $1 billion in the U.S. and resulted in 502 deaths.

March 2007 was the second driest March on record, increasing fire danger. August 2010 found stream flow in western and central Massachusetts was below normal levels from August into September. Record daily lows were recorded in early September in areas of western Massachusetts. Reservoir supply in the Northeast and Central Regions were also below normal.

The 2012 drought/heat wave was the most extensive drought to affect the U.S. since the 1930s. Drought conditions affected more than half the county for the majority of 2012. Drought impacts were most costly across the central agricultural states, resulting in widespread harvest failure for corn, sorghum, and soybean crops. The summer heat wave associated with this drought caused 123 direct deaths. In Massachusetts, January 2012 through March 2012 was the driest start to any year on record, with only 6 inches of total precipitation. Most areas in southern New England typically were running 6 to 8 inches below normal. April 2012 again found much of the Commonwealth under drought conditions, lasting until May 2012.

An analysis of historical rainfall data indicated that based on this index alone, between 1850 and 2012, the Commonwealth experienced drought emergency conditions in 1883, 1911, 1941, 1957, and 1965-1966. The 1965-1966 drought period is viewed as the most severe and longest duration drought to have occurred in Massachusetts. On a monthly basis, there is a 1-percent chance of the Commonwealth being in a drought emergency. Drought warning conditions not associated with drought emergencies occurred in 1894, 1915, 1930, and 1985. On a monthly basis, there is a 2-percent chance of the Massachusetts being in a drought warning level. Drought watch conditions not associated with higher levels of drought would have typically occurred in three to four years per decade between 1850 and 1950. The drought emergency dominated the 1960s. There were no drought watch conditions or above in the 1970s. In the 1980s, there was a drought watch level of precipitation between 1980 and 1981, followed by a drought warning in 1985. A frequency of drought watch conditions, at a rate of three years per decade, occurred in 1995, 1998, and 1999. In the 2000s, drought watches occurred in 2001 and 2002. The overall frequency of the Commonwealth being in a drought watch is 8-percent each month.

Agriculture-related drought disasters are quite common. One-half to two-thirds of the counties in the U.S. have been designated as disaster areas in each of the past several years. The Secretary of Agriculture is authorized to designate counties as disaster areas to make emergency loans to producers suffering losses in those counties and in counties that are contiguous to a designated county. Table 14-12 presents USDA declared drought and excessive heat events impacting the Commonwealth.

TABLE 14-12.
DROUGHT AND EXTREME HEAT EVENTS DECLARED BY USDA

Incidence Period	Event Type	USDA Designation Number	Counties Included in Disaster	Losses / Impacts
November 4, 2010	Drought and Excessive Heat	S3049	Franklin	N/A
December 17, 2010	Drought	S3072	Berkshire	N/A
January 18, 2011	Excessive Heat	S3091	Barnstable, Bristol, Dukes, Norfolk, Plymouth	N/A

Source: USDA, 2012
S = Secretarial National Disaster Determination

14.2.3 Severity

Many forms of severe weather can lead to injury and death as well as property damage. Figure 14-13 shows national fatality statistics associated with severe weather for 2011 and the preceding 10- and 30-year periods. The following sections describe severity of specific weather types.

High Winds

Windstorms have been known to cause damage to utilities. The predicted wind speed given in wind warnings issued by the National Weather Service is for a one-minute average; gusts may be 25 to 30 percent higher.

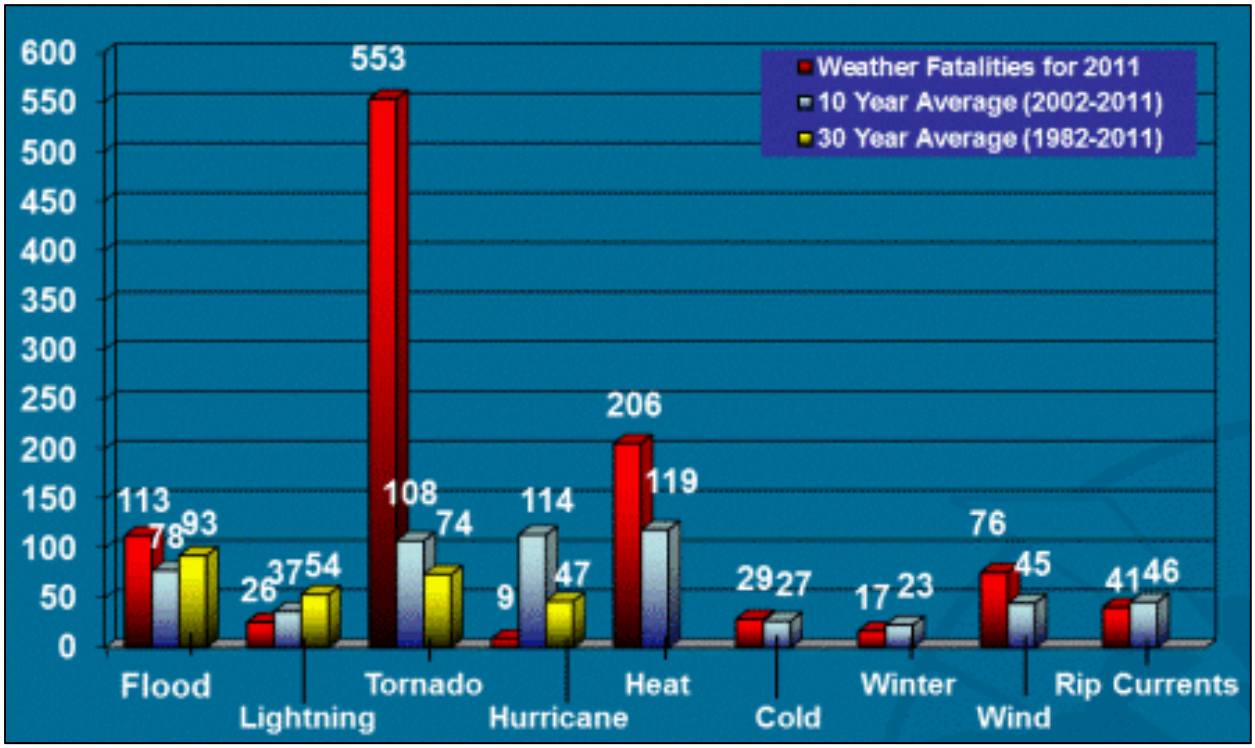


Figure 14-13. National Fatalities from Weather Events

Thunderstorms

The most common problems associated with severe storms are immobility and loss of utilities. Fatalities are uncommon, but can occur. Roads may become impassable due to flooding, downed trees, ice or snow, or a landslide. Power lines may be downed due to high winds or ice accumulation, and services such as water or phone may not be able to operate without power. Lightning can cause severe damage and injury. Windstorms can be a frequent problem and have been known to cause damage to utilities. The predicted wind speed given in wind advisories or high wind warnings issued by the National Weather Service is for a one-minute average; gusts may be 25 to 30 percent higher.

Tornadoes

Tornadoes are potentially the most dangerous of local storms. If a major tornado were to strike within the populated areas of the Commonwealth, damage could be widespread. Businesses could be forced to close for an extended period or permanently, fatalities could be high, many people could be homeless for an extended period, and routine services such as telephone or power could be disrupted. Buildings may be damaged or destroyed. Massachusetts ranks 35th among states for frequency of tornadoes, 14th for the frequency of tornadoes per square mile, 21st for injuries, and 12th for cost of damage.

Extreme Temperature

The severity of extreme cold temperatures is generally measured through the Wind Chill Temperature Index. Wind Chill Temperature is the temperature that people and animals feel when outside and it is based on the rate of heat loss from exposed skin by the effects of wind and cold. As the wind increases, the body is cooled at a faster rate causing the skin's temperature to drop. The severity of extreme heat temperatures are generally measured through the Heat Index. The Heat Index can be used to determine what effects the temperature and humidity can have on the population. Detailed information regarding the Wind Chill Temperature Index and Heat Index is found in Section 0.

Drought

The severity of a drought depends on the degree of moisture deficiency, the duration, and the size and location of the affected area. The longer the duration of the drought and the larger the area impacted, the more severe the potential impacts. Droughts are not usually associated with immediate impacts on people or property, but they can have significant impacts on agriculture, which can impact people indirectly. When measuring the severity of droughts, analysts typically look at economic impacts on a planning area.

Unlike most disasters, droughts normally occur slowly but may last a long time. On average, the nationwide annual impacts of drought are greater than the impacts of any other natural hazard. They are estimated to be between $6 billion and $8 billion annually in the United States and occur primarily in the agriculture, transportation, recreation and tourism, forestry, and energy sectors. Social and environmental impacts are also significant, although it is difficult to put a precise cost on these impacts.

Drought affects both groundwater sources and smaller surface water reservoir supplies. 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 pumping capacity or wells going dry. Shallow wells are more susceptible than deep wells. Reduced replenishment of groundwater affects streams. Much of the flow in streams comes from groundwater, especially during the summer when there is more evapotranspiration (plant uptake of water) and less rainfall infiltration. Reduced groundwater levels mean that even less water will enter streams when steam flows are lowest. This can contribute to warmer stream temperatures and decreased dissolved oxygen availability for aquatic organisms, in addition to diminished aquatic habitat. In terms of public water supply impacts of drought, ground water sources may develop water quality problems. Suppliers may struggle to meet system demands while maintaining adequate water supply 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 some cases, potable water may need to be supplied via distribution centers for residents.

A drought directly or indirectly impacts all people in affected areas. A drought can result in farmers not being able to plant crops or the failure of planted crops. This results in loss of work for farm workers and those in related food processing jobs. Other water-dependent industries are commonly forced to shut down all or a portion of their facilities, resulting in further layoffs. A drought can harm recreational companies that use water (e.g., swimming pools, water parks, and river rafting companies) as well as landscape and nursery businesses because people will not invest in new plants if water is not available to sustain them.

14.2.4 Warning Time

High Winds and Thunderstorms

Meteorologists can often predict the likelihood of a severe thunderstorm outbreak with several days of lead time. However, they can only pin this down to portions of states and cannot predict the exact time of onset or severity of individual events. Some events may develop quickly and have only a few minutes of advance warning time...such as "pulse" type / "popcorn" afternoon thunderstorms. Other storms, such as a well-organized squall line, can yield lead times of up to an hour (from the time a Severe Thunderstorm

Warning is issued to the time that severe criteria are observed). Tornadoes have the least amount of lead time. Doppler radar and a dense network of spotters and amateur radio operators across the region have helped increase warning lead time across southern New England.

Tornadoes

Tornado watches and warnings are issued by the local NWS office. A tornado watch is released when tornadoes are possible in an area. 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. Occasionally, tornadoes develop so rapidly, that little, if any, advance warning is possible.

Extreme Temperatures

Meteorologists can accurately forecast extreme temperature event development and the severity of the associated conditions with several days lead time. These forecasts provide an opportunity for public health and other officials to notify vulnerable populations. For heat events, the NWS issues excessive heat outlooks when the potential exists for an excessive heat event in the next three to seven days. 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. Winter temperatures may fall to extreme cold readings with no wind occurring. Currently, the only way to headline very cold temperatures is with the use of the Wind Chill Advisory or Warning products.

Drought

Droughts are climatic patterns that occur over long periods of time. Only generalized warning can take place due to the numerous variables that scientists have not pieced together well enough to make accurate and precise predictions. Drought levels are established at gradual levels to alert the public to conditions that, if continued, could result in more serious degrees of drought. Initial drought levels include Advisory and Watch levels. Voluntary water conservation efforts are advised during early stages of drought conditions. Increasing conservation requirements are expected when Drought Warning and Emergency conditions develop. These higher levels of drought require months of dry conditions to be reached. Therefore, there is a lot of lead time as drought conditions progress.

Empirical studies conducted over the past century have shown that meteorological drought is never the result of a single cause. It is the result of many causes, often synergistic in nature; these include global weather patterns that produce persistent, upper-level high-pressure systems along the West Coast with warm, dry air resulting in less precipitation.

Scientists at this time do not know how to predict drought more than a month in advance for most locations. Predicting drought depends on the ability to forecast precipitation and temperature. Anomalies of precipitation and temperature may last from several months to several decades. How long they last depends on interactions between the atmosphere and the oceans, soil moisture and land surface processes, topography, internal dynamics, and the accumulated influence of weather systems on the global scale.

Products produced by the National Drought Mitigation Center include a weekly Drought Monitor map for the United States (http://droughtmonitor.unl.edu/). The National Climate Prediction Center publishes a monthly U.S. Seasonal Drought Outlook that can be used to preview the potential for developing drought conditions (http://www.cpc.ncep.noaa.gov/products/expert_assessment/seasonal_drought.html).

14.2.5 Frequency of Occurrences

The Massachusetts Drought Management Plan (2013) has determined drought occurrence and frequency in the Commonwealth. Figure 14-14 summarizes statewide drought levels using the Standard Precipitation Index (SPI) parameter.

Review of EOEEA data demonstrates that on a monthly basis, the Commonwealth has been in a Drought Watch to Emergency condition 11-percent of the time between 1850 and 2012. On a monthly basis, there is a one-percent chance of being in a drought Emergency status, and a two-percent chance of being in a drought Warning.

Source: EOEEA and MEMA, 2013

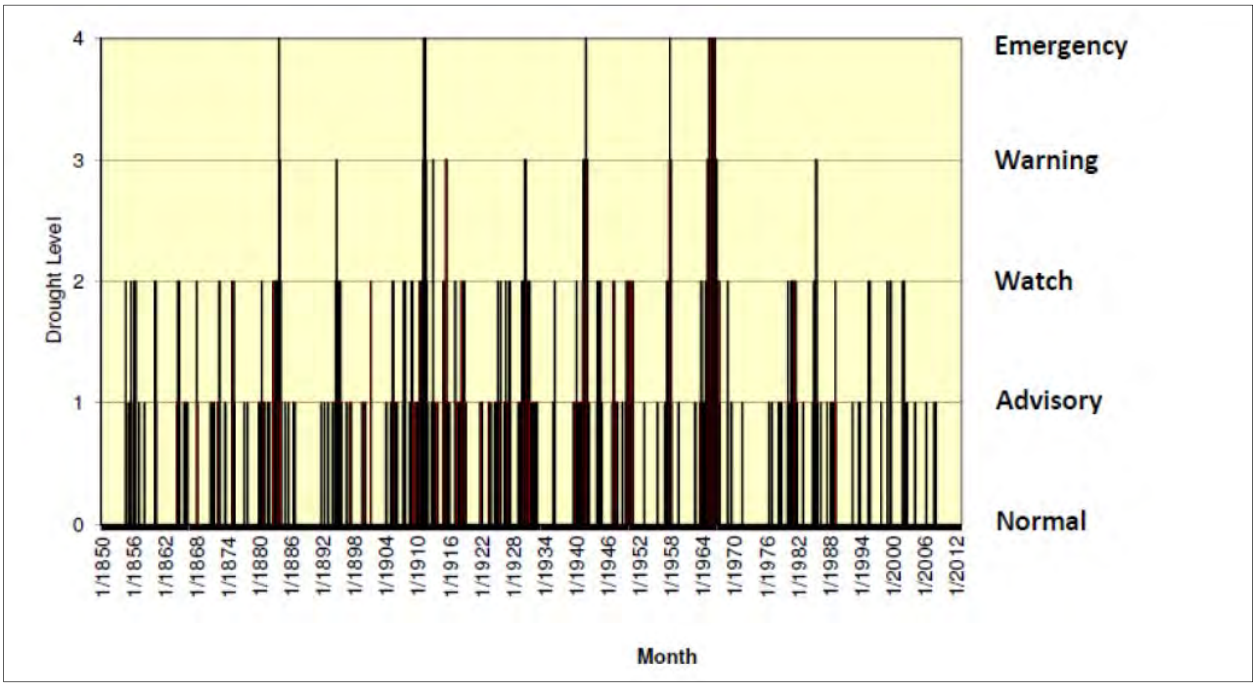


Figure 14-14. Statewide Drought Levels using SPI Thresholds from 1850 to 2012

Drought Watches not associated with higher levels of drought generally would have occurred three to four years per decade between 1850 and 1950. While drought Emergencies dominated the 1960s, there were no drought Watches or above during the 1970s. However, during the 1980s, there was a lengthy drought Watch level of precipitation between 1980 and 1981, followed by a drought Warning in 1985. A frequency of drought Watches at a rate of 3 years per decade resumed in the 1990s (1995, 1998, 1999). In the 2000s, Drought Watches occurred in 2001 and 2002. The overall frequency of being in a drought Watch is 8 percent in a month (EOEEA and MEMA, 2013).

14.3 SECONDARY HAZARDS

The most significant secondary hazards associated with severe local storms are floods, falling and downed trees, landslides, and downed power lines. Rapidly melting snow combined with heavy rain can overwhelm both natural and man-made drainage systems, causing overflow and property destruction. Landslides occur when the soil on slopes becomes oversaturated and fails.

The secondary hazard most commonly associated with drought is wildfire. A prolonged lack of precipitation dries out vegetation, which becomes increasingly susceptible to ignition as the duration of the drought extends.

14.4 CLIMATE CHANGE IMPACTS

Climate change presents a significant challenge for risk management associated with severe weather. The frequency of severe weather events has increased steadily over the last century. The number of weather-related disasters during the 1990s was four times that of the 1950s, and cost 14 times as much in economic losses. Historical data show that the probability for severe weather events increases in a warmer climate (see Figure 14-15). The changing hydrograph caused by climate change could have a significant

impact on the intensity, duration, and frequency of storm events. All of these impacts could have significant economic consequences.

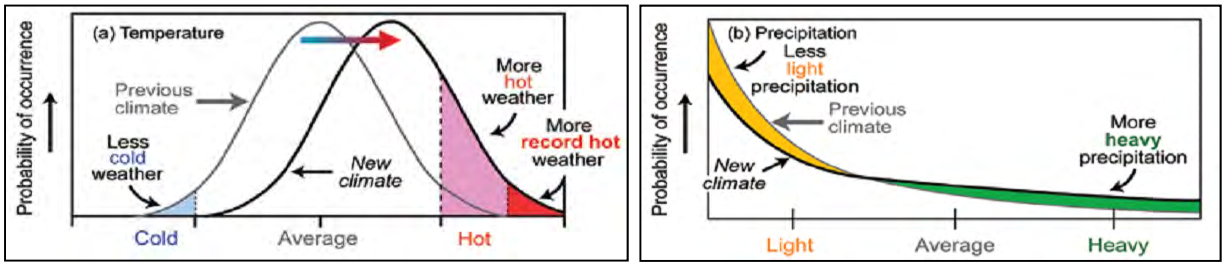


Figure 14-15. Severe Weather Probabilities in Warmer Climates

With a warmer climate, droughts could become more frequent, more severe, and longer-lasting. From 1987 to 1989, losses from drought in the U.S. totaled $39 billion (OTA, 1993). More frequent extreme events such as droughts could end up being more cause for concern than the long-term change in temperature and precipitation averages.

Extreme temperatures are among the most dangerous impacts associated with climate change. Additional impacts pose serious threats to the safety of urban areas, including droughts, rising sea level, and decrease biodiversity, but extreme heat is among the most harmful to public health and safety. It is expected that climate change will cause temperatures to increase, but it is difficult to predict by how much or at what rate.

14.5 EXPOSURE

To understand risk, the assets exposed to the hazard areas are identified. For the severe weather hazard the entire Commonwealth of Massachusetts is exposed. The following discusses the Commonwealth of Massachusetts' exposure to the severe weather hazard including:

- Population
- State facilities
- Critical facilities
- Economy

14.5.1 Population

For the purposes of this Plan, the entire population of the Commonwealth of Massachusetts is exposed to severe weather events. Certain areas are more vulnerable to specific severe weather events than others, due to geographic location and local weather patterns.

Residents may be displaced or require temporary to long-term sheltering due to severe weather events. In addition, downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life. Socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing.

14.5.2 State Facilities

High Winds and Thunderstorms

Damage to buildings is dependent upon several factors including wind speed, storm duration, path of the storm track or tornado, distance from the tornado funnel and building construction. According to Hazus-MH's wind model, direct wind-induced damage (wind pressures and windborne debris) to buildings is dependent upon the performance of components and cladding, including roof covering (shingles, tiles,

membrane), roof sheathing (wood frame construction only), windows and doors and is modeled as such. Structural wall failures can occur for masonry and wood frame walls and uplift of whole roof systems due to failure at the roof/wall connections. Foundation failures (i.e., sliding, overturning, and uplift) can potentially take place for manufactured homes.

Impacts to transportation lifelines affect both short-term (e.g., evacuation activities) and long-term (e.g., day-to-day commuting) transportation needs. Utility infrastructure (power lines, gas lines, electrical systems) could suffer damage and impacts can result in the loss of power, which can impact business operations and can impact heating or cooling provision to citizens (including the young and elderly, who are particularly vulnerable to temperature-related health impacts). Post-event, there is a risk of fire, electrocution or an explosion.

Massachusetts is divided into four wind zones, the limits of which are defined by the Massachusetts State Building Code (Seventh Edition). National wind data prepared by the American Society of Civil Engineers serve as the basis of these wind zones ("Minimum Design Loads for Buildings and Other Structures," ASCE-7). Generally speaking, structures should be designed to withstand the total wind load of the zone in which they are located. Refer to the State Building Code for appropriate reference wind pressures, wind forces on roofs, etc.

Using ArcMap GIS software, these data were overlaid with the DCAMM facility data; the appropriate wind load zone determination was assigned to each facility, as summarized in Table 14-13. Figure 14-16 illustrates the wind load zones.

TABLE 14-13.
NUMBER OF STATE-OWNED AND LEASED BUILDINGS IN WIND LOAD ZONES

	< 90 mph		90 mph		100 mph		110 mph		
County	Lease	Own	Lease	Own	Lease	Own	Lease	Own	Total
Barnstable	—	—	—	—	—	—	12	297	309
Berkshire	20	292	—	46	—	—	—	—	358
Bristol	—	—	—	—	18	205	33	226	482
Dukes	—	—	—	—	3	10	—	—	13
Essex	—	—	13	52	26	447	—	—	538
Franklin	6	75	1	129	—	—	—	—	211
Hampden	—	—	36	430	—	—	—	—	466
Hampshire	—	2	16	544	—	—	—	—	562
Middlesex	—	—	11	335	53	708	—	—	1,107
Nantucket	—	—	—	—	—	—	2	3	5
Norfolk	—	—	—	—	26	654	—	—	680
Plymouth	—	—	—	—	18	340	16	168	542
Suffolk	—	—	—	—	73	326	—	—	399
Worcester	—	—	44	837	5	207	—	—	1,093
Total	**26**	**369**	**121**	**2,373**	**222**	**2,897**	**63**	**694**	**6,765**

Source: DCAMM, 2012
Note: Building data are updated as agencies change or modify. State-owned building information is current as of October 3, 2012, and the state-leased building information is current as of October 10, 2010, with a total of 6,765 buildings.

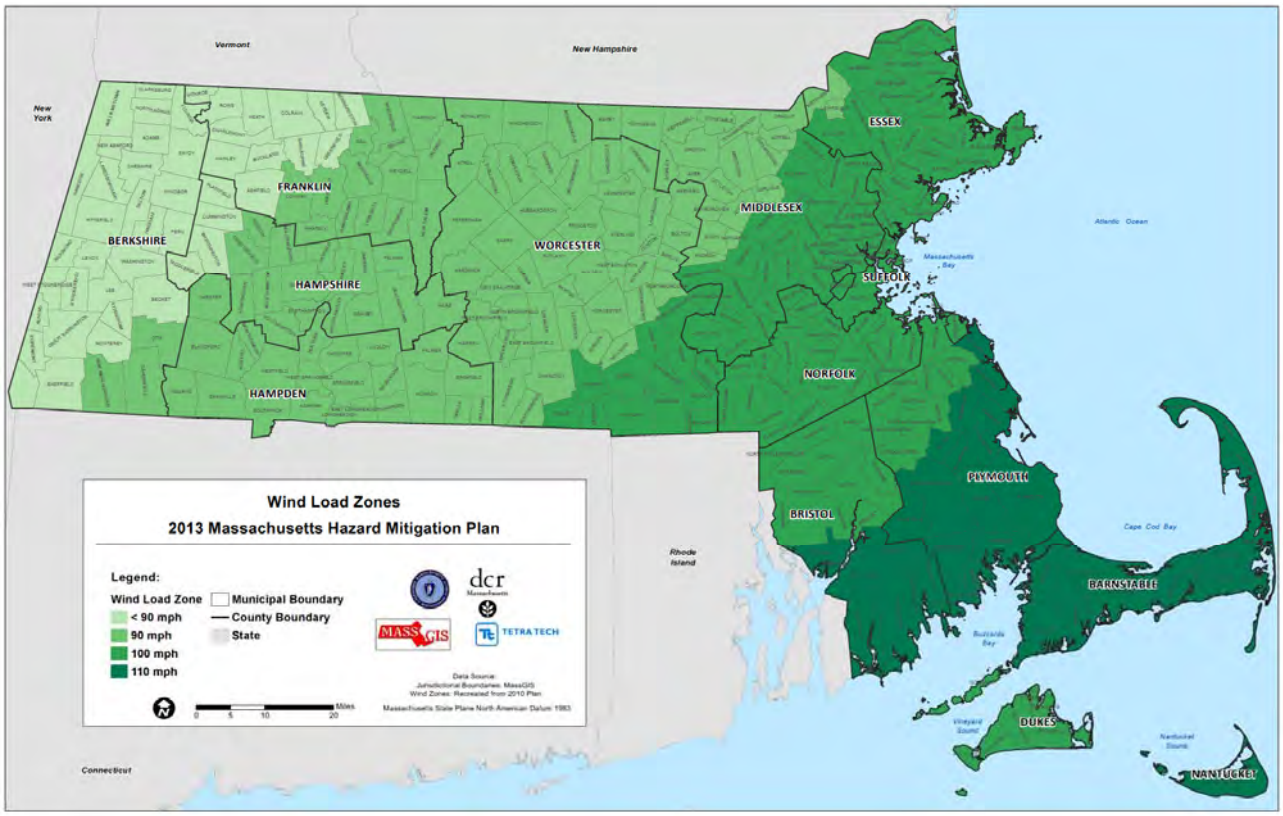


Figure 14-16. Wind Load Zones in the Commonwealth of Massachusetts

Tornadoes

Figure 14-17 illustrates the reported tornado occurrences, based on initial touch-down locations across the Commonwealth. The number of historical tornado touch-downs in 25 miles was updated using the NOAA Storm Prediction Center's dataset through 2011 (2012 data were not available at the time of the 2013 Plan update). To calculate density, the ArcGIS kernel density tool was used.

As was conducted in the 2010 SHMP, tornado risk for the 2013 update is based on probability of occurrence of past events. The density per 25 square miles indicates the probable number of tornado touchdowns for each 25 square mile cell within the contoured zone that can be expected over a similar period of record (approximately 60 years). It should be noted that the density number does not indicate the number of events that can be expected across the entire zone, but the percent probability of occurrence in the given area. The analysis indicated that the area at greatest risk for a tornado touchdown runs from central to northeastern Massachusetts, with the greatest historical touch-down density located in Hampden and Hampshire Counties.

To analyze how tornadoes could impact state facilities, DCAMM data were overlaid with the states area of greatest historical tornado density (0.011 to 0.014). There are over 397 state-owned and leased structures in this zone. The remaining 6,368 state facilities are in low tornado probability areas (<0.011).

Extreme Temperatures

All of the state-owned and leased buildings are exposed to the extreme temperature hazard. Extreme heat generally does not impact buildings. Losses may be associated with the overheating of HVAC systems. Extreme cold temperature events can damage buildings through freezing/bursting pipes and freeze/thaw cycles. Additionally, manufactured homes (mobile homes) and antiquated or poorly constructed facilities may have inadequate capabilities to withstand extreme temperatures.

Drought

No structures are anticipated to be directly affected by a drought, and all are expected to be operational during a drought event. However, droughts contribute to conditions conducive to wildfires. Risk to life and property is greatest in those areas where forested areas adjoin urbanized areas (high density residential, commercial, and industrial), also known as the wildland-urban interface. Therefore, all state facilities in and adjacent to the wildland-urban interface are considered vulnerable to wildfire. See Section 9 regarding the wildland fire hazard in the Commonwealth.

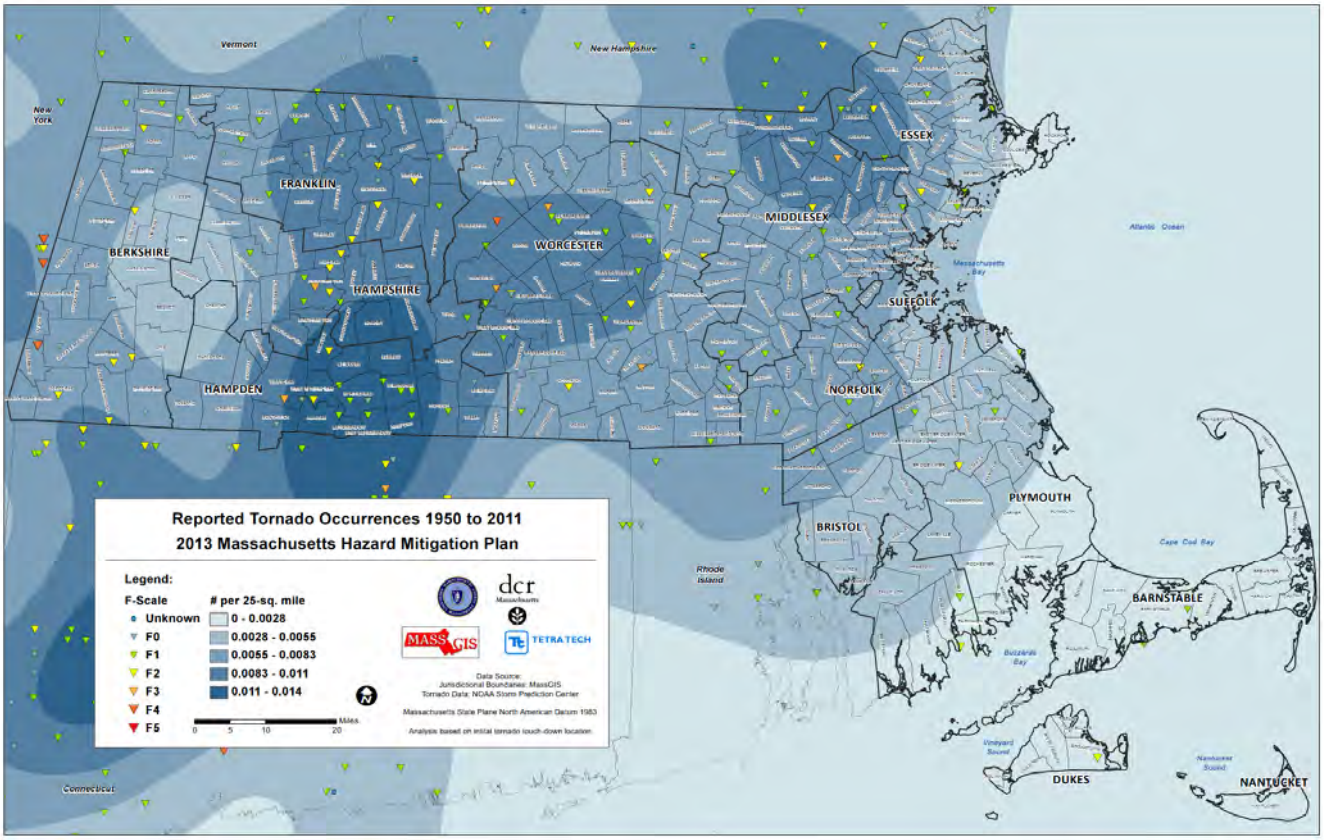


Figure 14-17. Reported Tornado Occurrences from 1950 to 2011

14.5.3 Critical Facilities

High Winds and Thunderstorms

All critical facilities are exposed to severe weather events such as high winds and thunderstorms. The most common problem associated with severe weather is loss of utilities. Downed power lines can cause blackouts, leaving large areas isolated. Phone, water, and sewer systems may not function. Roads may become impassable due to flash or urban flooding. As discussed earlier, there are four wind load zones in the Commonwealth. Table 14-14 summarizes the number of critical facilities within each wind load zone.

Tornadoes

All critical facilities and infrastructure are exposed to tornado events. Similar to the analysis conducted for state facilities, the number of critical facilities and bridges located within the greatest historical tornado touch-down area (density of 0.011 – 0.014), or area of highest probability of occurrence, are listed in Table 14-15. There are a total of 300 bridges in the 0.011-0.014 density zone.

TABLE 14-14.
NUMBER OF CRITICAL FACILITIES LOCATED IN EACH WIND LOAD ZONE

Wind Zone	Police	Fire	Emergency Operation Centers	Hospitals	Schools (pre-K-grade 12)	Colleges
< 90 mph	46	59	0	5	99	7
90 mph	137	240	1	22	830	46
100 mph	200	384	1	47	1,529	137
110 mph	54	106	0	8	309	15

Source: MassGIS, 2012

TABLE 14-15.
NUMBER OF CRITICAL FACILITIES IN THE TORNADO PROBABILITY ZONES

Density	Police	Fire	Emergency Operation Centers	Hospitals	Schools (pre-K-grade 12)	Colleges
0.011 to 0.014	20	41	1	5	215	16
< 0.011	417	748	1	77	2,552	189

Source: MassGIS, 2012

Extreme Temperatures

All critical facilities are exposed to the extreme temperature hazard. Extreme heat generally does not impact buildings. Losses may be associated with the overheating of HVAC systems. Extreme cold temperature events can damage buildings through freezing/bursting pipes and freeze/thaw cycles. Additionally, manufactured homes (mobile homes) and antiquated or poorly constructed facilities may have inadequate capabilities to withstand extreme temperatures.

Drought

No critical facilities are anticipated to be directly affected by a drought, and all are expected to be operational during a drought event. However, droughts contribute to conditions conducive to wildfires. All critical facilities in and adjacent to the wildland-urban interface are considered vulnerable to wildfire. See Section 9 regarding the wildland fire hazard in the Commonwealth.

14.5.4 Economy

High Winds, Thunderstorms and Tornadoes

Wind storms, thunderstorms, and tornado events may impact the economy, including loss of business function, water supply system damage, damage to inventory, relocation costs, wage loss, and rental loss due to the repair/replacement of buildings. Recovery and clean-up costs can also be costly and impact the economy as well. Tornado events are typically localized, whereas high wind and thunderstorm events can be more widespread. The impacts of high winds, thunderstorms, and tornadoes on the environment may include severe damage to plant species. This includes uprooting or total destruction of trees and increased threat of wildfire in areas of tree debris. Public drinking water reservoirs may also be damaged by widespread wind damage uprooting watershed forests and creating serious water quality disturbances.

Extreme Temperatures and Drought

Extreme temperature events also have impacts on the economy, including loss of business function and damage/loss of inventory. Business-owners may be faced with increased financial burdens due to unexpected repairs caused to the building (e.g., pipes bursting), higher than normal utility bills or business interruption due to power failure (i.e., loss of electricity, telecommunications).

The agricultural industry is most at risk in terms of economic impact and damage due to extreme temperature and drought events. Extreme heat can result in drought and dry conditions and directly impact livestock and crop production.

In 2007, there were 7,691 farms in the Commonwealth, with a total land area of 517,879 acres. The average size of a farm was 67 acres. According to the 2007 Census of Agriculture, approximately 3,688 farm operators reported farming as their primary occupation. Refer to Section 4 for additional information regarding the agricultural industry per County.

14.6 VULNERABILITY

14.6.1 Population

In general, vulnerable populations include the elderly, low income or linguistically isolated populations, people with life-threatening illnesses, and residents living in areas that are isolated from major roads. Power outages can be life threatening to those dependent on electricity for life support. Isolation of these populations is a significant concern. These populations face isolation and exposure during severe weather events and could suffer more secondary effects of the hazard.

High Winds and Thunderstorms

The entire population of the Commonwealth is considered exposed to high wind and thunderstorm events. Downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life. Socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing.

Lightning strikes primarily occur during the summer months. According to NOAA, there has been one fatality and 43 injuries as a result of lightning events from 1993 and 2012 in the Commonwealth (NCDC, 2012). Populations located outdoors are considered at risk and more vulnerable to a lightning strike compared to being inside a shelter. Moving to a lower risk location will decrease a person's vulnerability.

Tornadoes

The impact of tornado or high wind events on life, health, and safety depends on factors including the severity of the event and whether adequate warning time was provided. Unfortunately some tornadoes strike with little or no warning and residents must act quickly. The following populations are more vulnerable to a tornado or other type of wind or severe storm event: 1) population located in communities without or have ineffective early warning systems; 2) population with functional needs and/or over the age of 65 because they may have more difficulty evacuating or seeking shelter; 3) economically disadvantaged populations because they are likely to evaluate their risk and make decisions based on the major economic impact to their family and may not have funds to evacuate; 4) population with a language barrier unable to following warning messages; 5) population in mobile homes; and 5) population in automobiles at the time of a tornado. The elderly and functional needs populations are considered most vulnerable because they require extra time or outside assistance to seek shelter and are more likely to seek or need medical attention which may not be available due to isolation during and/or after an event.

Extreme Temperatures

According to the Centers for Disease Control and Prevention, populations most at risk to extreme cold and heat events include the following: 1) the elderly, who are less able to withstand temperatures extremes due to their age, health conditions, and limited mobility to access shelters; 2) infants and children up to four years of age; 3) individuals who are physically ill (e.g., heart disease or high blood pressure), 4) low-income persons who cannot afford proper heating and cooling; and 5) the general public who may overexert during work or exercise during extreme heat events or experience hypothermia during extreme cold events.

Meteorologists can accurately forecast extreme heat event development and the severity of the associated conditions with several days lead time. These forecasts provide an opportunity for public health and other officials to notify vulnerable populations, implement short-term emergency response actions, and focus on surveillance and relief efforts on those at greatest risk. Adhering to extreme temperature warnings can significantly reduce the risk of temperature-related deaths.

Drought

Drought conditions can cause a shortage of water for human consumption and reduce local firefighting capabilities. Populations which rely upon groundwater sources and surface water intakes for drinking water are more vulnerable to the drought hazard. Social impacts of a drought include mental and physical stress, public safety (increased threat from forest/grass fires), health, conflicts between water users, reduced quality of life, and inequities in the distribution of impacts and disaster relief. Impacts on the economy and environment may have social implications as well.

14.6.2 State Facilities

High Winds

Using ArcMap, GIS software, the wind load zones discussed earlier were overlaid with the DCAMM facilities; the appropriate wind load zone determination was assigned to each facility. Table 14-16 summarizes the replacement cost values (structure only) of the state-owned and leased facilities within each wind load zone.

TABLE 14-16.
ESTIMATED REPLACEMENT COST VALUE OF STATE-OWNED AND LEASED FACILITIES IN WIND LOAD ZONES (STRUCTURE ONLY)

	Replacement Cost Value of State Facilities, by Wind Zone				
County	< 90 mph	90 mph	100 mph	110 mph	Total
Barnstable					**$573,157,181**
Lease	—	—	—	$8,590,637	
Own	—	—	—	$564,566,544	
Berkshire					**$926,000,416**
Lease	$20,719,316		—	—	
Own	$898,331,435	$6,949,665	—	—	
Bristol					**$1,506,105,175**
Lease	—	—	$22,946,411	$51,885,878	
Own	—	—	$485,514,336	$945,758,550	
Dukes					**$8,112,024**
Lease	—	—	$3,129,480	—	
Own	—	—	$4,982,544	—	
Essex					**$2,236,600,714**
Lease	—	$22,058,887	$46,374,475	—	
Own	—	$116,974,057	$2,051,193,295	—	

TABLE 14-16.
ESTIMATED REPLACEMENT COST VALUE OF STATE-OWNED AND LEASED FACILITIES IN WIND LOAD ZONES (STRUCTURE ONLY)

	Replacement Cost Value of State Facilities, by Wind Zone				
County	< 90 mph	90 mph	100 mph	110 mph	Total
Franklin					**$406,618,464**
Lease	$9,844,613	$2,236,564	—	—	
Own	$248,444,666	$146,092,622	—	—	
Hampden					**$2,525,825,124**
Lease	—	$77,791,722	—	—	
Own	—	$2,448,033,402	—	—	
Hampshire					**$2,343,693,926**
Lease	—	$16,521,098	—	—	
Own	$67,597	$2,327,105,231	—	—	
Middlesex					**$4,940,998,327**
Lease	—	$30,099,561	$132,885,318	—	
Own	—	$1,947,910,576	$2,830,102,873	—	
Nantucket					**$15,690,622**
Lease	—	—	—	$470,593	
Own	—	—	—	$15,220,029	
Norfolk					**$2,570,915,628**
Lease	—	—	$73,911,176	—	
Own	—	—	$2,497,004,452	—	
Plymouth					**$1,591,202,077**
Lease	—	—	$25,132,602	$21,359,191	
Own	—	—	$1,190,279,233	$354,431,050	
Suffolk					**$4,141,536,865**
Lease	—	—	$243,913,967	—	
Own	—	—	$3,897,622,898	—	
Worcester					**$4,722,349,497**
Lease		$103,759,546	$5,157,862	—	
Own		$3,988,649,389	$624,782,701	—	
Total					**$28,508,806,041**
Lease	$30,563,929	$252,467,378	$553,451,291	$82,306,299	
Own	$1,146,843,697	$10,981,714,942	$13,581,482,332	$1,879,976,172	

Source: DCAMM, 2012

Thunderstorms

According to NOAA's Technical Paper on Lightning Fatalities, Injuries, and Damage Reports in the United States from 1959 - 1994, monetary losses for lightning events range from less than $50 to greater than $5 Million (the larger losses are associated with forest fires, with homes destroyed, and crop loss) (NOAA, 1997). Lightning can be responsible for damage to buildings; can cause electrical, forest and/or wildfires; and can damage infrastructure such as power transmission lines and communication towers. The total replacement cost value of all state-owned and leased facilities in the Commonwealth is $57 Billion (structure and contents).

Tornadoes

To estimate the potential losses to state-owned and leased structures, the exposure analysis methodology was used. As discussed, there are 6,765 state-owned/leased structures in the Commonwealth. Table 14-17

identifies the replacement cost value of the state-owned and leased buildings located in the defined tornado high hazard area. This figure assumes 100-percent loss to each structure and its contents.

TABLE 14-17.
STATE-OWNED AND LEASED BUILDINGS IN HISTORICAL TORNADO DENSITY ZONES

Density	Own	Lease	Total
High (0.011 to 0.014)	$4,351,752,095	$141,141,012	$4,492,893,107
Low (< 0.011)	$50,828,282,192	$1,696,436,782	$52,524,718,974

Source: DCAMM, 2012

Extreme Temperatures and Drought

Extreme heat and drought events generally do not impact buildings. Losses may be associated with the overheating of HVAC systems. Extreme cold temperature events can damage buildings through freezing/bursting pipes and freeze/thaw cycles. Additionally, manufactured homes (mobile homes) and antiquated or poorly constructed facilities may have inadequate capabilities to withstand extreme temperatures. Additionally, it is essential that certain state facilities remain operational during natural hazard events. Extreme heat events can sometimes cause short periods of utility failure commonly referred to as brown-outs, due to increased usage from air conditioners, appliances, etc. Similarly, heavy snowfall and ice storms, associated with extreme cold temperature events, can cause power interruption as well. Backup power is recommended for critical facilities and infrastructure.

14.6.3 Critical Facilities

The replacement cost values for critical facilities were not available for this planning effort. A total risk exposure would equal to the full replacement value of each critical facility exposed.

Incapacity and loss of roads are the primary transportation failures resulting from severe weather, mostly associated with secondary hazards such as landslide events. Landslides caused by heavy prolonged rains can block roads. High winds can cause significant damage to trees and power lines, blocking roads with debris, incapacitating transportation, isolating population, and disrupting ingress and egress. Of particular concern are roads providing access to isolated areas and to 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. Large, prolonged storms can have negative economic impacts for an entire region.

Severe windstorms causing downed trees can create serious impacts on power and above-ground communication lines. Freezing of power and communication lines can cause them to break, disrupting electricity and communication. Loss of electricity and phone connection would leave certain populations isolated because residents would be unable to call for assistance.

14.6.4 Economy

High Winds, Thunderstorms and Tornadoes

Economic losses include direct building losses, or the estimated costs to repair or replace the damage caused to the building. Agricultural losses can be devastating due to lightning and resulting fires.

Because of differences in building construction, residential structures are generally more susceptible to wind 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. High-rise buildings are also very vulnerable structures. Mobile homes are the most vulnerable to damage, even if tied down, and offer little protection to people inside. Table 14-18 summarizes the replacement cost value of the residential general building stock (structure only) for the Commonwealth by County. The total structural replacement cost value for residential buildings in the Commonwealth is greater than $426 Billion or approximately 70-percent of all occupancy classes. Refer to Section 11 (Hurricanes/Tropical Storms), which includes estimated potential losses to the Commonwealth's general building stock due to high wind speeds associated with historical tropical storm and hurricane events.

TABLE 14-18.
RESIDENTIAL GENERAL BUILDING STOCK REPLACEMENT COST VALUE FOR THE COMMONWEALTH

County	Total (All Occupancies) Replacement Cost Value	Residential Replacement Cost Value	% of Total
Barnstable	$29,472,545,000	$23,858,042,000	81.0
Berkshire	$12,320,794,000	$9,021,345,000	73.2
Bristol	$44,744,005,000	$32,571,342,000	72.8
Dukes	$3,037,454,000	$2,458,850,000	81.0
Essex	$61,243,002,000	$44,561,352,000	72.8
Franklin	$6,049,044,000	$4,371,893,000	72.3
Hampden	$39,337,031,000	$26,881,407,000	68.3
Hampshire	$12,609,441,000	$9,444,897,000	74.9
Middlesex	$143,825,613,000	$102,752,128,000	71.4
Nantucket	$2,225,512,000	$1,731,180,000	77.8
Norfolk	$66,668,319,000	$48,205,584,000	72.3
Plymouth	$42,892,528,000	$32,612,565,000	76.0
Suffolk	$65,816,336,000	$40,215,170,000	61.1
Worcester	$66,832,305,000	$47,390,524,000	70.9
Total	**$597,073,929,000**	**$426,076,279,000**	**71.4**

Source: Hazus-MH v. 2.1

Extreme Temperatures and Drought

Extreme temperature events also have impacts on the economy, including loss of business function and damage/loss of inventory. Business-owners may be faced with increased financial burdens due to unexpected repairs caused to the building (e.g., pipes bursting), higher than normal utility bills or business interruption due to power failure (i.e., loss of electricity, telecommunications). Increased demand for water and electricity may result in shortages and a higher cost for these resources. Industries that rely on water for business may be impacted the hardest (e.g., landscaping businesses). Even though most businesses will still be operational, they may be impacted aesthetically. These aesthetic impacts are most significant to the recreation and tourism industry.

The agricultural industry is most at risk in terms of economic impact and damage due to extreme temperature and drought events. Extreme heat events can result in drought and dry conditions and directly impact livestock and crop production.

In 2007, there were 7,691 farms in the Commonwealth, with a total land area of 517,879 acres. The average size of a farm was 67 acres. According to the 2007 Census of Agriculture, approximately 3,688 farm operators reported farming as their primary occupation. The market value of agricultural products sold from all farms in the Commonwealth total over $489.8 million, with total sales averaging $63,687. Crop sales, including nursery and greenhouse, accounted for over $364.4 million (74.4%) of total sales and livestock, poultry and their products accounted for over $125.3 million (25.5%) of total sales. The lead agricultural products sold were nursery, greenhouse, floriculture and sod ($169.1 million); fruits, tree nuts, and berries ($100.6 million); and vegetables, melons, potatoes, and sweet potatoes ($15.7 million) (U.S. Department of Agriculture National Agricultural Statistics Service, 2007).

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SECTION 15. SEVERE WINTER WEATHER

15.1 GENERAL BACKGROUND

15.1.1 Snow and Blizzards

Snow is frozen precipitation in the form of a six-sided ice crystal. Snow formation requires temperatures to be below freezing in all or most of the atmosphere from the surface up to cloud level.

Snow can fall when surface temperatures are above freezing in a relatively shallow layer. In situations like this, the snow will not have enough time to melt before reaching the ground - though it will be quite wet with large flakes, the result of wet snowflakes sticking to one another.

Generally, ten inches of snow will melt into one inch of water. Sometimes the snow-liquid ratio may be much higher - on the order of 20:1 or 30:1. This commonly happens when snow falls into a very cold air mass, with temperatures of 20 degrees or less at ground level.

Blowing snow is wind driven snow that reduces visibility to six 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.

A blizzard is a winter snowstorm with sustained or frequent wind gusts to 35 mph or more, accompanied by falling or blowing snow reducing visibility to or below a quarter-mile. These conditions must be the predominant condition over a 3-hour period. Extremely cold temperatures are often associated with blizzard conditions, but are not a formal part of the definition. However, the hazard created by the combination of snow, wind, and low visibility increases significantly with temperatures below 20ºF.

A severe blizzard is categorized as having temperatures near or below 10 °F, winds exceeding 45 mph, and visibility reduced by snow to near zero.

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 in the storm and the higher pressure to the west creates a tight pressure gradient, resulting in strong winds and extreme conditions due to the blowing snow.

Regional Snowfall Index (RSI)

NOAA's National Climatic Data Center (NCDC) is currently producing the Regional Snowfall Index (RSI) for significant snowstorms that impact the eastern two-thirds of the U.S. The RSI ranks snowstorm impacts on a scale from one to five, which is similar to the Fujita scale for tornadoes or the Saffir-Simpson scale for hurricanes. The RSI differs from the NESIS because it includes societal impacts. RSI is based on the spatial extent of the storm, the amount of snowfall, and the combination of the extent and snowfall totals with population (based on the 2000 Census) (NOAA-NCDC, 2011). Table 15-1 explains the five categories. The indices for RSI are calculated similar to those for NESIS; however, the new indices require region-specific parameters and thresholds for the calculations. The NCDC has analyzed and assigned RSI values to over 500 storms since 1900 (NOAA-NCDC, 2011).

TABLE 15-1.
RSI RANKING CATEGORIES

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

Source: NOAA-NCDC, 2011 (http://www.ncdc.noaa.gov/snow-and-ice/rsi/)

15.1.2 Ice Storms

Ice storm conditions are defined by liquid rain falling and freezing on contact with cold objects creating ice build-ups of 1/4th inch or more that can cause severe damage. An ice storm warning, now included in the criteria for a winter storm warning, is for severe icing. This is issued when 1/2 inch or more of accretion of freezing rain is expected. This may lead to dangerous walking or driving conditions and the pulling down of power lines and trees. A warning is used for winter weather conditions posing a threat to life and property.

Another form of freezing precipitation is ice pellets, which occur when snowflakes melt into raindrops as they pass through a thin layer of warmer air. The raindrops then refreeze into particles of ice when they fall into a layer of sub-freezing air near the surface of the earth.

Sleet occurs when raindrops fall into subfreezing air thick enough that the raindrops refreeze into ice before hitting the ground. Sleet is different from hail. Sleet is a wintertime phenomenon; hail falls from convective clouds (usually thunderstorms) under completely different atmospheric conditions - and often during the warm spring and summer months.

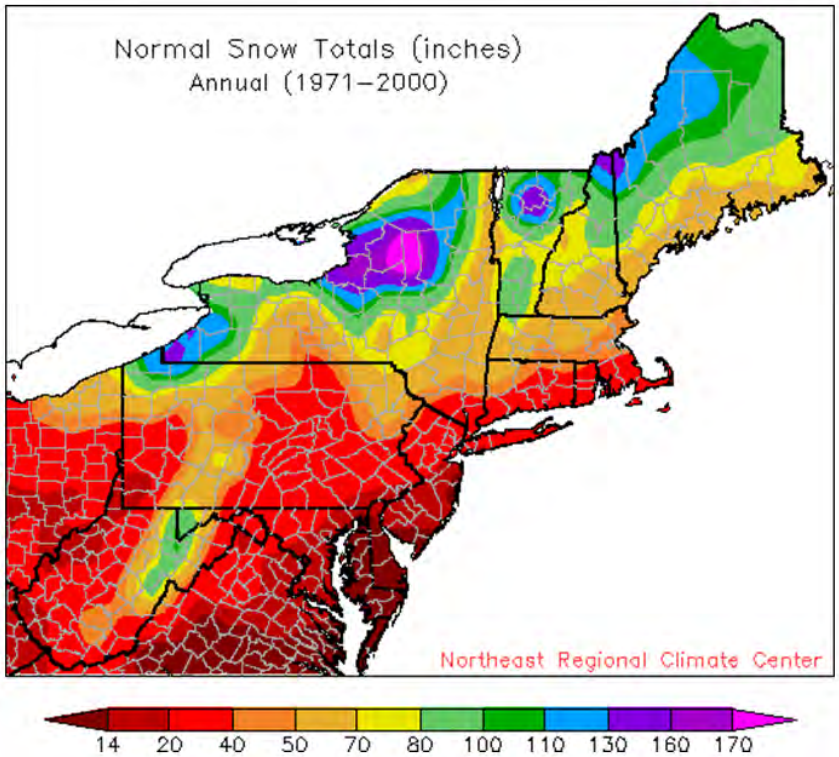
15.2 HAZARD PROFILE

15.2.1 Location

Snow and Blizzards

Figure 15-1 and Figure 15-2 illustrate the normal (30-year average) annual snow totals in New England and in the eastern U.S., respectively. Although the entire Commonwealth may be considered at risk, higher snow accumulations appear to be prevalent at higher elevations in Western and Central Massachusetts, and along the coast where snowfall can be enhanced by additional ocean moisture. The coastline is susceptible to the combination of both snow and coastal flooding during a nor'easter.

Source: Northeast Regional Climate Center



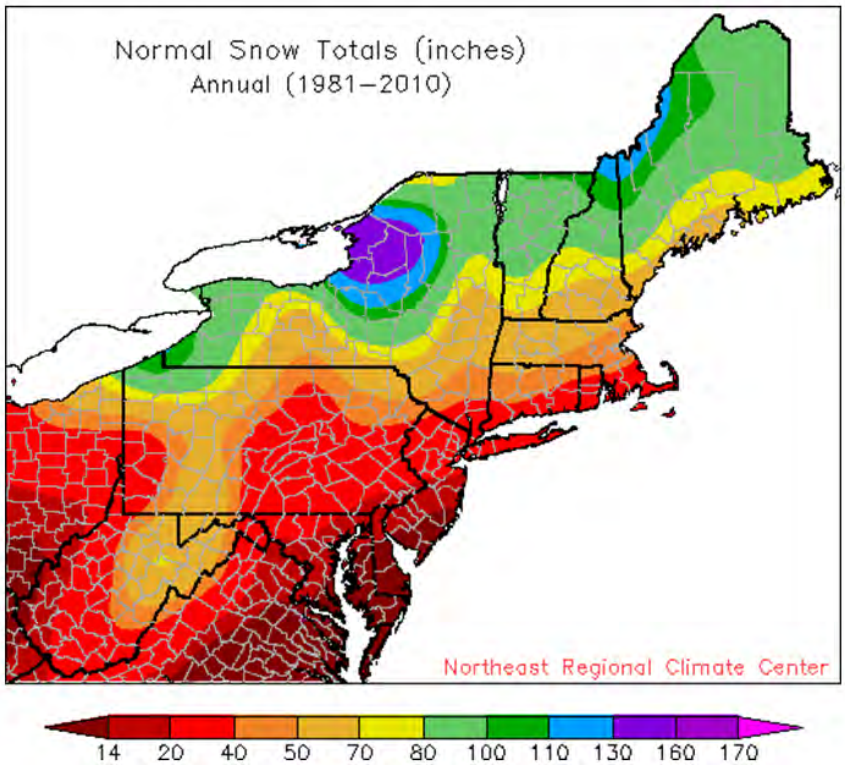


Figure 15-1. Normal Annual Snow Totals from 1971 to 2000 and 1981 to 2010

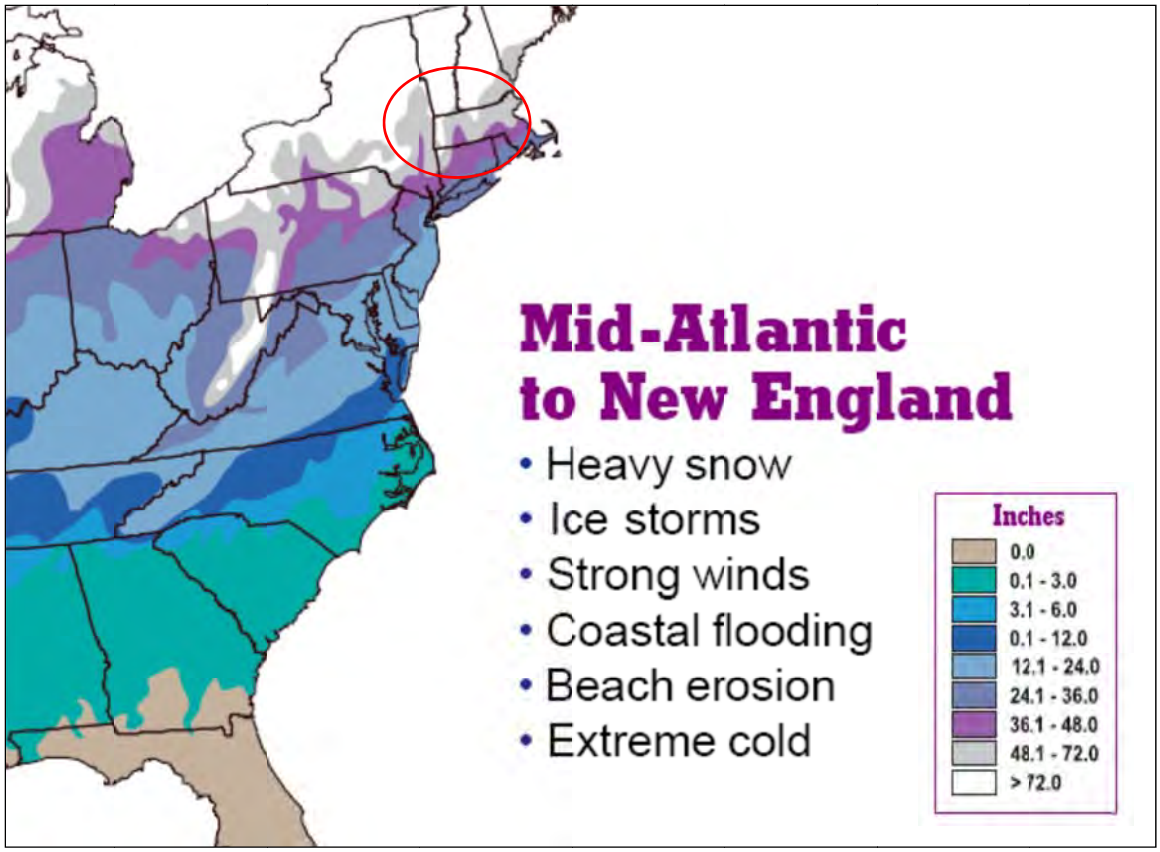


Figure 15-2. Annual Mean Snowfall Within the Eastern U.S.

Ice Storms

Ice storms can arise in any part of the Commonwealth, but they occur most frequently in the higher elevations of Western and Central Massachusetts. Table 15-2 and Figure 15-3 show the number of ice storm events each county has experienced since 1971.

TABLE 15-2.
ICE STORM EVENTS IN MASSACHUSETTS BY COUNTY

County	Number of Ice Events, 1971-2012	County	Number of Ice Events, 1971-2012
Worcester	27	Norfolk	9
Middlesex	22	Bristol	8
Essex	20	Plymouth	8
Hampshire	20	Suffolk	7
Hampden	19	Barnstable	3
Franklin	17	Dukes	0
Berkshire	13	Nantucket	0

Note: Incidents occurring within multiple counties are counted in each affected county.

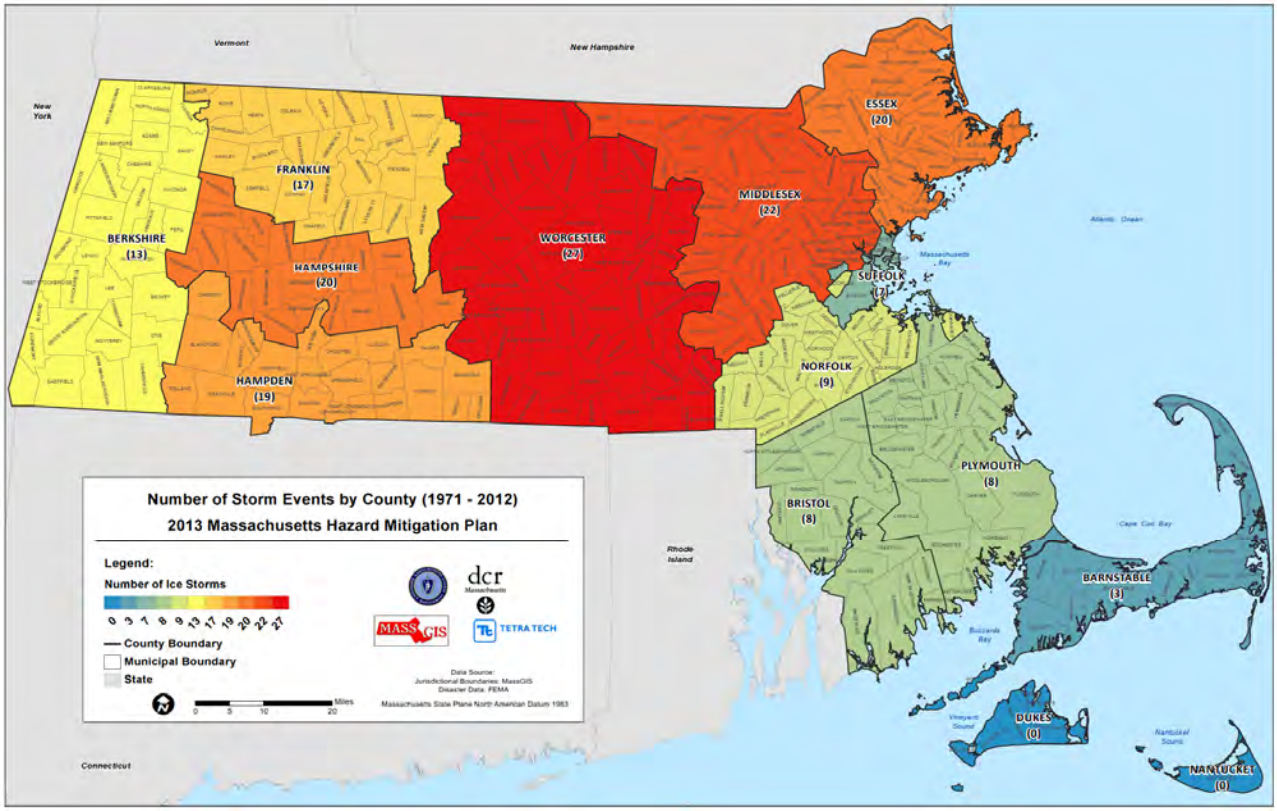


Figure 15-3. Number of Ice Storm Events in Massachusetts by County

15.2.2 Previous Occurrences

Snow and Blizzards

Snow and other winter precipitation occur very frequently across the entire Commonwealth. The total annual snowfall for 2011 is as follows (http://www.ncdc.noaa.gov/land-based-station-data/find-station):

- Blue Hill: 82.5 inches
- Boston: 60 inches
- Worcester: 94.6 inches

Ice Storms

From 1971 to 2012, there have been about 40 ice storm events which impacted at least one or more counties in the Commonwealth. All the storms within that period occurred between November and March, most frequently occurring in late December and early January. Ice storms of lesser magnitudes impact the Commonwealth on at least an annual basis.

Severe Winter Weather Events

Based on all sources researched, known winter weather events that have affected Massachusetts and were declared a FEMA disaster are identified in the following sections.

Coastal Storms, Flood, Ice, Snow (FEMA DR-546)—February 1978

The February 1978 blizzard was a life-threatening nor'easter that crippled most of the Commonwealth with blizzard conditions, extreme snowfall, high winds, and devastating coastal flooding. The storm claimed 73 lives in Massachusetts and 26 in Rhode Island. Over 10,000 people had to be sheltered. An unprecedented ban on non-emergency vehicle traffic lasted for a week in much of eastern Massachusetts.

This blizzard peaked during the Monday evening rush hour and caused over 3,500 vehicles to be stranded on Route 128 in eastern Massachusetts, with snowfall rates of at least 3 inches per hour and visibility near zero. Boston recorded a wind gust of 79 mph, and wind peaked at 93 mph in Chatham. Snowfall generally ranged from 1 to 3 feet with a large swath of the southwest suburbs of Boston receiving over 30 inches. Snowfall reports included 32.5 inches in Rockport, 27.1 inches in Boston and 20.2 inches in Worcester.

Major coastal flooding occurred over multiple high tide cycles and destroyed or severely damaged over 2,000 homes. This storm set a record high water mark of 15.25 feet above mean lower low water at the Boston Harbor National Ocean Service tide gage. Waves in excess of 30 feet were reported just offshore. The storm triggered evacuations and rescues along both the North and South Shores. This event did result in a federal disaster declaration (FEMA DR-546).

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, 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 federal disaster declaration (FEMA DR-975).

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 federal disaster declaration (FEMA EM-3103).

Heavy Snow / Nor'easter—March 1994

A strong Nor'easter passed to the southeast of Cape Cod, resulting in heavy snow and blowing and drifting snow. Snowfall totals ranged between six and 15 inches from the Boston metro area west and north. Over southeast Massachusetts, between three and six inches of snow fell before it changed to rain. Wind gusts of up to 40 and 60 mph resulted from this event and created snow drifts of up to three feet. Buildings were damaged, businesses and schools were closed, and highway travel was disrupted. The Commonwealth had approximately $5 million in property damage.

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 were 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 FEMA disaster declaration (FEMA DR-1090).

Heavy Snow (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 FEMA emergency declaration (FEMA EM-3165). Those counties included in the declaration received over $21 million in public assistance grants from FEMA.

Winter Storm (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 winter, 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 FEMA emergency declaration (FEMA EM-3175). Those counties included in the declaration received over $28 million in public assistance grants from FEMA.

Winter Storm (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 FEMA emergency declaration (FEMA EM-3191). Those counties included in the declaration received over $35 million in public assistance grants from FEMA.

Blizzard (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 FEMA emergency declaration (FEMA EM-3201). Those counties included in the disaster received over $49 million in public assistance from FEMA.

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 federal 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.

Severe Winter Storm and Flooding (FEMA DR-1813)—December 2008

A major ice storm and significant precipitation affected much of New England (December 11 through 12). 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 ice of ice accreted 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 to 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. This event resulted in a federal disaster declaration (FEMA DR-1813). Those counties included in the disaster received over $51 million in public assistance from FEMA.

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 federal 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.

Severe Storm/Nor'easter (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 federal emergency declaration (FEMA EM-3343) for the following counties: Berkshire, Essex, Franklin, Hampden, Hampshire, Middlesex, Norfolk, and Worcester.

RSI Events

Table 15-3 lists RSI values of winter storm events for the past 20 years. This table shows the regional RSI values for the Northeast region as well as the area and population of snowfall for those storms.

TABLE 15-3.
RSI AND SOCIETAL IMPACTS FOR THE NORTHEAST

Start Date	End Date	Category	RSI	Area of Snow	Population
2/13/1993	2/17/1993	1	2.223	174,671	57,059,500
2/19/1993	2/23/1993	1	2.291	174,690	57,062,555
3/11/1993	3/14/1993	5	20.465	174,690	57,062,622
12/31/1993	1/4/1994	1	2.911	173,556	56,914,705
1/3/1994	1/8/1994	1	2.62	173,393	56,887,967
1/15/1994	1/17/1994	1	2.995	174,680	57,062,212
2/21/1994	2/24/1994	1	1.917	173,345	56,885,145
2/27/1994	3/3/1994	2	4.448	174,690	57,062,623
2/1/1995	2/5/1995	2	4.535	174,690	57,062,563
12/17/1995	12/21/1995	2	3.551	174,680	57,061,297
1/5/1996	1/8/1996	5	20.281	162,082	56,617,484
1/31/1996	2/3/1996	1	1.349	128,600	52,977,105
3/2/1996	3/8/1996	2	3.259	174,681	57,050,954
4/8/1996	4/10/1996	1	1.726	174,498	57,033,178
1/7/1997	1/11/1997	1	1.597	174,690	57,062,621
3/30/1997	3/31/1997	2	4.666	172,730	57,025,596
1/12/1999	1/15/1999	1	2.554	172,653	56,794,660
3/11/1999	3/15/1999	1	1.913	164,907	54,530,770
1/23/2000	1/26/2000	1	2.567	174,680	57,060,450
1/23/2000	1/31/2000	1	1.469	173,787	56,932,414
2/15/2000	2/19/2000	1	1.395	172,730	57,041,310
12/27/2000	12/31/2000	2	3.369	168,174	52,797,525
12/22/2002	12/25/2002	2	3.75	170,048	56,788,225
2/13/2003	2/17/2003	4	14.452	162,812	56,921,974
12/3/2003	12/7/2003	3	9.024	174,690	57,062,588
2/27/2005	3/1/2005	2	3.159	174,690	57,062,575
2/9/2006	2/13/2006	2	5.128	174,690	57,062,590
2/10/2007	2/15/2007	3	7.316	174,690	57,062,546

TABLE 15-3.
RSI AND SOCIETAL IMPACTS FOR THE NORTHEAST

Start Date	End Date	Category	RSI	Area of Snow	Population
3/15/2007	3/17/2007	2	3.351	173,614	56,930,626
4/2/2007	4/5/2007	1	1.162	161,380	46,978,423
11/29/2007	12/3/2007	1	1.393	169,674	55,864,530
12/13/2007	12/16/2007	1	1.844	166,195	53,716,405
2/20/2008	2/23/2008	1	1.005	174,603	57,061,670
12/17/2008	12/21/2008	1	2.792	174,671	57,060,880
12/20/2008	12/22/2008	2	3.095	174,661	57,059,860
1/8/2009	1/11/2009	1	1.059	168,809	54,332,392
2/21/2009	2/23/2009	1	1.56	169,232	55,409,126
2/25/2009	3/2/2009	1	1.515	170,865	56,437,990
2/28/2009	3/2/2009	1	1.58	174,411	57,038,130
12/6/2009	12/10/2009	1	1.805	169,501	55,845,477
12/17/2009	12/20/2009	1	2.743	130,407	54,528,591
12/27/2009	1/3/2010	2	3.636	174,123	57,008,734
2/2/2010	2/6/2010	3	7.939	86,624	41,413,490
2/3/2010	2/7/2010	3	8.438	90,161	48,490,403
2/4/2010	2/10/2010	2	3.368	147,138	56,328,325
2/7/2010	2/10/2010	2	3.117	146,081	56,302,907
2/11/2010	2/18/2010	1	1.16	174,421	57,029,770
2/20/2010	2/28/2010	4	15.853	174,690	57,062,541
12/23/2010	12/27/2010	2	3.272	174,690	57,062,573
1/8/2011	1/12/2011	2	3.495	174,680	57,057,940
1/25/2011	1/26/2011	1	2.652	174,431	57,059,999
2/23/2011	2/26/2011	1	1.85	155,720	42,991,280
10/24/2011	10/30/2011	1	1.969	157,459	54,140,301
1/11/2012	1/13/2012	1	1.067	167,137	53,414,773
12/25/2012	12/27/2012	1	2.157	176,516	59,057,229
2/6/2013	2/9/2013	3	9.04	174,133	58,806,535

FEMA Declarations

Based on all sources researched, known severe winter weather events that have affected Massachusetts, and were declared a FEMA disaster, are identified in Table 15-4 and displayed on Figure 15-4. This table provides detailed information concerning the FEMA declarations for the Commonwealth.

15.2.3 Frequency

Severe winter weather is a common occurrence each season in Massachusetts. According to NOAA-NCDC storm database, over 200 winter storm events occurred in the Commonwealth between 2000 and 2012. Therefore, winter weather is likely to occur every year.

15.2.4 Severity

The magnitude or severity of a severe winter storm depends on several factors including 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.

TABLE 15-4.
FEMA WINTER STORM-RELATED DISASTER DECLARATIONS (1954 TO 2012)

Disaster #	Disaster Type	Declaration Date	Incident Period	Barnstable	Berkshire	Bristol	Dukes	Essex	Franklin	Hampden	Hampshire	Middlesex	Nantucket	Norfolk	Plymouth	Suffolk	Worcester	**Number of Counties Impacted**
DR-546	Coastal Storms, Flood, Ice, Snow	02/10/78	2/6/78 - 2/8/78	X		X	X	X					X	X	X	X		**8**
DR-975	Winter Coastal Storm	12/21/92	12/11/92 - 12/13/92	X			X	X				X	X	X	X	X	X	**9**
EM-3103	Blizzards, High Winds and Record Snowfall	03/16/93	3/13/93 - 3/17/93	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
DR-1090	Blizzard	01/24/96	1/7/96 - 1/13/96	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3165	Snowstorm	03/28/01	3/5/01 - 3/7/01		X			X	X		X	X		X			X	**7**
EM-3175	Snowstorm	03/11/03	2/17/03 - 2/18/03	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3191	Snow	01/15/04	12/6/03 - 12/7/03	X	X	X		X	X	X	X	X		X	X	X	X	**12**
EM-3201	Snow	02/17/05	1/22/05 - 1/23/05	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
DR-1701	Severe Storms and Inland and Coastal Flooding	05/16/07	4/15/07 - 4/25/07	X	X		X	X	X	X	X				X			**8**
DR-1813	Severe Winter Storm and Flooding	01/05/09	12/11/08 - 12/18/08		X			X	X	X	X	X					X	**7**
DR-1959	Severe Winter Storm and Snowstorm	03/07/11	1/11/11 - 1/12/11		X			X		X	X	X		X		X		**7**
DR-4051	Severe Storm	10/01/11	10/29/11 – 10/30/11		X			X	X	X	X	X		X			X	**8**
Total				**8**	**10**	**6**	**7**	**12**	**9**	**9**	**10**	**10**	**6**	**10**	**8**	**8**	**9**	

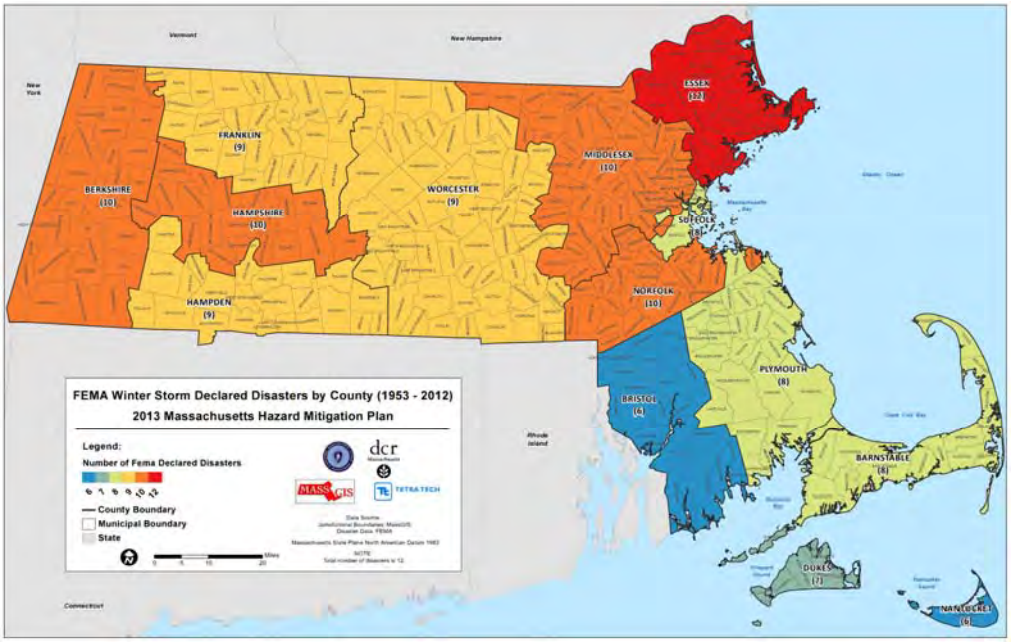


Figure 15-4. FEMA Winter Storm-Related Declared Disasters By County (1953 to 2012)

15.2.5 Warning Time

Meteorologists can often predict the likelihood of a severe storm. This can give several days of warning time. However, meteorologists cannot predict the exact time of onset or severity of the storm. Some storms may come on more quickly and have only a few hours of warning time.

15.3 SECONDARY HAZARDS

Structural damage (snow load); wind damage; impact to life safety; disruption of traffic; loss of productivity; economic impact; loss of ability to evacuate; taxing first responder capabilities; service disruption (power, water, etc.); communication disruption.

15.4 CLIMATE CHANGE IMPACTS

The climate of Massachusetts is changing and will continue to change over the course of this century. Since 1970, ambient air temperatures have increased by 1.8°F and the sea surface temperature by 2.3°F. These warming trends have been associated with other changes, including a 22-centimeter sea level rise between 1921 and 2006, more frequent days with temperatures above 90°F, reduced snowpack, and earlier snow melt and spring peak flows. By the end of the century, under the high emissions scenario of the Intergovernmental Panel on Climate Change, Massachusetts is expected to experience a 5°F to 10°F increase in average ambient temperature with several more days of extreme heat during the summer. Days with temperatures over 90°F are predicted to increase from five to 20 days annually; while up to 28 days annually are predicted to reach above 100°F. Sea surface temperatures are also expected to incase by 8°F (http://www.mass.gov/eea/docs/eea/energy/cca/eea-climate-adaptation-report.pdf).

Along with rising temperatures, it is expected that annual precipitation will increase by 14%, with a slight decrease in summer totals and a 30% increase in winter totals. Winter precipitation is predicted to be in the form of rain rather than snow. This change in precipitation will have significant effects on the amount of snow cover, winter recreation, spring snowmelt and peak stream flows, water supply, aquifer recharge, and water quality. The Commonwealth is located in an area where thresholds between snow and rain are sensitive and reductions in snow would be the largest. Snow is also predicted to fall later in the winter and cease falling earlier in the spring (http://www.mass.gov/eea/docs/eea/energy/cca/eea-climate-adaptation-report.pdf).

15.5 EXPOSURE

To understand risk, the assets exposed to the hazard areas are identified. For the severe winter weather hazard, the entire Commonwealth of Massachusetts is exposed. The following discusses the Commonwealth of Massachusetts' exposure to the severe winter weather hazard including:

- Population
- State facilities
- Critical facilities
- Economy

15.5.1 Population

According to the NOAA National Severe Storms Laboratory, every year, winter weather indirectly and deceptively kills hundreds of people in the U.S., primarily from 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. They are considered deceptive killers because most deaths and other impacts or losses are indirectly related to the storm. Injuries and fatalities may occur due to traffic accidents on icy roads, heart attacks while shoveling snow, or of hypothermia from prolonged exposure to cold.

Heavy snow can immobilize a region and paralyze a city, shutting down air and rail transportation, stopping the flow of supplies, and disrupting medical and emergency services. Accumulations of snow can collapse buildings and knock down trees and power lines. In rural areas, homes and farms may be isolated for days, and unprotected livestock may be lost. Storms near the coast can cause coastal flooding and beach erosion as well as sink ships at sea. In the mountains, heavy snow can lead to avalanches (NSSL, 2006).

For the purposes of this Plan, the entire population of the Commonwealth of Massachusetts is exposed to severe winter weather events.

15.5.2 State Facilities

As part of a FEMA Hazard Mitigation Grant Program funded study, in 2010 the Northeast States Emergency Consortium developed regional hazard maps for snowfall for the Northeast. Using their GIS data, Figure 15-5 was created to display the number of days with greater than five-inches of snow. Using ArcMap GIS software, these data were overlaid with the DCAMM facility data and the snow data. Table 15-5 summarizes the number of state-owned and leased buildings in each of the four snow bands.

TABLE 15-5.
STATE BUILDINGS VULNERABLE TO SNOW AND BLIZZARD

Number of Days of Storms Totaling More than 5 Inches of Snow	State Structures in each Snow Band
Less than a half day per year	3,236
Half day to 2.4 days per year	2,847
2.5 days to 4.4 days per year	608
4.5 days to 7.4 days per year	74
Total	**6,765**

Source: DCAMM, 2012; NESEC, 2010

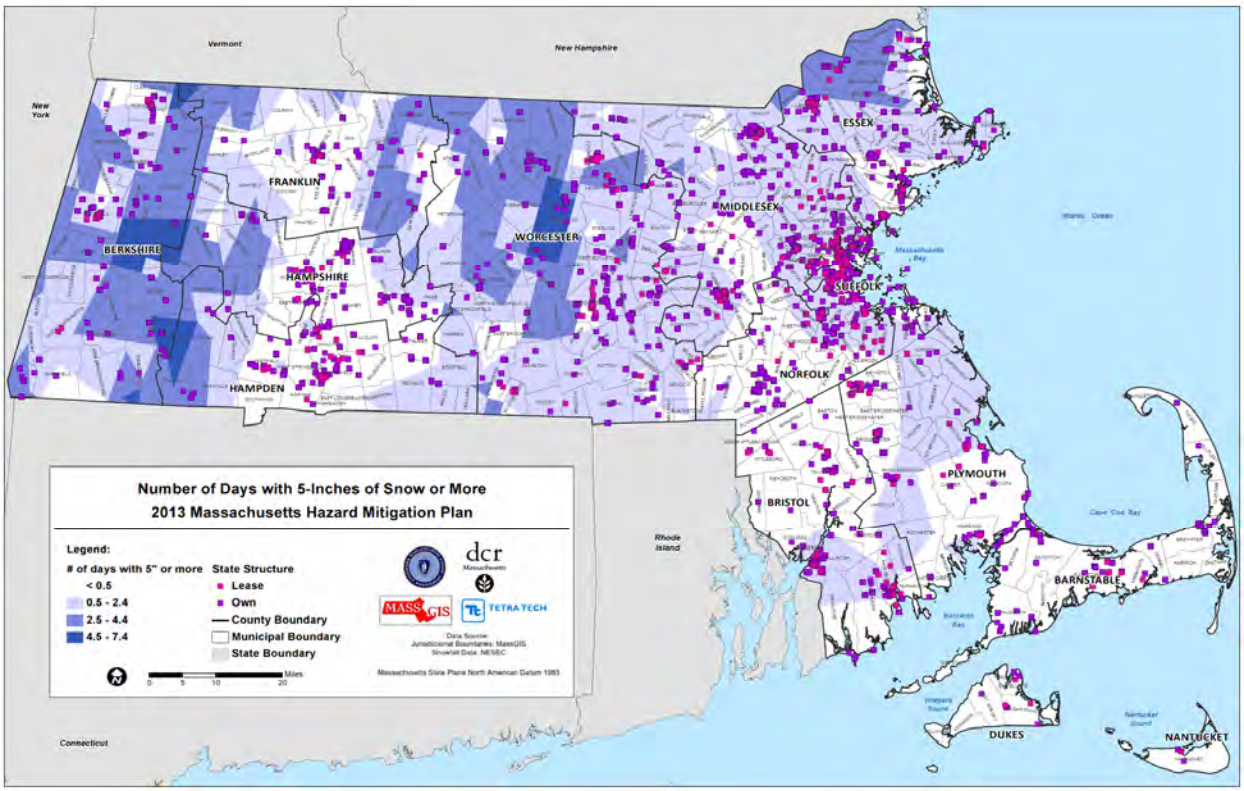


Figure 15-5. Number of Days with 5-inches of Snow or More

15.5.3 Critical Facilities

All critical facilities and infrastructure in the Commonwealth are exposed to the severe winter weather hazard. Table 15-6 summarizes the number of critical facilities in each of the four snow bands described earlier. Full functionality of critical facilities such as police, fire and medical facilities is essential for response during and after a winter storm event. Because power interruption can occur, backup power is recommended for critical facilities and infrastructure. Infrastructure at risk for this hazard includes roadways that could be damaged due to the application of salt and intermittent freezing and warming conditions that can damage roads over time.

TABLE 15-6
NUMBER OF CRITICAL FACILITIES EXPOSED TO THE SEVERE WINTER STORM HAZARD.

	Number of Facilities in each Snow Band					
Number of Days of Storms Totaling More than 5 Inches of Snow	Police	Fire	Emergency Operation Centers	Hospitals	Schools (pre-K-grade 12)	Colleges
Less than a half day per year	203	325	1	35	1,214	95
Half day to 2.4 days per year	181	382	1	42	1,383	106
2.5 days to 4.4 days per year	47	75	0	5	159	4
4.5 days to 7.4 days per year	6	7	0	0	11	0
Total	**437**	**789**	**2**	**82**	**2,767**	**205**

Source: DCAMM, 2012; NESEC, 2010

15.5.4 Economy

The entire general building stock inventory in the Commonwealth is exposed and vulnerable to the severe winter weather hazard. In general, structural impacts include damage to roofs and building frames, rather than building content. Figure 15-6 illustrates the snow loads on the roof for single-family construction. 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 extensive 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 (NSSL, 2006).

15.6 VULNERABILITY

15.6.1 Population

Although the entire population of the Commonwealth is exposed to the severe winter weather hazard, the elderly are considered most susceptible due to their increased risk of injury and death from falls and overexertion and/or hypothermia from attempts to clear snow and ice, or related to power failures. In addition, severe winter weather events can reduce the ability of these populations to access emergency services. Residents with low incomes may not have access to housing or their housing may be less able to withstand cold temperatures (e.g., homes with poor insulation and heating supply). Refer to Section 4 for population statistics summarizing the more vulnerable populations (over the age of 65 and individuals living below the Census poverty threshold).

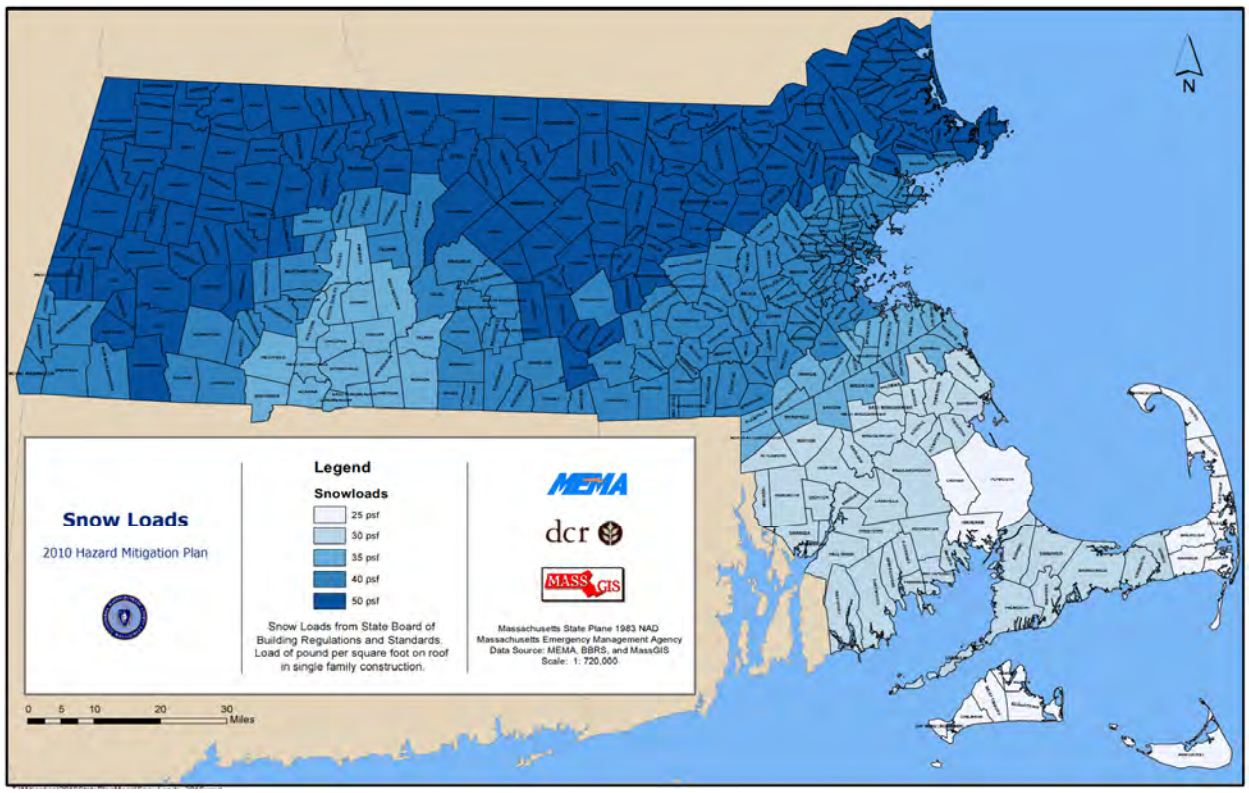


Figure 15-6. Roof Snow Loads for Single-Family Construction (pounds per square foot)

15.6.2 State Facilities

Potential structural damage to buildings may include damage to roofs and building frames. However, state facilities may not be fully operational due to workers' inability to travel to ensure continuity of operations

pre- and post-event. Current modeling tools are not available to estimate specific losses for this hazard. As an alternate approach, for the purposes of this plan, an estimated percent damage (one-percent) to a building's structure that could result from winter storm conditions is considered. Table 15-7 summarizes the Commonwealth's total state buildings (structure only) estimated potential loss replacement cost value. Given professional knowledge and the currently available information, the potential loss for this hazard is often considered to be overestimated due to varying factors (building structure type, age, load distribution, building codes in place, etc.). Therefore, the following information should be used as estimates only for planning purposes with the knowledge that the associated losses for severe winter storm events vary greatly

15.6.3 Critical Facilities

As stated earlier, full functionality of critical facilities is essential for response during and after a winter storm event. Potential structural damage to the facilities themselves may include damage to roofs and building frames. However, these facilities may not be fully operational due to workers unable to travel to ensure continuity of operations pre- and post-event. For future plan updates, the Commonwealth may consider determining which critical facilities have back-up power to enhance their critical facility inventory. The replacement cost values for critical facilities were not available for this planning effort. A total risk exposure would equal to the full replacement value of each critical facility exposed.

TABLE 15-7.
STATE BUILDING ESTIMATED POTENTIAL LOSS DUE TO A SEVERE WINTER STORM EVENT

County	Number of Buildings	Replacement Cost Value (Structure Only)	1% Loss
Barnstable	309	$573,157,181	$5,731,571.81
Berkshire	358	$926,000,416	$9,260,004.16
Bristol	482	$1,506,105,175	$15,061,051.75
Dukes	13	$8,112,024	$81,120.24
Essex	538	$2,236,600,714	$22,366,007.14
Franklin	211	$406,618,464	$4,066,184.64
Hampden	466	$2,525,825,124	$25,258,251.24
Hampshire	562	$2,343,693,926	$23,436,939.26
Middlesex	1,107	$4,940,998,327	$49,409,983.27
Nantucket	5	$15,690,622	$156,906.22
Norfolk	680	$2,570,915,628	$25,709,156.28
Plymouth	542	$1,591,202,077	$15,912,020.77
Suffolk	399	$4,141,536,865	$41,415,368.65
Worcester	1,093	$4,722,349,497	$47,223,494.97
Total	**6,765**	**$28,508,806,041**	**$285,088,060.41**

Source: DCAMM, 2012

15.6.4 Economy

Current modeling tools are not available to estimate specific losses for this hazard. As an alternate approach, this plan considers percentage damage that could result from winter storm conditions. Table 15-8 summarizes percent damage that could result from winter storm conditions on the Commonwealth's total general building stock (structure only).

A specific area that is vulnerable to the winter storm hazard is the floodplain. Snow and ice melt can cause both riverine and urban flooding. At-risk general building stock and infrastructure in floodplains are

presented in the flood hazard profile (Section 10). Estimated losses due to flooding in the Commonwealth are discussed in Sections 10 (Flood) and 11 (Hurricane/Tropical Storms).

The cost of snow and ice removal and repair of roads from the freeze/thaw process can drain local financial resources. The potential secondary impacts from winter storms also impact the local economy including loss of utilities, interruption of transportation corridors, and loss of business function.

TABLE 15-8.
GENERAL BUILDING STOCK ESTIMATED POTENTIAL LOSS DUE TO A WINTER STORM EVENT

County	Replacement Cost Value (Structure Only)	1% Loss
Barnstable	$29,472,545,000	$294,725,450
Berkshire	$12,320,794,000	$123,207,940
Bristol	$44,744,005,000	$447,440,050
Dukes	$3,037,454,000	$30,374,540
Essex	$61,243,002,000	$612,430,020
Franklin	$6,049,044,000	$60,490,440
Hampden	$39,337,031,000	$393,370,310
Hampshire	$12,609,441,000	$126,094,410
Middlesex	$143,825,613,000	$1,438,256,130
Nantucket	$2,225,512,000	$22,255,120
Norfolk	$66,668,319,000	$666,683,190
Plymouth	$42,892,528,000	$428,925,280
Suffolk	$65,816,336,000	$658,163,360
Worcester	$66,832,305,000	$668,323,050
Total	**$597,073,929,000**	**$5,970,739,290**

Source: HAZUS-MH v. 2.1

SECTION 16. TSUNAMI

A tsunami is a devastating onshore surge of water that can be triggered from geologic activity. This phenomenon can be defined as a string of waves created by an underwater disturbance such as an earthquake, landslide, volcanic eruption, or impact from a meteorite. A tsunami is a series of water waves that can move hundreds of miles per hour in the open ocean and can come ashore with waves as high as 100 feet or more. The height of a tsunami wave that comes onshore is related to the strength of the source that generated the tsunami and to the configuration of the ocean bottom along the shore affected by the tsunami.

DEFINITIONS

Tsunami—A series of traveling ocean waves of extremely long wavelength usually caused by displacement of the ocean floor and typically generated by seismic or volcanic activity or by underwater landslides.

An earthquake can also generate a tsunami if the earthquake causes a major landslide into a water body or if it causes a major slumping of submarine sediments:

- An earthquake results from a sudden shift in the subduction zone between continental and oceanic crusts. This abrupt motion displaces the overlying water upward and downward, which initiates a tsunami (Diagram A in Figure 16-1).
- The initial tsunami splits into a deep ocean and coastal tsunami, headed in opposite directions (Diagram B in Figure 16-1). The distant tsunami travels through deeper waters; therefore, it moves much faster.
- The local tsunami is amplified as it passes over the continental slope, due to the tsunami encountering shallower water (Diagram C in Figure 16-1). As it continues toward land, should the trough of the tsunami reach the coastline first, the water level along the coastline appears to fall rapidly, as if the tide is ebbing. This is called drawdown.

16.1 HAZARD PROFILE

16.1.1 Location

All of the coastal areas of Massachusetts are exposed to the threat of tsunamis. However, at the present time it is unknown what the probability is of a damaging tsunami along the Massachusetts coast.

According to a document titled *U.S. States and Territories National Tsunami Hazard Assessment: Historical Record and Sources for Waves*, the U.S. Atlantic coast and the Gulf Coast states have experienced very few tsunamis in the last 200 years. The states of Louisiana, Mississippi, Alabama, the Florida Gulf Coast, Georgia, Virginia, North Carolina, Pennsylvania, and Delaware have no known historical tsunami records. Only a total of six tsunamis have been recorded in the other 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 and one reported tsunami in the Mid-Atlantic states that may be related to an underwater explosion or landslide.

Unlike the Atlantic and Gulf Coasts, the Pacific Basin, Puerto Rico, and the U.S. Virgin Islands have a moderate to very high tsunami hazard. The Pacific territories including Guam, American Samoa, and the Northern Marianas all experience tsunamis, mostly a moderate hazard for these areas. For Washington, Oregon, California, Puerto Rico, and the Virgin Islands, studies show that these areas have a high hazard.

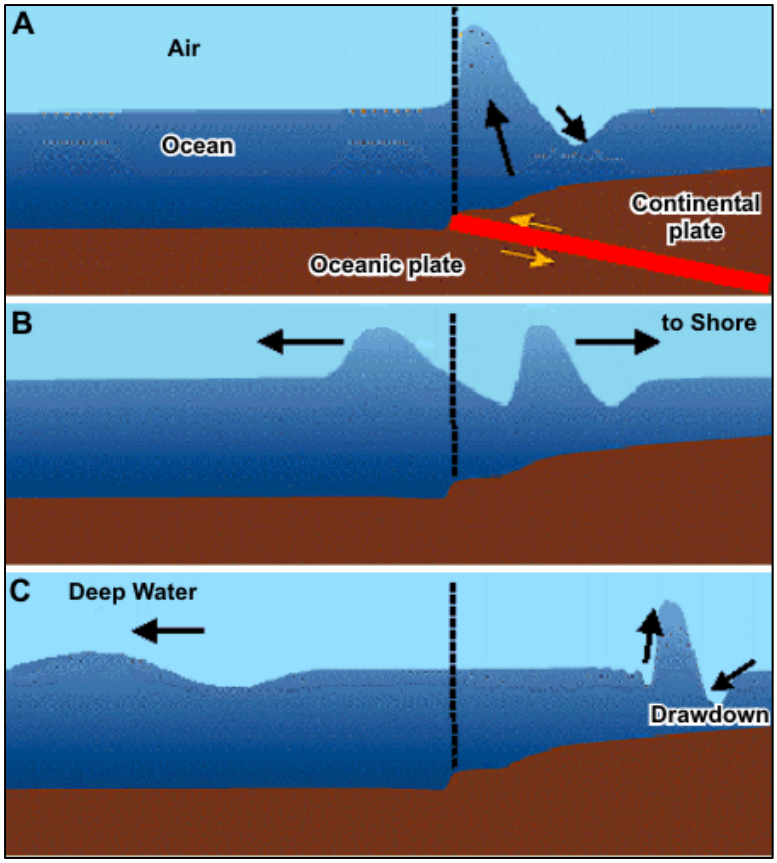


Figure 16-1. Generation of a Tsunami from an Earthquake

Tsunami and tsunami-like waves that have impacted the east coast of the U.S. were analyzed by Lockridge. The National Geophysical Data Center (NGDC) of NOAA compiled a listing of all tsunamis and tsunami-like waves of the eastern U.S. and Canada. Forty-nine potential tsunami events have been identified as possibly impacting the east coast of the U.S. between 1668 and 2008. Of these events, eight were categorized as definite or probable tsunamis.

Mid-Atlantic Ridge

The closest tectonic boundary to the U.S. east coast is the spreading Mid-Atlantic Ridge, which contains numerous faults and earthquakes that take place. However, according to the Maine Geological Survey, tsunamis are more likely to occur at convergent margins. In the Caribbean Sea, there is a convergent plate boundary and a region with a higher probability of generating earthquakes that could produce tsunamis. Tsunamis could potentially travel to New England from the Caribbean, the Mid-Atlantic Ridge, or from the Canary Islands.

Tsunami Threat to the East Coast of the U.S. and New England

Caribbean Islands

The Caribbean is home to some of the most geologically active areas outside of the Pacific Ocean. Similar to the Indonesian Islands, this area has a subduction zone that is located just north of Puerto Rico, where the North American plate is being subducted beneath the Caribbean Plate at the Puerto Rico Trench. This area includes other troughs and areas of plate tectonics that have produced numerous earthquakes, submarine landslides, volcanic eruptions, and resulting tsunami activity.

North Carolina/Virginia Continental Shelf

Although the U.S. east coast is much less likely to be affected by a tsunami than the west coast, tsunami threats do exist. Evidence has been found of a large submarine landslide 18,000 years ago off the coasts of Virginia and North Carolina, called the Albemarle-Currituck Slide, in which over 33 cubic miles of material slid seaward from the edge of the continental shelf, most likely causing a tsunami.

Canary Islands

The Canary Islands are a volcanic island-arc chain located in the eastern Atlantic Ocean, just west of the Moroccan coastline. La Palma is the western-most and the youngest of the Canary Islands and is volcanically active with three large volcanoes. It is also the location of the most active volcano of the Canary Islands, Cumbre Vieja, which last erupted in 1949 and 1971. Some researchers point to this volcano as the source of creating a large tsunami in the Atlantic Ocean.

Based on a study of past landslide deposits and existing geology of the volcano, it is suggested that the west flank of the Cumbre Vieja may experience failure during a future eruption, resulting in a landslide into the depths of the Atlantic Ocean of a block 15 to 20 kilometers wide and 15 to 25 kilometers long.

Although the flank instability of Cumbre Vieja is noted, many scientists disagree with massive failure of the western flank of the volcano. These scientists think it would happen in smaller, separate events that would not be capable of triggering a mega-tsunami. The International Tsunami Information Center stated the following in regards to the creation of a mega-tsunami by massive flank failure:

- While the active volcano of Cumbre Vieja on Las Palma is expected to erupt again, it will not send a large part of the island into the ocean, though small landslides could occur
- No mega tsunamis have occurred in the Atlantic or Pacific Oceans in recorded history
- The colossal collapses of Krakatau or Santorin generated catastrophic waves in the immediate area but hazardous waves did not propagate to distant shores. Numerical and experimental models of such events and of the Las Palma event verify that the relatively short waves from these small occurrences do not travel as tsunami waves from a major earthquake do.

16.1.2 Previous Occurrences

On April 13, 1668, an earthquake of intensity IV struck the Boston and Salem area. It was said that an unknown river was swallowed up and its course was altered. According to NOAA, two run-ups were associated with this event. (http://www.ngdc.noaa.gov/nndc/struts/form?t=101650&s=70&d=7; ftp://ftp.ngdc.noaa.gov/hazards/publications/ref0541_lockridge.pdf)

On November 18, 1755, a Magnitude-6.0 earthquake threw down chimneys and walls in Boston. Gabled ends of buildings collapsed and stone walls were shaken down. Shaking due to this earthquake was experienced by a ship located near the epicenter of Cape Ann, Massachusetts. The shock was felt over a 300,000 square mile area from the Chesapeake Bay to Nova Scotia. Aftershocks were felt for a month. This event was reported to have produced a noticeable sea wave.

In 1755, a major earthquake in Lisbon, Portugal caused a major tsunami along the Portuguese coast. Historical reports indicate that a small tsunami was observed across the Atlantic Ocean in the Caribbean from this Portuguese earthquake. Thus, history suggests that there is some tsunami hazard to Massachusetts, both from a strong, local offshore earthquake and from a major earthquake across the Atlantic Ocean. Some scientists have also suggested that a tsunami could be generated if a major landslide were to take place on Canary Islands in the eastern Atlantic Ocean. There is no specific information on previous occurrences.

In 1879, a wall of water was observed by small craft in channel between Nantucket and Tuckernuck Islands. There was one injury associated with this event

On November 18, 1929, a magnitude 7.3 earthquake and submarine slump along the Grand Banks of Newfoundland caused a significant tsunami that came ashore along the Newfoundland coast, inundating coastal villages and causing major damage. Twenty-eight persons died in Newfoundland, and one person drowned in Nova Scotia. The earthquake was felt as far south as Washington, D.C., and Baltimore, Maryland. Twelve trans-Atlantic cables were broken, all more than once for a total of 28 breaks over a large area, indicating a turbidity current. This event was recognized as the first documented turbidity current. The tsunami moved at 400 kilometers per hour south and east to Bermuda and Portugal, and impinged at 140 kilometers per hour on southern Newfoundland and Nova Scotia. Minor damage was reported in Bermuda and was seen on tide gages down the east coast of the U.S. and in the Azores in Portugal. In New England, records were complicated by waves produced by a severe storm. In Barnstable, Massachusetts, high tides were reported.

According to the 2008 NOAA study (*U.S. States and Territories National Tsunami Hazard Assessment: Historical Record and Sources for Waves*) tsunami events and losses were summarized for the Atlantic region. Table 16-1 is a summary of their findings for the Atlantic Region. Figure 16-2 shows the number of tsunami events and total number of events causing run-up heights from 0.1 meters to greater than 3.0 meters for the U.S. and its territories in the Atlantic, Gulf Coast, Puerto Rico, and the Virgin Islands.

Source: Dunbar and Weaver, 2008

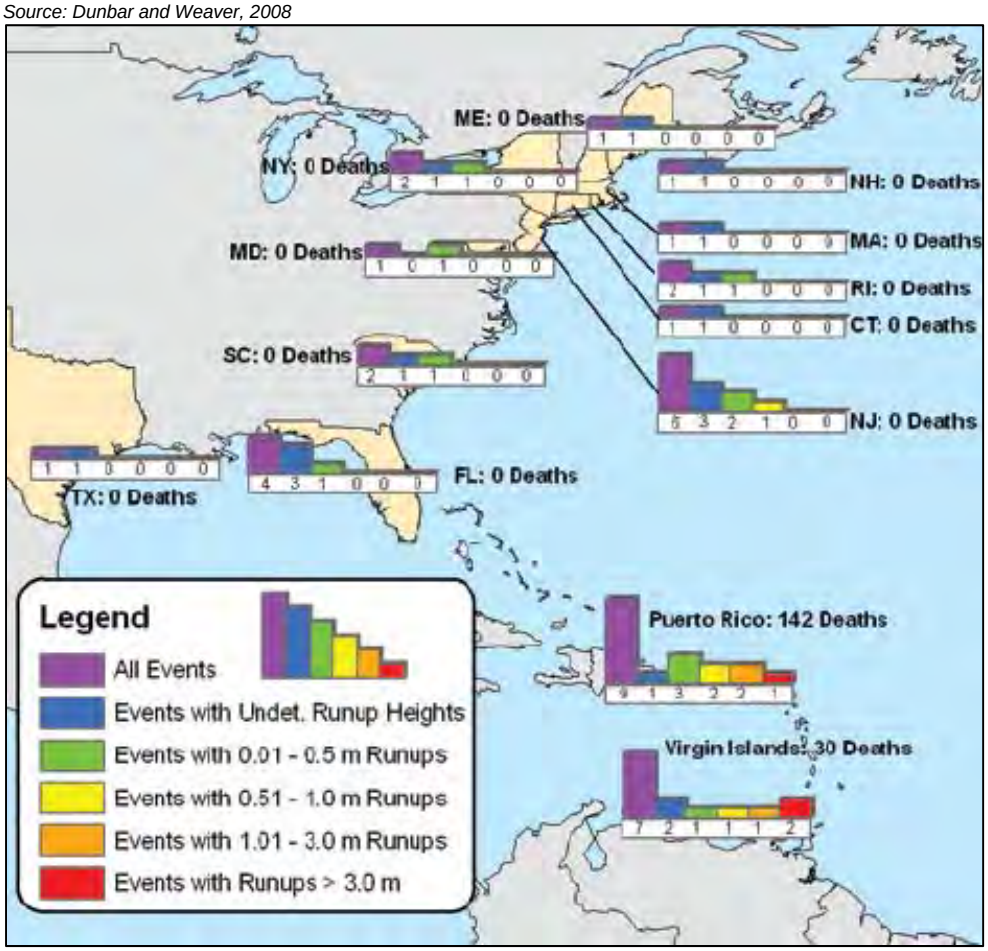


Figure 16-2. Total Number of Tsunami Events for the U.S. and its Territories

TABLE 16-1.
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
U.S. Atlantic Coast	Maine (1929)	1	1					3		
	New Hampshire (1929)	1	1					1		
	Massachusetts (1929)	1	1					2		
	Rhode Island (1929)	2	1	1				3		
	Connecticut (1964)	1	1					1		
	New York (1895)	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 and Weaver, 2008

16.1.3 Frequency

The frequency of tsunamis is related to the frequency of the events that cause them, so it is similar to the frequency of seismic or volcanic activities or landslides.

In the U.S. coastal areas, the frequency of damaging tsunamis is low compared to many other natural hazards; however, the impacts can be extremely high.

16.1.4 Severity

Tsunamis are a threat to life and property to anyone living near the ocean. From 1950 to 2007, 478 tsunamis were recorded globally. Fifty-one of these events caused fatalities, to a total of over 308,000 coastal residents. The overwhelming majority of these events occurred in the Pacific basin. Recent tsunamis have struck Nicaragua, Indonesia, and Japan, killing several thousand people. Property damage due to these waves was nearly $1 billion.

The West Coast and Alaska Tsunami Warning Center is one of two tsunami-warning centers that are operated by NOAA in the United States. The Warning Center is part of an international tsunami warning system program and serves as the operational center for all coastal regions of Canada, the United States (expect Hawaii), the Caribbean, and the Gulf of Mexico (NOAA, 2013). In addition, the USGS operates the U.S. National Seismograph Network, which is part of the Global Seismic Network that monitors seismic activity around the world. These networks are able to detect seismic events that are capable of resulting in a tsunami. Soon after an earthquake occurs, seismic activity is recorded by seismographs and sent to a satellite and to the U.S. National Seismograph Network in Colorado. There, it is analyzed and warnings, if needed, are issued.

16.1.5 Warning Time

The National Tsunami Hazard Mitigation Program was formed in 1995 by Congressional action which directed NOAA to form and lead a federal/state working group. The program is a partnership between NOAA, the USGS, FEMA, the National Science Foundation, and the 28 U.S. coastal states, territories, and commonwealths.

One of the actions outlined by the plan was the development of a tsunami monitoring system to monitor the ocean's activity and make citizens aware of a possible tsunami approaching land. In response, NOAA developed the DART tsunami monitoring buoys. To ensure early detection of tsunamis and to acquire data critical to real-time forecasts, NOAA has placed Deep-ocean Assessment and Reporting of Tsunami (DART) stations at sites in regions with a history of generating destructive tsunamis. NOAA completed the original 6-buoy operational array in 2001 and expanded to a full network of 39 stations in March 2008. The information collected by a network of DART™ buoys positioned at strategic locations throughout the ocean plays a critical role in tsunami forecasting.

When a tsunami event occurs, the first information available about the source of the tsunami is the seismic information for the earthquake. As the tsunami wave propagates across the ocean and successively reaches the DART systems, the systems report sea level measurements to the Tsunami Warning Centers, where the information is processed 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.

16.2 SECONDARY HAZARDS

Aside from the tremendous hydraulic force of the tsunami waves themselves, floating debris carried by a tsunami can endanger human lives and batter inland structures. Ships moored at piers and in harbors often are swamped and sunk or are left battered and stranded high on the shore. Breakwaters and piers collapse, sometimes because of scouring actions that sweep away their foundation material and sometimes because of the sheer impact of the waves. Railroad yards and oil tanks situated near the waterfront are particularly vulnerable. Oil fires frequently result and are spread by the waves.

Port facilities, naval facilities, fishing fleets, and public utilities are often the backbone of the economy of the affected areas, and these are the resources that 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. Wherever water transport is a vital means of supply, disruption of coastal systems caused by tsunamis can have far-reaching economic effects.

16.3 CLIMATE CHANGE IMPACTS

The impact of climate change on the frequency and severity of tsunami events could be significant. Global sea-level rise will affect all coastal societies, especially small island states and densely populated low-lying coastal areas. *The Scientific Basis* estimates a sea level rise of 0.3 to 2.9 feet from 1990 to 2100. Currently sea level is rising at a rate of about 0.1 inches per year. This rise has two effects on low-lying coastal regions: any structures located below the new level of the sea will be flooded, and the rise in sea

level may lead to coastal erosion that can further threaten coastal structures. As a rule-of-thumb, a sandy shoreline retreats about 100 feet for every 1-foot rise in sea level (IPCC, 2001).

16.4 EXPOSURE

To understand risk, the assets exposed to the hazard areas are identified. For the tsunami hazard, a one-mile buffer from the coast of the Commonwealth of Massachusetts was used to define the area exposed and thus vulnerable. The following discusses the Commonwealth of Massachusetts' exposure to the tsunami hazard including:

- Population
- State facilities
- Critical facilities
- Economy

NOAA's NGDC is building high-resolution digital elevation models (DEMs) of select U.S. coastal regions, including Nantucket. These integrated bathymetric-topographic DEMs are used to support tsunami forecasting and modeling efforts at the NOAA Center for Tsunami Research, Pacific Marine Environmental Laboratory. The DEMs are part of the tsunami forecast system currently being developed by the Laboratory for the NOAA Tsunami Warning Centers and are used in the Method of Splitting Tsunami model developed by the Laboratory to simulate tsunami generation, propagation, and inundation.

16.4.1 In October 2008, NGDC developed a DEM of Nantucket (refer to Population

For this 2013 update, a one-mile buffer from the coast was used to determine the coastal population exposed to the tsunami hazard. **Error! Reference source not found.** summarizes the 2010 Census population exposed to this hazard.

The impact of a tsunami on life, health, and safety depends on factors including the severity of the event and whether adequate warning time was provided to residents. The USGS operates the U.S. National Seismograph Network which is part of the Global Seismic Network that monitors seismic activity around the world. These networks are able to detect seismic events that are capable of resulting in a tsunami. Soon after an earthquake occurs, seismic activity is recorded by seismographs and sent to a satellite and the U.S. National Seismograph Network in Colorado. There, it is analyzed and warnings, if needed, are issued (Maine Geological Survey, 2008).

Source: Eakins et al, 2009

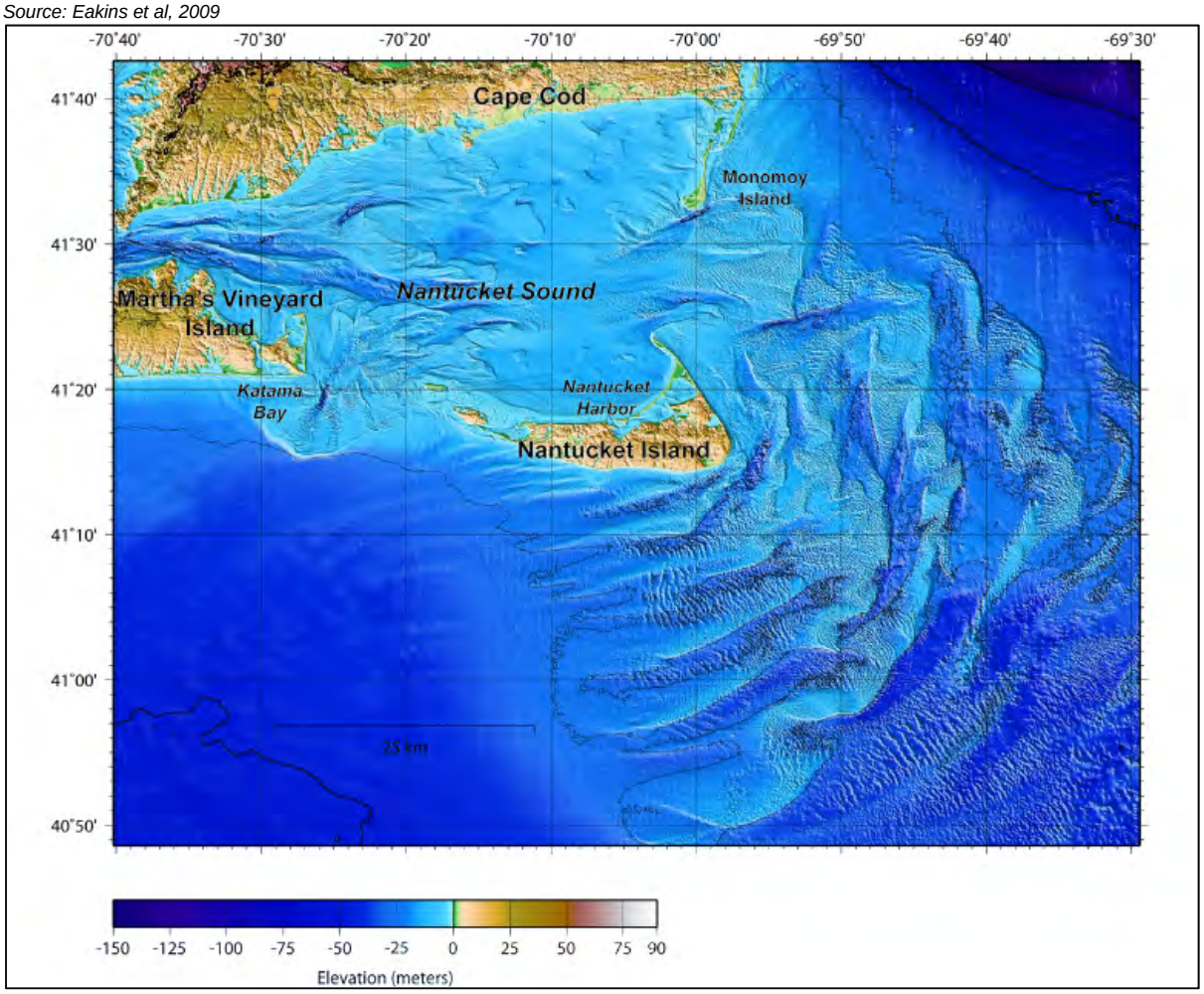


Figure 16-3) to be used as part of the tsunami forecast system. The Nantucket DEM integrates bathymetry and topography in the area spanning Nantucket Sound, from Martha's Vineyard to Nantucket Island, then north to Cape Cod, and extending into the Atlantic Ocean. The DEM has a 1/3 arc-second (approximately 10 meter) cell size, and is referenced to a vertical datum of mean high water.

Based on the research conducted for this planning process, tsunami inundation maps do not exist for the Massachusetts coast. For the purposes of the 2013 update, a one-mile buffer from the coastline was used to define the area exposed to the tsunami hazard until modeling and inundation mapping exists (portions of Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, and Suffolk). As modeling efforts continue and inundation areas are developed, additional spatial analysis will enhance the Commonwealth's exposure and vulnerability evaluation of this hazard.

16.4.2 Population

For this 2013 update, a one-mile buffer from the coast was used to determine the coastal population exposed to the tsunami hazard. **Error! Reference source not found.** summarizes the 2010 Census population exposed to this hazard.

The impact of a tsunami on life, health, and safety depends on factors including the severity of the event and whether adequate warning time was provided to residents. The USGS operates the U.S. National Seismograph Network which is part of the Global Seismic Network that monitors seismic activity around the world. These networks are able to detect seismic events that are capable of resulting in a tsunami. Soon after an earthquake occurs, seismic activity is recorded by seismographs and sent to a satellite and

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Source: Eakins et al, 2009

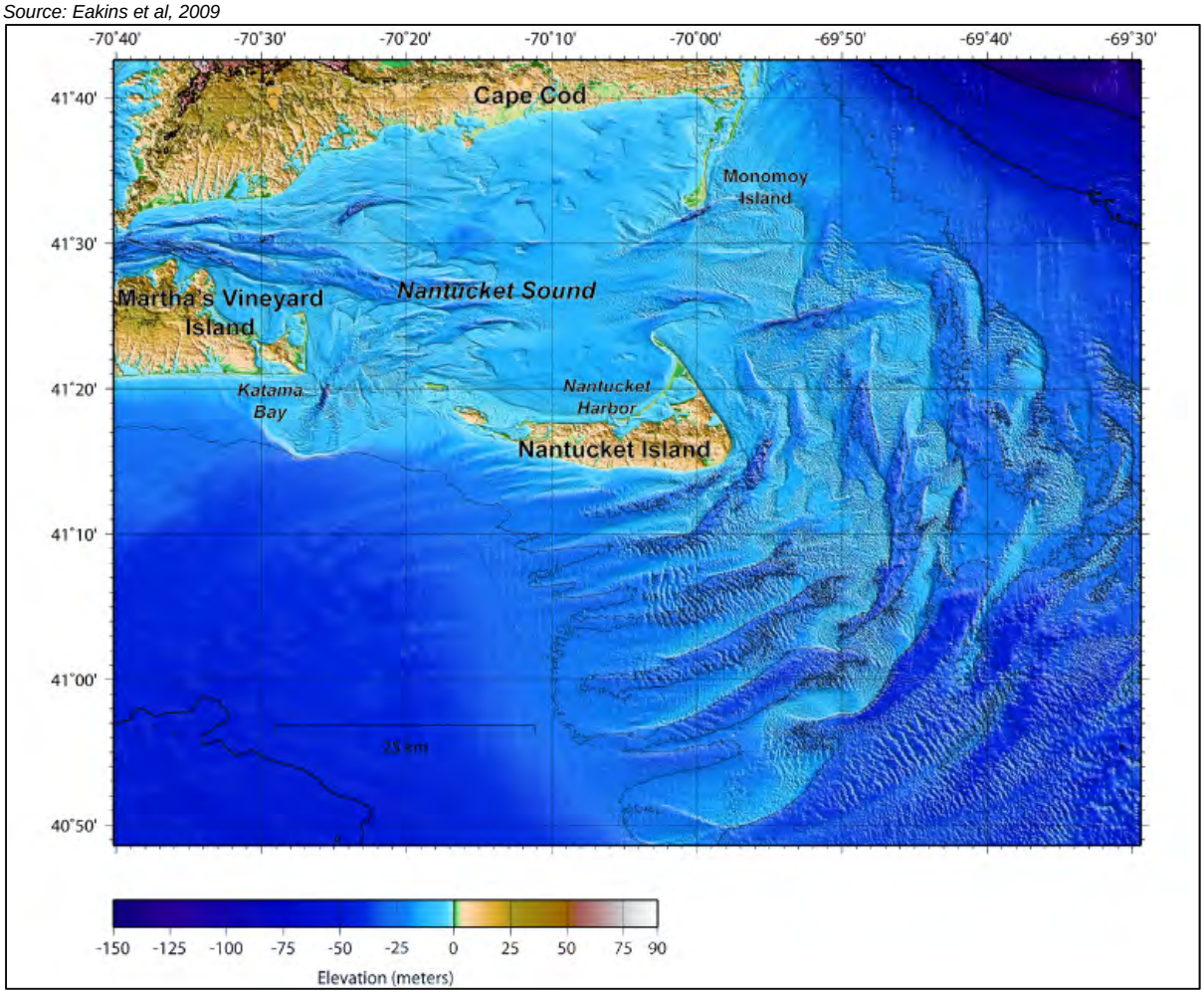

Figure 16-3. Shaded-Relief Image of the Nantucket Digital Elevation Model

TABLE 16-2.
ESTIMATED POPULATION EXPOSED TO THE TSUNAMI HAZARD

County	Population Exposed to the Tsunami Hazard
Barnstable	140,190
Bristol	221,968
Dukes	13,255
Essex	491,493
Middlesex	59,512
Nantucket	6,528
Norfolk	138,749
Plymouth	130,308
Suffolk	393,733
Total	**1,595,736**

TABLE 16-2.
ESTIMATED POPULATION EXPOSED TO THE TSUNAMI HAZARD

County	Population Exposed to the Tsunami Hazard

Source: U.S. Census 2010

As tsunami inundation or hazard areas are developed, they may be used to conduct a spatial analysis to identify the most vulnerable residents living in the tsunami hazard zone and be used to focus public education and outreach efforts on these communities. Further, tsunami inundation maps will provide information needed to create evacuation maps.

16.4.3 State Facilities

The impact of the waves and the scouring associated with debris that may be carried in the water could be very damaging to structures located in the tsunami's path. Structures that would be most vulnerable are those located in the front line of tsunami impact and those that are structurally unsound. Similar to the population exposed, all state buildings within 1-mile of the coastline are considered exposed to the tsunami hazard for the purposes of this plan. Table 16-3 summarizes the number and estimated replacement cost value (structure and contents) of state-owned and leased buildings in these coastal counties.

TABLE 16-3.
STATE-OWNED AND LEASED BUILDINGS EXPOSED TO THE TSUNAMI HAZARD

County	Number of Buildings	Replacement Cost Value (Structure and Contents)
Barnstable	239	$645,478,361
Bristol	139	$625,683,539
Dukes	6	$7,446,478
Essex	305	$3,380,458,220
Middlesex	23	$339,955,027
Nantucket	5	$31,381,244
Norfolk	115	$579,406,190
Plymouth	107	$431,990,607
Suffolk	261	$6,717,053,021
Total	**1,200**	**$12,758,852,687**

Source: DCAMM, 2012

16.4.4 Critical Facilities

All critical facilities within one-mile of the coastline are considered exposed to the tsunami hazard at this time. Table 16-4 and Table 16-5 summarize the number of critical facilities and bridges per County, respectively. Roads are the primary resource for evacuation to higher ground before and during the course of a tsunami event. Flooding caused by a tsunami will greatly impact this important component in the

management of tsunami related emergencies. Bridges exposed to tsunami events can be extremely vulnerable due to the forces transmitted by the wave run up and by the impact of debris carried by the wave action. The forces of tsunami waves can also impact above ground utilities by knocking down power lines and radio/cellular communication towers. Power generation facilities can be severely impacted by both the velocity impact of the wave action and the inundation of floodwaters.

TABLE 16-4.
NUMBER OF CRITICAL FACILITIES IN THE MASSACHUSETTS COASTAL COUNTIES

County	Police	Fire	Emergency Operation Centers	Hospitals	Schools (pre-K-grade 12)	Colleges
Barnstable	15	35	—	2	55	6
Bristol	11	27	—	3	100	3
Dukes	9	7	—	1	8	0
Essex	23	56	—	8	204	9
Middlesex	2	3	1	0	9	2
Nantucket	3	1	—	1	3	1
Norfolk	2	13	—	1	45	5
Plymouth	10	23	—	2	42	0
Suffolk	25	34	—	6	119	20
Total	**100**	**199**	**1**	**24**	**585**	**46**

Source: MassGIS, 2012

TABLE 16-5.
NUMBER OF BRIDGES IN THE MASSACHUSETTS COASTAL COUNTIES

County	Federal	State	Local
Barnstable	3	36	26
Bristol	—	97	30
Dukes	—	4	1
Essex	—	169	52
Middlesex	—	36	—
Nantucket	—	—	2
Norfolk	—	28	11
Plymouth	—	68	22
Suffolk	—	235	30
Total	**3**	**673**	**174**

Source: MassGIS, 2012

16.4.5 Economy

Economic losses from a tsunami include but are not limited to general building stock damage, business interruption/closure, closure of ports and related activities, and impacts on tourism and tax base to the Commonwealth. Tsunami waves can carry destructive debris and numerous pollutants that can have devastating impacts on all facets of the environment. Tsunamis may induce secondary hazards such as water quality and supply concerns, and public health concerns.

16.5 VULNERABILITY

Although tsunamis are infrequent events, especially in the Atlantic basin, their high impact can be devastating. The Commonwealth's vulnerability to the tsunami hazard is discussed below.

16.5.1 Population

The populations most vulnerable to the tsunami hazard are the elderly, disabled, and very young who reside near beaches, low-lying coastal areas, tidal flats, and river deltas that empty into ocean-going waters. In the event of a local tsunami generated in or near the Commonwealth, there would be little warning time, so more of the population would be vulnerable. The degree of vulnerability of the population exposed to the tsunami hazard event is based on a number of 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?

For this assessment, the population vulnerable to possible tsunami inundation is considered to be the same as the exposed population.

16.5.2 State Facilities

All structures, including state-owned and leased buildings, within one-mile of the coastline are considered exposed and vulnerable for the purposes of this plan. Table 16-3 summarizes the replacement cost values for state structures within coastal counties. Structures along beaches, low lying coastal areas, tidal flats, and river deltas would be more vulnerable to a tsunami, especially in an event with little or no warning time. The impact of the waves and the scouring associated with debris that may be carried in the water could be very damaging to structures located in the tsunami's path. Those that would be most vulnerable are those located in the front line of tsunami impact and those that are structurally unsound.

16.5.3 Critical Facilities

As mentioned for state facilities, all critical facilities within one-mile of the coastline are considered exposed but those along beaches, low-lying coastal areas, tidal flats, and river deltas would be more vulnerable to a tsunami event. The replacement cost values for critical facilities were not available for this planning effort. A total risk exposure would equal to the full replacement value of each critical facility exposed. As these data becomes available, the Commonwealth will update this section of the plan with new information. The functional down-time to restore these facilities to 100-percent of their functionality will be dependent upon the severity of the damage. The total estimated replacement cost value of the 850 bridges within one-mile of the coastline is $24 billion.

16.5.4 Economy

A tsunami's negative impact on the economy is difficult to quantify. As discussed above, losses include but are not limited to general building stock damage, business interruption/closures, port closures, utility and transportation damage, and impacts on tourism and tax base to the Commonwealth. Table 16-6

summarizes the replacement cost value (structure and contents) of the general building stock within one-mile of the coastline.

TABLE 16-6.
GENERAL BUILDING STOCK REPLACEMENT COST VALUE EXPOSED TO THE TSUNAMI HAZARD

County	Total Replacement Cost Value (Structure and Contents)
Barnstable	$35,456,688
Bristol	$30,500,534,000
Dukes	$4,095,763,000
Essex	$64,522,174,000
Middlesex	$9,049,260,000
Nantucket	$3,091,334,000
Norfolk	$19,071,731,000
Plymouth	$21,827,904,000
Suffolk	$69,651,038,000
Total	**$221,845,194,688**

Source: Hazus-MH v. 2.1

SECTION 17. STATEWIDE MITIGATION STRATEGY AND PROGRAM MANAGEMENT CAPABILITY

17.1 COMPREHENSIVE MITIGATION PROGRAM

The Mitigation Mission Statement and the Mitigation Goals serve as the framework for future mitigation funding and project decisions. They shape the long-term strategy of the Commonwealth of Massachusetts for hazard mitigation and assist in the development of a comprehensive program. The prioritization of local project requests and statewide initiatives will be representative of this strategy. The mitigation strategy will serve as the blueprint for reducing losses associated with the hazards of concern and their associated risks.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(3), which states the following:

Plan Content. To be effective the plan must include a Mitigation Strategy that provides the State's blueprint for reducing the losses identified in the risk assessment.

In order to develop a comprehensive hazard mitigation strategy for the future, the Commonwealth must analyze current programs, strategies, and public policies that address the impacts of natural hazards. The Commonwealth can then determine the gaps in protection and incorporate appropriate solutions into this SHMP. It can also provide out-of-the-box ideas and solutions that will further enhance the Commonwealth's resiliency. This section provides an overview of Massachusetts' current programs, policies, and agencies that address natural hazards through hazard mitigation, followed by an overview of commonly used hazard mitigation measures in Massachusetts. These programs form the basis for Massachusetts' recommended hazard mitigation goals and actions and potential resources to accomplish the identified actions.

Significant focus was placed on this section for the 2013 update, with a new mission statement being developed. The update also included a comprehensive review of hazard mitigation goals, a review of existing mitigation actions and development of new mitigation actions. The funding source matrix was enhanced to demonstrate a broader list of potential funding opportunities for both the Commonwealth and local jurisdictions. Enhanced and standard plan elements have been integrated throughout this section.

17.2 MITIGATION MISSION STATEMENT, GOALS AND ACTIONS

This section provides a list of Massachusetts' goals and the actions necessary to implement a comprehensive hazard mitigation strategy over the next three years. These statewide goals and actions are based on data provided in the previous sections of the SHMP, principally the risk and vulnerability assessments. The content of the 2013 SHMP is governed, in part, by rules drawn from the DMA 2000. Strategic planning elements included in the 2013 SHMP, such as the mission, goals, and mitigation actions, represent a direction-setting framework that considers both short-term and long-term outcomes. Massachusetts' comprehensive mitigation program consists of a combination of actions taken by multiple stakeholders over time, including the following:

- Legislative mandates for state and local agencies to undertake some form of mitigation activity (defined within the capability assessment)
- Governor's executive orders requiring state agencies to work with each other
- Updating of risk assessments
- Structural and non-structural mitigation actions taken by state and local agencies
- Regional agency coordination (regional planning commissions)

A sustained effort is being made to build on this framework by re-examining goals, priorities, and action programs. New challenges include implementation of a system for expanding the use of GIS through enhanced data sets (updated DCAMM data; development of a landslide database); systematically measuring mitigation progress through, among other alternatives, the inclusion of a loss avoidance study; expanding public/private sector mitigation communications and knowledge sharing, and integrating land use mitigation with other types of mitigation efforts on a statewide basis.

17.2.1 Mission Statement

It was determined for this update that a mission statement providing a guiding principle for development of the hazard mitigation plan would help to focus the 2013 plan and the mitigation program as a whole. The SHMT developed the following mission statement in January 2013:

> *Through partnerships, reduce the statewide loss of life, property, economy, infrastructure, and cultural resources from disasters through development of a comprehensive hazard mitigation program, which involves planning, awareness, coordination, project development, and implementation.*

17.2.2 Goals Update

For this plan update, the SHMT held a workshop on February 6, 2013, to evaluate mitigation goals and actions. The SHMT and SHMIC reviewed the 2010 statewide goals and actions for relevance, effectiveness and validity. The goals were also compared to goals used in local jurisdiction plans, as discussed in Section 3. It was determined that the 2010 goals were sufficient, but that, because the Commonwealth is seeking enhanced status and in order to more consistently match most of the local plans' goals, a broader set of goals for the SHMP would more accurately reflect the Commonwealth's intent. The SHMT used the following as a basis to develop its goals and mitigation actions:

- The goals will be used as general guidelines that explain what the Commonwealth wants to achieve.
- The goals will be broad statements, representing the long-term vision for hazard reduction and enhancement of mitigation capabilities statewide.
- The goals will be long-term (or short-term goals that assist in gaining long-term effects), and represent a global vision for the Commonwealth.
- The goals will be based any of the following:
  - Policy development
  - Programmatic design and/or support
  - Projects (structural and non-structural).

The SHMT identified the following preliminary mitigation options, all of which play a significant role in the Commonwealth's resiliency:

- Prevention
- Property protection
- Public education and awareness

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(3)(i & iii), which state the following:

Plan Content. To be effective the plan must include a Mitigation Strategy that includes:

- A description of the State goals to guide the selection of activities to mitigate and reduce potential losses.
- An identification, evaluation, and prioritization of cost-effective, environmentally sound, and technically feasible mitigation actions and activities the State is considering and an explanation of how each activity contributes to the overall mitigation strategy. This section should be linked to local plans, where specific local actions and projects are identified.

- Natural resource protection
- Emergency services
- Structural projects.

The 2010 goals and corresponding updated goals for the 2013 update are as follows:

- Goal 1:
  - 2010 Version: Meet the DMA 2000 planning requirements for hazard mitigation plans.
  - 2013 Version: Evaluate and analyze vulnerability in order to guide and promote sound mitigation activities through integrated planning to support a comprehensive state mitigation program.
- Goal 2:
  - 2010 Version: Increase awareness of the cost-savings and public safety benefits of hazard mitigation projects.
  - 2013 Version: Increase awareness of the benefits of hazard mitigation through outreach and education.
- Goal 3:
  - 2010 Version: Increase coordination and cooperation between state agencies in implementing sound hazard mitigation planning and project development.
  - 2013 Version: Increase coordination and cooperation among state agencies in implementing sound hazard mitigation planning and sustainable development.
- Goal 4:
  - 2010 Version: Fund cost-effective hazard mitigation projects through available federal grants and local cost share—PDM, HMGP, FMA, Severe Repetitive Loss, and 406 Mitigation Programs.
  - 2013 Version: Promote cost-effective hazard mitigation actions that protect and promote public health and safety from all hazards with a particular emphasis on reducing damage to repetitive and severe repetitive loss properties..
- Goal 5:
  - 2010 Version: Monitor, evaluate, and disseminate information on the effectiveness of completed hazard mitigation projects, especially after disaster events.
  - 2013 Version: Monitor, evaluate, and disseminate information on the effectiveness of hazard mitigation actions implemented by state, local, and private partnerships.

17.2.3 Mitigation Actions Update

Review of Existing Actions and Development of New Actions

The SHMT held a workshop to review the hazard mitigation action plan. During review, update, and development of new mitigation actions, existing actions were reviewed, and in some instances, slight revisions were made to correct grammatical errors, strengthen or expand the action, or provide more specificity. Realignment of the existing actions to coordinate with the new goals was not necessary. Participants reviewed each action and determined its status:

- No actions were removed during this update cycle.

- Revised actions are those which are still a priority to the Commonwealth, but needed to be modified for this update.
- Ongoing and continual actions are ones that the Commonwealth has worked on but that are perpetual.
- Unchanged actions are carried forward directly from 2010 plan.
- Completed actions are noted as such, but in most instances, they are also actions that will continue during the next update cycle. Although noted as completed, they remain in the state strategy for future updates as applicable.
- As a result of the February 6, 2013 and May 22, 2013 meetings, surveys, emails, and one-on-one discussions, a number of new actions were identified and added.

Prioritization Process

The STAPLEE planning criteria were applied to prioritize all of the new and ongoing actions as the method of prioritization (this is the same process followed in the 2010 plan):

- Social
  - Community Acceptance
  - Effects on Segment of Population
- Technical
  - Technical Feasibility
  - Long Term Solution
  - Secondary Impacts
- Administrative
  - Staffing
  - Funding Allocated
  - Maintenance/ Operations
- Political
  - Political Support
  - Local Support
  - Public Support
- Legal
  - State Authority
  - Existing Local Authority
  - Potential Legal Challenge
- Economic
  - Benefit of Action
  - Cost of Action
  - Contributes to Economic Goals

  - Outside Finding Required
- Environmental
  - Effects on Land/Water
  - Effects of Hazardous Materials/ Waste Sites
  - Consistent with Community Environmental Goals
  - Consistent with Federal Laws

Updated 2013 Mitigation Actions

Appendix G presents the results of the 2013 STAPLEE analysis. Table 17-1 presents the complete set of actions included in the 2013 hazard mitigation strategy. Actions that are new for this update are noted as such in the comments column of the table. Completed actions from 2010 are noted at the end of the table. The actions listed in the matrix are those that were considered to be the highest priority as they contribute to the overall state hazard mitigation strategy. The plan does not include all mitigation actions that the SHMT would consider and like to implement.

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
Goal 1. Evaluate and analyze vulnerability in order to guide and promote sound mitigation activities through integrated planning to support a comprehensive state mitigation program.				
a. Complete a standard State Hazard Mitigation Plan Update and submit for FEMA review and approval prior to the October 2013 deadline per DMA 2000. The Commonwealth has written the plan to enhanced status, with the hopes of gaining that status with the submission of the 2013 plan.				
SHMT, SHMIC	FEMA Final Approval by 10/ 11/ 2013	Current MEMA/ DCR staff and contractor; federal and state funds	Required by DMA 2000 planning regulations. A FEMA-approved state mitigation plan is needed to continue to implement the Statewide Mitigation Planning Strategy and to continue the availability of disaster assistance and hazard mitigation grants.	Progress made. The Commonwealth continues its commitment to a statewide mitigation program through the continual update of the Massachusetts SHMP. The 3-year required update started in fall 2012, in conjunction with development of the THIRA. A contractor was hired to assist.
b. Perform a statewide risk analysis for all hazards to include in future updates to this state hazard mitigation plan and other related plans				
SHMT, SHMIC, MEMA	1 year	HMGP, PDM Planning Grant, State funds	An updated hazards analysis would enhance the validity, accuracy, and practicality of the statewide risk analysis.	2013 progress made. This task is being accomplished through the SHMP risk assessment update and creation of the THIRA (see Goal 1 Action (l) below).

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
c. Develop State Hazard Mitigation Plan and submit to FEMA for approval.				
SHMT	1 year	Current MEMA/ DCR staff; HMGP funds	An enhanced plan will allow the Commonwealth to be eligible for up to 20% in available HMGP funding. Additional HMGP funding will support implementation of more hazard mitigation projects as identified in the state, regional, and local hazard mitigation plans.	2013 progress made. The SHMT continues to view this as an important step in strengthening the mitigation program. The SHMT continues to evaluate the feasibility of becoming an enhanced state. The contractor conducting the 2013 update has developed the plan to an enhanced status, and will be providing the SHMT with a gap analysis highlighting any areas in the mitigation program that may need strengthening to gain enhanced status.
d. Work with the SHMIC to research and develop a more realistic set of criteria by which to prioritize mitigation actions that capture timely and relevant mitigation needs throughout the Commonwealth.				
SHMT and SHMIC	1 year	Current MEMA/DCR Staff; HMGP funds	With the intent of increasing stakeholder participation at the state level, a different system may be needed to prioritize mitigation efforts. The current method prioritizes action items at a statewide level based on the STAPLEE. This may not be appropriate in determining priority for specific projects for each department or agency, as each department or agency has its own level of priority for projects.	New for 2013: The Commonwealth views this as a high priority as it will support Goal 4e.
e. Partner with regional planning agencies and other groups in Massachusetts to develop and implement regional and local multi-hazard mitigation plans by providing technical assistance.				
SHMT	3 years	Current MEMA/ DCR/ CZM staff; state funds	FEMA-approved local mitigation plans are needed to implement the Statewide Mitigation Planning Strategy and the availability of hazard mitigation grants to communities. Regional planning agencies bring local and regional planning expertise, knowledge, and contacts, especially in transportation issues and land use planning, to the mitigation planning process.	Progress made/ continual. From 2010 – 2012 sixty-six communities received FEMA formal approval for their local hazard mitigation plan. Through the continual implementation of the Massachusetts mitigation program, the SHMT will continue to work with local communities and/or regional planning agencies to assist with the development and update of local hazard mitigation plans through technical assistance and funding.

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
f. Apply for available federal funding to implement and update the completed and approved multi-jurisdictional and local hazard mitigation plans.				
SHMT	3 years	Future Hazard Mitigation Assistance programs (PDM-C, HMGP & FMA)	Obtain maximum available funding to implement identified mitigation projects. Federal mitigation grant funding is a key component to support implementation of hazard mitigation projects as identified in the state, regional, and local hazard mitigation plans.	Progress made/ continual. Through the implementation of the Massachusetts mitigation program, the SHMT continues to work with communities and regional planning agencies to assist with the development of single and multi-jurisdictional local hazard mitigation plans. From 2010 – 2012 the SHMT received 22 applications for planning grants to either update or develop HMP's.
g. Continue to incorporate new data and recommendations from the FEMA-approved regional and local mitigation plans into the SHMP, especially locations of critical facilities and assessments of vulnerability and estimates of potential losses by jurisdiction.				
SHMT	3 years	MEMA/ DCR staff	Analyze regional and local data and make recommendations to update the SHMP. Compile up-to-date lists of prioritized hazard mitigation projects and actions throughout the Commonwealth for consideration.	Progress made/ continual. MEMA is invested in increasing its capabilities to prevent, protect against, mitigate, respond to and recover from the threats and hazards that pose the greatest risk to the Commonwealth. In keeping with this desire, in 2012, MEMA hired a full-time GIS coordinator as well as a business systems specialist aimed to increase data and technical capabilities. The SHMT, along with the business systems specialist, is currently looking into database options to assist with capturing local plan data, including local GIS data.
h. Track potential hazard mitigation actions statewide in a database, using new information provided by the multi-jurisdictional plans with local annexes and state agencies.				
SHMT	3 years	Current MEMA/ DCR staff	Develop a statewide database of potential hazard mitigation actions that support the goals and objectives of completed mitigation plans.	Progress made. The resources needed to accomplish this action will be included in the same discussions as for Goal 1 Action (g). The SHMT, in coordination with the business systems specialist, will research and develop a resource that is able to provide project tracking.

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
i. Coordinate data collection and sharing with other statewide planning initiatives, such as the Statewide Homeland Security Planning process.				
SHMT, Executive Office of Public Safety and Security (EOPSS)	3 years	Current MEMA, DCR, EOPSS staff	Combining resources will allow for more accurate information in several statewide plans. Coordination of data collection methodology and new information will allow for a more accurate statewide plans and maps.	Progress made/ continual. Integration continues to be a priority for the SHMT. There have been several efforts conducted during the last 3 years. The development of the THIRA as well as the Massachusetts Local Public Health Departments utilized local and state hazard mitigation plan data to conduct risk assessments. Statewide evacuation and shelter plans are utilizing the new SLOSH mapping data, and the Risk MAP efforts integrate local hazard mitigation plans and promote resiliency.
j. Continue to support existing statewide mitigation planning, especially the Community Assistance Program-State Support Element Floodplain Management Plan, including activities under the National Flood Insurance Program, and the Risk MAP Business Plan.				
DCR Flood Hazard Management Program	3 years	Community Assistance Program-State Support Element funding; Risk MAP, CTP funding; Flood Hazard Management Program staff	Ongoing and improved compliance with the NFIP, in conjunction with the Risk MAP, will allow the Commonwealth to focus its resources, such as technical assistance and mitigation grants, in the highest flood risk communities.	This continues to be a priority for the Commonwealth. These efforts are part of the daily and yearly implementation of the program. See section 3.2.3 for the technical assistance and outreach the SHMT has provided since 2010.
k. Address data deficiencies and improve analysis, when available, by partnering with federal, state, local, and other subject matter experts.				
SHMT	3 years	PDM Planning Funds and/ or Current MEMA, DCR, EOPSS staff	Continue to improve the risk assessment for the Commonwealth and address data deficiencies. This action also encompasses the incorporation of all new or improved data that are made available to the Commonwealth.	Progress made. Data deficiencies highlighted in the 2010 risk assessment will be addressed where possible during the 2013 update. The consultant hired to develop the THIRA and the capabilities assessment was also hired to conduct the 2013 SHMP update. The purpose of this was to be able to garner the best possible integration between the two plans.

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
l. Create a statewide Threat and Hazard Identification and Risk Assessment (THIRA) as described in FEMA's April 2012 Threat and Hazard Identification and Risk Assessment Guide (CPG 201). In conjunction with the development of the THIRA conduct a statewide capabilities gap assessment. The THIRA will be the man-made-hazards portion of the risk assessment in the SHMP				
SHMT, SHMIC, THIRA Planning Committee	1 year	PDM and HMGP grants	In accordance with Presidential Policy Directive 8 and the National Preparedness Goal, the THIRA will be developed to create a "secure and resilient state with the capabilities required across the whole community to prevent, protect against, mitigate, respond to and recover from the threats and hazards that pose the greatest risk."	New. The THIRA was submitted to FEMA for review and approval January 31, 2013.
Goal 2. Increase awareness of the benefits of hazard mitigation through outreach and education.				
a. Develop and implement a statewide hazard mitigation training program, including educational materials for federal and state agencies				
SHMT, SHMIC	3 years	HMGP, state funds	Greater awareness among state and federal agencies will reduce risks from natural hazards by allowing for more effective implementation of the hazard mitigation strategy, especially the completion of mitigation actions.	Progress made: Completed for the 2010-2013 cycle. The Commonwealth continues to provide ongoing training and technical assistance of various types (discussed in Section 3 in greater detail) as a general course of action. This includes the development of studies and reports that help provide information concerning specific hazards, such as the ongoing landslide study and the various Coastal Erosion/ Climate Change reports that have been released since the 2010 plan. During the current update cycle, additional outreach was conducted. During the 2013-2016, items identified in the 2013 updated SHMP will be reviewed and additional training will occur as opportunities arise.
b. Conduct hazard mitigation community outreach and educational programs for the general public, such as programs in schools and at home improvement stores and events.				
SHMT, SHMIC	3 years	Hazard mitigation admin and technical assistance funds	Educated consumers will be better protected from natural disasters because they have reduced risks by implementing various hazard mitigation techniques, projects and actions.	This continues to be important to the Commonwealth and opportunities will be looked for throughout the 3-year planning cycle. Progress made: During the response to the 2010 spring flood, a special partnership was formed between Home Depot, the federal/ state joint field office, and North Quincy High School to work on a mitigation project called The Dawg Haus (also discussed in Section 2).

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
c. Continue to hold hazard mitigation grant workshops for state agencies and local governments after natural disasters, especially immediately following Presidential Disaster Declarations.				
SHMT	Within 2-3 months of disaster declaration	Hazard mitigation admin and technical assistance funds	Informed public officials will apply for funding for hazard mitigation projects and will motivate communities without plans to develop hazard mitigation strategies.	In addition to grant briefings (see Section 3), MEMA staff regularly speaks at area universities regarding mitigation and preparedness programs
d. Use the Internet to develop more consistent and timely tools for distributing information about current hazard mitigation programs and success stories in Massachusetts to other government agencies, the private sector, and the general public.				
SHMT	3 years	HMGP and technical assistance funds	Informed public officials will apply for funding for hazard mitigation projects as well as motivate communities without plans to develop hazard mitigation strategies. Informed local officials will apply for funding for hazard mitigation projects and actions that will help to reduce future risks.	Progress made/ continual. The Commonwealth continues to see this as a priority. In addition to the continued outreach with CZM and Storm Smart Coasts, the mitigation unit has developed electronic forms such as applications and quarterly reports to facilitate ease of submission from sub-applicants.
e. Provide improved outreach to all eligible applicants for mitigation projects and planning.				
SHMT	1 year	State resources	More partners in mitigation will increase the effectiveness of the overall mission of mitigation in Massachusetts.	Progress made/ continual. The Commonwealth continues to see this as a priority. The mitigation staff will look at the current program to determine areas of opportunity for improvement.
Goal 3. Increase coordination and cooperation among state agencies in implementing sound hazard mitigation planning and sustainable development.				
a. Investigate the possibility of creating a standardized format or model for local hazard mitigation plans to create consistency among all plans statewide.				
SHMT, CZM Staff	1-3 years	Staff resources	Massachusetts has 351 communities with the potential to have 351 different plans and formats. Having a standardized format will facilitate incorporation of data to state or regional mitigation plans	Progress made/ continual. The Commonwealth continues to see this as a priority. To that end, the mitigation planning staff is developing a tool to help communities standardize traditionally problematic sections of the plan.

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
b. Develop a strategy to reduce the overlap between Comprehensive Emergency Management Plans and Hazard Mitigation Plans				
SHMT, MEMA	1-3 years	Staff resources	Creating a comprehensive approach to all emergency and mitigation planning can eliminate local confusion and help to make planning funding more effective at the local level by not duplicating benefits of state and federal programs.	Progress made. MEMA mitigation planning staff has begun conversations with the MEMA All-Hazards planning staff to better coordinate/ integrate the local Comprehensive Emergency Management Plans and local hazard mitigation plans.
c. Build 'non-traditional' partners in mitigation by encouraging colleges and universities, non-governmental organizations, private non-profits, and the private sector to use their resources to study hazard vulnerability and implement mitigation projects and by prioritizing project applications for traditional funding sources that leverage funding and contributions from these non-traditional sources.				
SHMT lead, involves many agencies	3 years		Building partnership with all public and private partners to reach more citizens and increase awareness for mitigation and help to leverage funding for more diverse mitigation projects.	Progress made. The SHMT continues to view this as an important step in strengthening the mitigation program. The SHMT has worked hard to include non-traditional partners in the planning process, including outreach with funding opportunities. Multiple state universities have used Hazard Mitigation Assistance funding to study hazards. See Table 3-3 for HMGP grant applications received.
d. Educate all communities, state agencies, and the private sector—specifically building and insurance industries—about the benefits of mitigating against natural hazards by participating in planning and projects.				
SHMT	3 years	Staff resources	Greater awareness of mitigation at the local level will reduce risks from natural hazards by allowing for more effective implementation of the strategy, especially the completion of mitigation actions.	The Flood Hazard Management Program (FHMP) routinely visits and contacts communities to discuss National Flood Insurance Program issues and standards, as enforced primarily through state regulations, and floodplain management in a general sense. In the last three years this would have included about 72 communities. Additionally, workshops have been held each of the last three years with the South Eastern Massachusetts Building Officials Association (SEMBOA) in which a much wider audience can be reached as this annual two-day workshop is open to the whole state. Contacts made in these visits and workshops invariably leads to follow-up conversations with homeowners, design professionals, real estate and insurance professionals, and other interested parties with specific questions about insurance, proposed projects, mapping and other floodplain management issues.

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
e. Continue to make recommendations to the Board of Building Regulations and Standards as the Massachusetts State Building Code is updated to include updated NFIP standards and other building standards related to natural hazards, such as wind, snow, seismic loads, and other hazards.				
MEMA, DCR, SHMIC	3 years, as needed (dependent on Building Code update schedule)	MEMA, DCR staff	The inclusion of revised federal mitigation standards in the State Building Code will allow for consistent implementation of sound mitigation measures statewide, especially in new construction and in the repair/ renovation of substantially damaged structures. Allows for uniform application of mitigation measures by local officials.	FHMP staff, along with DEP and CZM coordinated extensively with BBRS staff to during the update of the Building Code to the 8th Edition. The Base Volume, 8th Edition, became effective in August 2010 and the Residential Volume, 8th Edition became effective in February 2011. Coordination between these agencies ensured that Massachusetts standards from the 7th Edition of the Code were brought forward to the 8th Edition and that the Codes remained consistent with NFIP standards.
f. Encourage project granting agencies in the Commonwealth, such as the Massachusetts Department of Housing and Community Development's review of Community Development Block Grants, to include the analysis of hazard impacts when reviewing applications for funding				
SHMT, SHMIC	3 years	MEMA, DCR, EOPSS	By avoiding the building of new structures in an area of potential natural hazard impacts, this coordinated action between agencies will reduce or mitigate future damage and costs following future hazard events.	Progress made. This continues to be a priority for the Commonwealth. The SHMT is looking beyond its own programs to expand outreach to other programs in order to better integrate hazard mitigation. One such program is the MassWorks Infrastructure Program. Mitigation staff has attended grant briefing meetings to start the conversation. Other such discussions have been a focus with existing SHMIC members to ensure maximum integration.
g. Recruit additional state agencies to become involved in the State Hazard Mitigation Interagency Committee.				
SHMT	3 years	MEMA, DCR Staff	Active participation of state agencies in the SHMIC will facilitate the sharing of information between agencies, expedite implementation, and ensure more widespread and consistent implementation of sound hazard mitigation measures throughout the Commonwealth.	Progress made. Since the 2010 plan approval a new department within an existing SHMIC agency has been added. An outreach plan was developed to increase the number of state agency SHMIC members. It is a goal to add six agencies/ departments within an agency to the list in the next 3 years.

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
h. Continue working with other state agencies, especially those on the State Hazard Interagency Committee, to ensure that all the necessary permits and requirements are being met before the execution of all hazard mitigation projects through the Hazard Mitigation Assistance Programs.				
SHMT, SHMIC	Through the 3 year planning cycle - especially following a federal disaster declaration	MEMA, DCR Staff, and State Grants Admin. Plan	By coordinating all the necessary federal and state permits, the Commonwealth will avoid future problems as projects are constructed. Coordination of permits and other requirements ensures a timely completion of an effective mitigation project.	Unchanged. The Commonwealth continues to see this as a priority. With the hiring of two new Project Specialists the SHMT is able to attend more preconstruction and FEMA EHP meetings to ensure all permits and requirements are being met. Section
Goal 4. Promote cost-effective hazard mitigation actions that protect and promote public health and safety from all hazards with a particular emphasis on reducing damage to repetitive and severe repetitive loss properties.				
a. Research the potential for implementing a source for a state investment in mitigation.				
SHMT, MEMA	Ongoing	Staff resources	Assessing state assets and potential for partnering with existing programs and funding sources allows the Commonwealth to maximize the potential local and state contribution to hazard mitigation projects.	Unchanged. Although no movement was made on this action, the Commonwealth continues to see this as a priority.
b. Enhance the effectiveness of 406 funding by working to further integrate mitigation into the FEMA Public Assistance Program.				
SHMT, MEMA	Ongoing	Staff resources	By working with FEMA Public Assistance Program, the Commonwealth can maximize the cost-effectiveness of federal grants by mitigating hazards during the recovery process.	Progress made. The Commonwealth continues to see this as a priority. The SHMT coordinates with the mitigation branch at the joint field office (when established) to imbed a state mitigation staff with the PA staff to ensure mitigation is investigated for every project worksheet. There have been 3 JFO's established since the 2010 plan. Only the March 2010 Floods had a MEMA/DCR staff person working at the JFO. The other events were handled remotely.

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
c. Apply for available federal hazard mitigation project grants through pre-disaster and post-disaster mitigation programs and other federal mitigation programs as the funding becomes available and explore.				
SHMT	Ongoing	MEMA, DCR staff, FEMA grants, State Grants Administrative Plan	Hazard mitigation projects are expensive and federal funding is needed by the Commonwealth and communities to complete most projects. Funding cost-effective hazard mitigation projects in high-risk areas, as identified in this plan as well as in regional and local hazard mitigation plans, will reduce future losses.	Progress made. The Commonwealth continues to see this as a priority. Massachusetts has experienced a series of disasters during the last 3 years. Based on this, the SHMT has focused on managing the HMGP program funds in an efficient and effective manner. When funds are made available, the SHMT manages the non-disaster funding program as well. See Section 3 for details on outreach efforts.
d. Notify all eligible applicants of available hazard mitigation project grant programs for mitigation projects, including available funding through the Unified Hazard Mitigation Assistance programs and other mitigation opportunities				
SHMT	Ongoing	MEMA, DCR staff, FEMA grants, State Grants Administrative Plan	Hazard mitigation projects are expensive and federal funding is needed by the Commonwealth and communities to complete most projects. Funding cost-effective hazard mitigation projects in high-risk areas, as identified in this plan and in regional and local hazard mitigation plans, will reduce future losses.	Progress made. The Commonwealth continues to see this as a priority. The Commonwealth of Massachusetts has experienced a series of disasters during the last 3 years. The SHMT manages an outreach program for FEMA's HMA programs. Based on this, the SHMT has focused on managing the HMGP program funds in an efficient and effective manner. When funds are made available, the SHMT manages the non-disaster funding program as well. See Section 3.
e. Work with state agencies that own state facilities believed to be at high or medium flood risk or overland tidal surge to further evaluate the flood and surge risk and to identify and implement appropriate mitigation actions.				
SHMT, SHMIC	3 to 5 years	MEMA, DCR staff; individual agency capital funding; FEMA planning and project grant funding	Individual analysis will provide a better assessment of the flood and surge risks and identify specific flood mitigation measures for implementation by state agencies. By further identifying these risks and mitigation measures for individual structures and facilities, the Commonwealth can make recommendations for funding appropriate projects that will reduce or eliminate these risks.	Progress made. As a result of the THIRA/ SHMP update, the consultant is providing detailed maps showing state-owned facilities located in high hazard areas. As part of the deliverables for this project, the consultant will supply an outreach strategy for the SHMT to work with agencies with buildings/ infrastructure in the hazard areas to develop actions to mitigate their risk.

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
f. Develop a methodology for collecting and assessing the natural hazard risks, especially flooding, erosion, and storm damage, for all current and future state-owned facilities and properties, to be used by agencies to identify and implement appropriate mitigation actions.				
SHMIC, MEMA, DCR, DCAMM	Ongoing	MEMA, DCR staff, SHMIC, MassDEP & CZM	Collecting such data will assist in identifying high-risk facilities and properties and incorporating hazard mitigation measures into the planning processes. Improving the data on high-risk facilities will assist in implementing hazard mitigation measures for specific facilities and properties.	Progress made. New process for 2013. As a result of the THIRA/ SHMP update processes, the consultant is providing detailed maps showing state-owned facilities located in high hazard areas. As part of the deliverables for this project, the consultant will supply an outreach strategy for the SHMT to work with agencies with buildings/ infrastructure in the hazard areas to develop actions to mitigate their risk.
g. Work with state agencies to fully identify all potential hazards to facilities before major repairs, or the construction of new facilities, to minimize future impacts from natural hazards, particularly flooding, storm damage, and erosion.				
SHMIC, MEMA, DCR	Ongoing	MEMA, DCR staff, SHMIC, MassDEP & CZM	Recognizing exposure to natural hazards prior to construction of all new state facilities and major renovations to such facilities will result in appropriate hazard mitigation measures being included in the master planning and design process. Inclusion of hazard mitigation measures during the planning of facilities will save future repair and disaster assistance costs.	Unchanged/ progress made. The Commonwealth continues to see this as a priority. There are a few mechanisms within the Commonwealth that help facilitate this action. Members of the SHMT are responsible to review projects as part of the Massachusetts Environmental Policy Act review process, primarily looking at the construction of buildings in the floodplain to determine if comments are warranted. This gives staff the ability to inject mitigation for consideration. It is also the SHMT's intent to incorporate this discussion in conjunction with helping state agencies develop mitigation actions for their vulnerable facilities.
h. Work with communities to implement cost-effective, environmentally sound, and feasible mitigation projects to severe repetitive loss properties.				
SHMT	Ongoing	Hazard Mitigation Assistance Program funds	Mitigation of severe repetitive loss structures will reduce or eliminate claims under the NFIP through project activities that will result in the greatest savings to the NFIP in the shortest period of time.	Progress made. This is a normal/ daily objective of the SHMT, specifically the State Floodplain office. See Section 3 for an overview of the technical assistance and outreach the SHMT provided since 2010.
Goal 5. Monitor, evaluate, and disseminate information on the effectiveness of hazard mitigation actions implemented by state, local, and private partnerships.				

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
a. Develop a process to track all completed mitigation projects in Massachusetts, including 406 mitigation and privately funded mitigation projects.				
SHMT	3-5 year	Staff resources	Evaluating existing successes can act as a public relations tool to create awareness to the importance of natural hazard mitigation.	Progress made. This continues to be a priority for the Commonwealth and will be incorporated into the discussions for the project database development action (Goal 5 Action (b) below). In addition, the SHMT, in conjunction with FEMA mitigation staff from the Hurricane Sandy joint field office, conducted a loss avoidance study. As a result, it is apparent that data collection is pivotal to a successful loss avoidance study and will therefore also be considered during database development to ensure proper data collection/tracking.
b. Evaluate the feasibility of maintaining a database of potential mitigation projects across the Commonwealth, taken from local hazard mitigation plans, project worksheets from the Public Assistance process, and other sources.				
SHMT, MEMA	3-5 years	Staff resources	Evaluating potential projects will allow the Commonwealth to maximize the cost-effectiveness of federal grants by mitigating hazards in a pre- and post-disaster setting.	Progress made. MEMA is invested in increasing its capabilities to prevent, protect against, mitigate, respond to and recover from the threats and hazards that pose the greatest risk to the Commonwealth. In keeping with this desire, MEMA has hired a full-time GIS coordinator as well as a business systems specialist, to increase data and technical capabilities. The SHMT, along with the business systems specialist, is currently looking into database options to assist with capturing local plan data, including local GIS data.
c. Prepare hazard mitigation best practices and case studies on a regular basis.				
SHMT, FEMA	Throughout the 3-year planning cycle and following future disasters	MEMA, DCR, and FEMA Public Information staff.	Sharing information on completed hazard mitigation projects that prevent loss and damage demonstrates the effectiveness of the hazard mitigation program and motivates other communities to undertake similar hazard mitigation projects in the future. Mitigation project "success stories" help to publicize communities and effective projects, thereby raising awareness of effective hazard mitigation measures.	Progress made. The most recent best practices were developed during the March 2010 flood joint field office. In the absence of a joint field office, the SHMT will capture best practices as projects are completed.

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
d. Implement a standard information-sharing procedure on disaster damage data collected by FEMA, PDA, Community Relations, and infrastructure inspectors to use in local hazard mitigation planning efforts and identifying potential hazard mitigation projects.				
SHMT, FEMA	Throughout the 3-year planning cycle and following future disasters	MEMA, DCR, and FEMA Infrastructure (Public Assistance) staff	In-the-field inspectors can provide useful information on opportunities for hazard mitigation projects. Timely, coordinated data can better identify areas that warrant mitigation actions and eliminate duplication of efforts by programs.	Progress made. The Commonwealth continues to see this as a priority. Starting with the March 2010 flood event, the SHMT coordinates with the mitigation branch at the joint field office (when established) to imbed state mitigation staff with the PA staff to ensure mitigation is investigated for every project worksheet.
e. Improve the Commonwealth's capabilities assessment by integrating the locally administered capabilities and the state level capabilities in order to demonstrate how mitigation efforts at various levels are implemented and integrated. This will also provide the Commonwealth with information concerning any gaps or areas in which improvement can occur, either at the state or local levels to increase mitigation potential.				
SHMT, SHMIC, and Local Jurisdictions	Throughout the 3-year planning cycle and as plans are submitted to the Commonwealth for review.	MEMA, DCR staff	Providing information of this type will help determine where emphasis needs to be placed with respect to the capabilities at both the local and state levels. Integration of the capabilities will enhance effectiveness and provide information on where to focus efforts.	New effort for 2013. The Commonwealth sees this as a priority with a high value. A new database will be designed that will allow the capturing of this information in greater detail. This will be supported by action (g) for Goal 1, with the hiring of a full-time GIS coordinator as well as a business systems specialist aimed to increase data and technical capabilities.
f. Research best practices and then work with the Regional Planning Agencies and local communities through outreach and education to help local communities strengthen the ownership of the planning process.				
SHMT, SHMIC	Throughout the 3-year planning cycle and following future disasters	MEMA, DCR, Regional Planning Agencies, and FEMA staff	With many of the Commonwealth's current local plans in the process of being updated, or about to expire, outreach will be very beneficial. Providing assistance during the development of the plans or encouraging development of local plans will be paramount in continuing a successful mitigation program. The use of the newly developed local survey will also provide guidance to the local planners, as well as providing relevant information to the Commonwealth.	New effort for 2013. The Commonwealth sees this as a high priority with a high value. The SHMT will develop an outreach strategy to assist the Regional Planning agencies and local communities in understanding the importance of plan integration and ownership. Enhanced outreach by all planning partnerships will help ensure a higher-level of plans and stronger mitigation programs. ,

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
Goal 1 Actions Completed, 2010 – 2013				
a. Complete a standard state hazard mitigation plan and submit for FEMA review and approval prior to the September 2010 deadline per DMA 2000.				
SHMT and SHMIC	Current	Current MEMA/ DCR staff; state funds	Required by DMA 2000 planning regulations. A FEMA-approved state mitigation plan is needed to continue to implement the Statewide Mitigation Planning Strategy and to continue the availability of disaster assistance and hazard mitigation grants.	The 2010 revised SHMP received FEMA formal approval 10/12/2010; 2013 submitted for review.
b. Perform a statewide risk analysis for all hazards to include in future updates to this state hazard mitigation plan and other related plans				
SHMT, Interagency Committee, MEMA	1-3 years	HMGP, PDM Planning Grant, State funds	An updated hazards analysis would enhance the validity, accuracy, and practicality of the statewide risk analysis.	Completed for 2010-2013 SHMP and THIRA
Goal 2 Actions Completed, 2010 – 2013				
a. Develop and implement a statewide hazard mitigation training program, including educational materials for federal and state agencies				
SHMT and SHMIC	Ongoing	HMGP, state funds	Greater awareness among state and federal agencies will reduce the risks from natural hazards by allowing for more effective implementation of the strategy, especially the completion of mitigation projects and actions.	
b. Conduct hazard mitigation community outreach and educational programs for the general public, such as programs in schools and at home improvement stores and events.				
SHMT and SHMIC	Ongoing	Hazard mitigation admin and technical assistance funds	Educated consumers will be better protected from natural disasters because they have reduced risks by implementing various hazard mitigation techniques, projects, and actions.	Completed. During the response to the 2010 spring flood, a special partnership was formed between Home Depot, the federal/state joint field office, and North Quincy High School to work on a mitigation project called The Dawg Haus. In addition, MEMA staff regularly speaks at area universities regarding mitigation and preparedness programs

TABLE 17-1.
UPDATED ACTIONS FOR 2013 HAZARD MITIGATION STRATEGY

Responsible Agency	Projected Timeline	Resources	Explanation	Update Comments and Revisions
Goal 5 Actions Completed, 2010 – 2013				
c. Prepare hazard mitigation best practices and case studies on a regular basis.				
SHMT & FEMA	Throughout the 3-year planning cycle and following future disasters	MEMA, DCR, and FEMA Public Information staff.	Sharing information on completed hazard mitigation projects that prevent loss and damage demonstrates the effectiveness of the hazard mitigation program and motivates other communities to undertake similar hazard mitigation projects in the future. Mitigation project "success stories" help to publicize communities and effective projects, thereby raising awareness of effective hazard mitigation measures.	Completed. The most recent best practices were developed during the March 2010 Flood joint field office.

Approach to Future Prioritizing of Mitigation Actions

The statewide mitigation goals, action items, and opportunities for improvement to existing mitigation programs represent a multi-faceted comprehensive approach to addressing natural hazards in the Commonwealth. The actions will be undertaken as resources and program improvement opportunities become available, the regional multi-jurisdictional plans and local annexes are completed, and the impacts of disasters events are analyzed. In most cases, the goals and actions draw from different sets of resources, so there is no competition for limited resources between alternative mitigation actions.

The 2013 update emphasizes increased state-agency participation (see Section 2). Based on the anticipated increased level of participation, SHMIC members determined that the previous method of prioritizing projects may not be as effective for future updates, for a variety of reasons:

- Because of the probability and severity of multiple risks faced by Massachusetts, the Commonwealth is continuously addressing multiple hazards, vulnerabilities, and risks as defined in the risk assessment and THIRA portions of the SHMP.
- Differences in diversity, socioeconomic factors, geographic variation, and levels of risks and vulnerabilities make it difficult to assign priority to one type of hazard over another on a statewide basis.
- Post-disaster assessments after large disasters often stimulate new recommendations for legislative and administrative actions. This can result in important new lines of mitigation policy for specific hazards. Actions that are a result of state legislation, or Governor's executive orders often carry the highest priorities.

Based on these considerations, the SHMT determined that a new method of prioritizing state-level actions and projects may be in order for future updates, which will be discussed and vetted with FEMA Region I after approval of the 2013 update. The concept of hazard mitigation must be embraced by all Massachusetts state agencies, as all play a vital role in protecting residents and providing resiliency and recovery through continuity of government. In order to foster holistic state and local programs that make

hazard mitigation a way of doing business, mitigation actions will not be ranked in numerical order as classified as high, medium or low priority.

Many state agencies also support mitigation efforts at the local level. In order for progress to be made on state mitigation actions, agencies, and organizations must maintain ownership and buy-in of the action items developed. Rather than encouraging agencies to develop a list of planning and construction projects geared only toward those eligible for federal hazard mitigation grants when they become available, the state program encourages agencies and organizations to include mitigation as they consider their normal course of business, such as when they develop strategic plans for their organizational operations, as well as during construction and location of new buildings, or when making existing facilities safer. Post-disaster assessments and ensuing legislative actions must also be considered.

The State Hazard Mitigation Program does not target available resources to only a handful of local jurisdictions or focus on just a few hazards. The reason for this is two-fold:

- The Commonwealth of Massachusetts has a home-rule style of governance. This means that local governments are responsible for maintaining control of government services and actions at the lowest possible level, rather than the Commonwealth providing top-down direction to control decisions that affect local citizens.
- It is not politically tenable to direct most or all of available resources to a limited area (such as a few flood-prone communities) or toward a restricted type of mitigation task (such as elevating or purchasing repetitive flood-loss properties). This discourages non-funded jurisdictions from developing and maintaining mitigation programs, plans, and projects.

Rather than establishing project priorities, the State Hazard Mitigation Program requires any mitigation project (including state-agency projects) proposed for funding through the federal hazard mitigation grant programs administered by the DCR and MEMA to do the following:

- Support the goals of the SHMP.
- Reduce identified hazard risk.
- Reduce repetitive losses, without regard to hazard.
- Protect critical areas, particularly frequently flooded and coastal areas, and geologically hazardous areas.
- Be cost-effective as well as environmentally sound and technically feasible.

Proposed state projects will compete with projects proposed by eligible local governments; this will ensure that federal grant-funded state and local projects address state hazard mitigation priorities. Given that the Commonwealth has attempted to gain participation from a wide-range of state agencies and seeks funding from many different sources, including its own operating funds, prioritizing specific projects would not be feasible, as each agency has an established priority schedule, and that schedule does not necessarily coincide among agencies. To prioritize projects based on a uniform approach is not practical. What an advisory team determines to be the greatest priority may, in reality, not be scheduled by an agency to occur at the time funding opportunities arise. Furthermore, impacts of a recent disaster may make other actions more important.

The SHMT agreed that the Administrative Plan, found in Annex 2, is the best option for prioritizing mitigation actions. Any state government projects funded by federal hazard mitigation grant programs administered by the Commonwealth must meet specific criteria related to cost-effectiveness, environmental soundness, and technical feasibility.

17.2.4 Local Mitigation Actions

In the Commonwealth of Massachusetts, most mitigation actions—from construction projects to community outreach—are done at the local level. While MEMA, DCR, the CZM, and the National Estuary Programs (such as the Buzzards Bay and Mass Bays Projects) provide technical assistance to local jurisdictions to develop projects if requested, city and town governments typically make the decisions governing projects for their jurisdictions, from project design to implementation. Local officials best know the problems and issues in their communities. Variations in local administration, hazards, and population make each jurisdiction unique, and what may work in one community, or what may be a priority in one community, may not work in another. Rather than dictating the projects that should be done at the local level, the Commonwealth typically acts as a guide and provides resources as possible. Therefore, only projects that are state-agency related or statewide initiatives are listed in this plan. However, the Coordination of Local Planning Efforts section of this plan provides greater detail on local mitigation activities and unique projects developed at the local level.

17.2.5 Local Mitigation Projects

Local mitigation projects and plan applications are prioritized per criteria found in the Massachusetts Mitigation Grants Administrative Plan contained in Annex 2, and as discussed in Section 3.

17.3 STATE CAPABILITY ASSESSMENT

The capability assessment reviews the Commonwealth's hazard mitigation capability through state laws, regulations, authorities, and agencies. This section describes the state agencies involved in mitigation and presents a matrix of current state laws, executive orders, regulations, policies, and programs.

In addition to the matrix, which is specific to natural hazard mitigation, the Commonwealth has a broad approach to improve capabilities to mitigate, prevent, prepare, and respond to non-natural hazards. One such approach is through the annual investment plans of the Commonwealth's Homeland Security Councils. These regional investments – which include funding and capacity-building for planning, training, equipment, etc. – build capacity and mitigate non-natural hazards. These programs and initiatives are outlined in detail in Annex 1.

17.3.1 State Agency Partnerships

The Commonwealth has taken many steps to enhance resiliency to the hazards of concern through partnerships among state agencies to expand planning and programmatic development, provide funding opportunities, and develop policies and procedures to enhance hazard mitigation at a statewide level.

Planning partnerships to develop the Commonwealth's mitigation program include many state agencies, as well as private non-profit and non-governmental agencies. Section 2 provides additional information concerning SHMIC and SHMT roles and responsibilities.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(3)(ii), and §201.5(b)(i), which states the following:

To be effective the plan must include a Mitigation Strategy that includes a discussion of the State's pre- and post-disaster hazard management policies, programs, and capabilities to mitigate the hazards in the area, including:

- An evaluation of State laws, regulations, policies, and programs related to hazard mitigation as well as to development in hazard-prone areas.
- A discussion of State funding capabilities for hazard mitigation projects.

Enhanced Element:

- Demonstrate that the plan is integrated to the extent practicable with other State and/or regional planning initiatives (comprehensive, growth management, economic development, capital improvement, land development, and/or emergency management plans) and FEMA mitigation programs and initiatives that provide guidance to State and regional agencies.

State Hazard Mitigation Team

The Commonwealth maintains a statewide effort of interagency cooperation in the administration and management of its Hazard Mitigation Program. This program is a joint staffing effort between the DCR Flood Hazard Management Program, which oversees the National Flood Insurance Program, and the MEMA Disaster Recovery and Mitigation Division.

The SHMT consists of staff members employed by DCR and MEMA who work full-time on hazard mitigation planning, grants management, and project management. The team is co-chaired by the State Hazard Mitigation Officer at DCR and the Disaster Recovery and Mitigation Manager at MEMA. The team meets on a monthly basis to coordinate team members' individual hazard mitigation work assignments and to give progress reports on statewide mitigation plans, mitigation projects, and technical assistance.

State Hazard Mitigation Interagency Committee

The SHMIC consists of representatives of federal, state, regional, and local agencies, including the SHMT, that play key roles in implementing hazard mitigation programs, policies, and projects. The SHMIC reviews policies, coordinates mitigation efforts, recommends recipients of hazard mitigation grants, and assists in the development, implementation, and maintenance of the SHMP. For the 2013 plan update, the SHMIC was encouraged to have greater involvement than previous plan updates through integration into all areas of the plan update.

Office of Coastal Zone Management

An agency that has drawn significant attention during this planning cycle is the Executive Office of Energy and Environmental Affairs, Office for Coastal Zone Management, Coastal Hazards Commission. The following are examples of initiatives supported by the CZM:

- The StormSmart Coasts team at the CZM worked with the Town of Hull and Applied Science Associates to develop a three-dimensional (3D) visualization tool to improve local understanding of the impacts of flood events and sea level rise. 3D models were developed for seven Hull facilities that are critical to public safety, health and welfare. The 3D models depict current and possible future storm-event water levels around the most important infrastructure, including an emergency shelter and a wastewater treatment plant. The project technical report provides details on the methodology and includes images of Hull's critical facilities under varying flooding scenarios. These images are being used by town officials and facility managers to evaluate options to protect these services as well as the residents and businesses using them. Google Earth served as the platform for this product for ease of viewing and sharing.
- The Buzzards Bay National Estuary Program and the CZM are evaluating the potential expansion of the existing FEMA 100-year floodplain using Flood Insurance Rate Map (FIRM) base-flood elevations for Buzzards Bay municipalities. The floodplain was expanded with 1-foot, 2-foot, and 4-foot increases in sea level. The existing floodplain was extrapolated upward based on the FIRM base-flood elevations. This baseline floodplain was then expanded to account for 1-, 2-, and 4-foot sea level rises by adjusting the boundaries to the LIDAR elevations that corresponded to the base-flood elevations identified on the FIRMS. Using a recent assessor's data set, the number of buildings and municipal structures within these sea level rise scenarios was enumerated, along with assessed values. Results were produced for each community.
- In 2006, the Coastal Hazards Commission recognized that existing shoreline stabilization structures needed to be maintained and initiated an inventory of publicly owned seawalls, revetments, groins, jetties, and other structures. A series of reports produced from 2006 to

2009 for the CZM and the DCR provide ratings for the condition of these structures and estimates for repair or reconstruction costs. These ratings and estimates were determined by civil engineers who surveyed the structures.

- To address current and future storm damage impacts, the Town of Hull sought to improve standards guiding development and redevelopment and to enhance education and outreach regarding the risks associated with coastal storms and sea level rise. In September 2009, the Hull Board of Selectmen unanimously voted to enact the Commonwealth's first freeboard incentive program to encourage the elevation of flood-prone buildings above currently predicted floodwater levels to account for future coastal storm events and sea level rise. Through this freeboard incentive program, the town seeks to protect the health and safety of citizens, prevent property damage, and reduce costly emergency services. Hull's Conservation Agent worked with CZM and the town's Building Commissioner to develop the freeboard incentive, which enables the Building Department to offer a credit up to $500 for permit fees to builders and homeowners who elevate new and renovated structures at least 2 feet above the highest federal or state requirement. (Buildings in A and V zones need to be elevated at least 2 and 4 feet above the base flood elevation, respectively, to meet the freeboard requirements.) In the first three years of the program, 20 of 24 permit requests for new construction or to elevate existing development included 2 or more feet of freeboard and qualified for the credit. An added benefit for property owners is significant discounts to flood insurance premiums. Many homeowners are building higher than required to maximize flood insurance savings and provide added protection from coastal storms. In May 2011, Hull's zoning bylaw was amended to address height restrictions and better accommodate freeboard. The Zoning Board of Appeals may now grant special permits to elevate existing buildings for flood protection. These building may exceed the height limit to provide a maximum of 4 feet of freeboard.
- As a CZM StormSmart Coasts pilot community, Oak Bluffs on Martha's Vineyard focused on changes to local bylaws and codes to minimize the town's storm risk. After numerous meetings and deliberations, a team of local officials and citizens identified several zoning changes as the most effective tools to address the town's concerns. Specifically, amendments to the town's floodplain overlay district will prohibit new residential development and expansion of existing development in the most hazardous flood zones—those designated by FEMA as V, VE, or AO zones. In less hazardous flood zones, designated as A zones, the town will require a special permit from the Zoning Board of Appeals. The amendments were presented to and approved by the town's selectmen and adopted at the town meeting held in May. In September, the Oak Bluffs Zoning Board of Appeals voted unanimously to adopt special permit regulations that clarify the process and parameters for development in the floodplain district.
- StormReporter is a web tool that enables rapid delivery and archiving of coastal storm damage information to inform emergency response activities, weather predictions, and project planning. With support from the Northeastern Regional Association of Coastal Ocean Observing Systems, StormReporter now has enhanced functionality, such as improved administration of the web tool, better user management of profiles, predefined site locations, a refined live report summary, a searchable table of reports, and a mobile site. StormReporter has also been made available to the other coastal states in New England through the national StormSmart Coasts Network's StormReporter's Notebook. CZM originally developed StormReporter in partnership with the National Weather Service and the StormSmart Coasts Network to standardize data collection for the Commonwealth's Rapid Response Coastal Storm Damage Assessment Team (Storm Team), as well as local beach teams and citizens interested in reporting coastal storm damage in Massachusetts communities. CZM has

provided regional and national web presentations to support the launch of this new version of StormReporter.

17.3.2 Massachusetts Existing Capabilities Matrix

Table 17-2 summarizes the Commonwealth's hazard mitigation capabilities. The most current information on all Massachusetts state agencies may be found on the Commonwealth of Massachusetts website at www.mass.gov. The matrix has been updated for the 2013 edition to include the agency responsible for the identified protection element. In addition, the column previously titled "Existing Protection Element" has been renamed "Existing Mitigation Efforts" to allow for the inclusion of expanded information.

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
Emergency Management				
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 the DCR. Maintains its effectiveness for enabling all intend programs.	Unchanged. Allows for statewide coordination of resources from numerous state agencies and the private sector allows for more effective program.
Massachusetts Executive Order 144 and Massachusetts Executive Order 242	MEMA and EOPSS	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.	Improvements to the CEMP are continual - Mitigation staff will work with Recovery staff to include components to the new Recovery Annex into the mitigation programs and procedures where appropriate
Massachusetts Executive Order 149 and Chapter 21 of Massachusetts General Laws (MGL)	DCR	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 Division of Water Resources serves as support staff for the Water Resources Commission. In 1980, 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.	Consistently assists flood-prone communities in obtaining and maintaining participation in NFIP and assists property owners in making sound decisions related to flood insurance purchase and coverage. This encourages flood mitigation activities that will reduce the risk of flood damage to existing property.	Unchanged

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
Mitigation-Related Grants for Plans & Projects				
Hazard Mitigation Grant Program	SHMT	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 Presidential 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. A way to improve the implementation of the HMGP Program is to complete a FEMA-approved state hazard mitigation plan could more than double the available HMGP funding.	. One improvement to the implementation of HMGP in 2012, the Project staff reviewed submitted local and multijurisdictional mitigation plans to help in the identification of possible projects.
Pre-Disaster Mitigation Program Grants for Mitigation Planning and Projects	SHMT	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 programs all 13 regional planning agencies at least once to develop regional and local hazard mitigation plans. Continued funding allows for ongoing focus on repetitive loss properties and complements current funding under the PDM and HMGP programs	One improvement to the implementation of PDM in 2012, the Project staff reviewed submitted local and multijurisdictional mitigation plans to help in the identification of possible projects. .

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
Flood Mitigation Assistance Planning & Project Grants	SHMT	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	This program will be evaluated in the next update due to the very recent changes in BW 2013. .	Updated. Major Changes have occurred in FMA. Now, SRL is included in the program. As of December 2012, Massachusetts has funded more than 15 plans and 7 projects.
Legislative Pre-Disaster Mitigation		Non-Competitive Earmark, the National Legislative Pre-Disaster Mitigation Fund to assist states and local governments in implementing cost-effective hazard mitigation activities that complement comprehensive mitigation programs, reduce injuries, loss of life, and damage and destruction of property.	The state has had limited applications for this funding. Program implementation continues when funded as part of the Commonwealth's Mitigation Program	Unchanged.
Severe Repetitive Loss	SHMT	This program targets severe repetitive loss residential structures insured under the NFIP with up to a 90% FEMA share for mitigation projects.	n/a	This program has been eliminated as of 2013
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.	Ongoing effort as funding allows
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 federal disaster declaration.	Very effective. Assists in restoring the local communities impacted by disasters for events not rising to the level of a federal disaster.	Ongoing effort as funding allows

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
Massachusetts State Revolving Fund	Massachusetts Executive Office of Energy and Environmental Affairs	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.	Ongoing effort
PARC Program	Massachusetts Executive Office of Energy and Environmental Affairs	Annual program that purchases private property to be used for open space, wetland protection, and floodplain preservation.	Very successful and well managed. Shortly after establishing the program, in excess of 100,000 acres had already been acquired, which has reduced the impact of flood issues within those areas.	No changes in the program.
Hazard Identification & Mapping				
Massachusetts Statewide Mitigation Planning Strategy – regional and local risk analysis	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. These plans will include hazard identification, risk assessment, and maps.	Improvements needed. One possible improvement would be to ensure new data from multi-jurisdictional plans will assist in better identification of critical facilities and other structures, which may be at risk from natural hazards. These data may be used by other state agencies as other plans are developed.	Ongoing effort

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
Massachusetts CZM Historical Shoreline Change Project	CZM	The CZM Shoreline Change Project illustrates how the shoreline of Massachusetts has shifted between the mid-1800s and 2009. Using data from historical and modern sources, up to eight shorelines depicting the local high water line have been generated with transects at 50-meter (164-foot) intervals along the ocean-facing shore. For each of these transects, data are provided on the net distance of shoreline movement, shoreline change, dates, and uncertainty values.	Measures the changes in the state's coastline as a result of erosion and accretion. Assists in identifying potential areas and structures at high risk from coastal erosion and shoreline change. Utilized by many stakeholders and is updated as need.	Update completed 2013
Massachusetts Risk MAP Business Plan	DCR	Developed by DCR as part of FEMA's nationwide program to update the maps of flood zones in most communities. Flood Insurance Rate Maps and the accompanying Flood Insurance Study data are used in the administration of the minimum requirements of the NFIP. Massachusetts cities and towns rely heavily on the flood hazard information contained in the FIRMs and Flood Insurance Study for review of proposed development.	Business plan includes a strategy and implementation schedule for the update of FIRMs throughout Massachusetts. This plan has been successful and has a process to make changes if needed to ensure that the administration is effective.	Ongoing effort with FEMA. See Flood profile for 2013 map status.
Massachusetts Ocean Resource Information System	MassGIS and CZM	The Massachusetts Ocean Resource Information System, 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.	Updated since last plan

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
Public Safety				
State Building Code (780 Code of Massachusetts Regulations (CMR)	State Board of Building Regulations & Standards/	Massachusetts State Building Code covers the entire state, applies to both public and private construction, and is administered through the local building inspectors with state oversight. Section 3107 of the State Building Code contains most of the NFIP construction requirements related to buildings or structures.	NFIP standards are an integral section of the state building code, 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.	Updated. In 2008 the code was updated to include several new components that are related to natural hazards, including flooding and wind. In 2013, Massachusetts was recognized for its progressiveness with respect to building codes.
Emergency Watershed Protection Program	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 federal declared natural disaster.	Unchanged
Massachusetts Dam Safety Program, Ch. 330, Acts of 2002; 302 CMR 10	Massachusetts 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.	There may be future opportunities for the Commonwealth and local governments to partner with NRCS to continue ongoing inspections and repairs. Helps ensure the structural integrity of dams, thus preventing downstream flood loss.	Unchanged
U.S. Army Corps of Engineers Dam Safety Program	U.S. Army Corps of Engineers	Built by the U.S. Army Corps of Engineers, these structures (dams, dikes, seawalls, and protection barriers) protect many cities in Massachusetts from riverine and tidal flooding. The Corps of Engineers assists the Commonwealth and local governments in conducting annual inspections.	Effective. Since completion, these structures have prevented flood damage in major Massachusetts urban areas estimated at millions of dollars.	Unchanged

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
PL 566 flood control dams, under state and local control and maintenance	USDA-NRCS	32 small flood control dams that provide flood control to small watersheds in the central and western sections of the Commonwealth.	Very valuable. The Commonwealth continues to inspect state-owned PL 566 dams and provides flood protection to watersheds susceptible to high flood flow.	Unchanged
Massachusetts Wildfire Program, MGL Chapter 48: Sections 8 through 28C	DCR 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
State Fire Assistance; the Cooperative Forestry Assistance Act (PL 95-313), Volunteer fire Assistance, and Federal Excess Property program	DCR 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 programs that provides critical support to local wildfire prevention programs.	Unchanged
Mutual Aid Agreements	Northeastern Forest Fire Protection Commission	Massachusetts is a party to mutual aid agreements with other state and provincial forest fire control agencies.	Enables Massachusetts to call upon additional out-of-state resources to combat extreme conflagrations in Massachusetts. An improvement to this program could be the creation of Mission Ready Packages.	Massachusetts was called on to assist in numerous training and real events in the past three years
Massachusetts Fire Academy	Massachusetts 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

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
Fire Management Assistance Grant Program	Massachusetts State Fire Marshal	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
Title III, Chapter 29, Section 2DDD Hazardous Materials Teams	Massachusetts 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. New, evaluation n/a.	New
Planning & Environmental Protection				
Massachusetts Zoning Enabling Act MGL Ch. 40A		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.	The act itself was amended in 2010 to improve the law.	Unchanged in this cycle.
Massachusetts Environmental Policy Act MGL Ch. 30, Sec. 61-62h; 301 CMR 11.00	Executive Office of Energy and Environmental Affairs (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.	Unchanged

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
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.	Unchanged. Additional "effects on loss" language was added to strengthen the plan's description.
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.	Effectively aligns with this plan because two of the eight interests promoted by this Act are providing flood control and preventing stormwater damage. Very effective .This Act expands the area along the Commonwealth's rivers in which flood control aspects of a proposed project are considered.	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.	Unchanged.
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.	Unchanged. The Commonwealth continues to provide technical assistance to participating communities and other communities interested in passing a local preservation act.

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
Coastal Development and Use-Chapter 91 Program; (MGL Ch. 91)		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.	Unchanged
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.	Ongoing
U.S. EPA Stormwater Management Program	U.S. EPA	Provides 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
Massachusetts CZM (Public Law 92-583, Section 306)	Massachusetts CZM	Undertakes comprehensive coastal education and protection programs. CZM ensures that projects located in or affecting the coastal zone are in compliance with CZM enforceable program and policies	New revisions have made the agency more adaptable and more flexible to better serve the municipalities.	Updated program plan and regulations
Massachusetts CZM Executive Order 181, Barrier Beach Protection (1980)	Massachusetts CZM	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.	Effective. 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.

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
Massachusetts CZM State Rapid Response Storm Damage Assessment Team	Massachusetts CZM	The team consists of coastal planning and engineering experts who are on call to conduct damage assessment surveys of coastal areas immediately following storm events.	Valuable assessments provide state and federal emergency managers with valuable 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.
State Sustainability Program, Executive Order No. 438, July 2002	EOEEA	This program helps state agencies minimize the environmental impacts of their operations and activities and promote innovative sustainable practices.	By sustaining the environment and by implementing long-range planning, more hazard mitigation measures may be implemented by state agencies.	With tens of thousands of employees, hundreds of facilities, thousands of buildings and vehicles, and a multi-billion dollar budget, state government can achieve significant savings in energy, water, and materials use through greater efficiency and effective long-range planning.
Land Acquisition/ Open Space Program-	EOEEA	This effort allows environmental agencies to acquire land for open space purposes to include outdoor recreation, promoting biodiversity, and protecting the natural resources of the Commonwealth.	Effectively promotes flood water retention and flood loss reduction by preserving many critical parcels along the coast and rivers of the Commonwealth as open space.	This program continues to receive funding from the state capital funding plans.
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. Changes will continue to be needed to keep up with the evolving demands on this topic.	New to plan (2013)

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
Cultural & Historic Resources				
National Historic Preservation Act of 1966 (36 CFR Part 800 – Protection of Historic Properties)	Massachusetts Historic Commission	Massachusetts Historic Commission 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, PDM, and Severe Repetitive Loss 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. Administered through the Massachusetts Historic Commission. Close coordination is facilitated through the Commission's director being a member of the SHMIC.	By focusing on cultural resources, hazard mitigation will reduce future losses of economic, cultural, and historical facilities that are vital to many Massachusetts communities. Also ensures that new hazard mitigation projects will not adversely affect cultural and historic sites.
State Board of Underwater Archaeological Resources	State Board of Underwater Archaeological Resources	The Board provides specialized technical assistance in support of project planning and environmental compliance as part of the review process for underwater archaeological resources.	n/a	New Through permitting, the purpose of Board is to preserve, recognize, and protect resources of substantial archaeological or historical value to the Commonwealth.
Emergency Assistance Program for Massachusetts Libraries	Massachusetts Board of Library Commissioners:	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.	This program continues to provide technical assistance on an as needed basis to many communities throughout the Commonwealth.

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
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.	n/a	New. One 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
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.	New

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
Technical Assistance				
Various types of technical assistance	Massachusetts State Mitigation Team at DCR & MEMA	A cooperative program between two state agencies, which has been in existence since 1993. Allows for the sharing of staff and agency resources in support of state and federal hazard mitigation programs.	Both agencies work cooperatively to provide 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 the PDM program, the HMGP, and FMA program.	The Commonwealth continues to provide technical assistance on hazard mitigation grants and projects on an as-needed basis, with a recent focus on working with regional planning agencies throughout the Commonwealth to complete the Statewide Mitigation Planning Strategy (See Section 2).
StormSmart Coasts Program	Massachusetts Office of Coastal Zone Management	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. Additionally, it has helped a community incentivize elevating structures out of the flood zone.	New studies have been completed and released during the 2010-2013 planning cycle.
Floodplain Management Services and Section 22 Planning Assistance to States Program	DCR	U.S. Army Corps of Engineers provides floodplain management and water resources technical assistance to states. This program is coordinated in Massachusetts by the DCR and the Water Resources Commission. Provides a continuing source of technical assistance for flood loss reduction plans and projects.	The Commonwealth continues to provide information and technical assistance to communities to help identify potential projects that would qualify for funding constantly improving with each year.	. Assistance was provided in this planning cycle.

TABLE 17-2.
2013 UPDATED STATE CAPABILITY ASSESSMENT SUMMARY

Existing Mitigation Effort	Responsible Agency or Department	Description of Capability	Evaluation on effect on Loss and/or Risk Reduction	Update 2013 Notes, Amendments, Comments
Landslide Data Enhancement Project	University of Massachusetts	Landslide data sets that provide information concerning landslide issues within the Commonwealth.	While still in its infancy, the study is intended to capture information with respect to landslide issues to assist communities by providing information concerning areas susceptible to landslide events, which can be used for land use planning and zoning requirements	New
Other Programs				
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	More collaboration is needed in this program to try and expand funding opportunities and maximize benefits of this funding.	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	Improvements are needed. Additional federal and state resources are needed to enhance seismic monitoring and to increase the delivery speed of accurate earthquake information to state agencies	.unchanged.
Stream Gauge Monitoring)	U.S. Geological Survey (USGS)	USGS researches processes that trigger natural hazards and manages real-time river flood stage monitoring and warning systems. USGS maintains 108 real-time stream-gauging stations in cooperation with state agencies. Real time river flood stage monitoring is essential for the operation of flood response plans.	Improvements are needed. More funding should be made available for the installation of stream gauges in smaller urban rivers throughout Massachusetts	Unchanged

17.4 LOCAL CAPABILITY ASSESSMENT

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(3)(ii), which states the following:

Plan Content. To be effective the plan must include a Mitigation Strategy that includes a general description and analysis of the effectiveness of local mitigation policies, programs, and capabilities.

Local municipalities, rather than counties, have the primary authority over land use and development in Massachusetts. Local governments for Massachusetts' 351 communities have a vital role in natural hazards mitigation, especially in floodplain management. Municipal departments and managers have the legal responsibility to implement local floodplain ordinances or bylaws. These critical programs include National Flood Insurance Program standards, Massachusetts State Building Code, Wetlands Protection Act, Title 5 of the State Environmental Code (wastewater disposal), and many other local mitigation policies.

Several types of plans and programs within the land use and environmental sector require communities to develop and maintain strategic or action plans to guide land use and development. These plans are the vehicle in which local mitigation actions can be integrated into everyday planning, zoning, and future improvements. For example, many communities have used local mitigation actions to update subdivision regulations or bylaws to include or clarify requirements relating to the NFIP or other flood-reduction measures.

Towns and cities in Massachusetts develop and enforce local laws and policies (including disaster recovery and mitigation), manage municipal budgets, and implement hazard mitigation planning and projects. Table 17-3 is an overview of departments found in most Massachusetts municipalities, based on review of regional and local mitigation plans. The table lists existing mitigation measures and discusses their effectiveness and possible opportunities for improvement. This analysis helps the SHMT understand the strengths and challenges faced by the local governments. A major challenge in smaller communities is that there are few paid part-time staff, with diverse responsibilities, or volunteers fulfill several functions.

TABLE 17-3.
LOCAL CAPABILITY ASSESSMENT SUMMARY

Building Departments and Local Building Inspectors	
Explanation	The building inspector implements and enforces the Massachusetts State Building Code (specifically Section 3107, "Flood Resistant Construction"), which incorporates NFIP construction standards. The state building code includes sections on wind, snow, structural loads and seismic retrofitting and ensures that NFIP standards and other mitigation standards are applied uniformly statewide. The building inspector also enforces local bylaws, especially to prevent floods. For instance, the building inspector is responsible for administering municipal zoning ordinances, including those addressing floodplains.
Effectiveness	Ensures that NFIP standards and other mitigation standards are uniformly applied across the communities of the Commonwealth. Building inspectors may often find problems or violations of the State Building Code related to other hazards in addition to flooding.
Opportunities	There may be more opportunities for the Commonwealth to provide additional training to local building inspectors concerning new hazard mitigation measures or increasing the local enforcement and encouragement of sound building practices

TABLE 17-3. LOCAL CAPABILITY ASSESSMENT SUMMARY	
Public Works Departments or Town Engineers	
Explanation	Public works departments or water and sewer departments, which are primarily responsible for municipal drainage and stormwater management systems, take the lead in ensuring communities' compliance with the EPA's Phase II Stormwater Regulations (National Pollutant Discharge Elimination System).
Effectiveness	Because stormwater is one of the major flood hazards in Massachusetts, ongoing maintenance and upgrading of local stormwater systems by public works departments is crucial to reducing flood risks. Public works staffs are integral in implementing local hazard mitigation plans, especially in identifying and implementing local hazard mitigation projects
Opportunities	A number of smaller communities do not have significant engineering or public works capabilities. Communities with a very small population and highly rural communities may not be required to comply with the National Pollutant Discharge Elimination System Phase I or II standards and may not regulate stormwater or surface water discharges as vigorously as those that must comply with the standards.
Conservation Commissions	
Explanation	Conservation commissions have primary responsibility for implementing the Massachusetts Rivers Protection Act (MGL Ch. 258, 310 CMR 10.58) and the Massachusetts Wetlands Protection Act (MGL Ch. 131, Section 40; 310 CMR 10.00). A conservation commission reviews, approves or denies applications for any project in the regulatory 100-year floodplain, in the floodplain of a small water body not covered by a FEMA study, or within 100 feet of any wetland or 200 feet of any river or stream (except in the case of densely developed urban areas, where buffers may extend only 25 feet from a river or stream).
Effectiveness	These regulations contain performance standards, which address flood control and storm damage prevention. For instance, the Wetlands Protection Act restricts development in wetlands and within a 100-foot buffer zone. Since most wetlands are within the 100-year floodplain, this adds an extra layer of protection to promote flood loss protection.
Opportunities	Local conservation commissions are required to review development with potential impacts on any type of river, stream, pond or wetland. These commissions play an important role in enforcing regulations that minimize flood impacts. Continuing to enforce the requirements of the regional planning agencies and other rules will continue to ensure proper development and lessen flood impacts.
Planning Boards, Planning Departments, or Town Planners	
Explanation	Planning boards and departments have general planning authority under the MGL Ch. 41 Zoning Act and implement local subdivision regulations. Their responsibilities include recommending land use regulations to protect public health, safety, and welfare. A planning board is the primary local vehicle to ensure that new development incorporates federal and state stormwater best management practices. Planning boards maintain floodplain bylaws and ordinances to address current floodplain issues and update them to ensure compliance with state and federal regulations. They often coordinate the hazard mitigation planning process and the implementation of hazard mitigation plans. These boards provide professional expertise in plan development, bylaw drafting, and grant application.

TABLE 17-3. LOCAL CAPABILITY ASSESSMENT SUMMARY	
Effectiveness	Planning boards can often bring in regional planning perspectives as well as information concerning new development. A planning board is able to adopt its own subdivision rules and regulations without an action at the town meeting.
Opportunities	There may be more opportunities for the Commonwealth to provide additional training to local planners concerning hazard mitigation planning opportunities. In many communities, the planning department coordinates the hazard mitigation planning process and the implementation of hazard mitigation plans.
Boards of Health	
Explanation	This local board implements the State Environmental Code, Title 5, and 310 CMR 15: *Minimum Requirements for the Subsurface Disposal of Sanitary Sewage*. The community may adopt local board of health requirements that are more restrictive than the state requirements. Title 5 protects public health and mitigates losses due to adverse effects of improper sewage treatment in high hazard areas. These boards are involved in issues related to water quality and infectious diseases following disasters.
Effectiveness	Some communities opt to adopt local board of health requirements that are stricter than the state requirements. At this time, the effectiveness of local boards of health is unknown.
Opportunities	By involvement of this board, additional public health issues may be included in the mitigation planning process. Title 5 protects public health and mitigates losses due to adverse effects of improper sewage treatment in high hazard areas.
Boards of Selectmen or City Council	
Explanation	Massachusetts communities with a city form of government are led by elected mayors and city councils. An elected board of selectmen governs towns. In most towns, town meetings of all registered voters meet at least annually. This tradition from Colonial times approves town budgets and all land use and zoning ordinances and regulations.
Effectiveness	These bodies are the chief elected officials of each municipality and provide leadership and approval for hazard mitigation grant applications, plans, and projects. The city council or board of selectmen must adopt the local pre-disaster mitigation plan. Their approval also is necessary for hazard mitigation grant applications and potential projects.
Opportunities	More education needed concerning the benefits of hazard mitigation planning and projects.
Emergency Management Director	
Explanation	Each Massachusetts community is required to appoint an emergency manager (Chapter 639 of the Acts of 1950) who is primarily responsible for local preparedness, mitigation, response, and recovery, as well as mutual aid for natural and manmade hazards. Emergency managers play a primary role in developing local comprehensive emergency management plans required by Massachusetts state law, as well as other plans required by MEMA and FEMA.
Effectiveness	Each community has an emergency management director who is the key point of contact for all MEMA- and FEMA-related business. This is a key link for outreach and involvement in mitigation planning and grants.

TABLE 17-3. LOCAL CAPABILITY ASSESSMENT SUMMARY	
Opportunities	Emergency medical dispatchers could have a more active role in the recovery and mitigation process in their communities. More education is needed concerning the benefits of hazard mitigation planning and projects. Most emergency medical dispatchers are unpaid volunteers or have other full-time jobs. More resources for the local emergency medical dispatchers would allow for enhanced planning and overall local capabilities.

An analysis was conducted to compare and collate the common existing hazard mitigation measures of the approved mitigation plans in the Commonwealth. The following are hazard mitigation measures appearing in a large majority of the mitigation plans as of January 2013:

- Capital improvement planning
- Emergency operations equipment
- EPA Phase II stormwater treatment
- Floodplain bylaw
- Beaver dam mitigation efforts
- Bridge mitigation projects
- Structural mitigation projects
- All hazards tree maintenance
- Local regulations—local bylaw cluster subdivisions, soil conservation, etc.
- Coastal erosion mitigation efforts (coastal community plans)
- State regulations—State Building Code, Wetlands Protection Act.

Additional information concerning local capabilities may be found in Section 3 and Appendix F.

17.5 PROGRAM MANAGEMENT AND IMPLEMENTATION

17.5.1 Implementation of Mitigation Program

The Commonwealth of Massachusetts has been committed to developing and implementing measures to reduce the impact of natural disasters since 1978 when the Commonwealth first joined NFIP. As of 2012, 336 out of 351 (96 percent) of Massachusetts communities participate in this program. In addition, as of 2012, 98 percent (86 out of 88) of communities receiving new flood maps have adopted the maps by the effective date; the remaining two communities adopted the maps and were reinstated within one month of the effective date. Extensive outreach has been conducted with respect to NFIP enrollment in light of FEMA's flood mapping efforts throughout the Commonwealth (see Sections 2 and 3 and the Flood Hazard Profile for additional information on NFIP implementation).

In addition to the NFIP, the Commonwealth has had a FEMA-approved state hazard mitigation plan since 1986. As of December 31, 2012, 39.3 percent of municipalities had plans in place, 8.2 percent had conditional approval, 11 percent were approved by FEMA pending adoption, 6.5 percent were in review by MEMA, and 13 percent had expired plans. Implementation of other mitigation efforts is also supported through the integration of other state agencies, programs, policies, and support provided by non-government and private non-profit agencies. Additional information concerning integration of programs is contained in Section 2.

Community Rating System Program

The CRS is a voluntary program within the NFIP that encourages floodplain management activities that exceed the minimum NFIP requirements. Flood insurance premiums are discounted to reflect the reduced flood risk resulting from community actions to meet the CRS goals of reducing flood losses, facilitating accurate insurance rating, and promoting awareness of flood insurance.

For participating communities, flood insurance premium rates are discounted in increments of 5 percent. CRS activities (discussed below) can help to save lives and reduce property damage. Communities participating in the CRS represent a significant portion of the nation's flood risk; over 66 percent of the NFIP's policy base is located in these communities. Communities receiving premium discounts through the CRS range from small to large and represent a broad mixture of flood risks, including both coastal and riverine flood risks. The CRS program is administered by the Insurance Services Office (ISO) under contract to FEMA.

Massachusetts Uniform Minimum CRS Credit

The CRS provides Uniform Minimum Credit (UMC) for certain state laws, regulations, and standards that support floodplain management and have proven effective in reducing flood damage. As of the 2013 update, the UMC credit is in the process of being recalculated to reflect new criteria being incorporated into the 2013 CRS Coordinator's Manual, which was not yet released at the time of this plan update. Table 17-4 summarizes UMC credit currently available to all Massachusetts communities under the CRS program, based on technical review by ISO. It also includes possible additional credit available for selected areas or activities. Credit for activities in the 400 series can increase based on the Community Growth Adjustment. The CRS requires participating communities to maintain elevation certificates, which provide an additional 56 points; 500 points are needed for Class 9.

ISO/CRS specialists and the communities need to determine which additional credits apply to their area. These UMCs do not necessarily apply to Tribal nations.

TABLE 17-4.
CREDITS AVAILABLE THROUGH COMMUNITY RATING SYSTEM

Activity	Element	Credit
Uniform Minimum Credit		
430	Protection of Floodplain Storage Capacity	70
430	State-Mandated Standards	10
450	Erosion and Sedimentation Control	30
630	State Dam Safety	51.6
	Total	**161.6**
Possible Additional Credit		
430	Building Codes	TBD
430	State-Mandated Standards	TBD

Activity 430, Higher Regulatory Standards: Protection of Floodplain Storage Capacity

The Massachusetts Wetlands Protection Act awards 70 points for protection of floodplain storage capacity. Compensatory storage is required for all flood storage volume that will be lost as a result of a proposed project on or bordering land subject to flooding, when the loss will cause an increase or contribute incrementally to an increase, in the level of flood waters during peak flows.

- **Legal Basis**—State of Massachusetts Wetlands Protection Act, Massachusetts General Law (MGL) 310 CMR 10.00: Wetlands Protection, 10.57 (4), General Performance Standards (page 94) at http://www.mass.gov/dep/service/regulations/310cmr10a.pdf.
- **Verification**—ISO/CRS specialists will verify credit by reviewing permits, site plans, and compensatory storage plans for new developments in the regulatory floodplain.
- **Annual UMC Verification**—The community must certify each year that the provisions are being enforced.

Activity 430, Higher Regulatory Standards: State-Mandated Standards

State-mandated regulatory standards are awarded 10 points. Credit equals 0.10 times the sum of credit points for floodplain management regulatory standards (see Table 17-5). Total credit available for state-mandated standards is limited to 25 points.

TABLE 17-5.
STATE-MANDATED STANDARDS

Activity	Element	Credit
430	Protection of Floodplain Storage Capacity	70
450	Erosion & Sedimentation Control	30
	Total	**100**
	x 0.1	***10***

Source: Section 431.l. of the CRS Coordinator's Manual.

Activity 450, Stormwater Management: Erosion and Sedimentation Control

Requiring construction projects larger than 1 acre to use erosion and sediment control measures is awarded 30 points.

- **Legal basis**—Massachusetts Department of Environmental Protection rules on stormwater permitting at http://www.mass.gov/dep/water/approvals/stormreg.htm.
- **Verification**—ISO/CRS specialists will verify credit by reviewing permits and erosion control plans, and conducting field verification.
- **Annual UMC Verification**—ISO/CSR specialists will verify the regulations still are in effect.

Activity 630, State Dam Safety

State Dam Safety Program activities are awarded 51.6 points based on the Dam Safety Program Management Tool.

- **Legal basis**—DCR maintains an Office of Dam Safety and implements regulations (see http://www.mass.gov/dcr/pe/damSafety/index.htm)
- **Verification**—ISO/CRS specialists will verify that the community is in compliance with the State Dam Safety Program.
- **Annual UMC Verification**—FEMA's Dam Safety Office annually verifies State Dam Safety credit.

17.5.2 Mitigation Measures and Projects

Implementing effective hazard mitigation in high-risk areas in the Commonwealth involves two general types of approaches: non-structural and structural. In support of efforts by municipalities, organizations, businesses, and private citizens to reduce damage after natural disasters, the Commonwealth's Hazard Mitigation Program emphasizes the use of a non-structural hazard mitigation approach before undertaking a structural approach. Massachusetts places a higher priority on funding non-structural projects. Although some non-structural hazard mitigation measures may be lower in cost (i.e. adoption of a floodplain ordinance), such measures may be very time intensive in terms of staff time and take several years to implement.

17.5.3 Non-Structural Hazard Mitigation Measures and Projects

Non-structural hazard mitigation is an approach that does not attempt to control or contain a natural hazard, but involves preventive actions that improve infrastructure to reduce damage or improve coordination of resources. The following are examples of non-structural projects:

- Building and construction design (Massachusetts State Building Code)
- Enforcement of building codes
- Planning and zoning
- Open space preservation and wetlands protection
- Floodplain development management (subdivision regulations, erosion control bylaws, floodplain ordinances)
- Stormwater management
- Relocation
- Acquisition
- Building elevation
- Floodproofing (barriers, dry floodproofing, wet floodproofing, elevation of essential utilities)
- Sewer backup protection insurance
- Erosion and sediment control
- Beach nourishment (through natural methods such as the placement of snow fencing and the planting of beach grass)
- Best management practices
- Weather forecasting
- Emergency measures (Comprehensive Emergency Management Plans for each community)
- Public information (flood map information, outreach projects, real estate disclosure, technical assistance, education programs).

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(4)(iii), and §201.5(b)(2)(i)and (ii) which states the following:

To be effective the plan must include a section on the Coordination of Local Mitigation Planning that includes criteria for prioritizing communities and local jurisdictions that would receive planning and project grants under available funding programs, which should include:

- Consideration for communities with the highest risks.
- Repetitive loss properties.
- Most intense development pressures.

Further, that for non-planning grants, a principal criterion for prioritizing grants shall be the extent to which benefits are maximized according to a cost benefit review of proposed projects and their associated costs.

Requirement §201.5(b)(2)(i)and (ii): [The Plan must demonstrate] the State's project implementation capability, identifying and demonstrating the ability to implement the plan, including:

- Established eligibility criteria for multi-hazard mitigation
- A system to determine the cost effectiveness of mitigation measures, consistent with OMB Circular A-94, Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs

17.5.4 Structural Mitigation Measures and Projects

Structural measures are used to prevent a natural hazard, such as flooding, from reaching property. These measures are "structural" because they involve construction of man-made structures to control a hazard, such as a dam or sea wall to control water flow. Most structural projects can be very expensive and have other shortcomings, such as destruction of natural habitat by disturbing land and natural water flow, increased erosion of adjacent unarmored shorelines or river banks, extensive damage when subjected to a flood greater than that for which the project was designed, and requiring continuous and high cost maintenance. Examples of structural measures are dikes, drainage modifications, dams, and seawalls.

Over the past decade, the Commonwealth has realized the high cost and maintenance involved with building any new structural hazard mitigation projects. While the Commonwealth's Hazard Mitigation Program emphasizes the use of non-structural approaches over structural approaches, the density of at-risk development in some areas combined with the high value of existing mitigation infrastructure (e.g., seawalls, drainage systems) at times makes it more cost-effective to upgrade existing structures to provide added levels of protection. In such cases a limited structural approach (e.g., upgrading an existing seawall or culvert) may be preferable to a non-structural approach.

17.5.5 Program Management Capabilities

FEMA certifies that the Commonwealth of Massachusetts has demonstrated that it has the capability to effectively manage FEMA-funded hazard mitigation grant programs. A copy of its most recent certification is shown in Figure 17-1.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.5(b)(iii)(A-D), which state the following:

Demonstrate that the State has the capability to effectively manage the HMGP as well as other mitigation grant programs, including a record of the following:

- Meeting HMGP and other mitigation grant application timeframes and submitting complete, technically feasible, and eligible project applications with appropriate supporting documentation.
- Preparing and submitting accurate environmental reviews and benefit-cost analyses.
- Submitting complete and accurate quarterly progress and financial reports on time.
- Completing HMGP and other mitigation grant projects within established performance periods, including financial reconciliation.

CERTIFICATION FROM FEMA TO BE INSERTED WHEN RECEIVED

Figure 17-1. FEMA Certification of Massachusetts Hazard Mitigation Capabilities

17.5.6 Local Hazard Mitigation Measures

As local hazard mitigation plans are completed, either as annexes to a regional plan or as single-jurisdiction plans, local mitigation measures, and projects are incorporated into the SHMP Data Capture Tool. These local measures and projects, like the regional hazard mitigation measures and projects, will be reviewed and analyzed by the SHMT. Depending on future funding, the Commonwealth will provide communities with technical assistance as needed to implement cost-effective hazard mitigation measures. Section 3 and Appendix F of this SHMP summarize some of the strategies and actions from approved local and regional plans. Information used for this section is updated by the Commonwealth with input from participating communities after each grant funding cycle.

17.5.7 Tracking Hazard Mitigation Measures and Projects

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.5(b)(3), which states the following:

Demonstrate that the State effectively uses existing mitigation programs to achieve its mitigation goals.

Since 1991, Massachusetts has supported more than 300 hazard mitigation projects and plans with over $92 million in federal funding from pre-disaster and post-disaster hazard mitigation grant programs, as summarized in Table 17-6. The Commonwealth emphasizes effectiveness in hazard mitigation, in part by marketing the grant programs to all eligible applicants and then working with them to develop the best possible projects. Section 3 describes the process of soliciting applications and working with applicants to develop their documents. For the HMGP, the Commonwealth typically receives applications for amounts far in excess of the amount of available funding. The Commonwealth selects and recommends for funding only the best and most cost-effective projects.

TABLE 17-6.
SUMMARY OF MITIGATION PROJECTS FUNDED IN MASSACHUSETTS

Disaster Name/ Grant Type	Program Number	Date	Federal Funding	# of Projects	Status
Hazard Mitigation Grant Program					
Hurricane Bob	914	Aug-91	$651,881	17	Closed
Winter Storm	920	Oct-91	$626,406	10	Closed
Winter Storm	975	Dec-92	$400,943	7	Closed
Flooding	1142	Oct-96	$12,262,500	37	Closed
Flooding	1224	Jun-98	$1,769,145	22	Closed
Flooding	1364	Apr-01	$1,562,356	17	Closed
Flooding	1512	Apr-04	$243,225	1	Closed
Flooding	1614	Oct-05	$763,899	4	Open
Flooding	1642	May-06	$2,600,528	14	Open
Nor'easter	1701	Apr-07	$1,364,794	5	Open
Ice Storm	1813	Dec-08	$8,325,842	26	Open
Flooding	1895	Mar-10	$13,280,510	34	Open
Snowstorm	1959	Mar-11	$3,805,002	14	Open
Tornadoes	1994	Jun-11	$7,044,043	11	Open
Tropical Storm Irene	4028	Sep-11	$5,481,585	TBD	Open
Snowstorm	4051	Jan-12	$10,148,177	TBD	Open
Hurricane Sandy	4097	Oct-12	TBD	TBD	

TABLE 17-6.
SUMMARY OF MITIGATION PROJECTS FUNDED IN MASSACHUSETTS

Disaster Name/ Grant Type	Program Number	Date	Federal Funding	# of Projects	Status
Flood Mitigation Assistance					
FMA	FY 97		$286,544	4	Closed
FMA	FY 98		$238,428	3	Closed
FMA	FY 99		$457,367	6	Closed
FMA	FY 00		$240,713	5	Closed
FMA	FY 01		$307,201	8	Closed
FMA	FY 02		$173,081	3	Closed
FMA	FY 03		$221,100	2	Closed
FMA	FY 04		$291,601	3	Closed
FMA	FY 05		$143,250	2	Open
FMA	FY 06		$1,119,737	3	Open
FMA	FY 07		$634,335	5	Open
FMA	FY 08		$0	0	Closed
FMA	FY 09		$240,889	1	Open
FMA	FY 10		$65,369	1	Open
FMA	FY 11		$0	0	Closed
FMA	FY 12		TBD	1	Pending
Pre-Disaster Mitigation					
PDM	FY 02		$352,990	4	Closed
PDM	FY 03		$222,497	4	Closed
PDM-C	FY 03		$483,272	3	Closed
PDM-C DRU	FY 04		$199,750	2	Closed
PDM-C	FY 05		$4,346,890	13	Open
PDM-C	FY 06		$255,750	2	Open
PDM-C	FY 07		$162,000	1	Open
PDM-C	FY 08		$3,000,000	1	Pending
PDM-Earmark	FY 08		$100,000	1	Open
PDM-C	FY 09		$516,421	4	Open
PDM-Earmark	FY 09		$100,000	1	Pending
PDM-C	FY 10		$949,583	4	Open
PDM-C	FY 11		$335,764	4	Open
Severe Repetitive Loss Program					
SRL	FY 08		$653,166	1	Open
SRL	FY 10		$0	0	Closed
SRL	FY 12		$335,305	1	Open
Community Development Block Grant					
CDBG	FY 97		$3,977,888.72	12	Closed
CDBG	FY 98		$1,494,878.76	2	Closed

In 1999, the SHMT developed a comprehensive database to track and monitor all open and completed hazard mitigation project and planning grants funded under the HMGP, FMA, HUD, and PDM programs. This tool has allowed the Commonwealth to track and monitor project and plan timelines and completion dates. It allows the Commonwealth to track projects and plans by a specific grant program, by community, by project type, by project cost balances, and by other related data. For instance, the database allows for tracking by project type, such as dam improvements, stormwater management, elevation, etc.

17.5.8 Repetitive Flood Claims and Severe Repetitive Loss Programs

Repetitive Flood Claims

The Repetitive Flood Claims (RFC) grant program was authorized by the Bunning-Bereuter-Blumenauer Flood Insurance Reform Act of 2004 (Public Law 108–264), which amended the National Flood Insurance Act of 1968 (42 U.S.C. 4001). Up to $10 million is available annually for FEMA to provide RFC funds to help states and communities reduce flood damage to insured properties that have had one or more claims to the NFIP. The Commonwealth of Massachusetts does not participate in the RFC program.

FEMA may contribute up to 100 percent of the total amount approved under the RFC grant award to implement approved activities, if the applicant has demonstrated that the proposed activities cannot be funded under the FMA program. An application may be submitted for RFC funding if neither the applicant nor the sub-applicant can currently meet the FMA non-federal share requirement. For RFC, FEMA may contribute up to 100 percent of the project cost. The application and sub-application must include certification (e.g., a signed letter from an authorized local government official) explaining why the FMA cost sharing requirement cannot be met. If a project to mitigate the project property was previously identified on a sub-application for Hazard Mitigation Assistance (HMA) funding and the project was not funded, the applicant or sub-applicant must explain why the 25 percent non-federal cost share is no longer available for this project. RFC applicants and sub-applicants can apply only for project grants; planning and management costs are not eligible under this program. In accordance with 44 CFR Part 201, all applicants for RFC must have a FEMA-approved state or tribal (standard or enhanced) hazard mitigation plan by the application deadline and at the time of obligation of the grant funds.

Residential or non-residential properties that have received one or more NFIP insurance payments are eligible for RFC funds. Properties included in a sub-application must be NFIP-insured at the time of the application. Flood insurance must be maintained at least through completion of the mitigation activity.

Severe Repetitive Loss Program

The Severe Repetitive Loss (SRL) program is authorized by Section 1361A of the National Flood Insurance Act (42 U.S.C. 4102a), with the goal of reducing flood damage to residential properties that have experienced severe repetitive losses under flood insurance coverage and whose mitigation will result in the greatest savings to the NFIP in the shortest period of time.

Massachusetts does participate in the SRL Program. The Commonwealth manages this program similarly to the other grant programs it currently manages, with the addition of directed contact via phone or email to jurisdictions that have SRL properties to ensure that they understand the new program requirements. This program has significant importance to the Commonwealth, as the Commonwealth ranks at the top of the list nationwide for SRL properties.

A severe repetitive loss property is a residential property that is covered under an NFIP flood insurance policy and:

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.5(b)(4)(i), which states the following:

Demonstrate that the State is committed to a comprehensive mitigation program, which might include any of the following:

- A commitment to support local mitigation planning by providing workshops and training, State planning grants, or coordinated capability development of local officials, including Emergency Management and Floodplain Management certifications.

- a) That has at least four NFIP claim payments (including building and contents) over $5,000 each, and the cumulative amount of such claims payments exceeds $20,000; or
- b) For which at least two separate claims payments (building payments only) have been made with the cumulative amount of the building portion of such claims exceeding the market value of the building.

For both (a) and (b) above, at least two of the referenced claims must have occurred within any 10-year period, and must be greater than 10 days apart.

The SRL program can fund projects only; it cannot be applied to planning or management costs. In accordance with 44 CFR Part 201, all applicants for SRL must have a FEMA-approved state or tribal (standard or enhanced) hazard mitigation plan by the application deadline and at the time of obligation of the grant funds.

In order to be eligible for an increased federal cost share of up to 90 percent, the property that is being submitted for consideration must be an SRL property, and a FEMA-approved state or tribal (standard or enhanced) hazard mitigation plan that addresses repetitive loss properties must be in effect at the time of grant award. Guidance on addressing repetitive loss properties can be found in the *State Multi-Hazard Mitigation Planning Guidance* and in 44 CFR Part 201.4(c)(3)(v). A repetitive loss strategy must identify specific actions the Commonwealth has taken to reduce the number of repetitive loss properties, which must include severe repetitive loss properties, and specify how the Commonwealth intends to reduce the number of such properties. The hazard mitigation plan must describe the Commonwealth's strategy to ensure that local jurisdictions with severe repetitive loss properties take actions to reduce the number of these properties, including the development of local hazard mitigation plans.

The Commonwealth's existing repetitive loss program does identify all repetitive and severe repetitive loss properties and provides that information to local communities as they develop their hazard mitigation plans. Repetitive loss data is available from the state NFIP coordinator through Bureau Net; strict protocols are in place to maintain confidentiality, of the information as required by the program. Jurisdictions requesting the information for inclusion in their mitigation plans are provided the data, which in turn allows them to develop specific actions to target repetitive loss properties as part of their overall strategy of resiliency.

The Commonwealth's repetitive loss program also includes outreach and training for local governments, as well as coordination with FEMA regional staff. Section 3 and Annex 2 provide additional information with respect to the technical assistance provided. The Flood Hazard Profile provides a comprehensive review of loss data for SRL properties, broken both at the community and county levels.

17.5.9 Mitigation in Post-Disaster Recovery Operations

Hazard mitigation is an integral part of the Commonwealth's post-disaster recovery operations. Staff from the MEMA Mitigation and Recovery Unit co-locates with mitigation staff from FEMA at joint field offices during immediate post-disaster operations. Staff from other state agencies that may have an interest or jurisdiction in the disaster and in recovery operations also co-locate at the joint field office. State and FEMA staffs work to identify mitigation opportunities through the Individuals and Households Program and the Public Assistance Program.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.5(b)(4)(v), which states the following:

Demonstrate that the State is committed to a comprehensive mitigation program, which might include any of the following:

- A comprehensive, multi-year plan to mitigate the risks posed to existing buildings that have been identified as necessary for post-disaster response and recovery operations.

Program staff members often provide mitigation information to disaster victims. State and federal mitigation staffs work together to identify public education opportunities and use existing materials or develop new materials specific to the hazard and disaster event.

Public Assistance program staff encourages potential project applicants to identify mitigation elements in repair and restoration projects. Mitigation and public assistance program staffs often jointly conduct applicant briefings to discuss mitigation opportunities through both public assistance and hazard mitigation grant programs. State mitigation staff quickly disseminates letters of intent and information on the HMGP to potential applicants, and provide technical assistance to potential applicants on the grant application process. In addition, MEMA staff attends semi-annual Recovery and Mitigation meetings to discuss important aspect of the programs, changes in priorities, and lessons learned for disaster events.

MEMA's fiscal department ensures that all disaster and non-disaster FEMA funding is obligated and spent in accordance with all state and local regulations. Having a singular contracting and fiscal approval process ensures proper fiscal management. With recent reorganization at MEMA, the Disaster Recovery Manager now also oversees the Mitigation Unit, providing a seamless coordination with the implementation of FEMA PA, IA, and mitigation programs.

17.5.10 Mitigating Risks to Existing Buildings and Structures: Hazard Mitigation Project Success Stories in Massachusetts

Projects funded by the various funding streams will mitigate the risks posed to local buildings used for disaster response and recovery operations. This includes facilities used by first responders, school buildings used for evacuation centers, and water facilities needed by communities. Projects funded include enhanced drain systems in frequently flooded areas, road elevations, bank stabilization, enhanced control systems to protect utility infrastructure, flood-proofing, pump station retrofits, utility relocation, and dam retrofits. A detailed list of the projects funded during the 2010-2013 update cycle is in Section 3.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.5(b)(4)(vi), which states the following:

Demonstrate that the State is committed to a comprehensive mitigation program, which might include any of the following:

- A comprehensive description of how the State integrates mitigation into its post-disaster recovery operations

In both the 2010 plan and this 2013 update, actions have been developed to prepare enhanced data sets that can be used to better determine risks to critical facilities at the state and local levels. This includes the landslide study currently underway with the University of Massachusetts, which was a funded HMGP project. The Commonwealth has also identified data gaps through this update process, as noted in various portions of this SHMP. The gaps will be an area of focus during the 2013-2016 update of the plan.

The Commonwealth also places emphasis on highlighting successes in mitigation. As often as funding is available, the SHMT and FEMA intend to create pamphlets and brochures to highlight these successes. Examples of current and previous success stories, as well as copies of newsletters discussing mitigation efforts, may be found in Appendix C.

17.5.11 Framework for Implementing Hazard Mitigation

A number of Massachusetts state agencies and offices conduct hazard mitigation as part of their organizational missions. The legal foundation for such work is part of each agency's enabling legislation. Descriptions of many of the agencies' hazard mitigation functions, including their enabling legislation and current hazard mitigation measures, can be found in Table 17-2. Additional information is also contained within Section 2. This is an area in which the SHMT is attempting to enhance information through one-on-one outreach and through deployment of the 2013 survey. Specific questions were included in the survey to expand information in this regard. Agencies that responded to the survey did

indicate proactive efforts supporting local and state mitigation efforts. More information on the survey results are available in Appendix D. Additional information on this topic may also be found in Section 2. The following sections describe examples of the legal framework currently in place in support of federal and state agencies' incorporation of hazard mitigation methods.

Floodplain Management Initiatives

Federal Executive Orders 11988 and 11990, *Floodplain Management* and *Protection of Wetlands*, require that federal agencies avoid direct or indirect support of development in the floodplain and work to minimize harm to floodplains and wetlands. State agencies reviewing federally funded projects or receiving federal grants for projects must take these Executive Orders into consideration.

Massachusetts Executive Order 149, *State Coordination and Participation with the Federal Administration under the National Flood Insurance Act*, designates the Massachusetts Water Resources Commission as the state agency to implement floodplain management programs in Massachusetts. Executive Order 181, *Barrier Beaches*, prohibits permitting development in velocity zones of primary dunes, as well as permitting of coastal engineering structures within barrier beaches. It also constrains the use of state funds and federal grants for construction projects that could encourage growth and development in barrier beach areas. Enacted in 1996, the Massachusetts Rivers Protection Act amends the Wetland Protection Act (MGL Chapter 131 Section 40) to provide protection to rivers and implements hazard mitigation by regulating activities within a 200-foot wide resource area called the Riverfront Area.

Massachusetts Building Code Update Initiatives

The State Board of Building Regulations and Standards administers the State Building Code, which incorporates FEMA's National Flood Insurance Construction Program Standards. As of the most recent edition of the State Building Code, these standards may be found in 780 CMR 3107.0, Flood Resistant Construction.

As of 2012, Massachusetts was ranked fourth among the 18 states most vulnerable to catastrophic hurricanes along the Atlantic Coast and Gulf of Mexico by the Insurance Institute for Business and Home Safety with respect to implementation and enforcement of the 2009 International Residential Code regulations and processes governing residential building construction. The Commonwealth requires mandatory enforcement and does not allow local amendments to the residential code. In addition, the Commonwealth adopts a plumbing and electrical code. The Commonwealth also has a program in place for code official certification that includes taking code classes prior to examination and certification, requires continuing education, and allows consumers to file complaints against inspectors. Massachusetts also requires licensing of general, plumbing, electrical, and roofing contractors, requires licensing candidates to pass an exam prior to licensing, and requires continuing education.

Landslide Mitigation Planning Initiative

Landslides are common in the Commonwealth, but limited data exist to support mitigation strategies or to use in developing building codes that reduce impact from landslide events. As a result of previously successful partnerships, the Commonwealth's geologist from the University of Massachusetts (a SHMIC member) applied for and received HMGP grant funding to develop landslide information to be used in future state and local hazard mitigation plan updates. This will enhance risk assessments to more accurately portray areas of impact and historical impact data.

Recovery Planning Initiative

MEMA staff attends semi-annual Recovery and Mitigation meetings to discuss important aspect of the programs, changes in priorities, and lessons learned for disaster events. In addition, Mitigation staff provides support to the Recovery Unit during immediate post-disaster operations, such as attending applicants' briefings for Public Assistance and other administrative duties.

MEMA's fiscal department ensures that all disaster and non-disaster FEMA funding is obligated and spent in accordance with all state and local regulations. Having a singular contracting and fiscal approval process ensures proper fiscal management. With recent reorganization at MEMA, the Disaster Recovery Manager now also oversees the Mitigation Unit, providing a seamless coordination with the implementation of FEMA PA, IA, and Mitigation programs. The Commonwealth's Comprehensive Emergency Management Plan will be revised to include a revised recovery annex that better aligns with the National Disaster Recovery Framework.

17.6 FUNDING SOURCES

The Commonwealth uses a variety of programs and funds to achieve its mitigation goals. This includes special appropriations from Congress and the State Legislature, as well as funds from local sources.

The availability of federal funding sources depends upon Congress' ongoing budget appropriations process. In 2003, the federal government established two comprehensive websites that track available funding from all the federal agencies: www.fedgrants.gov and www.grants.gov. It is also helpful to check current federal appropriations from Congress through the Federal Registers at thomas.loc.gov. Many other opportunities for mitigation funding exist both in the public and private sectors, such as foundations and philanthropic organizations. Section 2 describes other funding sources.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(3)(i, iii & iv), and §201.5(b)(3) which state the following:

Requirement §201.4(c)(3)(iv): *[The State mitigation strategy shall include an] identification of current and potential sources of Federal, State, local, or private funding to implement mitigation activities.*

Requirement §201.4(c)(4)(iii): *[The State mitigation strategy shall include]criteria for prioritizing communities and local jurisdictions that would receive planning and project grants under available funding programs, which should include consideration for communities with the highest risks, repetitive loss properties, and most intense development pressures.*

Requirement §201.5(b)(3): *[The Plan must demonstrate] that the State effectively uses existing mitigation programs to achieve its mitigation goals.*

17.6.1 Grant Support

As funding opportunities become available and are made known to the mitigation planning unit, they are forwarded to all applicable state and local mitigation counterparts. The Commonwealth makes full use of FEMA mitigation grant funding and encourages local communities to do the same. FEMA mitigation grants are used to leverage state, local, and other funds for maximum mitigation activity. For recent funding use, see Section 3. The SHMT and SHMIC meet regularly to review potential project applications, track progress, and prioritize efforts.

During the 2010-2013 update, MEMA and DCR have been successful in providing technical assistance to all interested parties statewide through workshops, one-on-one training, site visits, and policy/programmatic assistance, as detailed in Section 3. The 2013 update streamlines information about available funding programs by combining most program information in one table. All available funding sources were reviewed and updated as necessary. Project prioritization information is given in the Commonwealth's Administrative Plan contained in Annex 2.

17.6.2 Project Prioritization

The Commonwealth has had a FEMA-approved Hazard Mitigation Grant Program administrative plan since 1986, most recently updated in 2012, which details the process for prioritizing local assistance through post-disaster mitigation funding of local mitigation projects. Massachusetts has also used similar criteria to prioritize local pre-disaster mitigation grants applications. The Administrative Plan in Annex 2 includes the criteria for determining eligible projects for pre-disaster and post-disaster hazard mitigation funding in Massachusetts.

MEMA and DCR recommend only technically feasible and cost effective sub-applications to FEMA and provide pass-through funding for approved project grants to eligible sub-applicants. MEMA and DCR are also responsible for ensuring that projects funded by SRL were completed and that all performance and financial reporting requirements were met. The SRL program complements the intent of the FMA and RFC programs to reduce or eliminate future claims through the NFIP program.

17.6.3 Effective Use of Available Mitigation Funding

The Commonwealth of Massachusetts effectively uses mitigation programs to achieve its mitigation goals. Among the primary mitigation programs of the Commonwealth are the federally funded, state-administered hazard mitigation programs (HMGP, PDM, and FMA), and various state funding opportunities. Each of these programs has established its own mitigation goals and strategies.

17.6.4 Summary of Federal Funding Sources

Mitigation opportunities are pursued year-round in the Commonwealth. FEMA administers the NFIP, the Community Rating System, the Flood Mitigation Assistance Program, the Hazard Mitigation Grant Program, Severe Repetitive Loss, and the Pre-Disaster Mitigation Program. All of these programs are coordinated by DCR and MEMA. While various opportunities exist to fund projects, both the state and local applicants rely heavily on the use of these federal funds to implement mitigation projects.

Immediately following presidential disaster declarations, FEMA's Response and Recovery Division works closely with state agencies, especially MEMA, in assisting in short-term and long-term recovery efforts. FEMA assists disaster-affected communities through emergency funding programs, such as Public Assistance. In coordination with its Mitigation Division, Response and Recovery distributes information on hazard mitigation methods, acquisition/relocation initiatives, and coordinating HMGP grants for mitigation projects to protect eligible damaged public and private nonprofit facilities through the Public Assistance program. In addition to these programs, FEMA provides disaster recovery and hazard mitigation training at its Emergency Management Institute in Maryland. For the latest information on this and other mitigation funding programs, go to FEMA's website at www.fema.gov.

Table 17-7 summarizes the primary sources of federal funding for hazard mitigation in Massachusetts. This list is not all-inclusive. New funding mechanisms are regularly created, while others are discontinued. Funding sources to use will depend on specific project needs, but creative solutions in this time of economic difficulties should always be sought. Through continuous creativity and research, opportunities for mitigation funds in Massachusetts will continue.

TABLE 17-7.
SUMMARY OF POTENTIAL FUNDING SOURCES

Program	Type of Assistance	Availability	Managing Agency	Funding Source
National Flood Insurance Program	Pre-disaster insurance	Any time (pre & post disaster)	DCR Flood Hazard Management Program	Property Owner, FEMA
Community Assistance Program	State funds to provide assistance to communities in complying with NFIP requirements	Annually	DCR	FEMA/NFIP
Community Rating System (Part of the NFIP)	Flood insurance discounts	Any time (pre & post disaster)	DCR Flood Hazard Management Program	Property Owner

TABLE 17-7.
SUMMARY OF POTENTIAL FUNDING SOURCES

Program	Type of Assistance	Availability	Managing Agency	Funding Source
Flood Mitigation Assistance Program	Cost share grants for pre-disaster planning & projects	Annual pre-disaster grant program	MEMA	75% FEMA/ 25% non-federal
Hazard Mitigation Grant Program	Post-disaster cost-share Grants	Post disaster program	MEMA	75% FEMA/ 25% non-federal
Pre-Disaster Mitigation Program	National, competitive grant program for projects & planning	Annual, pre-disaster mitigation program	MEMA	75% FEMA/ 25% non-federal
Severe Repetitive Loss	For SRL structures insured under the NFIP.	Annual	MEMA	Authorized up to $40 million for each fiscal year 2005 through 2009
Small Business Administration Mitigation Loans	Pre- and post- disaster loans to qualified applicants	Ongoing	MEMA	Small Business Administration
Public Assistance	Post-disaster aid to state and local governments	Post Disaster	MEMA	FEMA/ plus a non-federal share
Dam Safety Program	Provides funding to state to promote dam safety through emergency action plans and exercises	Annual	DCR	FEMA
Homeland Security Grants	Multiple grant sources provide funding for homeland security activities, including THIRA development, planning, and training at the state and local levels	Annual	MEMA	DOJ, DHS, FEMA
National Fire Plan	Provides pre-disaster funds for wildfire mitigation and planning for all-hazards.	Annual	DCR	U.S. Land Management Agencies
Clean Water Act Section 319 Grants	Provides grants for wide variety of activities related to non-point source pollution runoff mitigation	Annual	MassDEP	EPA
Economic Development Administration Grants and Investment	Provides grants for community construction projects, including mitigation activities	Annual	Massachusetts Office of Business Development	U.S. Department of Commerce, Economic Development Administration

TABLE 17-7.
SUMMARY OF POTENTIAL FUNDING SOURCES

Program	Type of Assistance	Availability	Managing Agency	Funding Source
Emergency Watershed Protection	Provides funding and technical assistance for emergency measures, e.g., floodplain easements in impaired watersheds	Annual	DCR	USDA NRCS
Forest Land Enhancement Program	Provides educational, technical, and financial assistance to help landowners implement sustainable forest management objectives.	Annual	DCR	U.S. Forest Service
Housing and Urban Development	Provides various grant programs related to safe-housing initiatives	Annual	Department of Housing and Community Development	U.S. Dept. of Housing and Urban Development
Reclamation and Development Grants Program	Provides funding for water-related projects, studies, etc.	Annual	MassDEP and others	EPA
National Wildlife Wetland Refuge System	Provides funding for acquisition of lands into federal wildlife refuge system	Annual	U.S. Fish and Wildlife Service	U.S. Fish and Wildlife Service
North American Wetland Conservation Fund	Provides funding for wetland conservation projects	Annual	U.S. Fish and Wildlife Service	U.S. Fish and Wildlife Service
Rural Development Grants	Provides grants and loans for infrastructure and public safety development and enhancement in rural areas	Annual	Department of Housing and Community Development	USDA, Rural Development
Rural Fire Assistance Grants	Funds fire mitigation activities in rural communities	Annual	DCR	National Interagency Fire Center
Chapter 90 Program	Maintaining, repairing, improving and constructing town and county ways and bridges which qualify under the State Aid Highway Guidelines	Annual	Mass DOT	State Transportation Bond
2013 MassWorks Infrastructure Program	Targeted investments in infrastructure such as roadways, streetscapes, water, and sewer	Annual	Executive Office of Housing and Economic Development (EOHED),	State Appropriation-Section 11 of Chapter 238 of the Acts of 2012

TABLE 17-7.
SUMMARY OF POTENTIAL FUNDING SOURCES

Program	Type of Assistance	Availability	Managing Agency	Funding Source
Accelerated Bridge Program	Bridge Rehabilitation, Replacement, Preservation, Maintenance, painting and cleaning projects	Rolling basis (bridges are pre-selected)	MassDOT and DCR	State Appropriation - Chapter 233 of the Acts of 2008
Dam, Levee and Coastal Infrastructure Repair and Removal Program	Grants and loans for the repair and removal of dams, levees, seawalls, and other forms of inland and coastal flood control.	Annual	Executive Office of Energy and Environmental Affairs (EEA)	State Revolving Loan
Conservation Partnership	To assist not-for-profit corporations in acquiring land and interests in lands suitable for conservation or recreation.	Annual	Executive Office of Energy and Environmental Affairs (EEA)	Executive Office of Energy and Environmental Affairs (EEA)
PARC - Parkland Acquisitions and Renovations for Communities	Provides grant assistance to cities and towns to acquire parkland, develop new parks, or renovate existing outdoor public recreation facilities (formerly the Urban Self-Help Program).	Annual	Executive Office of Energy and Environmental Affairs (EEA)	State Appropriations

Other sources:

- Grants.gov, a source for federal government grants
- Grants.com, a source for private funding opportunities
- epa.gov/ogd/grants/funding_opportunities, U.S. Environmental Protection Agency
- corporateservices.noaa.gov/grantsonline, National Oceanic and Atmospheric Administration

Additional Projects of Interest:

Below is a summary of Massworks natural hazard mitigation projects funded in 2012:

- Buckland, Clesson Brook Road Project – $971,053 will repair a portion of Clesson Brook Road in need of immediate attention as a result of damages caused by Tropical Storm Irene. The MassWorks Award will complement approximately $4.1 million in federal funding for repairs in the project area.
- East Brookfield, Route 9 Embankment and Lake Lashaway Dam Rehabilitation – $594,400 will fund necessary repairs to the Lashaway Dam. The dam, now at risk of failing, supports Route 9, which carries an average of 17,500 vehicles per day. The award will complement over $800,000 in repairs made by MassDOT to the dam's bridge.
- Paxton, Davis Hill Road Culvert – $200,000 will replace an existing deteriorated wood, short-span bridge with a precast concrete culvert within the right of way on Davis
- Hill Road in Paxton. These improvements will increase public safety for Paxton's residents, neighboring communities and allow trucks to utilize the roadway.
- The City of Winthrop was awarded $500,000 under the MassWorks Infrastructure Program in the Fall of 2011. Construction began in June for the Ingleside Park Revitalization. The project will improve the park and provide necessary upgrades to the existing storm water system to decrease flooding in the park and nearby streets

Flood Mitigation Assistance Program

The Flood Mitigation Assistance (FMA) program was created as part of the National Flood Insurance Reform Act of 1994 (42 U.S.C. 4101) with the goal of reducing or eliminating claims under the NFIP. FEMA provides FMA funds to help states and communities implement measures that reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insured under the NFIP. The program is available to all communities having FEMA-approved hazard mitigation plans by the application deadline and at the time of obligation of grant funds. The program is funded through the National Flood Insurance fund. Three types of FMA grants are available:

- Planning grants to prepare flood mitigation plans.
- Project grants to implement measures to reduce flood losses, such as elevation, acquisition or relocation of NFIP-insured structures. States are encouraged to prioritize FMA funds for applications that include repetitive loss properties, including structures with two or more losses each with a claim of at least $1,000 within any 10-year period since 1978. Only NFIP-participating communities with approved flood mitigation plans can apply for FMA Project grants
- Management cost grants for the Commonwealth to help administer the FMA program and activities. Up to 10 percent of project grants may be awarded to states for management cost grants.

Increased cost shares may be available under the FMA program based on the completion of a repetitive loss strategy.

17.6.5 State Funding Sources

Matching FEMA Assistance

Following presidential disaster declarations, the Commonwealth may contribute half of a local applicant's share for federal infrastructure support funds (12.5 percent of the 25-percent non-federal share). Since 1991, the Commonwealth has contributed more than $27 million to match FEMA's funding following presidentially declared disasters.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.5(b)(4)(iii) which state the following:

Requirement §201.5(b)(4)(iii):*[The Plan must demonstrate] that the State is committed to a comprehensive state mitigation program, which might include: The State provides a portion of the non-Federal match for HMGP and/or mitigation projects.*

Special Appropriations Following State Disasters

Although there is no separate state disaster relief fund in Massachusetts, the state legislature may enact special appropriations for communities sustaining damage following a natural disaster that is not large enough for a federal disaster declaration.

State Revolving Fund

This statewide loan program through the Executive Office of Environmental Affairs assists communities in funding local stormwater management projects that help to minimize or eliminate flooding in poor drainage areas.

State Land Acquisition & Conservation Program

This annual program through the Massachusetts Executive Office of Energy and Environmental Affairs purchases private property for open space, wetland protection, and floodplain preservation. In 1998, the Commonwealth set a goal of protecting 200,000 acres of open space in the Commonwealth by 2010. In

August 2001, less than three years later, the Commonwealth announced that the Commonwealth and its land protection partners had reached the halfway mark in achieving that goal: 100,000 acres. Updated information may be found on line at http://www.mass.gov/envir/openspace/default.htm.

Major Flood Control Projects

The Commonwealth provides half of the non-federal share of the costs of major flood control projects developed in conjunction with the U.S. Army Corps of Engineers. This program is managed by DCR.

Flood Control Dams

The U.S. Natural Resource Conservation Service (NRCS) manages the Flood Control Dams Program, (Public Law 566), which funds operation and maintenance of 25 flood control dams on state property. This program also includes technical assistance and other smaller services from the NRCS and partners.

Flood Hazard Management Program Staff Funding

The Commonwealth provides the 25-percent non-federal share for FEMA's funding under the Community Assistance Program State Support Services Element. Funding from this program and the state match support the Flood Hazard Management Program within the DCR. The program works with FEMA to coordinate the NFIP throughout Massachusetts, providing technical assistance to participating communities, professionals, and individuals.

Weatherization Assistance Program

The Weatherization Assistance Program is funded each year by the U.S. Department of Energy, with supplemental funding from the U.S. Department of Health and Human Services and the 2009 American Recovery and Reinvestment Act. The extent of services to be provided depends on available funding. The program is intended to help low-income homeowners and renters lower their energy cost and reduce the potential impact from severe weather events. Weatherization service agencies throughout Massachusetts run the Weatherization Assistance Program.

17.7 LOSS AVOIDANCE METHODOLOGY

With public spending being closely scrutinized and governments becoming increasingly transparent in order to maintain public trust, it is important to determine whether public funds are expended efficiently and cost-effectively. Demonstration of a high return on investment on government activities helps to instill trust in citizens. In the eyes of citizens, an investment is viewed as sound if it can provide a positive return within a reasonable period of time.

With the potential for increased funding as a result of gaining enhanced status, the Commonwealth of Massachusetts must demonstrate its ability to continue to efficiently and effectively use the funds it will receive. Such determination will also help aid decision-making to appropriately allocate resources into the future, as similar projects can be compared for effectiveness.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.5(b)(2)(iv), which states the following:

Document the system and strategy by which the State will conduct an assessment of the completed mitigation actions and include a record of the effectiveness (actual cost avoidance) of each mitigation action.

Mitigation provides numerous benefits to the citizens of Massachusetts. Mitigation projects increase communities' resilience to disasters and can add jobs to the local economy (see the Economy portion of Section 4). As the Multi-Hazard Mitigation Council studies (2005) demonstrated, every dollar spent on mitigation provides $4 in savings.

There is no simpler way to express the benefits of mitigation efforts than to show losses avoided that would have occurred without the mitigation effort. A loss avoidance assessment is a way to quantify the value of mitigation. Most commonly, a loss avoidance assessment is performed after a disaster and

assesses how much money was saved due to mitigation. The customary approach is to re-create a similar incident to determine a "before and after" snapshot of the project. When no comparative disasters have occurred since project completion, the ability to complete studies of this nature may be limited.

While different approaches to various types of projects/hazards will be necessary, it is the Commonwealth's intent that loss avoidance assessments be integrated into the regular mitigation planning or grant management cycle to the extent possible. The Commonwealth has developed a comprehensive database to track and monitor all open and completed hazard mitigation projects and planning efforts funded under the HMGP, FMA, HUD, and PDM programs. This tool has allowed the Commonwealth to track and monitor project and plan timelines and completion dates. Data will be captured in the grants management database that will support future efforts of completing loss avoidance assessments. The primary tool for completing such studies will be FEMA's Benefit-Cost Analysis or a similar tool. MEMA will review opportunities to conduct loss avoidance assessments in other manners, such as through modeling (for flood, hurricane, wind, and earthquake related projects), historical loss data (including FEMA Public Assistance and Individual Assistance historical records), and other data, depending on the type of project involved.

In addition to this, the Commonwealth will investigate ways to use the SMRT Tool that was applied during development of the THIRA, further broadening the abilities of the Tool and providing valuable information for the evaluation of mitigation measures for all hazards. Currently, this tool is based on the 31 core capabilities defined in the National Preparedness Goal. With some time and technical assistance, the SHMT can add natural hazard mitigation capabilities to the tool, allowing the Commonwealth to have a standard methodology across all hazards to measure the effectiveness of prevention, preparedness, and mitigation activities. The SHMT could then enter completed actions into the tool and evaluate the effects those actions had on the risk that is presented in the THIRA. Comparing the cost of the mitigation investment to the reduced risk will allow the Commonwealth to make risk-informed decisions to support mitigation, as well as perform return-on-investment analyses and loss avoidance studies on potential investments in the context of reduced risk.

During the course of the 2013-2016 update, the Commonwealth will continue the process of capturing the data necessary for review of historical projects and select those on which a benefit-cost analysis can be completed, using information contained in project files and event data to calculate return on investment.

The Commonwealth previously worked with FEMA to evaluate avoided losses on FEMA-funded projects, such as the City of Melrose Ell Pond Flood Mitigation Project. FEMA completed a loss avoidance study of that project for MEMA in September 2010. FEMA's Hazus modeling tool and Benefit-Cost Analysis Flood Depth Damage Function demonstrated that "for the study as a whole, 246% of the project costs, for the Melrose Ell Pond Flood Reduction Project, have been recovered based on losses avoided since the project was completed in 2008" (FEMA, 2010). It is anticipated that once similar studies have been conducted, similar results will be found.

As part of the 2012 Hurricane Sandy Joint Field Office Mitigation Strategy, the SHMT worked with FEMA to conduct a loss avoidance study related to a number of elevation projects of homes that previously sustained damage as a result of a 100-year flood event. MEMA, FEMA, and DCR had completed a number of mitigation projects to elevate residential structures above the 100-year flood elevation. The SHMT provided four structures for inclusion in the loss avoidance study. Two models—the Florida Loss Avoidance Calculator and the FEMA Benefit Cost Analysis—were used to estimate losses avoided. However, a review of the storm surge and flooding in Plymouth County indicated that flooding associated with Hurricane Sandy was the equivalent of only a 10-year storm event. Following a detailed data review and flooding analysis of each structure, it was determined that the flooding due to Hurricane Sandy would not have impacted the structures prior to the mitigation projects. A report containing the data required for the loss avoidance software, as well as other information necessary to complete a detailed loss avoidance study following a significant flooding event, will be released in the

near future. The loss avoidance study contains data specific to the mitigated structures and storm event, and was created to estimate the dollar value of losses avoided due to the mitigation. Once the study is completed, that document will be incorporated in future updates to the loss avoidance portion of the SHMP.

SECTION 18. PLAN MAINTENANCE

18.1 MONITORING, EVALUATING AND UPDATING THE PLAN

The Massachusetts State Hazard Mitigation Plan is a living document that will be reviewed, updated, and adopted by state officials and submitted to FEMA for approval every three years. Per the statewide mitigation strategy outlined in this plan, the plan will be revised more frequently as multi-jurisdictional and local plans are completed and if conditions under which the plan was developed change, such as a major disaster or a new or revised state policy.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(5)(i), which states the following:

Plan Content. To be effective the plan must include a Plan Maintenance Process that includes an established method and schedule for monitoring, evaluating, and updating the plan.

This section describes the process for updating the SHMP. Federal hazard mitigation planning regulations (44 CFR 201.4) require the SHMP to be reviewed, revised and submitted to the FEMA regional director for approval every three years. The regulations require a plan maintenance process that establishes a method and schedule for monitoring, evaluating, and updating the plan, a system for monitoring implementation of mitigation actions and project closeouts, and a system for reviewing progress on achieving goals identified in the mitigation strategy.

Based on the capabilities assessment, the Commonwealth will develop a range of activities to enhance its capabilities and reduce identified gaps or shortfalls. The Commonwealth will use the SMRT Tool to evaluate risk reduction yielded by specific projects or programs. This is beginning to be done for non-natural hazards as the SMRT Tool is rolled out this year. For each potential investment related to non-natural hazards, the Commonwealth can identify core capabilities and individual capability indicators that will be impacted by the investment. The Commonwealth can then revise those indicators' values to show the level of capability that the Commonwealth will maintain after the investment is made. Running the SMRT analysis using the new capability indicators will provide revised consequence and risk values. The Commonwealth can compare the new values to the pre-investment values to determine the risk reduction associated with each project. Comparing the cost of the investment to the reduced risk will allow the Commonwealth to make risk-informed decisions to support homeland security strategic planning and future grant investments. More important, this allows return-on-investment analyses on potential investments in the context of reduced risk to the Commonwealth.

18.1.1 Responsibilities for Plan Maintenance

The SHMT is responsible for developing and maintaining the SHMP, under the oversight of the team's State Hazard Mitigation Planner. Additional participants in plan maintenance include the following:

- The SHMIC (see Section 2 for a list of participants)
- MEMA staff
- Representatives from regional planning agencies
- Representatives of local jurisdictions whose hazard mitigation plans were used in the development of the multi-jurisdictional plans or who developed a stand-alone" local plan.

18.1.2 Plan Reviews and Updates

The state plan review will include the following:

- Annual reviews for progress made on mitigation actions identified in the statewide mitigation strategy (see Section 17)

Annual Progress Review

The SHMP will be reviewed annually to reflect significant policy changes that took place during the preceding year and to report on progress made on funded statewide hazard mitigation projects. This annual review will take place at the end of each calendar year. The SHMIC and other participants will perform this review as follows:

- Examine progress or changes in natural hazards and disaster occurrences.
- Examine progress on mitigation actions in the statewide mitigation strategy, especially progress on multi-jurisdictional and local plans.
- Identify any implementation problems (financial, technical, political, and legal).
- Recommend how to solve such problems and to increase involvement of state agencies, local jurisdictions, and the private sector in hazard mitigation planning.
- Review, revise, and update the state capability assessment and the statewide mitigation strategy in Section 17 to reflect major changes in policies, priorities, programs, and funding.
- Review hazard profiles for which significant new information is available that could change the risk ranking or area of impact.

Post-Disaster Review

After each presidential disaster declaration and in coordination with FEMA, the SHMT will assist in documenting the effects of the disaster. The SHMT will convene a meeting of the SHMIC and other stakeholders to share observations and data related to the disaster and to review specific hazard mitigation needs related to the disaster-affected area. This will allow for development of hazard mitigation recommendations to FEMA during the disaster recovery operation and for updating the statewide mitigation strategy as needed. This will be especially important in assisting with expediting recovery efforts in impacted areas. This post-disaster review may replace an annual review in any year that a major disaster occurs, depending on the disaster event's severity and time of year.

Three-Year Plan Review and Revision

The SHMT will facilitate the review and revision of the Massachusetts SHMP every three years. The review and revision will begin approximately 18 months before plan expiration and will involve the SHMIC and other stakeholders, especially regional planning agencies that have completed single and multi-jurisdictional plans. This process will incorporate all revisions made during the annual and post-disaster reviews, particularly new hazard identification and risk assessment information from completed single and multi-jurisdictional plans. The SHMIC and planning partners develop the update as follows:

- Revise the hazard identification and risk assessment section to remain current and accurate. New data from completed single and multi-jurisdictional plans will be vital to updating these sections of the SHMP.
- Examine the progress on, and determine the effectiveness of, the mitigation actions outlined in the statewide mitigation strategy and in single and multi-jurisdictional plans and local annexes. Determine how the performance of such recommendations will influence the statewide mitigation strategy. Local governments and regional planning agencies, pending available funding, will review and revise their plans and annexes using processes that they identify in those plans and annexes.

- Examine the effectiveness of funded local mitigation projects and determine how the performance of those projects should influence the statewide mitigation strategy (see the following sections on monitoring projects and plans).
- Examine the overall implementation of the SHMP, identify problems (financial, technical, political, and legal), and develop recommendations to overcome them.
- Recommend ways to increase participation by state agencies and local jurisdictions in the hazard mitigation planning process.
- Recommend any necessary revisions to the risk assessment and to the statewide mitigation strategy to reflect changes in federal and state policies, priorities, programs, and funding. Incorporate new information following major disaster events.
- Following review and revision of the SHMP, analyze the plan maintenance process and the project monitoring process, and make changes to improve these processes as needed.

The 2013 update used a new template and layout and included a comprehensive, page-by-page review of the SHMP's content to ensure that all relevant revisions or changes were made. For the 2016 update, a page-by-page review of the plan's content will again occur. For future updates of the SHMP, new information will be highlighted in the executive summary and the introduction section.

The 2010 plan addressed "Future Natural Hazards" (page 114 in the 2010 plan), focusing on the inclusion of climate change impacts. Climate change has been addressed in the 2013 update, including the THIRA, with the assimilation of new relevant data and an enhanced risk assessment. Many of the hazard profiles contain climate change information. The Coastal Erosion profile maintains a significant amount of information related to the impacts of climate change.

18.2 MONITORING PROJECT IMPLEMENTATION AND CLOSEOUT

In addition to SHMIC monitoring activities, the SHMT will monitor the progress of hazard mitigation plans and projects, with regular site visits and reports at least quarterly. Project sub-applicants will document expenses for review by the SHMT during periodic inspection visits or audit. All records must be maintained for a minimum of six years from the date of project closeout. Quarterly reports on project status will identify how grant funds are being spent.

MEMA project files will be maintained in accordance with FEMA grant requirements. MEMA will create, maintain, and organize a separate project file for each project approved for FEMA HMA funding. The project file will include individual files for state contract, application, payments, FEMA award (including environmental review), quarterly reporting, and general correspondence.

WHY THIS SECTION?

This section of the State Hazard Mitigation Plan meets the requirements of 44 CFR §201.4(c)(5)(ii & iii), which state the following:

Plan Content. To be effective the plan must include a Plan Maintenance Process that includes:

- A system for monitoring implementation of mitigation measures and project closeouts.
- A system for reviewing progress on achieving goals as well as activities and projects identified in the Mitigation Strategy.

The project sub-applicant will submit a final accounting and reporting to MEMA upon project completion. This will include a thorough assessment of project accomplishments and shortfalls. MEMA will review all project costs and resolve any outstanding issues of non-compliance prior to final project payment. MEMA grant management will comply with all administrative and audit requirements outlined in 44 CFR Parts 13, 14 and §206 subparts M & N. At this time there are no major changes to the system or procedures of internal project management. As regulations change, the SHMT will update the

Mitigation Administration Plan as needed (see the current Administration Plan for the most current regulations).

18.3 MONITORING PLANNING AND THE 2013 UPDATE REVIEW

In order to adequately track and modify the statewide mitigation strategy presented in this plan, the strategy will be available at each SHMT meeting for discussion. A matrix has been developed for ongoing use as changes and notations are needed. This matrix will be regularly updated as an ongoing effort of the SHMT. For this plan update, the strategy was modified to detail all changes and accomplishments. The 2013 updated hazard mitigation strategy as presented in Table 17-1 includes a column in which the Commonwealth can indicate all changes made since the last update. During this update cycle, no mitigation actions were removed, eight new actions were developed, and 31 actions remained as continual (perpetual) actions. A number of actions were revised to more closely mirror the intended purpose or to reflect changes as a result of activities that occurred in the 2010-2012 timeframe.

The SHMT held a workshop on January 25, 2013 to evaluate existing mitigation goals and actions. The SHMIC gave concurrence to the results of this workshop at its February 6, 2013 meeting, The SHMIC also met on May 22, 2013, to review the draft 2013 SHMP and to discuss potential additions for future updates to the plan, including ways to increase stakeholder involvement and enhance the development of mitigation actions. The meeting also included a review and confirmation of ranking of the mitigation actions and pending grant applications. A facilitated process was conducted to review the plan, capture data to be included or modified, and gain concurrence for the plan. The SHMIC approved the plan as written, with slight modifications that have been incorporated. The February and May SHMIC meetings also served as brainstorming sessions to set forth actions for the 2016 plan update. The SHMT is confident that mitigation actions will continue to be addressed as resources and time become available.

The STAPLEE planning criteria, described in Section 17 and Appendix G, were applied to all of the actions to ensure consistency and that priorities are sound and justifiable. These criteria were also used by the SHMT to evaluate the implementation of actions that are in progress in the current statewide mitigation strategy. This system is recognizable and provides team members with uniform criteria.

During this plan update cycle, the Commonwealth's planning resources were challenged by several disaster events and by the task of completing a THIRA document. In addition, due to fiscal restraints and other staffing issues, not all of the state's hazard mitigation actions were addressed in the past three years. However, the SHMT is committed to the goals and actions in this plan and will continue to implement actions as resources and time become available. To help ensure continued focus on implementation of the actions, the Commonwealth developed two new grant coordinator positions to assist in the development, implementation, and monitoring of mitigation projects. These positions will provide added resources to help the Commonwealth work toward completion of more of the listed action items.

The following additional items will be considered for inclusion in future updates of the SHMP:

- Net SLOSH models were released as drafts in April 2013. These new models will be used during the update cycle to enhance risk profiles affected by the new information.
- DCAMM data continue to be enhanced and will be used to continue validating the potential risk to state-owned and leased facilities associated with each hazard.
- The SHMT may review a new method of prioritizing state agency mitigation actions, based on the intent to increase state-agency involvement (see discussion in Section 17).
- SHMT members will continue to provide recommendations for the Massachusetts Emergency Management Strategic Plan and to ensure that consistency is maintained between the SHMP and the Strategic Plan.

- SHMT members will conduct one-on-one outreach with state agencies that are not currently involved in the SHMP planning process in an effort to increase involvement. Information gained from the survey developed during the 2013 update cycle will help determine which agencies are interested in becoming involved but have not yet done so.
- The potential for a more refined analysis at the community level for the Coastal Erosion profile will be considered.
- Enhanced analysis using the Northeast Wildfire Risk Assessment Geospatial Workgroup fire risk layer (discovered too late in the process to incorporate in the 2013 update) will be incorporated into the wildfire risk assessment.

New studies underway that would be considered for inclusion in future editions include the following:

- Landslide data enhancement through the University of Massachusetts
- The Buzzards Bay Estuary Program—The Massachusetts Office of Coastal Zone Management is estimating the increase in flooding that would result from 1-foot, 2-foot, and 4-foot increases in sea level for Buzzards Bay municipalities (Fairhaven, Westport, Dartmouth, New Bedford, Mattapoisett, Marion, and Wareham). Using recent assessor's data, the number of buildings, their assessed values, and the number of municipal structures are being enumerated within various sea level rise expansion scenarios. (For more information and for the status of the reports and maps, refer to: http://buzzardsbay.org/floodzone-expansion-slr.html) These data should be reviewed and incorporated as appropriate to support future plan updates.
- Boston Harbor Coastal Flooding Analysis—The Boston Harbor Association is evaluating Boston's vulnerability to coastal flooding for three water levels above mean higher high water: 2.5 feet above, 5 feet above, and 7.5 feet above. For each scenario, the area of land affected by flooding was calculated. For future plan updates, depth grid data should be obtained to allow MEMA to conduct a spatial analysis for state owned/leased buildings. (During the 2013 update, access to these data was not available). For information, see: www.tbha.org/sites/tbha.org/files/documents/preparing_for_the_rising_tide_final.pdf.
- Fluvial erosion studies—Ongoing studies concerning fluvial erosion will be incorporated into the flood hazard profile, addressing its geomorphic impact on flood events throughout the Commonwealth.
- NEHRP Soil Data—Incorporate statewide NEHRP soils data as they become available to enhance earthquake modeling and assessment.

18.4 ONGOING PUBLIC PARTICIPATION AND COORDINATION

This plan will be posted on the Massachusetts Emergency Management Agency website at www.mass.gov/mema (link to Disaster Recovery and Mitigation) for comments from stakeholders prior to plan approval and throughout the next three years. In Section 2, information is provided relating to the ongoing participation of the public and coordination of stakeholders. Comments, questions, corrections or suggestions concerning any part of this plan should be addressed to the following:

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APPENDIX A.
METHODOLOGY

APPENDIX A. HAZARD MITIGATION PLANNING METHODOLOGY

To address the requirements of 44 CFR 201.4 and better understand potential risk associated with the identified hazards of concern, the Commonwealth of Massachusetts used standardized tools, combined with state and federal data and expertise to conduct the risk assessment. Our standardized tools used to support the risk assessment are described below.

HAZARDS U.S. – MULTI-HAZARD

In 1997, FEMA developed a standardized model for estimating losses caused by earthquakes, known as Hazards U.S. or Hazus. Hazus was developed in response to the need for more effective national-, state-, and community-level planning and the need to identify areas that face the highest risk and potential for loss. Hazus was expanded into a multi-hazard methodology, Hazus-MH, with new models for estimating potential losses from wind (hurricanes) and flood (riverine and coastal) hazards. Hazus-MH is a Geographic Information System (GIS)-based software tool that applies engineering and scientific risk calculations that have been developed by hazard and information technology experts to provide defensible damage and loss estimates. These methodologies are accepted by FEMA and provide a consistent framework for assessing risk across a variety of hazards. The GIS framework also supports the evaluation of hazards and assessment of inventory and loss estimates for these hazards.

Hazus-MH uses GIS technology to produce detailed maps and analytical reports that estimate a community's direct physical damage to building stock, critical facilities, transportation systems and utility systems. To generate this information, Hazus-MH uses default data for inventory, vulnerability, and hazards; this default data can be supplemented with local data to provide a more refined analysis. Damage reports can include induced damage (inundation, fire, threats posed by hazardous materials and debris) and direct economic and social losses (casualties, shelter requirements, and economic impact) depending on the hazard and available local data. Hazus-MH's open data architecture can be used to manage community GIS data in a central location. The use of this software also promotes consistency of data output now and in the future and standardization of data collection and storage. The guidance Using Hazus-MH for Risk Assessment: How-to Guide (FEMA 433) was used to support the application of Hazus-MH for this risk assessment and plan. More information on Hazus-MH is available at http://www.fema.gov/plan/prevent/hazus/index.shtm.

In general, both historic and probabilistic analyses were performed to develop estimated distribution of losses for the earthquake, flood, tropical storm/hurricane and nor'easter hazards. The following describes the inventory used and discusses more specifically the methodology for each of the hazards evaluated in Hazus-MH version 2.1 (Hazus-MH).

The default demographic and general building stock data in Hazus-MH 2.1 were used for the vulnerability analysis. The default demographic data is based on the 2000 U.S. Census statistics and the default aggregate building inventory is based on U.S. Census data for residential occupancies and Dun & Bradstreet for non-residential occupancies.

STATE FACILITIES

A custom table developed by DCAMM named MEMA_BDT_CAMIS.xls was used for this project. All locations were geocoded using ESRI's ArcGIS Online North America Streets 10.0 online geocoding service. Upon initial inspection of the MEMA-CAMIS spreadsheet of owned facilities, 6,422 facilities

were included and of these 5,398 facilities matched via geocoding to the street, rooftop, or street name geocoding level. Out of the initial set of facilities, 916 facilities contained no address and 108 facilities would not match via coding with the address provided. After the initial geocoding of the owned facilities data, these 1,024 facilities were sent back to Massachusetts for review and to obtain additional information that would allow them to be located. Of the 1,024 facilities sent back for updating, 935 were able to be successfully located with the inclusion of additional data. This allowed for 6,333 facilities to be included in the overall analysis of state owned facilities out of the 6,422 facilities that were provided, which is 98.6% of all owned facilities.

To include the owned facilities in Hazus-MH hazard models, assumptions had to be made for specific required variables that were missing from the supplied list of owned facilities. The description of the building (DescBldg field) was provided but had to be converted into Hazus specific building types for Flood and Earthquake modeling. When a building description was provided, the flood and earthquake Hazus specific building types were assigned accordingly, for facilities were this field was not provided, the default Wood (WOOD for Flood and W1 or W2 depending on area for Earthquake) was set as a default. The occupancy class for each facility was set to a default value of GOV1 or GOV2 depending on the description of the facility. For those facilities where the number of stories was not provided, a default value of 1 for buildings that were described as sheds or other smaller structures was assigned and a default value of 2 was assigned for all other buildings. Similarly, for those buildings where an area was not indicated a default value of 2,500 square feet was assigned, unless the building was described as something similar to a shed, which in case the default value was set to 100 square feet. The values for earthquake design level (EQ_DesignLevel), first floor elevation for flood models(FL_FFElev), foundation type for flood models, and the flood design level for each of the owned facilities was not indicated in the provided spreadsheet of owned facilities. For these variables the same default value was assigned to each facility according to the following:

- Earthquake Design Level (EQ_DesignLevel) = LC (for Low Code)
- First Floor Elevation (FL_FFElev) = 3 (3 feet)
- Foundation Type (FL_Found) = 7 (slab on grade)
- Flood Design Level (FL_DesignLevel) = 0 (Unknown)

The year built was a variable collected and provided in the owned facilities spreadsheet, for facilities where this variable was missing a default year built of 1970 was assigned. For the replacement and content cost, the provided replacement value was used as both the replacement cost and the content cost needed for Hazus-MH analysis. In cases where the replacement cost wasn't provided, a 2011 RS Means cost of $133.59/sq. ft. for GOV1 buildings was used. And lastly, a CAMIS ID and an Improvement Code was provided for most facilities in the owned facilities spreadsheet. To maintain this information with each facility, these numbers were concatenated into the Hazus Comment field as *CAMIS Code; Improvement Code* in case a facility needed to be further analyzed after the risk assessment was completed.

According to DCAMM, the *User Agency* provided in the MEMA_BDT_CAMIS.xls table of state-owned facilities was populated by the 10-digit *CAMIS BLDG Code*. This column is outdated because CAMIS cannot update their code; therefore the *User Agency* may reflect old agency names or may not reflect recent changes of ownership. For example, the Department of Environmental Management (DEM) and Metropolitan District Commission (MDC) were merged and are now Department of Conservation and Recreation (DCR); however DEM and MDC were still listed as agencies. To ensure our data set and risk assessment reports the results by the proper agency, the 13 character *Improve Code* from MASSETS (characters 7 through 9 in the code) was verified with DCAMM staff and used to list the agency and fill in

any blanks in the MEMA_BDT_CAMIS.xls table. There were no changes to the agencies for the State-leased data.

Please note the DCAMM building data is always being updated, changed and corrected as agencies change or modify.

There are more than 190 types of facilities in the DCAMM database that are included in the vulnerability assessment. The following list is just a short snapshot of some of the key critical facilities in DCAMM.

- Boat ramp
- Bridge
- Corrections
- Courthouse
- Dams/dam operations building
- Day care facility
- Docks/piers/marinas
- Electrical distribution/substation
- Fire station
- Fuel dispensing station
- Hospital / clinic
- Laboratory / research
- Library
- Marine & water transportation
- Military structure
- Miscellaneous
- Museum /monument
- Police station/barracks
- Pump house
- Residence/dormitory
- Salt/sand shed
- School
- Sewage treatment plant
- Telecommunications
- Water supply
- Office

Critical Facilities

All critical facilities, whether state or local, were used and obtained from MassGIS. Their data was more accurate in terms of location and more current than the default critical facility inventories in Hazus. The facility types used, in addition to those listed above, were police stations, fire stations, hospitals, emergency operation centers (state only) and schools (including pre-K through grade 12 and colleges).

Infrastructure

Hazus-MH default bridge inventory was used which includes federal, state, and locally-owned along with replacement cost values.

HAZARD-SPECIFIC METHODOLOGIES

Earthquake

Hazus-MH 2.1 was used to evaluate the Commonwealth's risk to the seismic hazard. A probabilistic assessment was performed to analyze the earthquake hazard estimated potential losses (100-, 500- 1,000- and 2,500-year mean return period losses). The probabilistic method uses information from historic earthquakes and inferred faults, locations and magnitudes, and computes the probable ground shaking levels that may be experienced during a recurrence period by Census tract.

The National Earthquake Hazard Reduction Program (NEHRP) developed five soil classifications that impact the severity of an earthquake. 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 damage and losses. For this analysis, available NEHRP soil data in portions of Franklin, Hampden and Hampshire Counties provided by the State Geologist, Mr. Stephen Mabee was incorporated into Hazus-MH 2.1 and used for all analyses. Groundwater was set as at a depth of five-feet (default setting). Damages and loss due to liquefaction,

landslide or surface fault rupture were not included in this analysis. Estimated damages to the general building stock were generated at the Census-tract level.

Flood

To assess the Commonwealth's exposure to the flood hazard, an analysis was conducted with the most current floodplain boundaries. This data includes the locations of the FEMA flood zones: the 100-year flood zones or 1-percent annual chance event (including both A zones and V zones) and the 500-year flood zones or 0.2-percent annual chance event. These flood events are generally those considered by planners and evaluated under federal programs such as the NFIP. Using ArcMap, GIS software, this data was overlaid with the population, general building stock, state facility data (owned and leased), critical facilities and bridges; and the appropriate flood zone determination was assigned.

The newest FEMA FIRM or DFIRMs were used in this analysis, including preliminary DFIRMs provided by the Department of Conservation and Recreation (DCR). Where DFIRMs were not available, Quality 3 (Q3) data was used. Franklin County does not have DFIRMs or Q3 data; however a digital floodplain layer that had been developed by the Franklin Regional Council of Governments (FRCOG), which only includes the floodplain in those communities along the Connecticut River, was used for this analysis. Table A-1 summarizes the data used for this risk assessment.

TABLE A-1.
DATA USED FOR 2013 PLAN UPDATE

County	Data Used	Source
Barnstable	Q3	MassGIS – August 2012
Berkshire	Q3	MassGIS – August 2012
Bristol	DFIRM (July 7, 2009)	DCR - September 2012
Dukes	DFIRM (July 6, 2010)	DCR - September 2012
Essex	DFIRM (July 3, 2012)	DCR - September 2012
Franklin	Digital floodplain layer (1-percent flood event only) for Connecticut River (and some of the tributaries) only (there is no Q3 data for the rest of Franklin County)	DCR - September 2012
Hampden	Revised Preliminary July 13, 2012 DFIRM	DCR - September 2012
Hampshire	Q3	MassGIS – August 2012
Middlesex	DFIRM (June 4, 2010) *Shawsheen Watershed is located partially within Middlesex County The preliminary Risk MAP deliverable for Shawsheen Watershed (2011) was used in place of the data in the 2010 DFIRM database for this area.	DCR - September 2012
Nantucket	Preliminary DFIRM (July 26, 2012)	DCR - September 2012
Norfolk	DFIRM (July 17, 2012) The Town of Canton was not included in the July 17, 2012 Norfolk Countywide FIS or DFIRMs. The Q3 for the Town of Canton was used.	DCR - January 2013

TABLE A-1.
DATA USED FOR 2013 PLAN UPDATE

County	Data Used	Source
Plymouth	Physical Map Revision (PMR) to Preliminary DFIRM DB on August 16, 2012 (PMR is only for Marion, Mattapoisett and Wareham). Remainder of the county has DFIRMs from July 17, 2012.	DCR - September 2012
Suffolk	DFIRM (September 25, 2009)	DCR - September 2012
Worcester	DFIRM (July 4, 2011) The DFIRM is only available for a portion of the County (Auburn, Berlin, Blackstone, Bolton, Boylston, Charlton, Clinton, Douglas, Dudley, Grafton, Harvard, Hopedale, Lancaster, Leicester, Mendon, Milford, Millbury, Millville, Northborough, Northbridge, Oxford, Paxton, Shrewsbury, Southborough, Southbridge, Spencer, Sturbridge, Sutton, Upton, Uxbridge, Webster, West Boylston, Westborough, and Worcester); the Q3 used for the remainder of the County	DCR - September 2012

A total risk exposure was estimated for state-owned and leased buildings located in the 1- and 0.2-percent annual chance flood zones. This methodology assumed 100-percent loss to each structure and its contents if located in the defined flood hazard zones.

Hurricane/Tropical Storm

Hazus-MH

The Commonwealth selected historic events (tropical storm, and categories one through three) for simulation in Hazus-MH 2.1: 2011 Tropical Storm Irene; 1985 Hurricane Gloria (category one); 1991 Hurricane Bob (category two); and 1938 hurricane (category three) also known as the Great New England Hurricane of 1938. If the historic storm were not in Hazus' database, the storm's characteristics were manually defined in Hazus-MH 2.1 using best available data. The Hazus-MH 2.1 wind model was run for the entire Commonwealth to obtain building wind-only potential loss estimates.

FEMA Region IV Coastal Flood Loss Atlas

FEMA Region IV Risk Analysis Team developed storm surge inundation grids in GIS format from the National Hurricane Center's Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model SLOSH Maximum of Maximums outputs, or the worst-case storm surge scenarios for each Saffir-Simpson hurricane category (1 through 4) under perfect storm conditions for the Commonwealth.

To assess the Commonwealth's exposure to hurricane storm surge, a spatial analysis was conducted using the SLOSH model provided by FEMA Region IV's Risk Analysis Team. Please note the SLOSH boundaries do not account for any inland flash flooding. Using ArcMap, GIS software, the SLOSH zones were overlaid with the population, general building stock, state facility data (owned and leased) and critical facilities; and the appropriate SLOSH zone determination (categories one through four) was assigned.

The Hurricane Category 4 SLOSH depth grids provided by FEMA Region IV were imported into the Hazus-MH flood model and the potential losses were estimated for the state-owned and leased facilities.

Nor'easter

A custom Nor'easter scenario was developed and incorporated into Hazus-MH v2.1 for this analysis. The Commonwealth selected the 1978 February Nor'easter as one of the most devastating Nor'easter events in their history. The storm's characteristics were manually defined in Hazus-MH 2.1 using best available data. Please note the maximum radius to maximum winds in Hazus-MH v2.1 is 93 and was utilized for this event.

The wind model was run for the entire Commonwealth. To obtain both wind and surge results, the near-shore wave model was run for the census blocks along the coastline. The census blocks selected for the analysis at minimum included all blocks within category one through four SLOSH zones. Initial water levels were obtained from the historic predicted normal tide levels from NOAA tide stations throughout the study region for the event. At this time, only building estimated potential losses are available from the Hazus-MH v2.1 surge model.

Severe Weather

High Winds/Thunderstorms

Massachusetts is divided into four wind zones, the limits of which are defined by the Massachusetts State Building Code Seventh Edition. The basis of these wind zones, as defined by the State Building Code, is a set of national wind data prepared by the American Society of Civil Engineers. The data can be found in a document titled, "Minimum Design Loads for Buildings and Other Structures (ASCE-7)." Generally speaking, structures should be designed to withstand the total wind load of the zone in which they are located. Refer to the State Building Code for appropriate reference wind pressures, wind forces on roofs, etc. Using ArcMap, GIS software, this data was overlaid with the DCAMM facility data; and the appropriate wind load zone determination was assigned to each facility

Tornado

The number of historic tornado touch-downs in 25 miles was updated using the NOAA Storm Prediction Center's dataset through 2011 (2012 data was not available at the time of the 2013 Plan update). To calculate density, the ArcGIS kernel density tool was used.

As was conducted in the 2010 hazard mitigation plan, tornado risk for the 2013 update is based on the probability of occurrence of past events. The density per 25 square miles indicates the probable number of tornado touchdowns for each 25 square mile cell within the contoured zone that can be expected over a similar period of record (approximately 60 years). It should be noted that the density number does not indicate the number of events that can be expected across the entire zone, but the percent probability of occurrence in the given area. To analyze how tornados could impact state facilities, critical facilities, and bridges, the DCAMM data was overlaid with the states area of greatest historic tornado density.

Extreme Temperature/Drought

Qualitative analyses were conducted for the extreme temperature and drought hazards.

Coastal Hazards

Coastal Erosion

In collaboration with the Massachusetts Office of Coastal Zone Management (CZM) the Massachusetts Department of Environmental Protection (MA DEP) wetlands spatial layer and specific wetland types (barrier beach, coastal beach, coastal dune, coastal bank, rocky intertidal shore, salt marsh and tidal flat)

were identified as vulnerable to coastal erosion. In determining risk, the assets within this area were evaluated.

Shoreline change, whether erosion or accretion, is dependent upon several factors including location (e.g., open-ocean facing shore) and exposure to high-energy storm waves. The exposure and vulnerability of assets in the coastal high hazard area (or V zone), and storm surge is discussed in Sections X and X (Flood and Hurricane/Tropical Storms).

Sea-Level Rise

Projected sea-level rise inundation and depth grids were not made available in time to conduct a quantitative analysis for the Commonwealth. This coastal hazard is discussed qualitatively using available studies.

Severe Winter Weather

As part of a FEMA Hazard Mitigation Grant Program funded study, in 2010 the Northeast States Emergency Consortium (NESEC) developed regional hazard maps for snowfall for the Northeast. Using their GIS data, a figure was created to display the number of days with more than 5 inches of snow. Using ArcMap GIS software, this data was overlaid with the DCAMM facility data and critical facilities to examine exposure. Current modeling tools are not available to estimate specific losses for this hazard. As an alternate approach, this plan considers percentage damages (one-percent) that could result from winter storm conditions on the Commonwealth's total general building stock (structure only).

Dam Failure

Dam failure inundation maps and downstream hazard areas are considered sensitive information and were not available to conduct a quantitative risk assessment. The Commonwealth of Massachusetts' exposure and vulnerability to the dam failure hazard are discussed in a qualitative nature.

Wildfire

For the purposes of this risk assessment, the interface and intermix obtained through the SILVIS Lab, Department of Forest Ecology and Management, University of Wisconsin-Madison defines the wildfire hazard area (Radeloff et al., 2011). The wildfire hazard areas are based on the 2010 Census and 2006 National Land Cover Dataset and the Protected Areas Database. The high-, medium- and low-density interface areas were combined and used as the 'interface' hazard area and the high-, medium- and low-density intermix areas were combined and used as the 'intermix' hazard areas.

The asset data (population, building stock and critical facilities) were used to support an evaluation of assets exposed and the potential impacts and losses associated with this hazard. To determine what assets are exposed to wildfire, available and appropriate GIS data was overlaid upon the hazard area. A total risk exposure was estimated for assets located in the intermix and interface zones. This methodology assumes 100-percent loss to each asset and its contents if located in the defined hazard zones. The limitations of this analysis are recognized, and as such the analysis is only used to provide a general estimate.

Landslide

In an attempt to estimate the Commonwealth's vulnerability to the landslide hazard, the Geology - Landslide Incidence and Susceptibility GIS layer from National Atlas was used to coarsely define the general landslide susceptible area (Godt, 2001). The asset data (population, building stock and critical facilities) were used to support an evaluation of assets exposed and the potential impacts and losses associated with this hazard. To determine what assets are exposed, available and appropriate GIS data

was overlaid upon the hazard area. A total risk exposure was estimated for assets located in the high incidence or high susceptibility zones. This methodology assumes 100-percent loss to each asset and its contents if located in the defined hazard zones. The limitations of this data set and analysis are recognized and are only used to provide a general estimate until higher resolution data is available Commonwealth-wide.

Tsunami

Tsunami inundation areas are not available for the Commonwealth. In an attempt to estimate the Commonwealth's vulnerability to the tsunami hazard, a one-mile buffer from the coast was used to define the area exposed and thus vulnerable.

APPENDIX B.
BEST AVAILABLE SCIENCE

APPENDIX B. BEST AVAILABLE SCIENCE

This appendix presents guidance that was provided for use in the preparation of hazard profiles for the Massachusetts State Hazard Mitigation Plan.

BEST AVAILABLE SCIENCE

The following are sources of information representing the best available science to use in the development of hazard profiles:

- All Hazards
  - NOAA-NCDC Storm Query: http://www.ncdc.noaa.gov/stormevents/
    - The website is being re-organized. You can only access data from 2006 to 2011 online and then have to download the entire database to access information from 1950 to present (this database is for ALL states; but you can run queries via Access to get specific info for the planning area)
  - SHELDUS: http://webra.cas.sc.edu/hvri/products/sheldus.aspx
  - NWS: http://www.weather.gov/
  - National Atlas: http://www.nationalatlas.gov/
  - FEMA:
    - http://www.fema.gov/news/disasters.fema
    - http://www.fema.gov/library/viewRecord.do?id=6292
  - NRCC: http://www.nrcc.cornell.edu/index.html
  - U.S. Census American Fact Finder: http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t
- Climate Change
  - EPA info: http://epa.gov/climatechange/
- Drought
  - Climate Division Map: http://www.esrl.noaa.gov/psd/data/usclimdivs/data/map.html
  - Climate Divisions w/ Counties: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/CLIM_DIVS/states_counties_climate-divisions.shtml
  - Drought Impact Reporter: http://droughtreporter.unl.edu/
    - Click on: Advanced Search—Impacts
    - Select State and County (and City if doing a single jurisdiction)
    - Select Time Interval and use the earliest date to the most recent date
    - Click on Search
    - Once you see the list of events, click on “See impact detail” and “See detail ion associated reports”
    - Go through this information and look for any specific information regarding the County or municipality you are researching

        - Most of the time the information found on this site is regional, but it is still a good tool to use to get an idea of the drought event
    - NRCC Drought: http://www.nrcc.cornell.edu/page_drought.html
        - Under Data Options, select "Periods of Drought or Extreme Drought" and select the State.
        - Using the Climate Division in which the county is found in, include those drought periods and lowest PDSI in the hazard events table.
- Earthquake
    - USGS Earthquake Archives: http://earthquake.usgs.gov/earthquakes/eqarchives/epic/
    - USGS Hazard Maps: http://earthquake.usgs.gov/hazards/products/conterminous/
    - USGS Did You Feel It: http://earthquake.usgs.gov/earthquakes/dyfi/
        - If you know the date of an earthquake, search for that and you will find a list of municipalities that reported having felt the earthquake
    - NEIC: http://earthquake.usgs.gov/regional/neic/
- Flood
    - FEMA CRS Info: http://www.fema.gov/library/viewRecord.do?id=3629
        - Use this site to see if any community in the county is a CRS community
    - Ice Jams are included in the Flood profile
        - CRREL Ice Jam database: https://rsgis.crrel.usace.army.mil/icejam/
        - You will get a certificate error message when you first go to this site; just click on continue to site anyway
- Severe Storm
    - NOAA Hurricane Tracker: http://www.csc.noaa.gov/hurricanes/
        - Use this site to create the historical hurricane tracker figure; use 65 nautical miles as search distance
        - Be sure to identify each of the tracked storms on the figure in the hazard profile
- Winter Storm
        - Use NOAA-NCDC Storm Query, SHELDUS, FEMA and NWS to obtain specific event information
        - Nor'easters are included in the Winter Storm profile
- Wildfire
    - GeoMAC: http://www.geomac.gov/index.shtml
        - Use this site to get information on current and historic wildfires (select "GeoMAC Viewer")
        - Use this site to identify whether or not the county or municipality is located in the WUI (Wildland Urban Interface)

HAZARD PROFILE LAYOUT

Each hazard profile section is to be written using the following outline:

- Description—Provide definition and details about the event. This is the same for every HMP that we do; however, need to make changes based on the county/town location, what state the county/town is located in, etc.
  - If there are specific types of the hazard (for example, flood and the county/town experiences flash floods, ice jam floods and dam break floods), those need to be defined/discussed as well. Check with PM to see what the county/town wants to include.
- Extent—Describe the magnitude and severity for a particular probability event (usually the same text as in previous HMPs)
- Location—Geographic area of the county/town affected by the hazard. Typically use the same text as previous HMPs; however, make sure the info regarding state is specific to the state the county/town is located in
  - Review the county/town Flood Insurance Study for flood (look at other HMPs to see how this is done).
  - For flood, include ice jams hazard area info
- Previous Occurrences and Losses—This is where we discuss the previous hazard events using the research tools listed above.
  - NOAA-NCDC and SHELDUS paragraph—Using the NOAA and SHELDUS data, complete this paragraph
  - FEMA paragraph—Using FEMA info, complete this paragraph
  - Table—Fill out this table with hazard events that occurred in the county/town; be sure to include all FEMA disasters where the county/town was included in the disaster. Use your best judgment when filing through the events to fill out the table—if there was a lot of damage from the event, property damage/crop damage, etc.
- Vulnerability Assessment— To understand risk, assets exposed and vulnerable to the identified hazard are evaluated. This section evaluates and estimates the potential impact of the hazards on the Commonwealth's population, state facilities, critical facilities and infrastructure and economy.

GENERAL NOTES

If doing an HMP Update, need to include all events from the previous HMP. Then update from the year left off in the original HMP to the most recent date.

Provide citations. Be sure to include all websites used as well (do this right in the document or leave the website as a comment). Keep a resource page with everything used. Keeping track of information sources is important.

APPENDIX C.
BEST PRACTICES

Best practices

Disaster Mitigation Working in Massachusetts

New Culverts Lower Flood Risks at Converse Lane

"There was no flooding on Converse Lane this March (2010), not even any puddles."

— Bob Beshara, Melrose City Engineer

City of Melrose Photo

Melrose, MA –Before mitigation, homes along Converse Lane used to flood almost every time there was any rain.

The City of Melrose took to heart the lessons of the Mother's Day Storm of 2006, when several feet of water inundated streets, school yards, and playing fields, causing damages to residences and businesses. Since then, Melrose officials have taken significant steps to reduce the risk of flooding in several areas of the city.

With financial grant assistance from the Federal Emergency Management Agency (FEMA), the city has completed drainage improvement projects at three locations where flooding proved troublesome in 2006 – at Ell Pond in the city's central core, in Ward 2 at Melrose's boundary with the Town of Wakefield, and in the Converse Lane neighborhood at the opposite (southwestern) corner of the city.

"The residents of Converse Lane had been hit by flooding too many times," said John Scenna, Deputy City Engineer and Director of the Operations and Engineering section of the city's Public Works Department. "We had to do something to give them some relief."

Historically, flooding in the Converse Lane area of Melrose has been an almost twice-a-year event. Lying just east of the Middlesex Fells Reservation (MFR), a 2,600-acre state park, the neighborhood was commonly flooded to depths of up to three feet, and occasionally much deeper, by water draining from the Reservation following even moderate rainfall.

The culverts beneath Washington Street (at the eastern boundary of the MFR) and Converse Lane could not handle all the water during the peak of the rainfall runoff. The water backed up, existing catch basins were filled to overflowing, and streets, yards, and basements would be temporarily awash. Floodwaters often covered vehicles parked on Converse Lane, and at least one house was flooded so many times that it was declared a "repetitive loss structure" by FEMA.

City of Melrose Photo

"We had to tear up streets, lawns and backyards with the least possible inconvenience to the residents," said John Scenna, Deputy City Engineer.

FEMA photo by Dale Bonza

Previously flooded neighborhood today, in photograph taken at same location. "You can't tell it was ever ripped up," said one resident.

In the Natural Hazards Mitigation Plan for the City of Melrose, completed in December 2004, flooding was recognized as a significant weather-related hazard to the city. Inadequate capacity of several of the main city culverts to transport the storm water runoff generated during large rainfall events was determined to be the immediate cause of the flooding, and the Converse Lane neighborhood was identified as one of nineteen high-flood-hazard areas in which such undersized culverts were the main cause of flooding.

In response to the conclusions of the Mitigation Plan, the city proposed replacement of the undersized culverts and construction of additional catch basins at Converse Lane. The existing 30-inch and 24-inch culverts beneath Washington Street and Converse Lane were replaced with 48-inch culverts.

Farther downstream, at the eastern end of the neighborhood, the 48-inch culvert beneath Pleasant Street that carried storm water to Spot Pond Brook was replaced with an 8-foot wide by 4-foot high concrete box culvert.

"While other drainage improvements in the city, such as those at Ell Pond and Ward 2, addressed flooding problems over larger areas, the Converse Lane project focused on a single, small neighborhood," said Scenna. "But it was no less challenging to complete, as we had to tear up streets, lawns, and backyards with the least possible inconvenience to the residents."

Did the Converse Lane project pass the test posed by the floods in March 2010? Bob Beshara, Melrose City Engineer and Superintendent of Public Works, thinks so.

"The neighborhood was a lot drier this spring than during past flood events," said Beshara, "even though this year's storm is considered the most severe to hit this area since Hurricane Diane in 1955. Thanks to the drainage improvements, there was no flooding on Converse Lane, not even any puddles. And Washington Street didn't flood either, because the new larger culvert kept up with the flow, even at the peak of the storm runoff."

Scott MacLeod, Hazard Mitigation Grants Coordinator for the Massachusetts Emergency Management Agency (MEMA), considers the Converse Lane project to be a mitigation success story, and "a best-practice model" for other communities.

Construction of the new drainage system for Converse Lane was made possible with a grant from FEMA's Pre-Disaster Mitigation Grant Program, which provides funding for hazard-mitigation planning and the implementation of mitigation projects prior to a disaster event. The Federal share of project costs was $1.08 million, leaving the remaining $400,000 the responsibility of the community.

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Mitigation Grants Manager
Telephone 508-820-1445

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Massachusetts Department of Conservation and Recreation
251 Causeway Street, 8th Floor
Boston, MA 02114

State Hazard Mitigation Officer
Telephone 617-626-1406

Best practices

Disaster Mitigation Working in Massachusetts

New Drainage System Averts Flooding in Melrose

"The new drain system at Ell Pond saved our city."
—Ed Kelly, Director
Melrose Emergency Management Agency

Photo—City of Melrose

Water surrounds the Melrose Towers Condominiums just north of Ell Pond during the Mother's Day Flood in 2006

Despite ten days of record-breaking flooding across northeastern Massachusetts in March 2010, the City of Melrose "dodged the bullet," thanks to the new drainage system for the city's Ell Pond.

Runoff from several previous storms, most recently the "Mother's Day Storm" in 2006, led to flood depths as high as six feet in buildings, yards, and streets to the north of Ell Pond. This Spring, the water barely topped the banks of the pond.

"The system worked almost flawlessly," said Bob Beshara, Melrose City Engineer and Superintendent of Public Works. "The new drainage system replaced part of the existing system and enhanced our ability to move floodwaters rapidly through the city's central core area, while at the same time minimizing their impact."

Ell Pond, a natural body of water within the City of Melrose, is bordered by homes, streets, recreational fields and landscaped park strips. The 23-acre pond receives water from an 1,100-acre watershed, which includes parts of the towns of Stoneham and Wakefield. Water leaves the pond through an outlet at its southeastern corner and flows southward beneath city streets to ultimately discharge to Lower Spot Pond Brook.

The original outlet channel allowed water to begin draining from the pond only when it became nearly full, so that the water level could not be lowered in anticipation of large storms and the resulting runoff.

The Ell Pond Project changed all that, and while storm runoff can't be prevented, it can now be managed to reduce its effects. A 2001 study of flooding at Ell Pond identified alternatives for eliminating, or at least

minimizing the problem. In early 2005, city officials began to seek funding for the design and construction of what became known as the "Ell Pond Project."

With funding of $1.75 million provided by the Federal Emergency Management Agency's (FEMA) Pre-Disaster Mitigation (PDM) program, supplemented by $1 million in city funds, construction of the new drainage system was completed in time for its first real test by the recent rainfall and accompanying floods of early 2010.

The Ell Pond drainage project consists of a control gate structure at the southeastern corner of the pond and a 3,500-foot long, 48-inch pipe that extends from the control gate to the outlet at Lower Spot Pond Brook.

FEMA photo by Michael Moore

Water enters the new drainage system through the crest gate at the southeast corner of Ell Pond

During periods of peak runoff following the storms of March 2010, the level of Ell Pond rose to as high as two feet above the top of the outlet pipe, and water was draining from the pond at a rate of 100 cubic feet (748 gallons) each second. Draining this much water this rapidly from Ell Pond reduced the extent and depth of inundation of areas around the pond compared to that in the March 2006 flood.

For instance, the West Knoll Soccer Field was flooded by 3 to 4 feet of water in March 2006; in March 2010, only the perimeter of the field was flooded. And the Cabbage Patch Park in front of the new middle school, which was covered by 2 to 3 feet of water in 2006, was not flooded at all this year.

"It's all about water-level management," said John Scenna, Deputy City Engineer and Project Manager for the Ell Pond work. "We can now adjust the level of the pond as conditions require, either raising it high enough to prevent wave action from eroding unvegetated parts of the shoreline or lowering it before storm runoff begins to enter. We did this in March, so the pond served as a temporary storage basin for at least part of that runoff."

The gate that controls the level of the pond is automatically activated to maintain or adjust the water to desired, preselected elevations, but the mechanism can also be manually activated. The control gate structure incorporates a sturdy debris trapping "trash rack," and a high, level platform that provides a safe perch from which maintenance workers can remove trees and other woody debris that become lodged against the rack.

The construction phase of the new drainage system brought a year of inconveniences – such as torn up roads and temporary water hookups – to the citizens of Melrose. The rewards for their patience, in addition to a lessening of the flood risk to the areas around Ell Pond, were amenities such as new sidewalks and street paving along the construction route, beautiful landscaping around Ell Pond, a skate park, and new baseball and soccer fields.

"The new drain system saved our city," said Ed Kelly, Director of Melrose's Emergency Management Agency. "During earlier floods that inundated parts of central Melrose, large areas were underwater for as long as a week to 10 days. But in 2010, much smaller areas and only scattered depressions near Ell Pond were flooded to much lower depths than in those earlier floods, and the water drained away within a few hours to a few days at most. Now that's a success story."

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Best practices

Disaster Mitigation Working in Massachusetts

Several Small Steps Lead to Safety

"The water goes down much more quickly now…...it gives us real peace of mind."

-Chris Tighe,
Peabody Director of Emergency Management

Photo— City of Peabody

A major contributor to the high water problems in Peabody was the large amount of debris that had accumulated in the local waterways

Flooding is the most common natural disaster threatening United States residents today. While each state has its own set of hazards and risks to deal with, the majority of states count flooding as the most likely disaster citizens will have to face, and Massachusetts is no exception. In the past 20 years alone, there have been at least 16 major floods in Massachusetts, causing hundreds of millions of dollars in damages.

The City of Peabody, which lies about 15 miles northeast of Boston and three miles from the Massachusetts coast, has seen its share of those floods. Three streams – Goldthwaite, Strongwater and Proctor Brooks – converge in downtown Peabody to form the North River, which flows into the Atlantic Ocean.

"The problem with the hydrology here is that all the water is going to one place," said Chris Tighe, Peabody's Director of Emergency Management. "If we can get the water to the North River, we're going to be ok. Our best asset is low tide, when the ocean just drains all the water out of the system. The problem is, when we get back-ups, there's no place for the water to go."

In May 2006, runoff from the famous "Mother's Day Storm" inundated downtown Peabody to depths of three to four feet, in some areas reaching as wide as a half-mile across. With no convenient means of egress, in some areas the water took as long as 48 hours to recede. In assessing the aftermath of the 2006 flood, Peabody officials realized they needed to make some changes to their drainage network to lessen effects of future floods, as well as upgrade several critical systems that had been threatened.

One of the first measures Tighe undertook was to secure funds to clean out the channels of several streams running throughout Peabody. To get the money needed to accomplish this considerable task, Tighe applied to the U.S. Department of Labor for a National Emergency Grant (NEG). NEGs allow communities to temporarily increase their workforce through the employment of individuals affected by large, unforeseen economic events that cause significant job losses. Peabody qualified for such assistance and, through the Valley Works NEG Northeast Flood project, was awarded $540,000 to conduct the stream cleanup.

Beginning in November 2006, Tighe and his crew canvassed more than 10 miles of waterways, clearing out debris and refuse. They discovered early on that a major contributor to the high water problems Peabody had suffered was the large amount of garbage that had accumulated in the channels through and around the city.

"As an example, we removed a mattress that had become wedged in one of our culverts," reported Tighe. "And as soon as we pulled it out, the water level immediately dropped drastically, probably as much as two to three feet."

The clean-up project took Tighe and his team almost two years to complete and ultimately resulted in the removal of more than twenty 44-cubic yard containers of recyclables, junk and organic material.

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An unexpected benefit of the streambed cleanup came when the team discovered that a culvert running beneath a railroad track had sustained major damage over the years. Though the openings appeared normal, the interior of the culvert had collapsed due to the constant vibration from passing trains. The obstructed pipe turned out to be responsible for many back-ups and the consequent flooding, and thanks to the clean-up efforts, the Peabody Department of Public Works was able to identify the problem and repair the pipe. In addition to fixing the damaged railroad culvert, Peabody has sought grant assistance from a number of sources to improve several other culverts in the city to increase the overall efficiency of their drainage network.

FEMA photo by Chris Smith

The Peabody fire station was built in the 1800s and is one of the oldest headquarters stations in the country.

Reducing future flood levels in Peabody has been only one step in the city officials' approach to mitigation. During the Mother's Day flooding in 2006, the ability of both the police and fire stations to respond to emergencies was nearly compromised. As the water rose in the basements of both buildings, it became clear that the city was in danger of losing several critical systems.

"We were within three inches of losing our 911 system," said Tighe. "The deputy police chief called and told me to get whatever I could to help, and that we were going to have to run our entire system from another community if we lost it."

In response to the risk posed by the high water, a decision was made to protect the utilities and services of both stations. To make the changes needed, Peabody officials applied for grant assistance from two of the Federal Emergency Management Agency's (FEMA) available grant programs.

The city received $225,000 from FEMA's Flood Mitigation Assistance (FMA) program [1] to redirect and upgrade the police station's electrical and 911 systems to protect them from future flood damage. In addition, a new generator was purchased, and new pumps were installed so that water levels could be managed more efficiently in future floods.

Peabody's fire station was built in the 1800s, and is one of the oldest headquarters stations in the country. In fact, the station harkens back to the days when fire trucks were pulled by horses. Like the police station, the fire department's systems had been installed in the basement. During the Mother's Day flood, the original pumps were incapable of dealing with the fast rising water.

"We had everything down there," said Joe DaSilva, a signal maintainer and electrician for the fire department. "Our electrical service, our meter, our main breakers, transfer switches and the entire communication system. In the 2006 flood, the water was about six inches away from shorting us out."

Peabody received a grant for $101,250 from FEMA's Hazard Mitigation Grant Program (HMGP) [2] to upgrade their at-risk utilities. Due to the amount of equipment that needed to be elevated, and the limited space available on the fire station's first floor, the fire department decided to use part of the grant to construct a separate, elevated room on the exterior of the station. The rest of the grant was used to purchase a new, larger generator and to transfer the fire department's remaining utilities to the new room.

In March 2010, a series of major rainstorms over a short period caused record-setting floods throughout Massachusetts. Several communities in the eastern and central parts of the state received as much as 12 inches of rain, and major flooding was reported on many rivers and streams.

While Peabody still had to contend with high water and some flooding in March 2010, the situation they faced was much easier to handle thanks to the efforts taken following the 2006 Mother's Day Storm. Neighborhoods and private homes that previously would have been inundated did not flood. In the past, many of these houses would have had as much as six feet of water in their basement, but this year some had less than a foot, and most were not flooded at all.

"The water goes down much more quickly now," said Tighe. "Instead of taking two days, it goes down in one cycle of the ocean. If we hadn't made these drainage improvements, our streets would have been closed for a longer period, possibly as long as 48 hours or more. And there would have been a lot more damage. In addition, the upgrades we made to the police and fire stations' systems allowed us to keep operating with no interruption of service. It gives us real peace of mind."

1. *Flood Mitigation Assistance (FMA) grants provide funds to assist States and communities to implement measures that reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insured under the National Flood Insurance Program.*
2. *The Hazard Mitigation Grant Program (HMGP) allows local governments to apply to their State government for federal grant assistance to implement long-term hazard mitigation measures after a major disaster declaration.*

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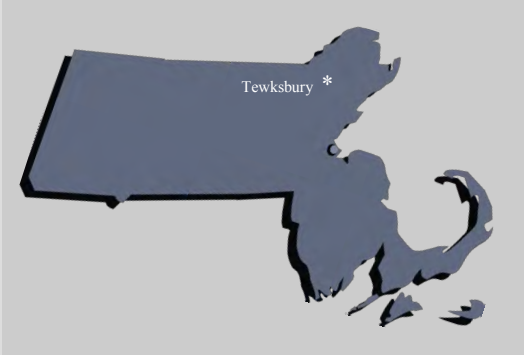
Best practices

Disaster Mitigation Working in Massachusetts

New Culvert Works: No Flooding at East Street



"East Street remained open to traffic throughout the flood. For a while, it was the only direct route into and out of town."
- Brian Gilbert, Superintendent of Public Works, Tewksbury, MA

Photo courtesy of Coughlin Environmental Services

Upstream side of new culverts at East Street during stormwater runoff in March 2010

Flooding and the closure of East Street, just east of the town center in Tewksbury, Massachusetts, has been an annual – and in some years an even more frequent – event.

Yet, when heavy rains in March 2010 brought record-breaking flows to streams across eastern Massachusetts, the floodwaters of Strongwater Brook topped out below the East Street roadway, thanks to recent improvements in the drainage system there.

"The backup of floodwaters at the East Street-Strongwater Brook crossing has long been a problem," said Brian Gilbert, Superintendent of Public Works in Tewksbury. "So it was good to finally get that resolved last summer (2009)."

Over the past several decades, flooding along the Shawsheen River and its tributary, Strongwater Brook, has overtopped stream crossings on major through streets in Tewksbury. Parts of the town were temporarily isolated, requiring the detour of traffic to alternate routes that quickly became congested, which also severely limited access for emergency response vehicles.

In an effort to mitigate the extent and duration of the disruptions caused by flooding of at least one of these streets, town officials proposed to install new, larger culverts at the East Street-Strongwater Brook crossing.

Prior to the reconstruction of the crossing, the brook passed through two old granite culverts, each with an opening of approximately 3 feet by 4 feet. During periods of high flow, the old culverts could not carry all the water, which then backed up and eventually overtopped the roadway.

The two new concrete box culverts, each 5 feet high by 10 feet wide, together provide an opening four times larger than the old culverts. As extra insurance against future flooding across East Street, the existing roadway was raised by three feet, so that it is now higher than the elevation of the 1-percent-annual-chance flood (known as the 100-year flood) at the crossing.

Because this reach of Strongwater Brook lies within a wetland, proposed drainage improvements had to consider wetlands issues. These include the maintenance of natural water levels and velocities, their fluctuations during periods of low flow, and the accommodation of high flood flows.

This dual requirement was resolved by incorporating two features into the design and installation of the new culverts. First, the bottoms of the culverts were set at one foot below the natural channel of the brook and then backfilled to establish a natural channel within the culverts. Secondly, the culverts were sized so that during a flood, water would back up and be temporarily stored in the large wetland area on the upstream side of the roadway. Under such conditions, the water would rise above the tops of the culverts, but not high enough to overtop East Street.

"Completion of the culvert upgrade on East Street last summer made it a lot easier on us during this spring's (2010) floods," said Gilbert. "While Main and Shawsheen Streets were flooded and temporarily closed, East Street remained open to traffic throughout the flood. For a while, it was the only direct route into and out of town."

Photo courtesy of Coughlin Environmental Services

Views to west along East Street at the Strongwater Brook Crossing under non-flood and flood conditions before culvert upgrade

Drainage improvements at East Street and Strongwater Brook were made possible by a grant from the Federal Emergency Management Agency's (FEMA) Hazard Mitigation Grant Program (HMGP). The HMGP provides 75 percent of the total cost of implementing long-term hazard mitigation measures following major disaster declarations.

For the East Street culvert upgrade project, HMGP provided $281,250 of the total cost of $375,000. The $93,750 remainder of the project cost was the responsibility of the Town of Tewksbury.

Evidence of a former railroad crossing that coincides with the present-day East Street crossing of Strongwater Brook can still be seen at the site, lending a sense of history to the project. A small part of the granite block abutment for the rail crossing is exposed on the downstream side of East Street, and pieces of granite from the old culverts and the abutment have been placed for erosion protection on the embankments on both sides of the street adjacent to the new culverts.

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Best practices

Disaster Mitigation Working in Massachusetts

High Marks for Building Higher: Hull's Freeboard Incentive Program

"Our community is in the top three highest number of repetitive-loss properties in the Commonwealth."

Anne Herbst
Hull's Conservation Administrator

Photo by Christopher Smith

Even prior to the introduction of the town's incentive program, many coastal residents of Hull have understood the need to build their homes up higher.

The Town of Hull, MA sits on a three-square-mile strip of land on the Nantasket Peninsula, extending into Massachusetts Bay. Despite its small size, it has one of

the largest population densities in the Commonwealth, averaging 11,000 year-round and swelling to 20,000 or more in the summer seasons. The high density has resulted in near-total development of all available land-space in the town.

Being on the bay, Hull is subject to frequent inundation from storms. Even mild wave action from seasonal storms called "Nor'easters" can cause significant damage to local properties, despite the protection of coastal banks and dunes, or even man-made defenses such as revetments and sea-walls. To date, the largest of these such storms, the Blizzard of 1978, filled the streets of Hull with water reaching depths of several feet, causing major damage to hundreds of buildings and homes throughout the town. Many of those same homes damaged in the Blizzard of '78 sustained considerable damage from a number of storms and floods over the years.

"Our community is in the top three highest number of repetitive-loss properties in the Commonwealth," said Anne Herbst, Hull's Conservation Administrator. "In the 30 years since the '78 Blizzard, we've had 23 coastal storms resulting in three or more flood claims to over 200 residential structures."

Because of restrictions in the Massachusetts building codes, local communities are unable to enforce stricter codes and ordinances than the state requires. This has resulted in towns and cities like Hull having to come up with creative forms of incentives to encourage the adoption of enhanced building techniques, such as the incorporation of freeboard. Put simply,

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freeboard is the practice of elevating a structure's lowest floor, either during or after its construction, to a level higher than predicted flood levels for that area's base flood elevation (BFE). Many communities throughout the United States encourage, or even require, the use of freeboard of at least one foot higher than their local BFE.

In September 2009, with the encouragement of Herbst, based on research she had undertaken, Hull's Board of Selectmen unanimously approved a new program available to new and existing residential structures. For those who elect to incorporate two-feet of freeboard into the construction, they will receive a $500 credit towards their permitting costs.

"Since we couldn't legally require people to build two feet higher, we had to find other alternatives" said Herbst. "So, we were looking into ways to move people in that direction, and this was considered to be a real attention grabber."

For those people who participate in the incentive program, there are a number of benefits beyond the $500 credit to their permit costs. The first, and most obvious, is the peace of mind a homeowner will have knowing their home has a greater safety margin above possible future flood levels. Another financial boon from such a program, is the substantial savings that such a homeowner will see in their flood insurance costs. On average, an increase of two feet of freeboard in a V-zone will potentially result in flood insurance savings of almost 50%. For those structures built in an A-zone that incorporate the two feet of freeboard, the savings can be even greater.

The Town of Hull was recently selected as a recipient of the National Oceanic and Atmospheric Administration's (NOAA) 2010 Walter B. Jones Memorial Award for Excellence in Local Government. The award was presented to Hull in recognition of the town's efforts in coastal hazard management, with specific focus on their freeboard incentive program.

While the program is still new, and has only recently begun to spark interest with Hull's citizens, Herbst is confident that as word spreads, more and more people will consider participating. As residents who choose to elevate their house start seeing the benefits of such actions, their neighbors and friends will take notice.

Photo by Christopher Smith

One of the first homes in Hull to participate in the freeboard incentive program.

"We're starting to get great feedback on this program," said Herbst. "We've received calls from other municipalities around the country interested in establishing their own incentive program. And it's really starting to grab the interest of our residents. They're taking note that in this troubled financial climate, the town is willing to rebate money in order to encourage residents to protect their property and their lives. The rebate may not be large compared to the cost of elevating a home, but it encourages people to take flood risks more seriously than they otherwise would."

V and A Zones: the V-Zone is referred to as the Special Flood Hazard Area (SFHA) with three of more feet of coastal wave action, and that will be inundated by a flood event having a 1-percent chance of being equaled or exceeded in any given year, and is also known as the 100-year flood plain. The A-Zone is an area still within the SFHA, but is considered at lower risk of flooding.

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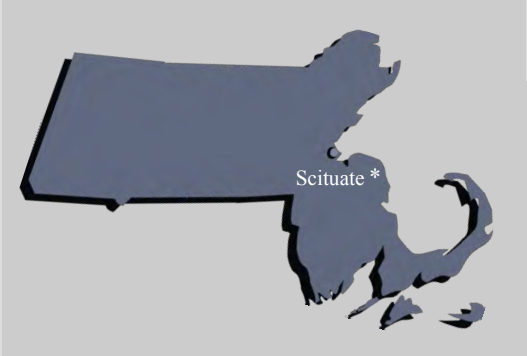
Best practices

Disaster Mitigation Working in Massachusetts

Get 'em Up: Scituate's Grant Committee Gets Homes in the Air



"Instead of being able to do three or four houses with one grant, we would be able to do ten."

Laura Harbottle
Scituate Town Planner

Photo by Christopher Smith

One of the 44 houses in Scituate that has undergone the elevation process.

Sitting on the Massachusetts Bay, the small seacoast town of Scituate, MA has seen its share of storms and floods. Most long-time residents would likely say that the Blizzard of '78 was the worst, when the tremendous waves from a record Nor'easter filled the streets of the town with several feet of water, and over 300 homes were destroyed, and many others severely damaged. Then there was the No-Name Storm of 1991, when an additional 100 local homes were destroyed, again by wave action pouring in from the Bay.

In 1997, town employee Joan Francis began investigating the possibility that federal grant assistance might be available through the Commonwealth of Massachusetts. The Federal Emergency Management Agency (FEMA) offers several grant programs to state and local governments to mitigate homes and buildings in order to prevent future damage. Mitigation actions can take the form of installing safety measures such as hurricane shutters, upgrading culverts to improve water flow, or utilizing building materials such as hurricane clips to strengthen the overall stability of a structure. Another popular form of mitigation, especially in coastal communities, is elevation, or the raising of a building above expected future flood levels.

"Our Board of Selectmen decided to form a committee to research all sorts of grants," said Neil Duggan, Scituate's building commissioner and zoning enforcement officer. "As we started looking into the flood mitigation grants, we realized we needed to concentrate on those, because a lot of townspeople started coming to our meetings, and asking questions about them."

The first grant Scituate was awarded was for $249,004, which allowed the town to elevate 14 homes. The grant came from FEMA's Flood Mitigation Assistance (FMA) program, which provides funds to states and communities to incorporate measures to reduce or eliminate long-term risks of flood damages to structures insured under the National Flood Insurance Program (NFIP). Seeing the success of their first grant application, the Scituate grant committee began applying for additional assistance on an almost yearly basis.

Typically, federal grant assistance provides up to 75% of the cost of a mitigation project, such as a structural elevation, leaving the remaining portion of the costs the responsibility of the individual homeowner or, in some cases, the applying community. Scituate's grant committee sought the means to get more for their money, making

the elevation assistance available to more homeowners by reducing the amount of grant funds awarded per home to 40-50%, instead of the usual higher figure. This allowed them to elevate more homes with the awarded federal money.

"We were looking to spread the wealth, as it were," said Laura Harbottle, Scituate's Town Planner, and the person who took over the grant program in 2006. "We saw lowering the amount each homeowner would get from the grant as a chance to get more homes raised. Instead of being able to do three or four houses with one grant, we would be able to do ten."

Prior to 2006, the town applied for four FMA grants, totaling $725,347. Since taking over management of the program in 2006, Harbottle has continued the aggressive pursuit of additional grant money, applying for another two FMA grants, as well as assistance from FEMA's Hazard Mitigation Grant Program (HMGP), which provides funds to states or communities to perform mitigation actions during the recovery period following a presidentially declared disaster.

In addition to the FMA and HMGP grants, a third form of assistance that Scituate has sought came from FEMA's Severe Repetitive Loss (SRL) grant program. SRL grants provide funding to reduce or eliminate the long-term risk of flood damage to residential structures insured under the NFIP. To qualify for an SRL grant, a structure must have had at least four separate flood insurance claims filed for it that total over $5,000 each, or for which two separate claims have been filed that cumulatively exceed the market value of the structure itself. In both cases, at least two of the claims must have occurred within a 10-year period.

Throughout the years since Scituate's grant committee began their campaign to help their fellow residents protect their homes, the town has received more than $1 million in mitigation grant funds to elevate homes above future flood levels. In total, thanks to the committee's efforts, the eager participation of Scituate's homeowners, and grant money provided by FEMA and the Commonwealth of Massachusetts, 44 homes in the town of Scituate have been successfully elevated.

The committee didn't stop at structural elevations, however. Recognizing that not everyone who was at risk from flooding would be able to afford the full amount of their portion of the elevation costs, the decision was made to add utility elevations to the mix.

"Neil encouraged us to include the utilities," said Harbottle. "We knew there would be people who wouldn't be able to afford a complete elevation, but who would definitely benefit from having their utilities raised. That way, even if they did get water in their home, their furnace, or hot water heater, or their electrical panel box would not be destroyed."

Photo by Christopher Smith

Impressive elevations like this protect coastal residences against flood damage.

The utility elevations were included in the applications for grant assistance, but listed separately from the structural projects. For those that elected to elevate their utilities, the portion of the grant awarded to them was 75% of the cost of the project, up to a maximum of $10,000. The remaining 25% then fell to the homeowner to cover. In addition to the 44 homes that have undergone the full elevation process, eight homeowners in Scituate have used grant money to raise their utilities.

While Scituate has been fortunate in not experiencing significant flooding in recent years, Duggan is convinced that the elevations have been a major reason they have seen less damage. Borrowing a philosophy from the arena of public safety, he believes that it is difficult, if not impossible, to fully quantify that which is prevented.

"From a public safety perspective, this is one of the best approaches for protecting coastal structures," said Duggan. "For every house we get up, that's one less we have to worry about the next time there's a big storm, which will happen. The key to making this work is having dedicated government workers, from the federal side, through the state, and down into the local levels. You need qualified volunteers; your Board of Selectmen, your town administrators. They have to be willing to work those extra hours. We don't do it for the extra pay, because there is none. We do it out of a sense of duty to our fellow citizens."

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Best practices

Disaster Mitigation Working in Massachusetts

Securing the Steele Building

"We didn't have to evacuate in the March 30 storm. It made it all worthwhile."

Ann St Pierre
Executive Director,
Melrose, MA Housing Authority

Photo by Christopher Smith

The Julian Steele Building in Melrose, MA has suffered through at least four major floods since its construction in the 70s.

The Julian Steele Apartments in the City of Melrose, MA is a nine story building consisting of 155 residential units serving as a sustainable community for elderly and disabled individuals. Built in the early 1970s, the Steele Building was constructed prior to the enforcement of today's more stringent building codes, resulting in half of the ground floor being built below-grade and exposed to repeated flood risks. While all of the residential units are above Melrose's Base Flood Elevation (BFE,) the lower portion of the structure, which contains the building's critical facilities, laundry room and maintenance shop, were all left at the mercy of numerous floods throughout the years.

Ann St. Pierre has been the Executive Director for the Melrose Housing Authority since 2005. One year after taking the job, over the days leading up to Mother's Day, 2006, Ms. St. Pierre and her staff watched nervously as a constant downpour caused the water levels in Melrose to steadily rise. Finally, on March 15, she received a phone call that the Melrose Fire Department and Emergency Services were on site at the Steele Building, and proceeding to evacuate the residents.

"By the time I got there, they had already started moving people out," said Ms. St. Pierre. "The maintenance staff had shut off the elevators under orders from the fire department, so they had to carry a lot of the residents down the stairs. We're talking about elderly and disabled people; people in wheelchairs. It was a hazard for everyone involved."

The residents of the Steele Building were bussed away to stay at a hotel for the next five days. During that time, Ms. St. Pierre returned to the building to review the damage. Approximately three feet of water had entered the structure's lowest floor, destroying the building's snow-blowers, as well as some lawn-care and security equipment. In addition, the laundry machines, elevator and boiler had to be taken off-line, dried out and repaired. The water had also come within inches of shorting out the building's backup generator.

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With assistance from employees of the Federal Emergency Management Agency (FEMA), Ms. St. Pierre learned how to fill out the application to recoup some of the losses suffered in the 2006 Mother's Day flood. At the same time, she was also informed that money was possibly available through FEMA's Public Assistance 406 Hazard Mitigation program to perform upgrades to the Steele Building that would reduce or even eliminate future flood damage.

"We had a retired engineer, Michael Casavoy, who was a volunteer on the Melrose Housing Authority Design and Selection committee, write up our mitigation plan," said Ms. St. Pierre. "He was very familiar with floods and flood mitigation. That had been his area of expertise when he was working in the private sector, so he did the whole design for us."

Mr. Casavoy knew that because the lowest part of the building was below grade, there would always be some risk of flooding during periods of high water. The design for the mitigation called for measures to not only keep water out of the threatened areas, but to also quickly deal with any water that did happen to get into the building. To this end, Mr. Casavoy recommended the installation of flood dams at several key points throughout the structure, including doorways, windows and garage doors. In addition, they treated the exterior of the building up to three feet in height with water-proofing paint, and sealed and water-proofed the interior floors and walls. An 18 inch barrier, or moat, was also installed around the backup generator to keep water from shorting out the building's power supply.

To deal with water that did enter the building, Mr. Casavoy recommended the installation of two new ejection pumps, one of which was positioned in the bottom of the elevator shaft, to swiftly lower water levels, pumping the water out into the drains at street level. Backflow preventers were also installed in the building's drains on the lowest level, ensuring that sewage backups could not occur.

On March 15, 2010, following several days of constant rain, Melrose flooded again. Unfortunately, not all of the mitigation measures had been completed in time, and some water was able to enter the building. Luckily, enough of the protections on Mr. Casavoy's list were in place, and Ms. St. Pierre feels confident that the damage was significantly reduced because of it. By the time Melrose flooded again on March 30 (to the highest levels recorded to date), all of Casavoy's suggested mitigation measures were completed, and the Steele Building suffered no water damage whatsoever.

"We didn't have to evacuate during the March 30 storm," concluded Ms. St. Pierre. "It made it all worthwhile. We may still bring everyone down to the first floor as a precaution, but now we don't have to shut off the electricity, or the elevators, because this mitigation is working. These measures were never intended to fully solve the problem of the Julian Steele Building from ever flooding again. They were intended to give the Melrose Fire Department and the Housing Authority the time to evacuate the building safely if necessary, and that's well worth it."

Photo by Melrose Housing Authority

These three foot high door dams must be installed manually prior to flood events, and prevent water from entering through doorways, windows and garage doors.

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DRAFT

Reducing Future Flood Damage in Massachusetts:

Mitigation measures to make your home safer and stronger after a flood

There are three major causes of flooding in Massachusetts, each affecting different areas of the state. In the 1990s, coastal storms and hurricanes were seen as the most common source of floods, while more recently flooding has been attributed to intense rainfall causing many of the rivers and streams to overflow. The final piece of the puzzle stems from storm water and local drainage issues, which can swiftly and unexpectedly present serious problems for affected communities.

Regardless of the cause of a flood or the resulting damage, you can take steps to reduce your risk of damages and loss of life from future floods. Taken together, these steps are called *hazard mitigation*, which is defined as actions taken to reduce or eliminate long-term risk to people and property from natural hazards and their effects.

Following a flood, you will have many decisions to make about rebuilding or making repairs to your flood-damaged property. These decisions will affect you, your family, and your community.

A great deal of information is available for you to consider, including suggestions on changes you can make to a building and property to increase your protection against future events. Ideally, mitigation steps are taken before a disaster happens. However, the availability of post-disaster financial assistance is often what makes it possible to take those steps.

This fact sheet briefly outlines some flood mitigation options and resources that may be available to you, your business, and your community through information and funding support from the Federal Emergency Management Agency (FEMA).

No matter what decisions you make, don't forget to coordinate with your local officials to ensure you obtain all necessary permits and approvals for any work you intend to do on your house, commercial building or property.

This publication was produced by FEMA Region I Mitigation Division in cooperation with the Commonwealth of Massachusetts as part of Disaster 1895

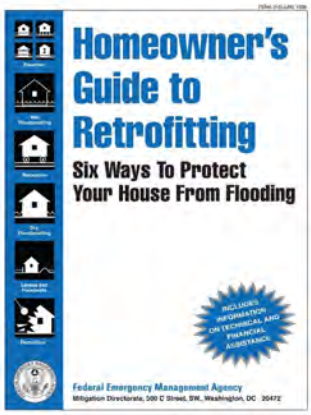
Making your home safe from floods: Five ways to RETROFIT

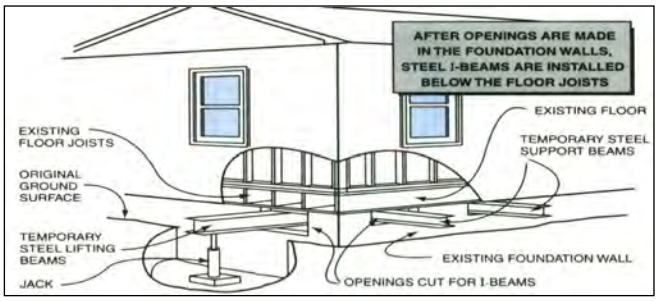
What is Retrofitting?

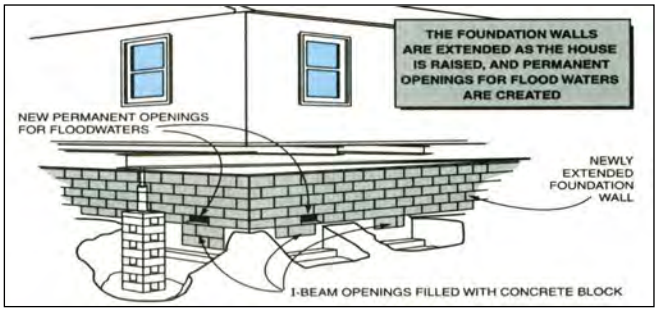
RETROFITTING means making changes to an existing building to protect it from flooding or other hazards such as high winds and earthquakes.

FEMA PUBLICATION 312

Home Owner's Guide to Retrofitting: Six Ways to Protect Your House From Flooding, provides information that will help you decide whether your house is a candidate for retrofitting.







Basic Steps in Elevating a Building:	
1	Have appropriate professionals disconnect all utilities.
2	Hire a professional house mover to disconnect your house from the existing foundation, jack it up to the new height and provide a temporary foundation.
3	Build a temporary access stair to meet the new height.
4	Build a new, permanent foundation.
5	Have the house mover lower the house onto the new foundation and connect the anchor bolts.
6	Have the utilities permanently reconnected.

Elevation: Raising your house so that the floor of the lowest living space is above the Base Flood Elevation, which is determined in studies conducted by FEMA.

Relocation: Moving your house to a new, safer location.

Dry Floodproofing: Sealing your house to prevent floodwaters from entering.

Demolition: Razing your house and rebuilding on the same property or buying a house elsewhere.

Wet Floodproofing: Using vents or breakaway walls to reduce structural damage by allowing floodwaters to flow through uninhabited parts of a building.

The ultimate retrofit? Move your home away from a flood-prone area.

NFIP Explained

What is the National Flood Insurance Program?

The National Flood Insurance Program (NFIP) is a federal program enabling property owners to purchase flood insurance. If your community adopts and enforces floodplain management regulations that meet minimum federal requirements, the federal government makes flood insurance and flood disaster assistance available in your community.

BILLERICA, MA -- A resident wades through a flooded area on Elsie Avenue.

If you live in an area that has been designated as "high risk" for flooding, your home has a 26 percent chance of being damaged by a flood over the life of a 30-year mortgage.

Why you need Flood Insurance

The Risk is Real

You can live miles away from water and still be the victim of flooding. Nearly 1 in 4 flood insurance claims is paid on policies in low-to-moderate-risk areas. It doesn't take a major body of water, or even a major storm, to cause a flood. Anything from a broken sewer line to a slow-moving rainstorm can cause flooding. In high-risk areas, your home has a 26% chance of being damaged by a flood over the life of a 30-year mortgage.

Flood Insurance is Affordable

A large number of private insurance companies nationwide offer affordable flood insurance backed by the federal government. Policies are available to home, condo, apartment and business owners, as well as renters.

If you live in a low-to-moderate-risk area, affordable coverage may be available to insure your home and its contents against flooding, which causes more than $2 billion damage in the U.S. every year.

How Do I Purchase Flood Insurance?

Flood insurance is available in more than 20,000 communities nationwide. Only a small number of municipalities in Massachusetts have not joined the National Flood Insurance Program (NFIP). To find out if your community participates in the program call **800-427-4661.**

If your community is a participant, you can purchase flood insurance for your property from any insurance agent. If your agent is not familiar with the program, you can call 800-720-1093 to find an agent in your area who is.

The Challenge with Mold and Mildew

A problem that often arises after a home is flooded is the development of mold and mildew. These microscopic organisms can begin to grow on virtually any damp surface within 24 to 48 hours. They can damage and eventually destroy the material they grow on, and can also cause mild to severe respiratory, nervous system, and other health problems.

If your home has been inundated by a flood, or if wet or damp conditions have resulted from sewage backup, plumbing or roofing leaks, or overflows from sinks, showers, or bathtubs, mold and mildew will begin and continue to grow until you eliminate the source of the moisture, dry out the area, and deal with the mold and mildew problem.

A FEMA booklet, "Dealing with Mold and Mildew in Your Flood Damaged Home," will help you determine the severity of your mold problem and provide steps you can take to eliminate the problem. This booklet is available in a printable document online.

You can download your own PDF copy of **FEMA Publication 606** from http://www.fema.gov
Enter "mold and mildew" to go to the correct site.

Federal Mitigation and Recovery Assistance May Be Available

FEMA

For States and Local Governments:

Funding is available from FEMA through one or more Hazard Mitigation Assistance (HMA) programs. These funds enable states and communities to implement mitigation measures before, during, and after recovery from a disaster.

Hazard Mitigation Grant Program (HMGP) – Assists implementation of long-term hazard mitigation measures following major disaster declarations.

Pre-Disaster Mitigation (PDM) – Provides funds on an annual basis for hazard mitigation planning and implementation of hazard mitigation projects.

Flood Mitigation Assistance (FMA) – Provides funds on an annual basis for measures that can reduce or eliminate risk of flood damage to buildings insured under the National Flood Insurance Program (NFIP).

Severe Repetitive Loss (SRL) – Provides funds on an annual basis to reduce the risk of flood damage to residential structures insured under the NFIP that are qualified as severe repetitive loss structures.

To get information online, go to
http://www.fema.gov/government/grant/hma/index.shtm

For more information on the specific criteria for each HMA program, contact your local community official, State Hazard Mitigation Officer, or the FEMA staff at a Disaster Recovery Center.

FEMA

For individuals and households:

When disaster strikes, FEMA's **Individuals and Households Program (IHP)** provides money and services to people in the disaster area when their property has been damaged or destroyed and the losses are not covered by insurance. While some money is available through IHP, most disaster aid from the Federal government is in the form of loans from the Small Business Administration, and must be repaid. IHP provides the following types of assistance:

Temporary Housing – A place to live for a limited time. Money is available to rent an alternate place to live. Government provided housing may also be made available when local rental properties are not available.

Repair – Money is available to repair damage that is not covered by insurance. The goal is to make the home safe, sanitary, and functional.

Replacement – Money is available to homeowners to replace a home destroyed in a disaster but not covered by insurance.

Permanent Housing Construction – Direct assistance or money for the construction of a home. This type of help is available only in insular areas or remote locations, specified by FEMA, where no other type of housing is available.

Other Needs – Money is available for expenses incurred because of the disaster, such as medical, dental, replacement of personal property, transportation, moving and storage, and other expenses that are authorized by law.

For additional information call **800-621-FEMA (3362),**
TTY 800-462-7585 for people with speech or hearing disabilities from 7 a.m. to 10 p.m. Multilingual assistance is available. For information online, go to
http://www/fema/gov/media/fact_sheets/individual-assistance.shtm

SBA

The U.S. Small Business Administration (SBA) provides low-interest disaster loans to homeowners, renters, businesses of all sizes, and certain private, non-profit organizations to repair or replace real estate, personal property, machinery and equipment, inventory and business assets that have been damaged or destroyed in a declared disaster. Businesses also may apply for loans for loss of income as a result of the disaster.

If your loan application is approved, you may be eligible for additional funds to cover the cost of improvements that will protect your property against future damage. Examples of improvements include: structural elevation, storm shutters, flood-proofing of a basement, or reinforcing garage doors. Mitigation loan money would be in addition to the amount of the approved loan, but may not exceed 20 percent of the total amount of disaster damage to real estate and/or leasehold improvements as verified by SBA to a maximum of $200,000 for home loans.

For additional information, contact the SBA Help Line at **1-800-659-2955** or SBA staff at the nearest Disaster Recovery Center. To get information online, go to http://www.sba.gov/services/disasterassistance

DAWG HAUS

Disaster Avoidance With Good Home Attenuating Unionization System.

As a part of the recovery process from the March 2010 Flood several Massachusetts home building stores such as Home Depot and Lowe's coordinated with the Federal Emergency Management Agency (FEMA) Hazard Mitigation Group to focus attention on smart building techniques.

FEMA assisted staff at the stores in the construction of this "dawg haus" model. The concept of this model is to provide a user-friendly, and visual, example of everyday mitigation construction techniques and materials.

The models are constructed to demonstrate strong and safe building practices. Key to the design is the incorporation of a strap-and-connector system that ensures proper load path construction in a structure. While the construction resembles a traditional dog house, the unusual spelling is actually an acronym for Disaster Avoidance With Good Home Attenuating Unionization System.

"Think of a house like a box," said Cris Nery, a FEMA Hazard Mitigation Engineer. "When you push on one side of a box, all the pressure is transferred to the other side. If any part of the box fails, the whole thing collapses. But if the box is properly secured on all sides, then pressure from one side will not allow the box to move. It's really pretty simple, but it can make all the difference in the world."

Construction of this "dawg haus" took about one week and was donated by the H**ome Depot.**

EXAMPLE PAST BEST-MANAGEMENT PROJECTS

BANK STABILIZATION PROJECT

The Town of Becket, faced with a roadway in jeopardy of erosion, developed a plan to permanently stabilize this roadway through an environmentally sensitive bank stabilization structure. Brooker Hill Road was collapsing into adjoining Shaker Mill Brook and was in serious danger of additional failure. One lane of the road had collapsed, causing the road to be reduced to one lane, one-way. This put a hardship on residents, emergency response vehicles, and traffic to the elementary school. Tourism also had been hurt by the restrictions on this road, which connects one side of town to the other, putting a strain on the economic development and growth of North Becket Village. Becket applied for and received a grant from FEMA to help fund the project costs, which totaled $259,383. FEMA provided a grant for $186,348 through the Pre-Disaster Mitigation Competitive (PDM-C) Grant Program. The success of the project was dependent on the intergovernmental coordination and cooperation among the various town departments, MEMA, DCR, the National Park Service and FEMA. The project site involved a sensitive design because Shaker Hill Brook, a tributary of the Westfield River, is a Nationally Designated Wild and Scenic River. The National Wild and Scenic Rivers System was created by Congress in 1968 to preserve certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations. The project, completed in September 2008, provides permanent stabilization to the affected portion of Brooker Hill Road through the placement of a slope retention system made of an interlocking retention wall. Not only does this system provide a sound technique for solving road erosion, it also allows for native vegetation to grow which adds to the stability of the slope and its natural characteristics. Most significantly, the project has allowed the roadway to re-open as a two-lane, two-way road, which greatly enhances the safety of residents, and the elementary school children, and restore adequate emergency response time to at least pre-disaster conditions. It will also allow for continued tourism in the area, which will help in the economic growth of the town.

TOWN OF DRACUT COMPLETES A SEWER LIFT STATION PROJECT

The Town of Dracut, concerned over the ongoing potential for flooding of the sewer lift station at 150 Turtle Hill Road, developed a solution that would enable the town to mitigate a potential public health risk. During normal operations, sewage is pumped up from the neighborhood to the station. If the lift station were to be flooded, operations would cease. Houses in this neighborhood would become threatened by a risk of sewage back-up which ultimately could lead to a significant public health issue if the lift station was inoperable for an extended period of time. Dracut applied for and received a grant through the HMGP to offset the majority of the project costs required to fund this risk mitigation project. The total cost of the project was $48,000. This sewer lift station currently services 311 residences. At full build-out, it would service 415 residences. The lift station was originally built to a half-foot above the base flood elevation of 121 feet. The lift station was still threatened by flooding from nearby Beaver Brook, because the flood hazard appears to have increased since the original Flood Insurance Study was published; therefore the station required additional protection. If this pump were to sustain flooding in excess of the base flood elevation, the pump and related electrical components could fail. That failure could cause sewage to back up into homes, causing a significant risk to public health. The project consisted of building a 12-inch thick concrete wall surrounding the station. The wall is centered on one-foot thick, two-foot wide footings. The wall is 10 feet total in height, with 6’6” below grade, and 3’6” above grade, to prevent floodwaters from damaging the electrical components. The floodwall is providing an additional 3 feet of protection above the existing base flood elevation. There is a 4-foot wide service opening to allow access to the station. The opening will be closed with stop logs, already stored at the site, when the lift station is at risk of flooding. The project was completed in November of 2008. This

neighborhood was vulnerable to the potential impact of a failed sewer lift station before this wall was installed. Now there is an increased level of protection to this pump station and related electrical components as well as the homes serviced by this sewage pump.

HARWICH COMMUNITY CENTER SHUTTER PROJECT

In times of emergency the Harwich Community Center, located at 100 Oak Street, serves as a Red Cross Shelter. Additionally, it houses Channel 18, the local access cable network. In order to ensure that the shelter workers and residents are as safe as possible during an emergency, the town of Harwich decided to invest in hurricane panels that could be installed to protect the building and its occupants. Harwich applied for and received a grant through FEMA's Hazard Mitigation Grant Program. The total project cost was $53,900. The project consists of the installation of corrugated polycarbonate resin hurricane shutter panels. By protecting the windows from high velocity wind damage and flying debris, it enhances the integrity of the building, and insures the safety of the local residents and workers utilizing it as a shelter. These shutters protect not only the windows and doors they cover, but also the people and equipment inside the building. Once a window or door has been breached by hurricane winds tremendous pressure is brought to bear on interior walls and upward pressure on the building's roof. This can lead to roof failure, which exposes the entire contents of the building to the storm. Shutters are a first line of defense against a hurricane. Studies show that engineered storm shutters are more effective and safer to use than plywood panels. The shutter panels are "see-through," therefore everyone can remain safely inside and still monitor the situation outside. Having hurricane panels at the Harwich Community Shelter provides a safe place for residents and workers to ride out the storm.

INSTALLATION OF BACK FLOW PREVENTERS

Town of Framingham was faced with recurring flooding on Auburn Street and the Auburn Street Extension causing repetitive damage to the town and private properties as a result of the Sudbury River backing up at these locations into the town's storm water drainage system. In order to mitigate this problem, the town decided to install two backflow preventers, a component of which is a "duckbill" style check valve. This valve allows liquids to flow in a single direction. These valves are used in situations where the direction of liquid flow must not be allowed to reverse itself. At the first installation, located at 18 Auburn Street, a 24" duckbill style backflow preventer was installed over and around a 24" reinforced concrete outfall pipe. The installation required the assistance of an excavator as the preventer weighed 220 pounds. At the second location, 18 Auburn Street Extension, a 12" duckbill style backflow preventer was installed around a 12" reinforced concrete outfall pipe. The preventer weighed 50 pounds and was installed by hand. However, due to continued high water conditions, the contractor first installed a cofferdam to remove water from the immediate site of installation. A cofferdam is an enclosure within a water environment constructed to allow water to be removed for the purpose of creating a dry work environment. The total cost of the project was $16, 387. Framingham was successful in receiving a Flood Mitigation Assistance grant from FEMA for $12, 290. The mitigation grant award included final design, permitting, and construction.

APPENDIX D.
STATE AGENCY SURVEY

State Hazard Mitigation Interagency Committee

Massachusetts has had an active State Hazard Mitigation Interagency Committee (SHMIC) since its creation in 1991, following two Presidential Disaster Declarations, Hurricane Bob in August and the Halloween Storm in October of that year. This committee, which consists of state, federal, and private sector organizations, is responsible for contributing to the development of the State Hazard Mitigation Plan as well as reviewing and endorsing project applications proposed by applicants for grant funding. Mitigation activities in Massachusetts are administered by an executive team called the State Hazard Mitigation Team (SHMT) comprised of staff from Department of Conservation and Recreation and Massachusetts Emergency Management Agency. The SHMT is always seeking expansion of the Interagency Committee to improve the coordination of the mitigation activities in the Commonwealth.

Current active members of the State Mitigation Interagency Committee include representatives from the State Hazard Mitigation Team and representatives from the following government agencies and private organizations:

STATE AGENCIES
Executive Office of Energy and Environmental Affairs
Department of Conservation and Recreation
Department of Environmental Protection
Office of Coastal Zone Management
Department of Fish and Game
Massachusetts Emergency Management Agency
Department of Public Safety
Division of Capital Asset Management
Massachusetts Historical Commission
Board of Building Regulation & Standards
Massachusetts Board of Library Commissioners

FEDERAL AGENCIES
US Geologic Survey
US Army Corp of Engineers, New England District
Federal Emergency Management Agency
National Weather Service
US Coast Guard

OTHER AGENCIES
Massachusetts Association of Regional Planning Agencies
Weston Observatory at Boston College
American Red Cross
Franklin Regional Council of Governments
Salvation Army
Northeast States Emergency Consortium
University of Massachusetts

COMMITTEE RESPONSIBILITIES

- Provide assistance and input in the review and update the State Hazard Mitigation Plan as required by the Disaster Mitigation Act of 2000 and 44 CFR, Subpart M. These activities include:
    - Assist in the development of a State Risk Assessment
    - Review, update, and prioritize recommendations in the State Hazard Mitigation Plan.
    - Develop a comprehensive strategy for the development and implementation of the State's mitigation program.
- Establish internal/agency policies and support the statewide mitigation goals in the State Hazard Mitigation Plan.
- Review recommended project applications for the Unified Hazard Mitigation Assistance Programs.
- Identify additional federal, state and local funding sources for mitigation projects.
- Act as "subject matter experts" for ongoing hazard mitigation projects from initiation to close-out.
- Meet a minimum of once a year during non-disaster years and more frequently if needed

Hazard Mitigation State Agency Survey

Agency Name:_____ Department/Bureau:_____

Describe Primary Responsibility: _____

Point of Contact Name: _____ Title: _____

Phone: _____ Email: _____

Please indicate whether you are completing this survey for your entire agency or your particular Department/Bureau as noted above.

- ☐ Agency
- ☐ Department/Bureau
- ☐ Other _____

---

1. Is your agency/department a current Planning Partner to the State's Hazard Mitigation Plan?
   - ☐ Yes
   - ☐ No
   - ☐ Unknown

2. Is your agency/department currently a member of the *State Hazard Mitigation Interagency Committee* participating in the development of the Hazard Mitigation Plan?
   - ☐ Yes
   - ☐ No
   - ☐ Unknown

3. If no, are there roadblocks preventing your agency from participating?
   - ☐ Yes
   - ☐ No

   If yes, please describe _____

4. Would your agency/department like to become a member of the *State Hazard Mitigation Interagency Committee*?
   - ☐ Yes
   - ☐ No

   Other Comments:_____
   _____

5. What are your agency/department's primary concerns regarding natural hazards?
   - ☐ Vulnerability of specific facilities
   - ☐ Response Capabilities
   - ☐ Likelihood of specific hazard events
   - ☐ Ability to assist clients/stakeholders
   - ☐ Loss of Workforce Productivity
   - ☐ Other _____

6. Does your agency/department own, operate, or manage facilities? *[A facility can be defined as a building, infrastructure (road, bridge, pump station), park, engineered beach, etc.]*
   - ☐ Yes
   - ☐ No

7. Are the facilities your agency/department owns susceptible to impacts from natural hazards?
   - ☐ Yes
   - ☐ No

8. What actions within your agency/department have been initiated to reduce the general impact from disaster events and to enhance recovery efforts for the Commonwealth?
   - ☐ Agency Emergency Operations Plan
   - ☐ Participation as an Emergency Support Function at State EOC
   - ☐ Continuity of Operations Plan
   - ☐ Back-up of critical data
   - ☐ Education of staff concerning individual safety
   - ☐ Activities safety within the work place, e.g., skid mats to reduce sliding of computers during earthquakes; affixing large items to wall, etc.;
   - ☐ Other planning initiatives: (list)_____
   - ☐ Programmatic policies (list): _____

9. Has your agency/department taken actions to reduce its physical risk to natural hazards? If so, indicate which initiatives below:
   - ☐ Relocation of a structure or facility
   - ☐ Structural retrofit of facilities
   - ☐ Educational outreach regarding hazards of concern
   - ☐ Incentives to customers/clients which support mitigation
   - ☐ Other _____

10. Please select all of the mitigation activities for which your agency/department interacts with MEMA or any other state agency which supports mitigation:
    - ☐ Education
    - ☐ Planning
    - ☐ Mapping/GIS (i.e. LiDAR)
    - ☐ Historical Disaster Data (i.e. financial or structural losses)
    - ☐ Grants
    - ☐ Technical advice
    - ☐ Training
    - ☐ Structural Projects

11. Does your agency/department have any responsibility at the local level (i.e enforcement of any policies/regulatory authority, programs, funding opportunities, etc.).
    - ☐ Yes
    - ☐ No

12. Is your agency/department currently involved in conducting any studies or developing any plans and/or programs which would further support the State's hazard mitigation program? *Studies*

can include hazard specific information, data gathering which supports risk assessments, including economic data, or statistical data of other types.

- ☐ Yes
- ☐ No

If yes, please briefly describe the type of study, plan and/or program underway, and list the anticipated year of completion:

_____
_____
_____

13. Does your agency agency/department possess any subject matter expertise with respect to the hazards of concern within the Commonwealth?
    - ☐ Yes
    - ☐ No

14. Please use this space to provide any additional comments.
    _____

Q1: **Using the text box below enter your contact information as follows: Agency Name Department/Bureau Your Name/Title Your primary responsibility Email Phone Number Also please indicate whether you are completing this survey for your entire agency or your particular Department/Bureau as noted above.**

Department of Public Safety
MA Office of Coastal Zone Management
Division of Fisheries and Wildlife
DCR/ OWR - WRC Staff to MA Water Resource Commission
Mass. Dept. of Environmental Protection Bureau of Resource Protection/Wetlands Program
Department of Conservation and Recreation Flood Hazard Management Program
Division of Fisheries & Wildlife Department of Fish & Game
Massachusetts Geological Survey
Massachusetts Board of Library Commissioners

2. Is your agency/department currently a member of the State Hazard Mitigation Interagency Committee participating in the development of the Hazard Mitigation Plan? Create Chart Download

	Response Percent	Response Count
Current member	**88.9%**	**8**
Not a current member	11.1%	1
Unknown	0.0%	0
Would your agency/department like to become a member of the State Hazard Mitigation Interagency Committee?	0.0%	0
If no, are there roadblocks preventing your agency from participating?	0.0%	0
	answered question	**9**
	skipped question	**0**

3. What are your agency/department's primary concerns regarding natural hazards?

Create Chart Download

	Response Percent	Response Count
Vulnerability of specific facilities	33.3%	3
Response Capabilities	11.1%	1
Likelihood of specific hazard events	44.4%	4
Ability to assist clients/stakeholders	44.4%	4
Loss of Workforce Productivity	11.1%	1
Other (please specify) Show Responses	55.6%	5
	answered question	9
	skipped question	0

Other responses:

- Amount of development in high hazard areas.
- Want to create an atmosphere of cooperation where our regulatory responsibility for the natural resources of the Commonwealth interacts with the need to make repairs to infrastructure after natural disasters. We are in a position to help municipalities plan for mutually beneficial outcomes for fish and wildlife resources and built infrastructure.
- Public safety floods, droughts, geologic seismic events
- Meeting regulatory requirements to repair damage to structures caused by natural hazards (primarily flood damage)
- Hazard identification

4. Does your agency/department own, operate, or manage facilities? [A facility can be defined as a building, infrastructure (road, bridge, pump station), park, engineered beach, etc.] Create Chart Download

	Response Percent	Response Count
Yes	33.3%	3
No	**66.7%**	**6**
If yes, Are the facilities your agency/department owns susceptible to impacts from natural hazards?(please specify) Show Responses		3
	answered question	**9**
	skipped question	**0**

Question 4 - If yes responses:

- MassDEP owns only one facility, the Wall Experiment Station in Lawrence. A portion of the parking lot for this facility is located in the floodplain of the Merrimack River in Lawrence, within a FEMA Zone AE. Other facilities utilized by MassDEP are leased. The leased facilities are not located within areas identified as having natural hazards.
- My agency (DCR) does, and some are clearly susceptible to hazards. I am answering this and subsequent questions for the FHMP rather than for DCR as a whole. FHMP has no facilities.
- Yes, some more than others. Facilities such as our Sandwich Fish Hatchery are more susceptible to environmental impacts and natural hazards being on the coast. .

5. What actions within your agency/department have been initiated to reduce the general impact from disaster events and to enhance recovery efforts for the Commonwealth?

Create Chart Download

	Response Percent	Response Count
Agency Emergency Operations Plan	50.0%	4
Participation as an Emergency Support Function at State EOC	**62.5%**	**5**
Continuity of Operations Plan	50.0%	4
Back-up of critical data	25.0%	2
Education of staff concerning individual safety	50.0%	4
Activities safety within the work place, e.g., skid mats to reduce sliding of computers during earthquakes; affixing large items to wall, etc.;	0.0%	0
Other (please specify) Show Responses	37.5%	3
	answered question	**8**
	skipped question	**1**

Question 5 – Other: the results above shows 3 “other” responses but 1 was left blank…)

- Adoption of emergency regulations to provide for speedy debris cleanup located in wetland resource areas and repair of structures damaged during flooding, provided the structural damage is less than 50% of the structure monetary value. Provision of SRF funds for public wastewater and drinking water facilities located in floodprone areas to reduce possibility of flooding impacting operations.
- We will soon be part of a University of Massachusetts Amherst Hazard Mitigation Plan

6. Has your agency/department taken actions to reduce its physical risk to natural hazards? If so, indicate which initiatives below:

Create Chart Download

	Response Percent	Response Count
Location of a structure or facility	14.3%	1
Structural retrofit of facilities	14.3%	1
Educational outreach regarding hazards of concern	**42.9%**	**3**
Incentives to customers/clients which support mitigation	14.3%	1
Other (please specify) Show Responses	**42.9%**	**3**
	answered question	**7**
	skipped question	**2**

Question 6 – Other: (the results above shows 3 “other” responses but 2 were left blank…)

- Umass Amherst Hazard Mitigation Plan

7. Please select all of the mitigation activities for which your agency/department interacts with MEMA or any other state agency which supports mitigation:

Create Chart Download

	Response Percent	Response Count
Education	55.6%	5
Planning	66.7%	6
Mapping/GIS (i.e. LiDAR)	55.6%	5
Historical Disaster Data (i.e. financial or structural losses)	33.3%	3
Grants	**77.8%**	**7**
Technical advice	55.6%	5
Training	44.4%	4
Structural Projects	22.2%	2
Other (please specify) Show Responses	22.2%	2
	answered question	**9**
	skipped question	**0**

Question 7 – Other: the results above shows 2 “other” responses but both were left blank…

8. Does your agency/department have any responsibility at the local level (i.e enforcement of any policies/regulatory authority, programs, funding opportunities, etc.).

Create Chart Download

	Response Percent	Response Count
Yes	**77.8%**	**7**
No	22.2%	2
	If yes (please specify) Show Responses	6
	answered question	**9**
	skipped question	**0**

Question 8 – If yes responses:

- Assist municipal building inspectors with post-event damages assessments.
- CZM's Program Policies are implemented through other State Regulations, some of which are implemented first at the local level (e.g Wetlands Protection Act Regualtions).
- The Massachusetts Wetlands Protection Act is jointly enforced by the MassDEP and local municipal boards known as Conservation Commisisons. This Act requires submission of an application for work conducted in floodplains. The Wetland regulations require compensatory flood storage for work within inland floodplains.
- Hazard mitigation grants Also floodplain technical assistance to communities
- Our Natural Heritage & Endangered Species Program reviews and oversees the protection of critical habitat for rare and endangered species. Their responsibilities include the review of construction permitting with the local Conservation Commissions to protect and buffer critical habitat in areas of new development.
- We provide funding though state line items as well as through LSTA grant opportunities. In addition we run the Public Library Construction Program through whose regulations building modifications can be enforced.

9. Is your agency/department currently involved in conducting any studies or developing any plans and/or programs which would further support the State's hazard mitigation program? Studies can include hazard specific information, data gathering which supports risk assessments, including economic data, or statistical data of other types.

Create Chart Download

	Response Percent	Response Count
Yes	**77.8%**	**7**
No	22.2%	2
If yes, please briefly describe the type of study, plan and/or program underway, and list the anticipated year of completion Show Responses		7
	answered question	**9**
	skipped question	**0**

Question 9 – If yes responses:

- Update to the Massachusetts Shoreline Change 1) Project, which adds several new shorelines and updates the shoreline change rates. See: http://www.mass.gov/czm/hazards/shoreline_change/shorelinechangeproject.htm 2) We are completing an inventory of all privately owned shore protection structures. This, combined with the inventory of state owned structures can be used to help inform hazard mitigation discussions. 3) Developing a series of fact sheets for coastal property owners on options for reducing eroison and storm damage on coastal properties. 4) CZM is developing a StormSmart Properties website. This will be part of StormSmart Coasts, with

infromation targeting coastal property owners. The fact sheet series mentioned above will be part of this. 5) Buzzards Bay Project is developing reports with maps for each community in their area entitled: Projected Expansion of the Floodplain with Sea Level Rise. 6) CZM is working with NOAA to create a sea level inundation viewer for Massachusetts.

- Climate Change Vulnerability Assessments of key Wildlife Habitats at the State and Regional Level as well as Climate Change Adaptation Planning.
- Updated MA Drought Management Plan scheduled to be voted for approval at April 11, 2013 Water Resources Commission Meeting
- Pilot project is being planned to look at culvert sizing.
- State hazard mitigation plan update; helping with hazard profiles.
- Landslide susceptibility Fluvial erosion hazard mapping Shear wave analysis for estimating ground motion in HAZUS
- The MBLC is currently the fiscal agent for COSTEP MA's HMGP grant to address risk assessment and mitigation planning as well as community building between the cultural resource and emergency management communities.
-

10. Does your agency agency/department possess any subject matter expertise with respect to the hazards within the Commonwealth? Create Chart Download

	Response Percent	Response Count
Yes	88.9%	8
No	11.1%	1
Please use this space to provide any additional comments on this or other sections of this survey. Show Responses		7
	answered question	9
	skipped question	0

Question 10 – additional responses:

- Yes. All Department building inspectors have been educated in the use of Applied Technology Council's (ATC) programs to assess building damage due to either natural or man-made disasters.
- We have two staff with extensive backgrounds in coastal hazards.
- Yes Impacts to fish and wildlife resources from projected changes to climate
- Conducting damage assessments to structures and resources after flooding in cooperation with the Massachusetts Office of Coastal Zone Management. Characterizing annual exceedence probabilities of extreme flooding events.
- Flooding and floodplain management
- Natural hazards (erosion, mass wasting, rockfall, landslides). For seismic risk refer to Weston Observatory
- This deals specifically with library, archives, and museum collections and the buildings that house them.

APPENDIX E.
LOCAL PLAN SURVEY

Local Jurisdiction Data Capture

Jurisdiction: _____ Point of Contact Name and Title: _____

Phone: _____ Email: _____

1. **Planning and Regulatory Capability:** Please indicate whether the following planning or regulatory tools and programs are currently in place or under development for your jurisdiction by placing an "X" in the appropriate box, followed by the date of adoption/update. Then, for each particular item in place, identify the department or agency responsible for its implementation and indicate its estimated or anticipated effect on hazard loss reduction (Supports, Neutral or Hinders) with the appropriate symbol and also indicate if there has been a change in the ability of the tool/program to result in loss reduction. Finally, please provide additional comments or explanations in the space provided.

Tool / Program	Status			Dept./Agency Responsible	Effect on Loss Reduction: + Support O Neutral - Hinder	Change Since Last Plan: + Positive - Negative	Comments
	In Place	Date Adopted or Updated	Under Develop-ment				
EXAMPLE: Hazard Mitigation Plan	X	1/1/2010		Hazard County EMA	+	+	Interim update in 2008 revised mitigation strategy; completed one action.
Hazard Mitigation Plan							
Emergency Operations Plan							
Disaster Recovery Plan							
Evacuation Plan							
Continuity of Operations Plan							
Shelter Plan							
Access and Functional Needs Plan							
NFIP Participant							
NFIP – Community Rating System							
Floodplain Regulations (spec. NFIP							

Tool / Program	Status			Dept./Agency Responsible	Effect on Loss Reduction: + Support O Neutral - Hinder	Change Since Last Plan: + Positive - Negative	Comments
	In Place	Date Adopted or Updated	Under Develop-ment				
Flood Damage Prevention Ordinance)							
Floodplain Management Plan							
Zoning Regulations							
Subdivision Regulations							
Comprehensive Land Use Plan (or General, Master or Growth Mgt.)							
Open Space Management Plan (or Parks/Rec or Greenways Plan)							
Stormwater Management Plan / Ordinance							
Natural Resource Protection Plan							
Capital Improvement Plan							
Economic Development Plan							
Historic Preservation Plan							
Farmland Preservation							
Building Code							
Fire Code							
Firewise							
Storm Ready							
Other							

2. **Administrative and Technical Capability:** Please indicate whether your jurisdiction maintains the following staff members within its current personnel resources by placing an "X" in the appropriate box. Then, if YES, please identify the department or agency they work under and provide any other comments you may have in the space provided or with attachments.

Staff/Personnel Resources	Yes	No	Department/Agency	Comments
Planners (with land use / land development knowledge)				
Planners or engineers (with natural and/or human caused hazards knowledge)				
Engineers or professionals trained in building and/or infrastructure construction practices (includes building inspectors)				
Emergency Manager				
NFIP Floodplain Administrator				
Land Surveyors				
Scientists or staff familiar with the hazards of the community				
Personnel skilled in Geographic Information Systems (GIS) and/or FEMA's HAZUS program				
Grant writers or fiscal staff to handle large/complex grants				
Staff with expertise or training in Benefit-Cost Analysis				
Other				

3. **Fiscal Capability:** Please indicate whether your jurisdiction has access to or is eligible to use the following local financial resources ***for hazard mitigation purposes*** (including as match funds for State of Federal mitigation grant funds). Then, identify the primary department or agency responsible for its administration or allocation and provide any other comments you may have in the space provided or with attachments.

Financial Resources	Yes	No	Department/Agency	Comments
Capital Improvement Programming				
Community Development Block Grants (CDBG)				
Special Purpose Taxes				
Gas / Electric Utility Fees				
Water / Sewer Fees				
Stormwater Utility Fees				
Development Impact Fees				
Permitting Fees				
General Obligation, Revenue, and/or Special Tax Bonds				
Partnering Arrangements or Intergovernmental Agreements				
Other				

4. **Self-Assessment of Capability:** Please provide an approximate measure of your jurisdiction's capability to effectively implement hazard mitigation strategies to reduce hazard vulnerabilities. Using the following table, please place an "**X**" in the box marking the most appropriate degree of capability (Limited, Moderate or High) based upon best available information and the responses provided in Sections 1-3 of this survey. For purposes of this self-assessment, ***Limited*** means there are some capabilities in place, but not at a robust level. ***Moderate*** means there are multiple plans/programs in place which are enforced and assist in reducing hazard impacts. A ***high*** rating would indicate that there are several mechanisms in place – policies, codes, regulations, permitting requirements, and enforcement capabilities.

Area	Degree of Capability		
	Limited	Moderate	High
Planning and Regulatory Capability			
Administrative and Technical Capability			
Fiscal Capability			
Community Political Capability			
Community Resiliency Capability			

5. **Have you participated in the development of your local Hazard Mitigation Plan?** ☐ Yes ☐ No

6. **Plan Development Resources:** Please indicate what resources you utilized during plan development.

Plan Development Resources Utilized		
☐ Own agency planning personnel	☐ Contracted	☐ GIS Support – Agency/Local
☐ Local Planning Councils	☐ Regional Planning Councils	☐ HAZUS-MH Software
☐ MEMA Technical Planning Staff	☐ Grant Funding	☐ Other _____

7. If you did not use MEMA Technical Planning Staff, was there a particular reason why you did not? _____

_____

_____

8. What type of resources could you have used during your agency's plan development, or would be beneficial for future efforts?

Resource Needs		
☐ Technical/Planning Support	☐ Risk Assessment Support	☐ GIS Support
☐ Funding Support	☐ Completion of Grant Application	☐ HAZUS-MH Software

9. What type of or risk assessment does your jurisdiction's plan include?

Type of Risk Assessment		
☐ Qualitative (High/Medium/Low)	☐ Quantitative (Dollar Loss Estimations)	☐ Other

10. Did you utilize MEMA resources to assist in the development of your risk assessment? If so, did you feel the assistance was beneficial?

MEMA Resources Used		
☐ Yes, our jurisdiction used MEMA Resources to complete the Risk Assessment Portion of the Plan	☐ No, we did not utilize MEMA resources to complete the Risk Assessment portion of our plan	
If yes, were the resources beneficial?	☐ Yes	☐ No

If no, please provide us feedback as to why the assistance was not beneficial, and what could be done to improve our services.

11. Hazards of Concern: Please indicate by placing an "X" in the appropriate column below those hazards which are addressed in your current Hazard Mitigation Plan, indicating if they are of High, Medium or Low concern to your jurisdiction based on your risk assessment.

H	M	L	Natural Hazards	H	M	L	Technological Hazards	H	M	L	Human Caused
			Coastal Erosion				Blackout				Chemical
			Dam Failure				Bridge Failures/Accidents				Biological
			Drought				Commodity Shortage				Explosive
			Earthquake				Invasive Species				Nuclear
			Fire – Major Urban				Public Health				Radiological
			Fire - Wildland				Transportation				Terrorism
			Flood/Ice Jam				Other: List				Other: List
			Hurricane and Tropical Storm								
			Landslide								
			Nor'Easter								
			Sea-Level Rise								
			Severe Weather (Extreme Temperatures –Heat/Cold, Drought, Thunderstorms, Wind)								
			Severe Winter Storm (Snow, Blizzard, Ice Storm, Freezing Rain)								
			Snow/Blizzard								

			Thunderstorm/Hail								
			Tornado/Wind								
			Tsunami								
			Other: List								

Special Needs Assessment

12. Does your jurisdiction's current plan capture data with respect to individuals with access and functional needs? ☐ Yes ☐ No

13. If the answer to the preceding question was yes, what type of data has been captured?

Special Needs Data Captured		
☐ Number	☐ Type of Need	☐ Shelter Location to be utilized?
Local of special needs individuals mapped?	☐ Yes	☐ No
Does your jurisdiction have written plans in place to assist individuals with access or functional needs?	☐ Yes	☐ No

Strategy Implementation

14. Strategy Implementation: Has your jurisdiction completed any of the mitigation strategies outlined within their plan during the previous three years?

☐ Yes ☐ No

If so, how many? 1-5 _____ 6-8 _____ 9-10 _____ More than 10 _____

Were these strategies: Projects _____ Policies _____ Programs _____ Public Education/Outreach _____

APPENDIX F.
SYNOPSES OF LOCAL PLAN DATA

APPENDIX F. LOCAL PLAN SYNOPSES

INTRODUCTION

Data Capture

Data contained within this appendix may include information from expired plans. In some instances, if a planning region submitted an updated plan to state/FEMA for review, that plan information was utilized in an effort to use best available data. It is understood that this information may be modified based on FEMA and State comments stemming from the review; however, the information concerning regional geographic makeup and census data should not be impacted by these reviews. Likewise, the hazards of concern as determined by the planning region should also not be impacted. The plan from which the information has been assimilated is noted accordingly.

Breakdown of Regional Profile

Each regional profile is divided into two sections. The first provides a brief description of the region as extracted from the most current local hazard mitigation plan in place at the time of the 2013 update, as well as more up-to-date data gathered for development of the State's plan (such as for population data).

The second section provides a synopsis of the hazards of concern throughout the planning regions, with a focus on the specific hazard of greatest concern as identified by the regional planning commission in conjunction with the planning partnership. The hazard matrix, when available, is included for review. Information also includes relevant risk data.

BERKSHIRE REGIONAL PLANNING COMMISSION

Contents for the Berkshire Regional Planning Commission is based on the February 8, 2012 plan currently approved pending adoption. Nineteen of the 32 Berkshire County communities participated in this plan.

This region consists of 30 towns and 2 cities and has a total population of 130,458, which is a decrease of 3.3% since 2000. Only 7% of the county is developed mostly due to its topography. Additional information on the land use distribution is provided in Figure 1 below. The population density is 141 persons per square mile. Growth is defined as being on a declining trend overall due to major industry and jobs relocating out of the county. Pittsfield is the largest community in the county.

Source: (MassGIS 2010)

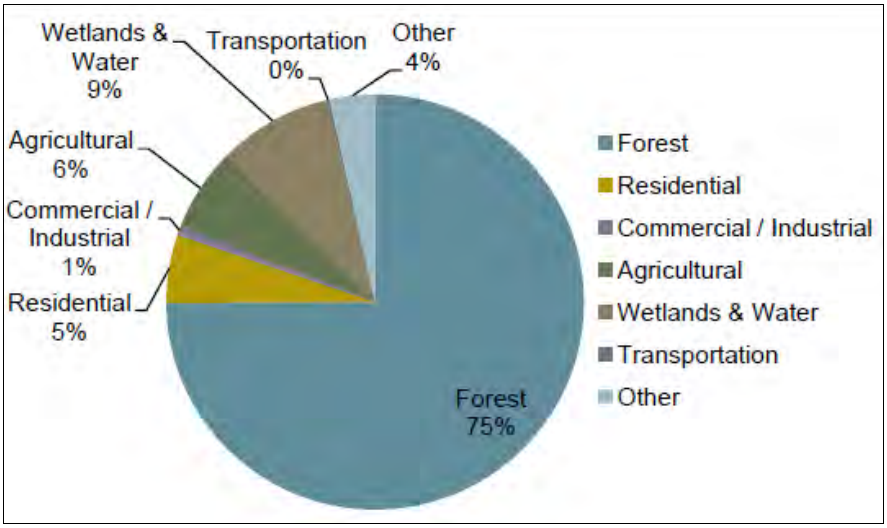


Figure 1. Land Use Distribution

Link to Hazard Mitigation Plan: *Majority Plans Expired 2011; Under MEMA review 2012; Only Lanesborough is active until 10/31/13*

Adams
Alford
Becket
Cheshire
Clarksburg
Dalton Egremeont
Florida
Great Barrington
Hancock
Hinsdale
Lanesborough
Lenox
Monterey
Mount Washington
New Ashford
New Marlborough
North Adams
Otis
Peru
Pittsfield
Richmond
Sandisfield
Savoy
Sheffield
Stockbridge
Tyringham
Washington
West Stockbridge
Williamstown
Windsor

The Berkshires is a hilly region in the western part of Massachusetts, stretching north to the Vermont border and south to Connecticut. Berkshire County is 945 square miles, of which 30% is protected from development. This area is home to world-class arts and cultural venues and year-round recreational activities. There are also commercial centers in the Berkshires and home of corporate headquarters for SABIC Innovative Plastics (formerly GE Plastics), KB Toys, Crane & Company, General Dynamics Advanced Information Systems, and Berkshire Life Insurance Company of America.

Risk Assessments within the regional plan utilized Hazus, and according to the planning commission's loss estimates, the total value of buildings and their contents at risk from flooding in the region is approximately $2.4 billion (Berkshire, 2012, p. 178).

While flood is one of the top hazards for the Commonwealth, this planning region has sustained on the low-end of Federal disaster declarations as they relate to floods with six (6) incidents. According to the 2012 plan, approximately 7.43% of the region is in a floodplain, which demonstrates a relatively low amount.

Combined hazard rankings for the region shown in Table 1.

TABLE 1.
COMBINED HAZARD RANKINGS FOR BERKSHIRE REGIONAL PLANNING COMMISSION

Natural Hazard:	Area of Impact	Frequency	Severity	Hazard Ranking
Flooding	Local	High	Extensive	8
Winter Storm (Nor'easter, Snow, Blizzard, Ice Storm)	Regional	High	Serious	8
Severe Storms (thunderstorm, wind, hail, lightning)	Regional	High	Serious	8
Dam Failure	Local	Low	Catastrophic	7
Tornado	Local	Medium	Extensive	7
Hurricane & Tropical Storms	Regional	Medium	Serious	7
Extreme Temperatures	Regional	Medium	Minor	6
Drought	Regional	Medium	Minor	6
Wildfire	Local	High	Minor	6
Beaver Dams	Local	Low	Serious	5
Landslides	Isolated	Medium	Minor	4
Earthquake	Local	Low	Minor	4
Ice Jam	Isolated	Medium	Minor	4

CAPE COD COMMISSION

This region consists of 15 towns, has a total population of 215,769, which is a decrease of 2.9% population since 2000. The region has a density of approximately 548 persons per square mile. There is a large summer populations on the Cape with estimates reaching over 500,000. Considering only current zoning and land use regulations, the region could reach its maximum build out by 2040. One unique feature of this region is that it is only accessible through the two four-lane bridges at the Cape Cod Canal.

Link to Hazard Mitigation Plan: *http://www.capecodcommission.org/resources/coastalresources/Final_RegMHM_031910.pdf; Approved 6/3/11*

Barnstable
Bourne
Brewster
Chatham
Dennis
Eastham
Falmouth
Harwich
Mashpee
Orleans
Provincetown
Sandwich
Truro
Wellfleet
Yarmouth

The 2010 Cape Cod Hazard Mitigation Plan (HMP) includes five of the County's jurisdictions, including two new jurisdictions, Dennis and Truro. The plan identifies hurricanes having the 'potential to cause the most property damage and loss of life if adequate planning and preparation is not undertaken" (Cape, 2010, p. 16). The regional plan identifies various types of critical facilities (34 total) within various hazard zones, including airports, ferry terminals, bus and rail stations, group day care facilities, senior/youth recreation facilities, marinas, police, fire, hospitals and government facilities. No dollar loss estimations are provided. The Region identified those hazards illustrated in Table 2.

The Region has been successful in obtaining mitigation funds for various types of mitigation efforts during the time period from 1991-2009, as illustrated in Table 3.

Utilizing the STAPLEE (social, technical, administrative, political, legal, environmental and economic) method for strategy development, the Region identified and prioritized the following mitigation activities within the 2010 plan:

- High = 15 actions
- Medium = 6 actions
- Low = 2 actions

TABLE 2.
COMBINED HAZARD RANKINGS FOR CAPE COD COMMISSION

Natural Hazard:	Location[†] Rate: 1=small 2=medium 3= large	Frequency of Occurrence[††] Rate: 0=unlikely 1=possible 2=likely 3=highly likely	Magnitude / Severity[†††] Rate: 1=limited 2=significant 3=critical 4=catastrophic	Hazard Ranking
Flood	2	3	4	9
Shoreline change (long term, sea level rise, or storm-induced)	2	3	4	9
Heavy downpours	3	2	2	7
Wildfire	2	2	4	8
Snow and Ice Accumulation	3	3	2	8
Wind	3	3	2	8
Tornado	1	2	3	6
Drought	3	1	1	5
Earthquake	2	1	2	5

[†] **Location**

1=small	(isolated to a specific town during one event)
2=medium	(occurring in multiple towns across county during one event)
3= large	(affecting a significant portion of Barnstable County during one event)

[††] ***Frequency of Occurrence***

0=unlikely	(less than 1% probability in the next 100 years)
1=possible	(between 1 and 10% probability in the next year; or at least one chance in next 100 years)
2=likely	(between 10 and 100% probability in the next year; or at least one chance in next 10 years)
3=highly likely	(near 100% probability in the next year)

[†††] ***Magnitude/Severity***

1=limited	(injuries and/or illnesses are treatable with first aid; minor "quality of life" loss; shutdown of critical facilities and services for 24 hours or less; property severely damaged < 10%)
2=significant	(injuries and/or illnesses do not result in permanent disability; shutdown of several critical facilities for more than one week; property severely damaged <25% and >10%)
3=critical	(injuries and/or illnesses result in permanent disability; complete shutdown of critical facilities for at least two weeks; property severely damaged <50%, >25%)
4=catastrophic	(multiple deaths; complete shutdown of facilities for 30 days or more; property severely damaged >50%)

TABLE 3.
MITIGATION FUNDING FOR CAPE COD COMMISSION

Town	Grant (year granted)	Project Title	Scope of Work	Total Project Cost ($)	Federal Funding Amount ($)	Local Funding Amount ($)
Brewster	HMGP 1224-08 (1998)	Breakwater Beach Drainage Improvements	Extension of corrugated metal drainage pipe towards Cape Cod Bay, restoration of sand over pipe, emplacement of pre-cast concrete.	7,200	5,400	1,800
Cape Cod Commission	PDM 02-02 (2002)	Regional Natural Hazard Plan	Community outreach and training; regional/local risk assessment and GIS mapping; development of regional/local mitigation strategy.	53,333	40,000	13,333
Chatham	HMGP 914-07 (1991)	Retrofitting – Home Protection	Retrofitting homes to protect against flood damage.	279,840	200,000	66,660
Falmouth	HMGP 914-06 (1991)	Acquisition and Demolition	Purchase of three beachfront lots and clearing of properties to restore locations to open space.	31,013	21,925	7,307
Falmouth	FEMA Section 1362 (ended)	Acquisition and Demolition	Purchase of 1.1 acres for 360 feet of beachfront property now protected as open space	400,000	300,000	100,000
Northeast States Emergency Consortium	HMGP 1364-14	Remote Wind Sensing for Hurricane Safety	Installation of remote ultrasonic wind sensor on top of the Buzzards Bay Vertical Lift Railroad Bridge over Cape Cod Canal in Bourne, MA.	9,950	7,463	2,487
Orleans	HMGP 920-05 (1992)	Retrofitting – Home Protection	Retrofitting homes to protect against flood damage.	20,780	14,691	4,896
Sandwich	FMA 00-02 (2000)	Flood Mitigation Plan	Develop a comprehensive flood mitigation plan for the town.	10,160	6,111	2,560
Yarmouth	HMGP 914-08 (1991)	Sea Gull Beach dune restoration	Design, permitting, and construction of a primary dune.	6,291	4,448	1,482

Town of Barnstable

During review of the various local plans, the 2010 Town of Barnstable HMP was selected for inclusion independent of the regional plans due to the fact that the Town's population during daytime hours increases significantly when compared to its year-round population. Additionally, there are a significant number of Native American archaeological sites within its boundaries. The Town of Barnstable is located in Barnstable County in Cape Cod, Massachusetts. The total land area of the Town is approximately 40,000 acres. Barnstable is one of the most urbanized towns on the Cape and is a regional center of administrative and commercial activity; Hyannis Village functions as a regional commercial center and Barnstable Village is the Barnstable County seat. Originally founded in 1639, the Town contains numerous historic resources; there are more than 40 known Native American archaeological sites, 14 national historic districts, two local historic districts, and an additional 74 individually designated sites. The town's coastal location, wetland habitats, and forested open spaces collectively create a high susceptibility to natural hazards.

General background from HMP:

- .....Year-Round Population 47,380
- .....Seasonal Population 78,333
- .....Peak Daytime Population 126,000
- .....Acres of Developed Land 17,764
- .....Acres of Conservation Land 7,198
- .....Miles of Coastline 170
- .....Acres of Open Water 1,868
- .....Acres of Forested Woodland 12,348
- .....Acres of Salt Marsh 3,817
- .....Acres of Fresh Marsh 264
- .....Acres of Cranberry Bogs 242
- .....Acres of Shrub Swamp 468
- .....Acres of Barrier Beach/Dunes 932
- .....Tidally Restricted Wetland Sites 17
- .....Acres in Hurricane Surge Zones 7,475
- .....Acres in Flood Zones 8,000
- .....Hazardous Waste Sites 30, plus 40 monitored sites
- .....Critical Facilities 105
- .....Regional Critical Facilities 11
- .....Repetitive Loss Properties 18

Loss estimation data is available for assessed building values within the flood zone. The Town has adequately identified an enhanced element of critical facilities, including nursing homes and churches, etc. The mitigation strategies are "designed to holistically address the threat of natural disasters through prevention, regulation, property and natural resource protection, structural improvements and increased public awareness" (Barnstable, 2010). The capabilities of the town include land use regulations enhancing mitigation efforts, including zoning ordinances, building construction ordinances, a general ordinance (Chapter 237) for wetlands protection; the 2010 Open Space and Recreation Plan, and a subset of the Town's Comprehensive Plan, which presents land preservation strategies for flood mitigation. Capabilities also include emergency response planning. Strategies include initiatives such as reclassification of two town-owned dams; erosion control in barrier beaches and coastal banks to protect wildlife habitat from storm surge; wildfire hazard reduction efforts; and development regulations applicable to land, structures and wastewater systems in hazard-prone areas to ensure structures are designed to withstand potential events and to prevent the disturbance of natural areas. Of significant value is a strategy to incorporate hazard mitigation goals into the "Town's land acquisition strategy, considering both direct acquisition and acquisition of development rights." The strategy focuses "on acquiring parcels with high development pressure in hazard-prone areas and reducing the number of repetitive loss properties" (Barnstable, 2010). The plan identifies 18 repetitive loss properties. The hazards identified by the Town of Barnstable identify flood as its number one hazard (see Table 4). This ranking is consistent with the overall Cape Cod Regional Plan.

TABLE 4.
TOWN OF BARNSTABLE HAZARD IDENTIFICATION MATRIX

Hazard Identification Matrix				
Natural Hazard	Frequency (0-3)	Location (1-3)	Extent (1-4)	**Hazard Ranking**
Flood	3	3	4	**10**
Hurricane	2	3	4	**9**
Wind	3	3	3	**9**
Snow & Ice Accumulation (winter storm or nor'easter)	3	3	2	**8**
Shoreline Change/Coastal Erosion (long-term or episodic)	3	2	3	**8**
Drought/Wildfire	1	3	3	**7**
Tornado	1	2	3	**6**
Sea Level Rise	1	2	2	**5**
Earthquake	1	2	2	**5**
Dam Failure	1	1	2	**4**

Rating System

Frequency of Occurrence

0= Unlikely less than 1% probability in the next 100 years
1= Possible between 1-10% probability in the next year; or at least 1 chance in next 100 years
2= Likely between 1-100% probability in the next year; or at least 1 chance in next 10 years
3= Highly Likely near 100% probability in the next year

Location

1= Small isolated to a specific parcel, building, intersection, or neighborhood
2= Medium occurring in multiple locations across town during one event
3= Large affecting a significant portion of town during one event

Extent

1= Limited injuries and/or illnesses are treatable with first aid; minor "quality of life" loss; shutdown of critical facilities for 24 hours or less; properly severely damaged is <10%
2= Significant injuries and/or illnesses do not result in permanent disability; shutdown of several critical facilities for more than one week; property severely damaged <25% and >10%
3= Critical injuries and/or illnesses result in permanent disability; complete shutdown of critical facilities for at least two weeks; property severely damaged <50% and >25%
4= Catastrophic multiple deaths; complete shutdown of facilities for 30 days or more; property severely damaged >50%

Note that one hazard can be the result of numerous events. For example, flooding is a natural hazard that can be caused by a hurricane, winter storm, or nor'easter.

CENTRAL MASSACHUSETTS REGIONAL PLANNING COMMISSION

During this process, 27 communities actively participated in the planning process, including the development of action plans specific to their municipality. The Central Massachusetts Regional Planning Commission region occupies 1000 square miles of area in the southern two-thirds of Worcester County, Massachusetts. The area surrounds the City of Worcester, which is the second-largest city in Massachusetts and second largest in all of New England, with a population of 182,000. More than 550,000 people live in the Central Massachusetts Region.

Generally, the Region varies greatly. Worcester represents a highly urbanized center, surrounded by communities that are generally considered rural, including New Braintree, with a 2010 population of only 999 and a density of only one-one-hundredth (1/100th) that of Worcester, with only 48 people/square mile.

Each of the 40 communities in the Central Massachusetts region participates in the National Flood Insurance Program (NFIP).

Worcester receives about 50% more snowfall than Boston, averaging approximately 69 inches per year. Worcester's 49 inches of annual precipitation is about 15% higher than in Boston, and Worcester will experience precipitation on about 30% of the days each year. Worcester's average relative humidity ranges from 67%-81% in the mornings, and between 49%-62% in the afternoons. The average relative humidity in the morning is 75% and the average in the afternoon is 57%.

At the time of the writing of the plan, the 2010 Census data in its entirety had not yet been released. Therefore, the plan utilizes the 2000 census data unless otherwise noted. The median value of owner occupied housing units in 2000 was substantially less in the Region as compared to the State ($146,000 vs. $186,000). However, the housing "boom" in the early decade may have altered this comparison, or at least the values. Household income values in the Region ($61,791 in 2007) are similar to those of the state ($62,383), and 9.5% of the area falls below the poverty level. Additional population data is available in Table 5 and Figure 2.

Elevations within the planning area range from 201 feet above mean sea level to elevations greater than 1,201 feet above mean sea level are rare, found only in three towns in the North Sub-region: in Barre on several hilltops, in Princeton on portions of Mt. Wachusett, and in Paxton on Asnebumkit Hill.

Link to Hazard Mitigation Plan *(Original Submission January 2010; to FEMA 10/10/12 for Review): http://cmrpc.org/sites/default/files/Documents/CDAP/CMRPC%20Regional%20PDM%20Plan%20Jan%202010.pdf (2012 plan on line)*

Auburn
Barre
Berlin
Blackstone
Boylston
Brookfield
Charlton
Douglas
Dudley
East Brookfield
Grafton
Hardwick
Holden
Hopedale
Leicester
Mendon
Millbury
Millville
New Braintree
North Brookfield
Northborough
Northbridge
Oakham
Oxford
Paxton
Princeton
Rutland
Shrewsbury
Southbridge
Spencer
Sturbridge
Sutton
Upton
Uxbridge
Warren
Webster
West Boylston
West Brookfield
Westborough
Worcester

In Central Massachusetts, storm surges are unlikely to affect any part of the region except in the most epic catastrophe producing a storm surge that travels 18 miles from the Hurricane Barrier in Providence Rhode Island to the Uxbridge/Millville/Blackstone portion of the region in Massachusetts.

TABLE 5.
AREA AND POPULATION DATA FOR CENTRAL MASSACHUSETTS REGION TOWNS

Geographic Area Municipality	Land Area (sq. mi.)	Total Population 2010 US Census	Pop. Density pop/ sq mi
Auburn	15.36	16,188	1,054
Barre	44.33	5,398	122
Berlin	12.93	2,866	222
Blackstone	10.90	9,026	828
Boylston	16.03	4,355	272
Brookfield	15.52	3,390	218
Charlton	42.53	12,981	305
Douglas		8471	
Dudley	21.05	11,390	541
East Brookfield	9.84	2,183	222
Grafton	22.74	17,765	781
Hardwick	38.59	2,990	77
Holden	34.99	17,346	496
Hopedale	5.16	5,911	1,146
Leicester	23.36	10,970	470
Mendon	18.10	5,839	323
Millbury	15.73	13,261	843
Millville	4.93	3,190	647
New Braintree	20.70	999	48
North Brookfield	21.06	4,680	222
Northborough	18.53	14,155	764
Northbridge	17.18	15,707	914
Oakham	21.12	1,902	90
Oxford	26.63	13,709	515
Paxton	14.73	4,806	326
Princeton	35.44	3,413	96
Rutland	35.26	7,973	226
Shrewsbury	20.73	35,608	1,718
Southbridge	20.36	16,719	821
Spencer	32.85	11,688	356
Sturbridge	37.41	9,268	248
Sutton	32.38	8,963	277
Upton	21.52	7,542	350
Uxbridge		13,457	
Warren	27.53	5,135	187
Webster	12.49	16,767	1,342
West Boylston	12.90	7,669	594
West Brookfield	20.47	3,701	181
Westborough	20.52	18,272	890
Worcester	37.56	181,045	4,820
CMRPC Region	**925.37**	**556,698**	**602**

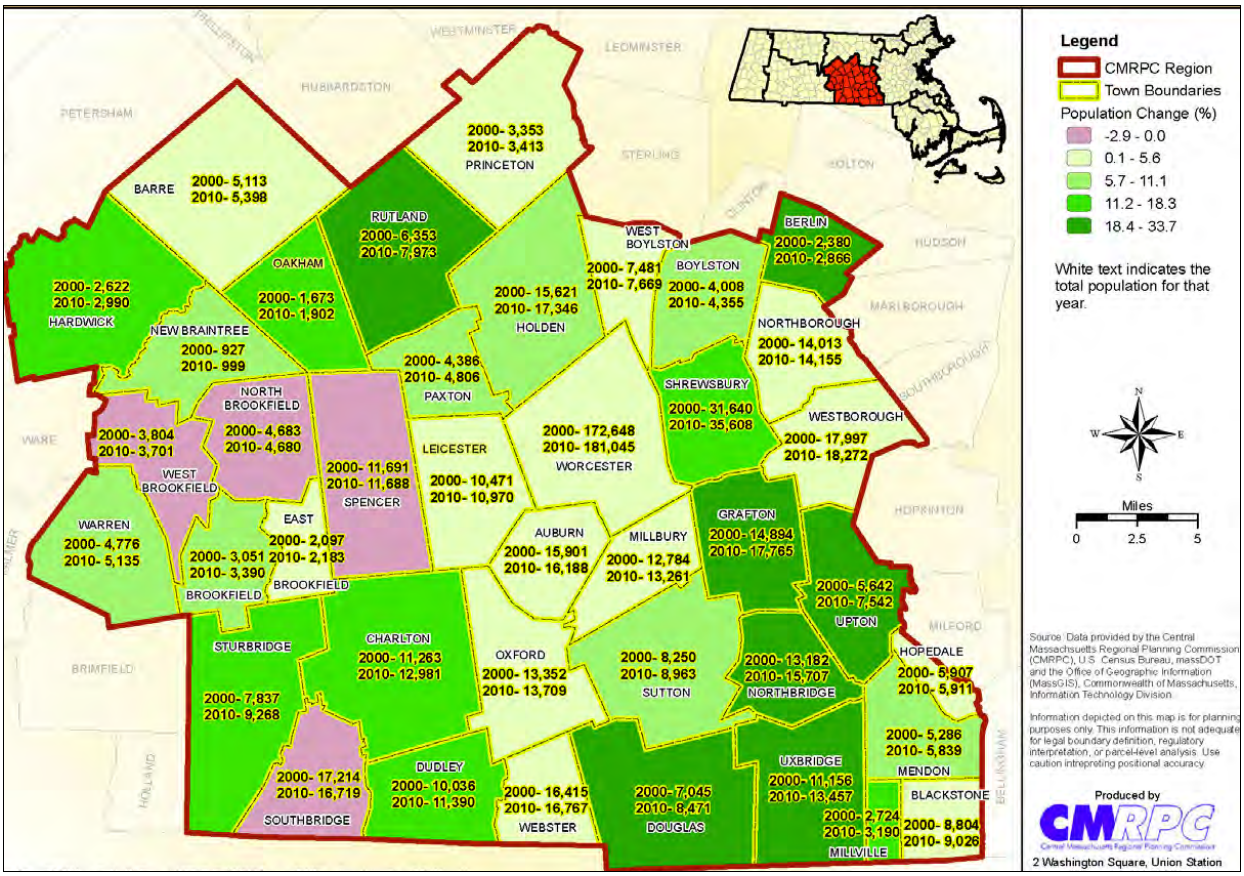


Figure 2: Percent Population Change for Central Massachusetts Region Communities, 2000 - 2010

This Region is at moderate risk for flood threats, which may result in serious or extensive damage. The most extensive damage would result from the highly infrequent dam failure. However, the most frequent flood threat is due to riverine and stormwater flooding. Stormwater floods occur frequently in isolated locations throughout the region, although the impacts are typically minor.

According to the 2010 plan, this Region is at medium risk for Hurricane threats, and may experience serious impacts wind, vegetative debris, flooding, stormwater flooding, and rain. Impacts are typically isolated, but may be serious and potentially extensive.

In Worcester County, there have been a number of F1 tornadoes occurring sporadically over the years. However, a data search for tornadoes rating 3 or above, or resulting in death/injury, or significant property damage, identifies the following events:

- In 1953, an F4 tornado struck Worcester. The event resulted in at least 90 fatalities, and more than 1200 injured. There was extensive property damage
- In 1981 an F3 tornado struck, resulting in just 3 injuries and very little reported property damage.
- In June 2011, an F3 tornado struck Massachusetts. Few deaths were reported, all in Hamden County. No deaths were reported in Worcester County. Property damage assessments in this Region were focused on Sturbridge (more than $100,000 damage) and Southbridge (more than $3/4 million).

Figure 3. October 2005 Flooding

Notwithstanding the events of 1953 and 2011, tornados are not common in this Region and, when they do occur, are typically small and specific. They are considered to be an extremely minor threat in this Region.

Winter storms and related hazards are high-frequency events in this Region, although their impacts are typically minor. Earthquakes are extremely rare in this Region and, when they do occur, are small and specific. They are considered to be a low threat in this Region.

This plan also analyzes other natural hazards such as drought, wildfire, earthquake, landslide, tsunami, extreme temperatures, and conflagrations; however, based on the fact that no Disaster Declarations have been issued for any of these conditions in the entire state dating back more than 50 years, none of these is considered to be a risk for the Region. Riverine flooding is also a risk, relative to the Blackstone, Quaboag, Quinebaug, and Ware rivers in particular. While riverine flooding may cause more severe impacts, those impacts are more likely to be isolated and relatively infrequent. The region also addresses volcano at a very low threat. The regional vulnerability matrix is below in Table 6.

Using data provided through MassGIS and MEMA, the Region was able to determine the number of critical facilities, other than dams, in the vulnerable portions of our Region. For the purpose of this exercise, it was determined by the planning partners that the Region was vulnerable to flooding. In order to use a methodical approach to the assessment, the planning commission determined that vulnerable areas were deemed those falling within the 100-year flood plain on the Flood Insurance Rate Maps.

The 45 critical infrastructure and facilities in the region are listed in Table 7 and Table 8.

TABLE 6.
HAZARD VULNERABILITY MATRIX FOR CENTRAL MASSACHUSETTS REGION

Hazards	Frequency			Severity				Affected Geography		
	Low	Med	High	Minor	Serious	Exten-sive	Catas-trophic	Local-ized	Sub Region s	Region wide
1. Flood-related Hazards § Riverine	All			BER BOY BRK EBRK HOL MEN NBRA NBRK OAK PAX PRI RUT SHR SPE UPT WAR WEB WBOY WBOR	AUB BAR BLK CHA DOU DUD GRA HAR HPD LEI MBY MVL MBOR NBRI OXF SOU STU SUT UXB WBRK WORC			X		X
2. Flood-related Hazards § Dam Failures	All			BER BOY BRK EBRK MEN NBRA NBRK OAK PAX PRI RUT SHR WAR WBOY WBOR	DUD HOL NBOR OXF SPE WEB WBRK	AUB BAR BLK CHA DOU GRA HAR HPD LEI MBY MVIL NBRI SOU STU SUT UPT UXB WORC		X		X
3. Flood-related Hazards § Stormwater	All			All				X		X
4. Flood-related Hazards § T'storms			All	All						X

TABLE 6 (continued).
HAZARD VULNERABILITY MATRIX FOR CENTRAL MASSACHUSETTS REGION

	Frequency			Severity				Affected Geography		
	Low	Med	High	Minor	Serious	Exten-sive	Catas-trophic	Local-ized	Sub Region s	Region wide
5. Flood-related Hazards § Winter Storms			All	All				X		X
6. Flood-related § Nor'easters			All		All			X		X
7. Flood-related Hazards § Hurricanes		All			All			X		
8. Hurricanes/ Tropical storms (wind/rain)	All					All			SE & SW Sub-regions	X
9. Severe Storms (Wind, Hail, Lighting)	All				All			X		X
10. Wind-Related Hazards § Hurricanes § Nor'easters § Winter Storms		All	 All All		 All All All					 X X X
11. Tornados	All				All					X
12. Severe Winter Storms			All		All				NW & N Sub-Regions	X
13. Drought	All			All						X
14. Fire Hazards	All			All						X
15. Geologic Hazards* Tsunami Earthquake Landslide	All				All			X		
16. Extreme Cold**			All	X						X
17. Extreme Heat***			All	X						X
18. Conflagrations	All						All			X

TABLE 7.
CRITICAL INFRASTRUCTURE AND FACILITIES IN CENTRAL MASSACHUSETTS REGION

SUMMARY Type of Facility	# in Vulnerable Areas	SUMMARY Type of Facility	# in Vulnerable Areas
Day Care Centers (>20 children)	16	Power Generating Plants	1
Electrical Power Substations	1	Schools; Elementary, Middle, High	1
Emergency Facilities/Shelters	4	Sewage Treatment Plants	2
Fire Stations	7	Water Treatment Plants	3
Government offices/ Town Halls	10		

TABLE 8.
CRITICAL INFRASTRUCTURE AND FACILITIES IN CENTRAL MASSACHUSETTS REGION, BY COMMUNITY

Town	Day Care Centers (>20 Children)	Electrical Power Substations	Emergency Facilities/ Shelters	Fire Stations	Gov. Offices/ Town Halls	Power Genera. Plants	Schools; Elem, Middle, High	Sewage Treat. Plants	Water Treat. Plants
Auburn				1	3				1
Barre				1					
Charlton	2				1				
Dudley	1					1			
East Brookfield			1						
Hopedale					1				
Leicester	1			1					
Millbury	1	1							1
North Brookfield								1	
Northborough	1		1	1			1		
Northbridge					1				
Oxford			1	1	1				
Rutland			1						
Sturbridge								1	
Sutton									1
Uxbridge	1								
West Boylston					2				
Webster	1								
Worcester	8			2	1				
Total	16	1	4	7	10	1	1	2	3

indicates a community in the CMRPC region which has a vulnerable critical facility, but which is not participating in this PDM Planning process at this time.

FRANKLIN REGIONAL COUNCIL OF GOVERNMENTS

This region consists of 26 communities, has a total population of 71,599, and has a population density of 102 people per square mile, making it the most rural county in Massachusetts. In addition, 16 of 26 communities have a per capita income lower than the national average, and 20 of 26 have a per capita income less that the state average. The largest community is Greenfield, in the center of the county with a population of about 17,511. 18 of the 26 towns have a population fewer than 2,000. The county's population growth has slowed significantly since 1980. For some communities the population decline is considerable; region wide, the increase from 2000 to 2011 is only 0.1%. Only 5.2% of the county is developed residential and 0.4% is commercial.

Franklin County is located along the northern tier of western Massachusetts, bordering Vermont and New Hampshire to the north and Hampshire County and the Springfield metropolitan area to the south. Franklin County is the most rural area in the Commonwealth. The County continues to expand its natural-resource-based business opportunities and has retained an active manufacturing sector that includes major employers manufacturing plastics, fabricated metals and other products. Franklin County has several educational institutions and museums, year-round outdoor recreation activities, and other amenities.

As of the 2013 Update to the State's HMP, the Franking County COG plan had expired, but information contained within the document constitutes best available data, and the decision was made by the State Hazard Mitigation Team to utilize the information. Several of the local jurisdictions are in the process of developing their own plans, which should be completed relatively soon.

Link to Hazard Mitigation Plan: *http://www.frcog.org/pubs/natural_res/HazMit/2005_FC_NatHazMitPlan.pdf*

Ashfield
Bernardston
Buckland
Charlemont
Colrain
Conway
Deerfield
Erving
Gill
Greenfield
Hawley
Heath
Leverett
Leyden
Monroe
Montague
New Salem
Northfield
Orange
Rowe
Shelburne
Shutesbury
Sunderland
Warwick
Wendell
Whately

TABLE 9.
FRANKLIN REGIONAL COUNCIL OF GOVERNMENTS HAZARD IDENTIFICATION AND ANALYSIS WORKSHEET

TYPE OF HAZARD	FREQUENCY OF OCCURRENCE	LOCATION OF OCCURRENCE	IMPACT	HAZARD RISK INDEX RATING
Flooding	Low-Moderate	Small	Limited	2
Severe Snowstorms/Ice Storms	High	Large	Limited	1
Hurricanes	Moderate	Large	Limited/Critical	2
Tornadoes	Low-Moderate	Small	Critical	2
Wildfire/Brushfire	Low-Moderate	Small	Minor	4
Earthquakes	Low	Large	Critical	3
Dam Failure	Very Low	Small	Critical/Catastrophic	3

No dollar loss information was provided within the existing plan; however, the Commonwealth, during completion of the risk assessment associated with update to the 2013 State HMP, did include data which can be utilized to determine local risk and loss estimations for some of the hazards within its risk assessment document contained in Section 5.

Goals, objectives, strategies and capability information from the expired plan have been incorporated into the general data contained previously within this section.

MARTHA'S VINEYARD COMMISSION

This island region is comprised of seven (7) towns on several islands with a population of 15,000 off-season, and a summer population of 75,000. It is estimated that within the next 50 years, development could increase more than 53% in currently developable areas. However this estimate is unlikely because it does not account for areas with current conservation restrictions or agricultural restrictions. Currently, the County's population is approximately 16,766, which is an 11.9% increase from 2000 population counts. 2020 estimated population puts the count at 21,822, or a 30% increase from the 2011 levels.

Link to Hazard Mitigation Plan (Expires: 5/13/13): *http://www.mvcommission.org/doc.php/Pre-Disaster%20Mitigation%20Plan%20for%20Dukes%20County.pdf?id=1443*

Aquinnah
Chilmark
Edgartown
Gosnold
Oak Bluffs
Tisbury
West Tisbury

Martha's Vineyard is an ~87-square-mile island located seven miles off the coast of Cape Cod (MV Commission, 2008, p. 10). Its topography results from its location at the southern extremity, or terminal moraine, of the part of North America covered by ice during the last Ice Age. Home to the Wampanoag Tribe, it was settled by Europeans in the mid-17th century.

The cornerstone of the Island's economy is providing services to seasonal residents and visitors. The service, retail trade, construction, and finance, insurance and real estate sectors—mainly seasonal industries—account for 54% of Island jobs. A large majority of the businesses on the Island employ four or fewer workers each. The tourism and service industry is highly image-conscious, seasonal and labor intensive.

Review of the plan indicates that 123 critical facilities were identified from MassGIS data, in conjunction with emergency management personnel. These facilities include day care facilities, schools, senior centers, etc., as well as the customary critical infrastructure of police, fire, hospitals, etc. The plan goes on to indicate that the major bridges on Martha's Vineyard are in the process of being replaced, and there was no need to plan for hazard mitigation associated with structurally deficient bridges.

Loss statistics varied in nature, and included assessed building values; applied average exempt building values, and various other data source. The SLOSH model was utilized to determine loss estimations for storm surge events for residential (and some limited commercial) structures. For flooding, the plan identifies NFIP data as demonstrated in Table 10.

Included within the plan, the planning commission has included a detailed assessment of the impact of coastal erosion on Martha's Vineyard.

The risk assessment identifies the overall rating matrix identified in Table 11. A vulnerability matrix was prepared for each community, using numeric points (one point for each step of higher frequency or impact) and the resulting scores were averaged for the following table of vulnerability for the overall area of Dukes County:

Unique capabilities include the Coastal District of Critical Planning Councils, which are specific to individual ponds, harbors and shores. These regulations for "districts of critical planning concern" are, in most cases, more restrictive than the FEMA floodplain by-laws. Also unique is the state Department of Conservation and Recreation-established fire-wise program on the Vineyard, which is "staffed 24/5 by an outreach worker who speaks to groups and distributes literature, as well as responding to fires" (MV Commission, 2008 p. 69).

TABLE 10.
MARTHA'S VINEYARD LOSS STATISTICS AS OF APRIL 30, 2008

Community Name	Total Losses	Total Payments	Repeat Claims Properties	Repeat Claims Claims	Repeat Claims Total Paid
Aquinnah	2	13,462.39	1	2	13,462.39
Edgartown	33	606,587.69	4	10	301,823.68
Gosnold	1	2,214.00	0	0	0
Oak Bluffs	54	723,872.98	9	23	559,418.42
Tisbury	24	257,608.95	3	6	148,302.98
Totals	114	$1,603,746.03	17	41	$1,023,007.47

TABLE 11.
OVERALL VULNERABILITY FOR DUKES COUNTY

Natural Hazard	**Frequency of Occurrence**	**Location**	**Impacts**	**Hazard Index**
	(very low, low, medium, high)	(local or small, medium, multiple towns or large)	(minor, serious, extensive, catastrophic)	(rank by combining how much impact & how frequently this affects the community - average for all planning areas)
Flood-Related Hazards				
Riverine	very low	n/a	n/a	0
Coastal	medium	large	serious	8
Erosion	high	large	serious	7.4
Dam Failures	very low	local	serious	1
Thunderstorms	medium	local	minor	4.1
Winter Storms (snow)	low	local	minor	4
Coastal Storms/Nor'easters	high	medium	serious	9.4
Hurricanes	medium	large	extensive	9
Wind-Related Hazards				
Hurricanes	medium	large	extensive	9.1
Coastal Storms	high	large	serious	9.1
Winter Storms (snow)	low	local	serious	5
Downspouts	very low	local	serious	3
Tornadoes	very low	local	serious	4.1
Fire-Related Hazards				
Drought	medium	medium	serious	6
Wildfires	low	local	serious	6
Geologic Hazards				
Earthquakes	very low	n/a	n/a	0
Landslides	very low	local	minor	3.6
Sink Holes	very low	n/a	n/a	0
Other Hazards				
Ice	very low	local	serious	3.4
Sea Level Rise	high	large	serious	6.6

MERRIMACK VALLEY PLANNING COMMISSION

Information for this local plan review was gathered from the 2008 plan, which is currently being updated for renewal during 2013. This plan covers the majority of Essex County. The existing plan covers 13 of the 15 communities, with two electing not to be part of the regional planning effort.

Link to Hazard Mitigation Plan *(Expires 2/25/13—currently in update process): http://mvpc.org/wp-content/uploads/MEMA_PDM_Complete4.11.2011.pdf*

Amesbury
Andover
Boxford
Georgetown
Groveland
Haverhill
Lawrence
Merrimac
Methuen
Newbury
Newburyport
North Andover
Rowley
Salisbury
West Newbury

This region consists of 15 towns and cities, referred to as the Merrimack Valley. The region encompasses ~267 square miles of divergent towns and cities, and is where over 330,000 residents call home. The Upper, or western portion of the Valley is where you will find large, former industrial cities such as Lawrence and Haverhill. Seaside communities dominate the Lower, or eastern portion of the Valley. Small, picturesque communities and villages, such as West Newbury and Groveland dot the center of the Region. The plan indicates a density of 1,192 persons per square mile.

Based on a regional build out analysis (discussed below) there is the potential to increase population by an additional 27% within this region. Single family residential units are the principle form of growth in this region with an average of about 1000 new homes per year since 1980. Approximately 40% of the region's population is in two communities, Lawrence and Haverhill.

The Valley's makeup is as follows:

- 40% of the Region is forested
- 26% is devoted to residential uses
- 20.2% consist of farmland, wetlands & water
- 5 communities are considered cities

In 2002, "the Merrimack Valley Planning Commission conducted a 'buildout' analysis for each of the 15 communities. (Buildout is a calculation of a community's maximum land development potential under current zoning.) Based on these analyses, the planning commission projects a maximum regional population of 406,149 if all remaining residential building sites are developed. This represents a 27.5% increase over the current (2000) population (MVPC, 2008).

Review of the plan demonstrates that employment diversification into various sectors have resulted in what appears to be a fairly stable economic region. Construction accounted for less than 10% of the region's economic sector, so the most recent recession period (2009-2012) may have had a less than average economic impact on the region.

The region encompasses parts of five of the Commonwealth's 28 watersheds, with the Merrimack Watershed area encompassing 147 square miles, or 55% of the region. The Merrimack River has an average daily flow of 7,500 cubic feet per second at the Lowell gage, and is greater than the average flow of any other eastern Massachusetts rivers combined. The highest flow of record, 170 cubic feet per second, occurred during the 1936 flood event.

Figure 4. Shawsheen River Flooding, Lawrence - May 2006 (MVPC, 2008).

According to the Regional 2008 HMP, the region is vulnerable to a wide array of natural hazards, including floods, hurricanes, northeasters, snow and ice storms, drought, wildfires, and tornadoes and earthquakes.

Review of the Commonwealth's 2013 risk assessment data confirms the Merrimack Region's hazard ranking of 'high' for flooding events, including coastal hazards, Nor'easters, snow and blizzards, and ice storms, all of which have the potential to enhance flooding. Historic gage data reveals a number of the flood disasters occurring in the region raising to the level of a 100 year event in certain areas (DR-790, 1987 event), while a number of other events, such as DR-1642 (May 2006) range from a 40 to 3 year event within the Region.

Review of the MV HMP identifies 18 various types of critical facilities, including those identified within the Hazus model, as well as public works garages, treatment plants, communications facilities, hospitals and medical clinics, libraries, senior centers, nursing homes and "hotspots" based on local knowledge (MVPC, 2008). The risk assessment portion of the plan indicates that risk assessment for the region (based on composite analysis of all 13 communities) was based primarily on information contained in the County's Comprehensive Emergency Management Plan, and utilizes high, moderate-high, moderate, low-moderate and low risk scaling system identified by the table extracted below.

Limited dollar loss estimations were included, and are based on 2007 building valuation estimations within the flood and SLOSH models. In some instances, land value is designated as the loss. It is unclear whether the assessor's data has been manipulated to include only structure values, or land and structure values for other loss estimations.

TABLE 12.
MERRIMACK VALLEY REGION-WIDE NATURAL HAZARDS RISK ASSESSMENT

(13 Communities)		
Natural Hazard	Composite Score	Regional Risk
Floods/Storm Surges	65	HIGH
Winter Storms (blizzard/snow/ice)	65	HIGH
Hurricanes	39	Moderate
Dam Failure	37	Moderate
Wildfire/Brush Fires	36	Moderate
Drought	33	Moderate
Earthquakes	19	Low
Tornadoes	16	Low
Landslides	13	Low

TABLE 13.
MERRIMACK VALLEY REGION POTENTIAL VULNERABILITY TO FUTURE NATURAL HAZARDS

Hazard	Frequency	Severity
Flood	High	Extensive
Dam Failure	Medium	Extensive
Hurricane and Tropical Storms	Medium	Serious
Severe storms (wind, hail, lightning)	Medium	Serious
Tornadoes	Medium	Extensive/Catastrophic
Severe Winter Weather (snow, ice, wind)	High	Extensive
Drought	Medium	Serious
Earthquake	Low	Catastrophic
Wildfire	Medium	Serious
Landslide	Low	Minor
Heat Wave	Medium	Serious

METROPOLITAN AREA PLANNING COUNCILS

Stretching west from Boston to include most of the communities inside the I-495 corridor, the planning area for the Metropolitan Area Planning Councils (MAPCs) consists of 22 cities and 79 towns that include coastal communities, older industrial centers, rural towns and modern cities. MAPC works with its cities and towns through eight subregional committees (identified above). Inclusion of information from these MAPC areas was completed through review of a number of local hazard mitigation plans (LHMPs), as well as regional plans, as appropriate.

Link to Hazard Mitigation Plan (Multiple): *MAPC Expired; MAPC 1 Expired 4/29/10 - 9/12 to FEMA; MAPC 2 Exp. 4/29/10/ MEMA Review; MAPC 3 Expires 7/22/13; MAPC 4 Expires 2013, 2015, 2016, 2017; MAPC 5 Expires 11/20/13-2017; MAPC 6 Expires 8/3/17; MAPC 7 Expired except: Framingham 10/12/17; Wakefield 3/26/13*

Inner Core Committee
Minuteman Advisory Group on Interlocal Coordination
MetroWest Regional Collaborative
North Shore Task Force
North Suburban Planning Council
South Shore Coalition
SouthWest Advisory Planning Committee
Three Rivers Interlocal Council

City of Boston 2008 LHMP

The largest city within the MAPC planning region is also the largest city within the Commonwealth of Massachusetts—the City of Boston, which is also the capital of the Commonwealth and home to the State House. Located in Suffolk County, the City of Boston attracts in excess of 12 million tourists annually, and is ranked the 21st largest City in the United States according to the 2011 U.S. Census Bureau. Major attractions in the city range from the Museum of Science, Museum of Fine Arts, numerous theaters, Fenway Park, and the Harbor Islands. Boston is also home to many historic buildings and structures that are of symbolic significance to not only the Commonwealth but also the nation as a whole. These include large and well-known sites and structures such as the U.S. Constitution, numerous burying grounds, the Paul Revere House, and Old North Church, as well as many smaller, lesser known, but historically important sites scattered around the City. In addition to state and local level critical infrastructure, Boston is also home to many Federal agencies, financial institutions, medical facilities and institutions of higher education.

When discussing its critical facilities, the 2008 LHMP indicates that due to the fact that "such a large portion of Boston was constructed on fill and because of the city's extensive coast line, a large number of critical facilities and vulnerable populations are located in hazard zones and a number are located in more than one hazard zone" (p. 16). In addition, the plan indicates that many of its "critical facilities not listed as being in a flood zone could actually be located in one" given the age of the flood maps used during development of the 2008 plan. Preliminary digital Flood Insurance Rate Maps were issued in 2012, which include new coastal modeling and mapping for the impacted communities within Suffolk County. This will enhanced the City's ability to enhance their ability to determine associated risk during the next plan update. While not all-inclusive, the plan identifies in excess of 800 critical facilities.

According to the 2008 LHMP, "Boston has a unique history of land reclamation. According the city's *Open Space Plan*, the city grew from 1,000 acres to 30,000 acres due to land reclamation and annexation. As a result, large areas of Boston are built on fill" (p. 3). The plan indicates, and history has demonstrated, that filled land affects a jurisdiction's vulnerability to certain natural hazards.

The numerous cultural facilities within Boston are also of great concern, given that many of the facilities are older, and built to lower building code standards. The plan indicates that while newer buildings housing cultural artifacts, "the vast majority of collections, both in storage and on display, have not been retrofitted to protect fragile objects during tremors. Fire remains one of the great risks to cultural heritage because the resultant loss is so often irrecoverable and irreplaceable" (Boston LHMP, 2008, p. 16).

The 2008 plan lists nine hazards to which the City of Boston is susceptible, identified in Table 14.

TABLE 14.
FREQUENCY AND SEVERITY OF NATURAL HAZARDS IN THE STATE AND BOSTON

Hazard	Frequency	Severity	Comments
Flood	High	Serious to extensive	
Dam Failure	Low	Extensive	
Hurricanes	Medium	Extensive to catastrophic	Boston has an extensive coast line
Severe Storms (wind, hail, lightning)	Medium	Serious	High density and on-street parking in urban areas can make street tree damage a concern
Tornados	Medium	Extensive to catastrophic	No tornadoes recorded in Boston
Winter Storms	High	Serious	High density can pose challenges
Earthquakes	Low	Catastrophic	Higher potential for damage in areas prone to liquefaction. Boston area at higher risk than rest of state
Landslides	Low	Minor	Coastal erosion issues in Boston
Brush Fires	Medium	Serious	

Definitions Used in the Commonwealth of Massachusetts State Hazard Mitigation Plan

Frequency
- Very Low Frequency: Events that occur less frequently than once in 1,000 years (less than 0.1% per year).
- Low Frequency: Events that occur from once in 100 years to once in 1,000 years (0.1% to 1% per year).
- Medium Frequency: Events that occur from once in 10 years to once in 100 years (1% to 10% per year).
- High Frequency: Events that occur more frequently than once in 10 years (greater than 10% per year).

Severity
- Minor: Limited and scattered property damage; no damage to public infrastructure (roads, bridges, trains, airports, public parks, etc.); contained geographic area (i.e., 1 or 2 communities); essential services (utilities, hospitals, schools, etc.) not interrupted; no injuries or fatalities.
- Serious: Scattered major property damage (more than 50% destroyed); some minor infrastructure damage; wider geographic area (several communities); essential services are briefly interrupted; some injuries and/or fatalities.
- Extensive: Consistent major property damage; major damage to public infrastructure (up to several days for repairs); essential services are interrupted from several hours to several days; many injuries and fatalities.
- Catastrophic: Property and public infrastructure destroyed; essential services stopped, thousands of injuries and fatalities.

The 2008 LHMP identifies 17 repetitive loss structures in Boston, located throughout the city. Review of state data for the 2013 update demonstrates an increase of five (5) properties since the 2008 Boston LHMP was written, for a total of 23 repetitive loss (RL) properties.

While Hazus was utilized to some extent, it was not utilized to determine flood losses due to the fact that it was felt to be “subject to a great deal of uncertainty” (Boston LHMP, 2008, p. 44). In lieu of using Hazus, the plan indicates that actual damages were “calculated for the city’s largest and most damaging area of flooding—the Muddy River. Flooding in 1996 caused $63 million in damages, though this damage extends beyond the Boston boundary” (Boston LHMP, 2008, p. 46).

For the remaining hazards for which loss estimations were provided, 2002 replacement value was utilized. Loss estimations for Category 2 and 4 hurricane events are estimated in Table 15.

TABLE 15.
HURRICANE LOSS ESTIMATES FOR BOSTON

	Cat. 2	Cat 4*
Building Characteristics		
Estimated total buildings	76,183	
Estimated total building value (Year 2002 $)=	$38,104,000,000	
General Building Damage		
# of buildings sustaining minor damage	2,173	17,890
# of buildings sustaining moderate damage	432	21,178
# of buildings sustaining severe damage	19	13,329
# of buildings destroyed	2	7,396
Population Needs		
% of hospital beds available on day of event	90%	0%
# of households displaced	389	85,535
# of displaced people seeking public shelter	102	23,576
Debris		
Building debris generated (tons)	27,722	1,553,786
Tree debris generated (tons)	87,786	153,671
# of truckloads to clear building debris	1,129	62,046
Value of Damages		
Total property damage	$125,748,980	$14,114,728,370
Total business interruption loss	$14,441,700	$2,330,165,600

Existing mitigation measures identified by the City of Boston include the following:

- The City of Boston's Emergency Management Division is staffed by five, full time, inter-disciplinary members that work to mitigate, plan, and prepare for emergencies; educate the public about preparedness, coordinate resources for emergency response and recovery efforts; collect and disseminate critical information; and, seek further opportunities to support the overall preparedness of the City of Boston. In addition, the Emergency Management Division plays a critical role within routine and non-routine emergencies by maintaining on-scene and remote situational awareness of the incident as well as coordinating inter-agency response. Moreover, the Emergency Management Division also has the responsibility of managing and utilizing the Emergency Operations Center during a time of need. Such Division will work with other entities throughout the Region to ensure proper hazard mitigation measures are put into place.
- The city recently prepared and distributed *Ready Boston: An Emergency Preparedness and Evacuation Guide for City Residents*. The guide is available in English, Spanish, French, Chinese, Portuguese, and Vietnamese. Highlights of the plan include:

  - How to assemble an emergency supply kit and create a household preparedness plan
  - Small and large scale evacuations, including provisions for those without cars
  - The city set up a phone system that can contact 60,000 residents in an hour
- The importance of ensuring that communications systems work during a natural event was reiterated by local officials. The city is currently addressing this issue through its homeland security work.
- The Public Health Commission provides information on disaster preparedness for residents, employers, and health care providers. See http://www.bphc.org/programs/program.asp?b=7&d=0&p=200
- The city, along with the Town of Brookline and the state are undertaking the Muddy River Flood Control, Water Quality and Habitat Enhancement and Historic Landscape Preservation Project. The project proposes to fix the current problem (increase the river's hydraulic capacity) and address the cause of the problem (establish management practices to reduce sediment and debris in the watershed). Camp Dresser & McKee Inc., has been designing the mitigation project and preparing environmental permit applications.

Existing goals of the plan closely align with those of the Commonwealth's 2013 Update.

North Shore MAPC 1

Beverly, Massachusetts

The City of Beverly, Massachusetts, located within the boundary of Essex County, is one of the oldest communities in the state. Residents describe their City as the birthplace of the United States Navy, noting that the first ship commissioned by the Navy first sailed from Beverly Harbor. Review for the 2013 Commonwealth's update included the City of Beverly's February 2012 plan.

Review of the plan identifies similar hazards and hazard ranking as surrounding communities as identified in Table 16.

TABLE 16.
BEVERLY, MA HAZARD RANKING

Hazard	Frequency	Severity
Flooding	High	Serious
Winter storms	High	Serious
Hurricanes	Medium	Serious
Earthquakes	Low	Extensive
Tornadoes	Low	Serious
Landslides	Low	Minor
Brush fires	Medium	Minor
Dam failures	Low	Serious

Review of the 2012 plan identifies 15 repetitive loss (RL) structures in Beverly, which is identified as an increase of nine structure from the 2005 plan. Comparison to information contained within the 2013 update to the Commonwealth's plan identifies 17 RL properties, which coincides with the fact that Essex County is rated in the top five counties for claims filed throughout the Commonwealth. Flooding is also

rated as one of the highest ranked hazards of concern within both the community and the county, followed by winter storms.

Capabilities include ones which cross jurisdictional boundaries, referred to as "Inter-Community Considerations" in the Town's attempt to preserve its coastal areas. Strategies developed demonstrate the significance of this perception and include activities involving municipalities along the North Shore working together to determine "mutually beneficial means of protecting their shore side communities from the impacts of storm damage and sea-level rise" (MAPC, 2010).

The City of Beverly utilizes Hazus at a Level 1 for analysis of their loss estimations. Various hazard information representing dollar losses are demonstrated in Table 17 and Table 18.

TABLE 17.
BEVERLY DAMAGE ESTIMATES FOR CATEGORY 2 AND 4 HURRICANES

	Category 2	Category 4[1]
Building Characteristics		
Estimated total number of buildings	11,054	11,054
Estimated total building replacement value (Year 2002 $) (Millions of Dollars)	$3,478	$3,478
Building Damages		
# of buildings sustaining minor damage	355	1,121
# of buildings sustaining moderate damage	39	170
# of buildings sustaining severe damage	1	6
# of buildings destroyed	0	1
Population Needs		
# of households displaced	13	63
# of people seeking public shelter	3	14
Debris		
Building debris generated (tons)	5,192	11,283
Tree debris generated (tons)	3,219	5,980
# of truckloads to clear building debris	79	213
Value of Damages (Thousands of dollars)		
Total property damage	$.12,555	$33,331.79
Total losses due to business interruption	$1,052.06	$4,024.29

[1]No Category 4 or 5 hurricanes have been recorded in New England. However, a Category 4 hurricane was included to help the communities understand the impacts of a hurricane beyond what has historically occurred in New England.

TABLE 18.
BEVERLY DAMAGE ESTIMATES FOR EARTHQUAKES

	Magnitude 5.0	Magnitude 7.0
Building Characteristics		
Estimated total number of buildings	11,054	11,054
Estimated total building replacement value (Year 2002 $) (Millions of dollars)	$3,478	$3,478
Building Damages		
# of buildings sustaining slight damage	415	3,691
# of buildings sustaining moderate damage	82	3,319
# of buildings sustaining extensive damage	10	1,153
# of buildings completely damaged	1	391
Population Needs		
# of households displaced	16	1,811
# of people seeking public shelter	3	406
Debris		
Building debris generated (tons)	Not available	Not available
Value of Damages (Millions of dollars)		
Total property damage	$55.95	$961.05
Total losses due to business interruption	$2.80	$170.80

Hazus-MH was not utilized to estimate flood damages in Beverly due to technical difficulties with the software, and the fact that the jurisdiction felt the riverine module was not a reliable indicator. Rather, the jurisdiction utilized an exposure analysis based on the number of structures identified by the hurricane and earthquake modules. Based on their method of analysis, the City estimated a range for flood damages to be "$16,927,470- $84,637,350"; however, the calculations were "not based solely on location within the floodplain or a particular type of storm (i.e. 100 year flood)" (City of Beverly, 2012, p. 36).

Review of the relationship between critical infrastructure and the various hazards of concern shows a low rate of impact, with the exception potentially of snow-fall accumulations, for which loss estimations cannot be adequately determined beyond a potential exposure analysis due to the inability to determine with any certainty the geographic boundary which is potentially vulnerable.

The City's goals closely align with those identified within the remaining MAPC region, as well as the Commonwealth's 2013 updated goals.

Lexington (Middlesex County) 2011 LHMP Review

Review was focused on the 2011 MAPC plan for the Town of Lexington. Lexington is located in Middlesex County in Eastern Massachusetts and is bordered by Lincoln on the southwest; Bedford on the northwest; Burlington on the northeast; Woburn, Winchester, and Arlington on the east; and Belmont and Waltham on the south. Lexington is 11 miles northwest of Boston and 18 miles south of Lowell. As of the writing of the plan, the 2000 Census indicated that "just over 30,000 people live in Lexington. The town has a fairly high percentage of residents that are over age 65 (19%). Of the town's 11,333 housing units, one quarter were built before 1940" (Lexington, 2011, p. 3). Table 19 demonstrates the hazard rankings for the Town of Lexington.

TABLE 19.
LEXINGTON HAZARD RANKING

Hazard	Frequency in State	Severity in State	Issues in Lexington
Flood	High	Serious to extensive	Same as state
Dam Failure	Low	Extensive	Same as state
Hurricanes	Medium	Extensive to catastrophic	Same as state
Severe Storms (wind, hail)	Medium	Serious	Same as state
Tornadoes	Medium	Extensive to catastrophic	Not a major issue in Lexington
Winter Storms	High	Serious	Same as state
Earthquakes	Low	Catastrophic	Not a major issue in Lexington
Landslides	Low	Minor	Not a major issue in Lexington
Brush Fires	Medium	Serious	Not a major issue in Lexington

Definitions Used in the Commonwealth of Massachusetts State Hazard Mitigation Plan

Frequency
- Very Low Frequency: Events that occur less frequently than once in 1,000 years (less than 0.1% per year).
- Low Frequency: Events that occur from once in 100 years to once in 1,000 years (0.1% to 1% per year).
- Medium Frequency: Events that occur from once in 10 years to once in 100 years (1% to 10% per year).
- High Frequency: Events that occur more frequently than once in 10 years (greater than 10% per year).

Severity
- Minor: Limited and scattered property damage; no damage to public infrastructure (roads, bridges, trains, airports, public parks, etc.); contained geographic area (i.e., 1 or 2 communities); essential services (utilities, hospitals, schools, etc.) not interrupted; no injuries or fatalities.
- Serious: Scattered major property damage (more than 50% destroyed); some minor infrastructure damage; wider geographic area (several communities); essential services are briefly interrupted; some injuries and/or fatalities.
- Extensive: Consistent major property damage; major damage to public infrastructure (up to several days for repairs); essential services are interrupted from several hours to several days; many injuries and fatalities.
- Catastrophic: Property and public infrastructure destroyed; essential services stopped, thousands of injuries and fatalities.

There were no repetitive loss properties within the Town of Lexington as of the writing of the 2011, however, analysis conducted during the 2013 State plan update indicate the Town now has five repetitive flood losses.

North Reading (Updated January 2012)

North Reading is located in Northeastern Massachusetts, bordered by Wilmington on the west, Andover and North Andover on the north, Middleton and Lynnfield on the east, and Reading on the south. North

Reading is 10 miles south of Lawrence and 15 miles north of Boston. The total land area is 13.26 square miles, with a total area of 13.52 square miles. The elevation of the town is 100 feet above sea level.

The Town of North Reading is an outlying suburban town in Middlesex County, lying entirely within the watershed of the Ipswich River. North Reading is situated in the Greater Boston Area, which has excellent rail, air, and highway facilities.

During development of its risk assessment, the planning team established the hazard categories listed in Table 20. Based on the Hazard Ranking Index shown in Table 21, the planning committee determined the hazards of concern as illustrated in Table 22.

Risk estimations for dollar losses are based on Hazus analysis for some of the hazards of concern (see section 6, beginning page 6-6 of the Pre-Disaster Mitigation Plan, North Reading, 2012). Based on additional Hazus analysis, the planning committee identified the potential losses for the planning region shown in Table 23 and Table 24 (Section 7 of the 2012 North Reading HMP).

The capabilities of the jurisdiction are comparable to those in the surrounding area. The plan does speak of a Wastewater and Stormwater Advisory Committee, which has been active with respect to planning purposes. The Committee has "identified and prioritized the areas of Town that represent the greatest need for alternative wastewater disposal options, evaluated two parcels capable of serving as subsurface disposal areas (the former Berry Rehabilitation Center and a property off Chestnut Street), quantified the volume of treated wastewater that could be discharged on those parcels, developed a preliminary wastewater collection and treatment scheme utilizing this information and started a public outreach program designed to provide information to the various stakeholders relative to the plan" North Reading HMP, 2012, p 8-3). The four goals as identified by the plan committee coincide with those goals identified by the Commonwealth.

TABLE 20.
NORTH READING HAZARD CATEGORIES

Flood – Related Hazards
- Beaver Dams
- Dam breaches
- Flood
- Heavy rainstorms and thunderstorms

Wind – Related Hazards
- Hurricanes
- Microburst
- Tornadoes

Winter – Related Hazards
- Ice jams
- Nor'easter and Blizzards
- Snow events

Fire – Related Hazards
- Drought
- Wildfire

Geologic – Related Hazards
- Earthquake
- Landslide

Other Potential Hazards
- Extreme cold
- Extreme heat and heat wave
- Technological/man-made disasters/accidents *
  - Critical infrastructure threats, terrorism, criminal acts
  - Oil, chemical, bio-hazards spills and accidents
  - Building fires

* Not covered under this PDM Plan

TABLE 21.
NORTH READING HAZARD RANKING INDEX

Impact ⇨ / Frequency of occurrence ⇩	Catastrophic	Critical	Limited	Negligible
Highly likely	5 (Highest)	4 (High)	4 (High)	3 (Moderate)
Likely	5 (Highest)	4 (High)	3 (Moderate)	2 (Low)
Possible	4 (High)	3 (Moderate)	2 (Low)	2 (Low)
Unlikely	3 (Moderate)	2 (Low)	1 (Lowest)	1 (Lowest)
Highly unlikely	2 (Low)	1 (Lowest)	1 (Lowest)	1 (Lowest)

Hazard Index Scale: 1-5, with 5 indicating the highest priority for considering mitigation measures and 1indicating the lowest priority. (Highest, High, Moderate, Low, Lowest)

TABLE 22.
NORTH READING HAZARD RISK LEVEL

Hazard	Level of Risk
Flood Related	High
Beaver Dams	**Very Low**
Dam breaches	**Low**
Heavy rainstorms & thunderstorms	**Moderate**
Wind Related	Moderate
Hurricanes	**Moderate**
Microburst	**Very Low**
Tornado	**Very Low**
Winter Related	High
Ice Jams	**Low**
Nor'easter and Blizzard	**High**
Snow Events	**High**
Fire Related	Very Low
Drought	**Very Low**
Wildfire	**Very Low**
Geologic Related	Low
Earthquake	**Low**
Landslide	**Very Low**
Other Potential Hazards	Low
Extreme Cold	**Moderate**
Extreme Heat	**Very Low**
Technological & Man made disasters/accidents	**Very Low**

TABLE 23.
NORTH READING ESTIMATED BUILDING LOSSES FROM A 100-YEAR FLOOD EVENT

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss						
	Building	0.10	0.01	0.00	0.00	0.11
	Content	0.05	0.03	0.01	0.02	0.11
	Inventory	0.00	0.00	0.00	0.00	0.00
	Subtotal	**0.15**	**0.04**	**0.01**	**0.03**	**0.22**
Business Interruption						
	Income	0.00	0.07	0.00	0.04	0.11
	Relocation	0.00	0.00	0.00	0.00	0.00
	Rental Income	0.00	0.00	0.00	0.00	0.00
	Wage	0.00	0.06	0.00	0.10	0.16
	Subtotal	**0.00**	**0.13**	**0.00**	**0.14**	**0.26**
ALL	**Total**	**0.15**	**0.17**	**0.01**	**0.17**	**0.49**

TABLE 24.
NORTH READING ESTIMATED ANNUAL BUILDING LOSSES FROM A 100-YEAR HURRICANE

Category	Area	Residential	Commercial	Industrial	Others	Total
Property Damage						
	Building	12,869.28	994.30	206.45	67.14	14,137.17
	Content	2,508.89	337.17	123.73	22.17	2,991.95
	Inventory	0.00	14.20	20.60	1.02	35.83
	Subtotal	**15,378.17**	**1,345.66**	**350.78**	**90.33**	**17,164.95**
Business Interruption Loss						
	Income	0.00	86.27	2.73	4.61	93.62
	Relocation	964.39	156.37	21.78	12.13	1,154.65
	Rental	362.98	63.57	2.86	0.59	430.00
	Wage	0.00	88.26	4.55	31.99	124.80
	Subtotal	**1,327.37**	**394.48**	**31.90**	**49.32**	**1,803.07**
Total	**Total**	**16,705.54**	**1,740.14**	**382.68**	**139.66**	**18,968.02**

South West MAPC 5

Franklin (Norfolk County)

Franklin belongs to the Southwest Subregion of the Metropolitan Area Planning Council. The Town of Franklin is a suburban industrial community on the watershed between the Charles and the Blackstone Rivers. It is one of the highest elevated towns in Norfolk County. Franklin is located in southeastern Massachusetts and bordered by Norfolk and Wrentham on the east and south, Bellingham on the west, and Medway on the north. Franklin is about 26 miles southeast of Worcester; 28 miles southwest of Boston; 26 miles north of Providence, Rhode Island. Franklin is situated in the Greater Boston Area.

Review of this local plan indicates a summary of hazards identified in Table 25. The evaluation considered the frequency of the hazard, historical records and variations in land use. This analysis used the same vulnerability assessment methodology used in the Commonwealth of Massachusetts' 2004 State Hazard Mitigation Plan. These risks were reviewed with the Local Committee, and the local officials concurred that flooding and brush fires were the primary hazards facing the town.

TABLE 25.
FRANKLIN HAZARD RANKING

Hazard	Frequency in State	Severity in State	Issue in Franklin
Flood	High	Serious to extensive	Same as state
Dam Failure	Low	Extensive	Same as state
Hurricanes	Medium	Extensive to catastrophic	Same as state
Severe Storms (wind, hail, lightning)	Medium	Serious	Same as state
Tornadoes	Medium	Extensive to catastrophic	Same as state
Winter Storms	High	Serious	Same as state
Earthquakes	Low	Catastrophic	Same as state
Landslides	Low	Minor	Not a major issue in Franklin
Brush Fires	Medium	Serious	Same as state

Definitions Used in the Commonwealth of Massachusetts State Hazard Mitigation Plan

Frequency
- Very Low Frequency: Events that occur less frequently than once in 1,000 years (less than 0.1% per year).
- Low Frequency: Events that occur from once in 100 years to once in 1,000 years (0.1% to 1% per year).
- Medium Frequency: Events that occur from once in 10 years to once in 100 years (1% to 10% per year).
- High Frequency: Events that occur more frequently than once in 10 years (greater than 10% per year).

At the time of this plan, the Town had three repetitive loss properties, all three (3) single family residences totally seven loses between 1979 and 2005. During the 2013 update of the Commonwealth's HMP, State review of the 2012 statistics now indicate five (5) repetitive loss properties.

The plan does utilize the Hazus hurricane module at a Level 1, for a Category 3 and 4 storm events. The risk assessment did not use Hazus to estimate flood damages due to technical difficulties with the software and un-reliability of certain modules. However, the planning commission did attempt to demonstrate some losses by melding a combination of Hazus identified buildings and the location within the floodplain for a particular storm. Based on the analysis, the range of estimates for flood damages was $~132,000 to ~$4,296,000.

Table 26 demonstrates losses. It should be noted that at the time of writing of the plan, the area had never been impacted by a Category 4 or 5 hurricane.

The risk assessment did not use Hazus to estimate flood damages due to technical difficulties with the software and un-reliability of certain modules. However, the planning commission did attempt to demonstrate some losses by melding a combination of Hazus identified buildings and the location within the floodplain for a particular storm. Based on the analysis, the range of estimates for flood damages was $~132,000 to ~$4,296,000.

TABLE 26.
FRANKLIN ESTIMATED LOSSES FROM HURRICANES

	Category 3	Category 4
Building Characteristics		
Estimated total number of buildings	8,739	8,739
Estimated total building replacement value (Year 2002 $) (Millions of Dollars)	$2,888	$2,888
Building Damages		
# of buildings sustaining minor damage	1,196	2,466
# of buildings sustaining moderate damage	174	683
# of buildings sustaining severe damage	7	72
# of buildings destroyed	4	45
Population Needs		
# of households displaced	33	147
# of people seeking public shelter	7	30
Debris		
Building debris generated (tons)	3,991	11,775
Tree debris generated (tons)	10,791	28,827
# of truckloads to clear building debris	160	470
Value of Damages		
Total property damage	$29,135,350	$103,145,520
Total losses due to business interruption	$3,323,080	$13,311,860

Milford (Worcester County)

Review included the March 2009 Town of Milford LHMP. The Town of Milford is located in east central Massachusetts, bordered by Upton on the west; Hopkinton on the north; Holliston, Medway, and Bellingham on the east; and Hopedale on the south. Milford is 18 miles southeast of Worcester; 30 miles southwest of Boston; and 32 miles north of Providence, Rhode Island. Land use statistics from the plan are based on 1999 data.

Hazards of concern within the town are indicated in Similar to the Town of Franklin, the risk assessment did not use Hazus to estimate flood damages due to technical difficulties with the software and un-reliability of certain modules. However, the planning commission did attempt to demonstrate some losses by melding a combination of Hazus identified buildings and the location within the floodplain for a particular storm. In addition, the planning committee met with the town engineer and was able to obtain a more accurate count of the number of structures in the floodplain within the hazard area. Based on the analysis, the range of estimates for flood damages was $~1,066,464 to ~$27,493,495.

Table 27 Similar to the Town of Franklin process, the risks were based on the Commonwealth's 2004 HMP. Flooding was the most prevalent serious natural hazard identified by local officials in Milford, with hurricanes, nor'easters, severe rainstorms and thunderstorms being attributing factors. The existing plan for the Town of Milford identifies no repetitive loss properties, yet review of 2012 data utilized for the 2013 update to the State's HMP indicates the Town of Milford now has one repetitive loss.

The town identified 50 critical facilities within its boundaries being susceptible to the various hazards.

The plan does utilize the Hazus hurricane module at a Level 1, for a Category 3 and 4 storm events. Table 28 demonstrates losses. It should be noted that at the time of writing of the plan, the area had never been impacted by a Category 4 or 5 hurricane.

Similar to the Town of Franklin, the risk assessment did not use Hazus to estimate flood damages due to technical difficulties with the software and un-reliability of certain modules. However, the planning commission did attempt to demonstrate some losses by melding a combination of Hazus identified buildings and the location within the floodplain for a particular storm. In addition, the planning committee met with the town engineer and was able to obtain a more accurate count of the number of structures in the floodplain within the hazard area. Based on the analysis, the range of estimates for flood damages was $~1,066,464 to ~$27,493,495.

TABLE 27.
MILFORD HAZARD RANKING

Hazard	Frequency in State	Severity in State	Issues in Milford
Flood	High	Serious to extensive	Same as state
Dam Failure	Low	Extensive	Same as state
Hurricanes	Medium	Extensive to catastrophic	Same as state
Severe Storms (wind, hail, lightning)	Medium	Serious	Same as state
Tornadoes	Medium	Extensive to catastrophic	Same as state
Winter Storms	High	Serious	Same as state
Earthquakes	Low	Catastrophic	Same as state
Landslides	Low	Minor	Not a major issue in Milford
Brush Fires	Medium	Serious	A number of areas in Milford are prone to frequent brush fires; concerns about residential damages

TABLE 28.
MILFORD ESTIMATED LOSSES FROM HURRICANES

	Category 3	Category 4
Building Characteristics		
Estimated total number of buildings	7,940	7,940
Estimated total building replacement value (Year 2002 $) (Millions of Dollars)	$2,563	$2,563
Building Damages		
# of buildings sustaining minor damage	1,365	1,631
# of buildings sustaining moderate damage	261	358
# of buildings sustaining severe damage	15	25
# of buildings destroyed	7	11
Population Needs		
# of households displaced	73	102
# of people seeking public shelter	18	25
Debris		
Building debris generated (tons)	6,083	7809
Tree debris generated (tons)	6,590	8,128
# of truckloads to clear building debris	245	316
Value of Damages		
Total property damage	$37,947,340	$51,162,020
Total losses due to business interruption	$5,579,180	$8,036,340

Walpole (Norfolk County) 2008 LHMP Plan Review

The Town of Walpole is located 19 miles south of Boston and 26 miles north of Providence. As of the writing of the plan, the 2000 population was 22,824 people and there were 8,229 housing units. The plan indicates that much of "the critical infrastructure in the town is located in clusters, often near areas of floodplain. These facilities are therefore at higher risk during natural hazards, (Walpole, 2008, p. 10).

As indicated within the plan, the Town of Walpole is at a higher elevation than its neighboring communities; "nor is it impacted by as many bodies of water as its neighboring communities. However, the town still has a problem with water inundation during high rain and storm events and during the spring snowmelt season" (ibid).

Hazards of concern as determined by the planning committee are listed in Table 29. Based on analysis, Flooding and potential for brush fires were the most prevalent serious natural hazards identified by local officials in Walpole. Flooding is caused by hurricanes, nor'easters, severe rainstorms and thunderstorms. At the time of the writing of the LHMP, there were no repetitive flood losses within the Town, and review of the 2012 data for the 2013 State Hazard Mitigation Plan indicates that that information remains valid.

In order to determine damages from hurricanes, the Hazus-MH hurricane module was used. For the purposes of the plan, Category 3 (Hurricane Gloria 1985) and a Category 4 (Hurricane Donna 1960) storms were chosen to illustrate damages. The results of that analysis are shown in Table 30. Of note,

while the methodology indicates Category 3, the table illustrates a Category 2 event, so it is uncertain what storm event was actually utilized in determining damages.

The Town's risk assessment also used Hazus for determining loss estimations for the earthquake hazard. For the purposes of this plan two earthquakes were selected: an 1847 earthquake with a magnitude of 5.0 and an 1817 earthquake with a magnitude of 5.7. The results are demonstrated in Table 31.

Estimating flood damages did not include the use of Hazus: "MAPC did not use Hazus-MH to estimate flood damages in Walpole. In addition to technical difficulties with the software, the riverine module is not a reliable indicator of flooding in areas where inadequate drainage systems, beaver activity, and increased impervious surfaces contribute to flooding even in areas outside of mapped flood zones. In lieu of using Hazus, MAPC developed a methodology to give a rough approximation of flood damages" (2008, p. 32). Based on the analysis conducted (similar to those described within the Town of Franklin and Milford), loss estimates for flood damages ranged from $9,857,445 to $49,287,227. These calculations were not based solely on location within the floodplain or a particular type of storm (i.e. 100 year flood). Review of the LHMP reveals that while "the flood zones have not been properly studied as a system, town officials believe that many of the town's more frequent flooding problems are related to insufficient or inoperable flood management structures, such as culverts, dams and drain pipes that are not large enough to quickly transport flood waters away from town streets and neighborhoods and toward the nearby wetlands" Walpole, 2008, p. 38). The LHMP does identify a number of mitigation strategies to assist in management and mitigation of these issues. Those strategies are incorporated in the State's overall strategy review discussed previously in this section.

TABLE 29.
WALPOLE HAZARDS OF CONCERN

Hazard	Frequency in State	Severity in State	Issues in Walpole
Flood	High	Serious to extensive	Same as state
Dam Failure	Low	Extensive	Same as state
Hurricanes	Medium	Extensive to catastrophic	Same as state
Severe Storms (wind, hail, lightning)	Medium	Serious	Same as state
Tornadoes	Medium	Extensive to catastrophic	Not a major issue in Walpole
Winter Storms	High	Serious	Same as state
Earthquakes	Low	Catastrophic	Not a major issue in Walpole
Landslides	Low	Minor	Not a major issue in Walpole
Brush Fires	Medium	Serious	Not a major issue in Walpole

TABLE 29.
WALPOLE HAZARDS OF CONCERN

Hazard	Frequency in State	Severity in State	Issues in Walpole

Definitions Used in the Commonwealth of Massachusetts State Hazard Mitigation Plan

Frequency

- Very Low Frequency: Events that occur less frequently than once in 1,000 years (less than 0.1% per year).
- Low Frequency: Events that occur from once in 100 years to once in 1,000 years (0.1% to 1% per year).
- Medium Frequency: Events that occur from once in 10 years to once in 100 years (1% to 10% per year).
- High Frequency: Events that occur more frequently than once in 10 years (greater than 10% per year).

Severity

- Minor: Limited and scattered property damage; no damage to public infrastructure (roads, bridges, trains, airports, public parks, etc.); contained geographic area (i.e., 1 or 2 communities); essential services (utilities, hospitals, schools, etc.) not interrupted; no injuries or fatalities.
- Serious: Scattered major property damage (more than 50% destroyed); some minor infrastructure damage; wider geographic area (several communities); essential services are briefly interrupted; some injuries and/or fatalities.
- Extensive: Consistent major property damage; major damage to public infrastructure (up to several days for repairs); essential services are interrupted from several hours to several days; many injuries and fatalities.
- Catastrophic: Property and public infrastructure destroyed; essential services stopped, thousands of injuries and fatalities.

TABLE 30.
WALPOLE ESTIMATED DAMAGE FROM HURRICANE

	Cat. 2	Cat 4*
Building Characteristics		
Estimated total buildings	7,168	
Estimated total building replacement value (Year 2002 $)	$2,479,234,000	
General Building Damage		
# of buildings sustaining minor damage	842	2,549
# of buildings sustaining moderate damage	117	1,070
# of buildings sustaining severe damage	5	216
# of buildings destroyed	2	141
Population Needs		
% of hospital beds available on day of event	0	0
# of households displaced	24	358
# of people seeking public shelter	4	71
Debris	15,159	58,172
Building debris generated (tons)	2,728	19,778
Tree debris generated (tons)	12,430	38,394
# of truckloads to clear building debris	109	795
Value of Damages (Thousands of dollars)		
Total property damage	$20,950.28	$209,395.40
Total business interruption loss	$2,055.91	$28,116.53

*No category 4 or 5 hurricanes have been recorded in New England. However, a Category 4 hurricane was included to help the communities understand the impacts of a hurricane beyond what has historically occurred in New England.

TABLE 31.
WALPOLE ESTIMATED DAMAGE FROM EARTHQUAKE

	Magnitude 5.0	Magnitude 5.7
Building Characteristics		
Estimated total number of buildings	7,168	
Estimated total building replacement value (Year 2002 $)	$2,479,234,000	
Building Damages		
# of buildings sustaining slight damage	89	445
# of buildings sustaining moderate damage	15	89
# of buildings sustaining extensive damage	1	10
# of buildings completely damaged	0	1
Population Needs		
# of households displaced	1	8
# of people seeking public shelter	0	1
Debris		
Building debris generated (tons)	0	0
# of truckloads to clear building debris	0	0
Value of Damages (Millions of dollars)		
Total property damage	$0.48	$2.14
Total losses due to business interruption	$11.19	$23.03

MONTACHUSETT REGIONAL PLANNING COMMISSION

This region consists of 22 towns and cities, has a total population of 228,005, and has a density of 337 persons per square mile. The largest communities are Fitchburg, Leominster and Gardner. Growth is defined as slowly increasing at about 6% between 1990 and 2000, less than the national average of 13.2%. New residential development is important and "Approval Not Required" is a major trend in residential development. Only 50 square miles of 100-year flood zone are in the region.

Review of the local planning efforts demonstrates varied methods of conducting risk assessment: the Town of Ashby provides limited dollar losses for the 100 year flood event only, and does not include content losses. The Town of Harvard utilizes Q3 Flood Zones within their risk assessment. The plan also includes the following statement when discussing dollar loss estimations: "These figures do not take into account monetary damages to property and personal property as well as Critical Infrastructure that are not buildings such as bridges and dams." Also, "At the recommendation of the Federal Insurance Administration, a 250-foot buffer was applied to the FEMA Q3 Flood Zones in determining whether structures are located within the Special Flood Hazard Area boundaries. If any part of the parcel, building or structure intersected this buffer, then it was considered to have the potential to be inside the flood zone."

Link to Hazard Mitigation Plan (Expires 5/29/14): *Not available on-line.*

Ashburnham
Ashby
Athol
Ayer
Clinton
Devens
Fitchburg
Gardner
Groton
Harvard
Hubbardston
Lancaster
Leominster
Lunenburg
Petersham
Phillipston
Royalston
Shirley
Sterling
Templeton
Townsend
Westminster
Winchendon

The Town of Clinton (Worcester County)—November 2008 LHMP

The Town of Clinton is located in North Central Massachusetts, bordered by Bolton and Berlin on the east, and Boylston on the south, Sterling on the west, and Lancaster on the northwest and north. Clinton is 13 miles north of Worcester, 16 miles south of Fitchburg, 35 miles west of Boston, and 200 miles from New York City.

Strategies for the town were developed throughout the planning process and ultimately prioritized based on those having a low to moderate cost to implement, due to the limited resources of the Town. The local action items "represent a multi-faceted approach to addressing natural hazards in the Town and will be undertaken as resources become available, and will be integrated into ongoing planning activities" (Clinton LHMP, 2008, p. 12). The planning team clearly understands the benefits of the intent behind mitigation planning, as it discusses how "mitigation planning will also lead to benefits that go beyond solely reducing the costs associated with hazard vulnerability. Measures such as the acquisition or regulation of land in known hazard areas can help achieve multiple community goals, such as preserving open space, maintaining environmental health and natural features, and enhancing recreational opportunities" (Clinton LHMP, 2008, p. 14). The planning partnership further discusses the "Good Common Sense" when it discusses the fact that as "responsible people, hazard mitigation should become common language and practice among regional and local officials. For example, regularly scheduled clean-ups of waterways, catch basins, and streets prevent water pollution and debris, and runoff into brooks and rivers—these actions can also prevent flooding during heavy rainfall" (ibid). Robust concepts such as this demonstrate a holistic approach to mitigation, fitting into FEMA's *whole community* concept of operation.

Review of the Town's risk assessment demonstrates additional hazards which were not included in other plans, specifically sewer back-up and sink holes. Table 32 demonstrates the hazard ranking matrix utilized, which also differs from those of other planning councils, but is well documented and organized. Critical facilities are identified for some of the hazards; however, limited dollar estimations are provided. The plan identifies one repetitive loss property; review of the 2013 State updated data indicates three RL properties.

TABLE 32.
CLINTON RISK MATRIX TABLE

Table 3 Hazard & Vulnerability Session Matrix Review Town of Clinton				
Natural Hazard **Natural Hazard Separated by Flood, Wind, Fire, Geologic and Ice & Snow Related Hazards**	**Likelihood of Occurrence** **3 = Highly Likely** **2 = Possible** **1 = Unlikely**	**Location** **3 = Large/Multi-Community** **2 = Medium/Regional** **1 = Small/Local**	**Impacts** **4 = Catastrophic** **3 = Critical** **2 = Limited** **1 = Negligible**	**Hazard Index** **Ranking Determined by Combining the Likelihood, Location and Impacts of a Natural Hazard**
Flood-Related Hazards: Dam Failures	2.00	3.00	4.00	**9.00**
Geologic Hazards: Earthquakes	2.00	3.00	4.00	**9.00**
Fire-Related Hazards: Drought	0.50	3.00	4.00	**7.50**
Ice & Snow Hazards: Snow Storms	3.00	2.00	2.50	**7.50**
Flood-Related Hazards: Thunderstorms	2.00	2.00	3.00	**7.00**
Flood-Related Hazards: Beavers	3.00	2.00	1.00	**6.00**
Flood-Related Hazards: Drainage	3.00	1.00	2.00	**6.00**
Flood-Related Hazards: Storm Water Run-off	3.00	1.00	2.00	**6.00**
Wind-Related Hazards: Hurricane	1.50	2.00	2.50	**6.00**
Fire-Related Hazards: Urban Fires	1.50	1.00	3.00	**5.50**
Flood-Related Hazards: Sewer Back-up	1.50	1.00	1.50	**4.00**
Wind-Related Hazards: Tornadoes	1.00	2.00	2.50	**5.50**
Flood-Related Hazards: Flooding	2.50	1.00	1.00	**4.50**
Fire-Related Hazards: Wildfires	1.00	1.00	1.50	**3.50**
Flood-Related Hazards: Erosion	1.00	1.00	1.00	**3.00**
Flood-Related Hazards: Land Slides	1.00	1.00	1.00	**3.00**
Ice & Snow Hazards: Ice Jams	1.00	1.00	1.00	**3.00**

Town of Townsend (Middlesex County) December 2008 LHMP Review:

Townsend is located in the extreme northwestern part of Middlesex County, in north central Massachusetts. It is the north of Worcester on the New Hampshire border. The Town is bordered by Ashby on the west, Mason and Brookline on the north, Pepperell, Gorton and Shirley on the east, and Lunenburg on the South. The town is located 42 miles northwest of Boston, 33 miles north of Worcester, and 210 miles from New York City.

Towsend lies almost entirely within the Nashua River Watershed, with over 85% of the town's land draining into the Squannacook River. There are approximately 206 acres of open water, with three water bodies ranging from 17 to 42 acres.

Concepts similar to those discussed for the Town of Clinton exist within this plan, demonstrating a holistic approach to mitigation, fitting into FEMA's *whole community* concept of operation.

The Town of Townsend identified similar hazards as other plans within this planning region, including storm sewer and sink holes, as identified in Table 33

Review of the plan identifies approximately 54 pieces of critical infrastructure have the potential to be affected by these flood hazards, with loss estimations "due to loss of all buildings in these flood zones is approximately $210,900,200 for the 100 Year Flood Zone and $259,989,800 for the 500 Year Flood Zone, which includes the 100 Year Flood Zone (source: Townsend Assessor's Office)" (Townsend LHMP, 2008, p. 25). While some other hazard profiles identify critical infrastructure at risk by number, no dollar loss estimations are provided.

Review of the goals and strategies of the jurisdiction demonstrate a close alignment with the Commonwealth's 2013 goals as identified. Strategies include structural and non-structural activities. STAPLEE is used as the method to prioritize strategies.

TABLE 33.
TOWNSEND HAZARD RANKING

Natural Hazard Natural Hazard Separated by Flood, Wind, Fire, Geologic and Ice & Snow Related Hazards	Likelihood of Occurrence 3 = Highly Likely 2 = Possible 1 = Unlikely	Location 3 = Large/ Multi-Community 2 = Medium/ Regional 1 = Small/Local	Impacts 4 = Catastrophic 3 = Critical 2 = Limited 1 = Negligible	Hazard Index Ranking Determined by Combining the Likelihood, Location and Impacts of a Natural Hazard
Flood-Related Hazards: Thunderstorms	3.00	3.00	3.00	9.00
Wind-Related Hazards: Hurricanes	2.00	3.00	3.50	8.50
Wind-Related Hazards: Tornadoes	2.00	3.00	3.50	8.50
Fire-Related Hazards: Wildfires	3.00	2.00	3.00	8.00
Ice & Snow Hazards: Snow Storms	3.00	2.00	3.00	8.00
Flood-Related Hazards: Beavers	3.00	1.00	3.00	7.00
Geologic Hazards: Earthquakes	2.00	2.00	3.00	7.00
Flood-Related Hazards: Flooding	2.00	1.00	3.00	6.00
Fire-Related Hazards: Urban Fires	2.00	1.00	3.00	6.00
Flood-Related Hazards: Dam Failures	2.00	1.00	2.00	5.00
Flood-Related Hazards: Drainage	2.00	1.00	2.00	5.00
Flood-Related Hazards: Stormwater Run-off	2.00	1.00	2.00	5.00
Fire-Related Hazards: Drought	2.00	1.00	2.00	5.00
Flood-Related Hazards: Erosion	1.00	1.00	1.00	3.00
Flood-Related Hazards: Land Slides	1.00	1.00	1.00	3.00
Flood-Related Hazards: Sewer Back-up	1.00	1.00	1.00	3.00
Geologic Hazards: Sink Holes	1.00	1.00	1.00	3.00
Ice & Snow Hazards: Ice Jams	1.00	1.00	1.00	3.00

NANTUCKET PLANNING & ECONOMIC DEVELOPMENT COMMISSION

No plan in place.

Town and County of Nantucket

This island community has a population of 10,142. While historically there has been a stable increase in population over the past 5 years, 2011 saw a decline in population of over 1,000, yet this is still a 6.5% increase from the 2000 population count. There are 226 people per square mile. Unlike most coastal communities in the US, residential development is not concentrated on the coastline, mainly due to conservation and current zoning. Large developments are low; most of the increases are seen in individual residential developments. Historically, there are approximately 100 new residential developments per year, including single and multi-unit development. Estimated 2020 population for Nantucket shows a 42% increase from 2011 levels.

Nantucket's hazard mitigation plan is currently expired, therefore, updated data concerning risk for this area may be obtained within the various risk profile data contained within Section 5—Risk Assessment. However, information concerning the goals, objectives, strategies and capabilities are captured from the expired plan.

NORTHERN MIDDLESEX COUNCIL OF GOVERNMENTS

Link to Hazard Mitigation Plan: *http://www.nmcog.org/2012%20PDM_June%2012.pdf Expired 9/8/11; Under MEMA Review 10/12.*

Town of Billerica
Town of Chelmsford
Town of Dracut
Town of Dunstable
City of Lowell
Town of Pepperell
Town of Tewksbury
Town of Tyngsborough
Town of Westford

The Greater Lowell region consists of the City of Lowell and its eight suburbs—Billerica, Chelmsford, Dracut, Dunstable, Pepperell, Tewksbury, Tyngsborough and Westford—and has a land area of approximately 196 square miles and an inland water area of 5.76 square miles. The City of Lowell serves as the central city and economic center of the region. According to the U.S. Census Bureau, the Greater Lowell region had a population of 286,901 in 2010, which represented an increase of 2.2% since 2000. This growth rate was one-third of what the region experienced between 1990 and 2000.

The City of Lowell accounts for the largest percent of the region's population and is the largest community and continues to have the highest population density, at over 7,325 persons per square mile. Billerica, Chelmsford, Dracut and Tewksbury, the early suburbanizing communities with population densities over 1,000 persons per square mile, collectively account for ~46% of the region's population. The remaining communities, where much of the development activity occurred during the 1990s, account for 17% of the region's population. In 2010, there were 296,000 households in the region. The total number of housing units in the region increased from 101,973 units in 2000 to 109,446 units in 2010, an increase of 7,473 units or 7.3%. The City of Lowell accounted for the largest share of housing units in the region, however, its percentage share of the total housing units in the region decreased slightly from 38.7% in 2000 to 37.9% in 2010. The number of vacant units in the region nearly doubled from 2.6% in 2000 to 5 % in 2010. In terms of housing unit density, the City of Lowell was the only community in 2010 that had more than 600 housing units per square mile at ~2,849 housing units, with the next highest community being Chelmsford at 593 housing units per square mile.

Figure 5. 2007 Flooding at the Lawrence Mill in Lowell

Notwithstanding the current housing slump, the number of households in the region is projected to increase from 104,022 in 2010 to 118,900 households in 2035, an increase of 14.3%. The principal areas of household growth will be in Dunstable (55.2%), Pepperell (38.2%), Tyngsborough (33.8%), Westford (25.8%), and Dracut (25.7%), as outlined in Table 10 below. The more developed communities, such as the City of Lowell (5.7%), Billerica (10.6%), Chelmsford (11.6%) and Tewksbury (15.8%), will experience more restrained household growth between 2010 and 2035.

The trend toward urbanization/suburbanization of the region has implications for natural hazard planning. As more land is developed, additional impervious surface is created, potentially increasing the flood risk and decreasing the area available for flood storage. As population and housing density increases, the potential for property damage and economic loss as a result of a natural disaster also increases.

According to the National Climatic Data Center, 53 flood events were reported in Middlesex County from January 1, 1950 and July 2010.

Billerica has more repetitive loss structures than any other community in the region. It ranks eleventh in the state in terms of National Flood Insurance Program repetitive flood loss properties. Fifty structures have experienced repetitive losses due to flooding.

In 2010, new FEMA floodplain maps were released for the communities located in the Northern Middlesex region. The updated Flood Insurance Rate Maps indicate a net increase of approximately 532 acres now determined to be located in the flood plain. The greatest increases are in the towns of Chelmsford, Lowell and Dunstable, as shown in Table 34.

No dollar losses were established for critical infrastructure within the planning document.

TABLE 34.
NORTHERN MIDDLESEX PERCENT CHANGE OF FLOODPLAIN AREA, 1979 – 2010

Community	Acres of floodplain as shown on 1979 FIRM maps	Acres of floodplain as shown on 2010 FIRM maps	Difference in acres (1979-2010 FIRM maps)	% Change 1979-2010	Total Land Area in Acres	% Land Area in Flood Plain (according to the 2010 FIRM maps)
Billerica	2,267.94	2,284.43	16.49	0.73	16,815.68	13.58
Chelmsford	1,947.67	2,076.28	128.61	6.60	14,749.89	14.08
Dracut	1,128.86	1,144.05	15.19	1.35	13,647.04	8.38
Dunstable	1,847.58	1,960.73	113.15	6.12	10,717.41	18.29
Lowell	1,226.20	1,285.33	59.13	4.82	9,299.48	13.82
Pepperell	1,470.85	1,518.10	47.25	3.21	14,846.93	10.23
Tewksbury	1,602.31	1,617.72	15.41	0.96	13,511.40	11.97
Tyngsborough	1,731.76	1,814.20	82.44	4.76	11,545.96	15.71
Westford	2,991.97	3,045.77	53.80	1.80	20,036.33	15.20
Regional Total	**16,215.14**	**16,746.61**	**531.47**	**3.28**	**125,170.10**	**13.38**

TABLE 35.
ASSESSED VALUE OF BUILDINGS IN THE 100 YEAR FLOOD PLAIN BY COMMUNITY WITHIN THE NORTHERN MIDDLESEX COUNCIL OF GOVERNMENTS PLANNING REGION:

	Number of Structures	Residential	Commercial	Industrial	Governmental /Institutional	Total Value
Billerica	321	$46,852,100	$5,771,300	$1,779,200	$3,682,400	$58,085,000
Chelmsford [1]	400	50,197,574	8,959,400	8,307,900	1,191,600	89,301,774
Dracut	68	9,811,200	3,342,900	8,092,700	100,000	21,346,800
Dunstable	28	5,230,900	0	0	0	5,230,900
Lowell	451	113,199,600	16,304,900	9,084,500	8,744,800	147,333,800
Pepperell	30	4,082,885	187,600	81,100	87,900	4,439,485
Tewksbury	246	26,027,600	5,211,200	1,837,200	810,400	33,886,400
Tyngsborough	111	16,852,800	7,466,800	383,400	221,200	24,924,200
Westford	113	20,645,300	5,883,100	9,366,600	0	50,733,300
Total	1788	$292,899,959	$53,127,200	$38,932,600	$14,838,300	$435,281,659 [2]

[1]Includes 118 Condo units, representing $28,506,204 in the Williamsburg Condominium Complex
[2]Based on assessed value of structures and adjusted for condo units when majority of building is out of the flood zone.

TABLE 36.
ESTIMATED CONTENTS REPLACEMENT COSTS FOR BUILDINGS IN THE NORTHERN MIDDLESEX 100-YEAR FLOODPLAIN

Community	Residential Contents Value	Commercial Contents Value	Industrial Contents Value	Governmental/ Institutional Contents Value	Total Contents Value
Billerica	$23,426,050	$5,771,300	$2,224,400	$3,682,400	$35,104,150.00
Chelmsford[1]	25,098,787	8,959,400	10,384,875	1,191,600	45,634,662
Dracut	4,905,600	3,342,900	10,115,875	100,000	18,464,375
Dunstable	2,615,450	0	0	0	2,615,450
Lowell	56,599,800	16,304,900	11,355,635	8,744,800	93,005,135
Pepperell	2,041,279	187,600	101,375	87,900	2,418,154
Tewksbury	13,013,800	5,211,200	2,296,500	810,400	21,331,900
Tyngsborough	8,426,400	7,466,800	479,250	221,200	16,593,650
Westford	10,322,650	5,883,100	11,708,250	0	27,914,000
Total	$146,449,816	$53,127,200	$48,666,160	$14,838,300	$263,081,476.00

Source: Local Assessor records, FIRM maps, contents value calculations utilize HAZUS methodology.

TABLE 37.
NORTHERN MIDDLESEX HAZARDS OF CONCERN

HAZARD	FREQUENCY				SEVERITY				AREA OF IMPACT			AREA OF OCCURRENCE		
	VERY LOW	LOW	MODERATE	HIGH	MINOR	SERIOUS	EXTENSIVE	CATASTRO-PHIC	ISOLATED	LOCAL/ MUNICIPAL	REGIONAL	ISOLATED	LOCAL/ MUNICIPAL	REGIONAL
FLOOD				X		X				X	X		X	X
DAM FAILURE	X					X				X			X	
HURRICANE			X			X					X			X
TORNADO			X				X			X	X		X	X
THUNDERSTORM				X	X						X			X
NOR'EASTER				X			X				X			X
SNOWSTORM/ BLIZZARD				X		X					X			X
ICE STORM			X			X					X			X
ICE JAM	X				X				X	X			X	
DROUGHT		X			X						X			X
WILDFIRE			X			X				X			X	
EARTHQUAKE		X				X					X			X
LANDSLIDES	X				X				X	X		X	X	
CLIMATE CHANGE			X				X				X			X

KEY:

FREQUENCY:

Very Low:	Occurs less frequently than once in 100 years
Low:	Occurs from once in 50 years to once in 100 years
Moderate:	Occurs from once in 5 years to once in 50 years
High:	Occurs more frequently than once in 5 years

SEVERITY:

Minor:	Limited and scattered property and infrastructure damage; essential services not interrupted
Serious:	Scattered major public and private property and infrastructure damage, brief service interruptions, injuries and deaths possible
Extensive:	Widespread major public and private property and infrastructure damage with long term public service interruptions, many injuries and fatalities probable
Catastrophic:	Destruction of private and public property and infrastructure with numerous deaths and injuries

AREA OF IMPACT:

Isolated:	Impact will only be realized in a small area within a local jurisdiction or parts of one of more local jurisdictions
Local municipal:	Impact will only be realized within a local jurisdiction or parts of one of more local jurisdictions
Regional:	Impact will be realized within two or more local jurisdictions on a more widespread basis

AREA OF OCCURRENCE:

Isolated:	Impact will only be realized in a small area within a local jurisdiction or parts of one of more local jurisdictions
Local municipal:	Impact will only be realized within a local jurisdiction or parts of one of more local jurisdictions
Regional:	Impact will be realized within two or more local jurisdictions on a more widespread basis

OLD COLONY PLANNING COUNCIL

This plan covers the 344 square mile Old Colony Planning Council region in Southeastern Massachusetts. The Old Colony region is comprised of the City of Brockton and 14 towns: Abington, Avon, Bridgewater, East Bridgewater, Easton, Halifax, Hanson, Kingston, Pembroke, Plymouth, Plympton, Stoughton, West Bridgewater and Whitman. The City of Brockton and the Town of Plymouth serve as the anchor of the northern and southern part of the region respectively. All fifteen communities are participants in the current 2012 hazard mitigation plan. The fifteen communities run northwest to southeast from Brockton and Stoughton along Route 24 in the northwestern part of the region down to Plymouth and Kingston along Route 3 and the Atlantic Ocean in the southeastern part of the region. The region is situated south of the metropolitan concentration of activity and population around Boston and Cambridge, but is oriented towards that center and largely cuts across the north-south transportation lines between Greater Boston and the rest of Southeastern Massachusetts. The Old Colony region's terrain consists of generally low and gently rolling glaciated land with many drumlins, eskers and other glacial features, as well as a generally north-south drainage system and extensive wetlands including the Hockmock Swamp in parts of Bridgewater, Easton and West Bridgewater and the Great Cedar Swamp in Halifax and Hanson.

Link to Hazard Mitigation Plan (Expired 8/23/11): *http://www.ocpcrpa.org/docs/comprehensive/Draft_Old_Colony_Hazard_Mitigation_Plan.pdf Draft Plan Dated 9/12/2012.*

Abington
Avon
Bridgewater
Brockton
Duxbury
East Bridgewater
Easton
Halifax
Hanson
Kingston
Pembroke
Plymouth
Plympton
Stoughton
West Bridgewater
Whitman

According to the 2010 U.S. Census Bureau, the Old Colony region had a population of 333,468 in 2010, which represented an increase of 3.7% since 2000. The rate of growth was one-third of what the region experienced between 1990 and 2000.

The region is located in the southeastern section of Massachusetts, with its eastern-most communities located along the Atlantic Ocean. The City of Brockton is located 20 miles south of the City of Boston, 24 miles northeast of the Town of Plymouth and 30 miles east of Providence, Rhode Island and the Town of Plymouth is located 24 miles southeast of Brockton, 37 miles southeast of Boston and 44 miles east of Providence, Rhode Island.

The region's 15 communities can be categorized into three groups:

- Greater Brockton (Abington, Avon, Bridgewater, Brockton, East Bridgewater, Easton, Stoughton, West Bridgewater, and Whitman). This relatively developed area has many streams, scattered, often man-made ponds, and commonly tight glacial soils. While the extensive drainage system has many streams, none are very large because the communities are close to the headwaters of the several basins. Though the streams are small, some segments are confined to narrow walled channels to allow or protect nearby buildings. This leaves no room for safe flooding and informal flood storage. Thus streams can overflow during storms into nearby developed areas. The area also has many sections with relatively tight soils limiting on-site disposal opportunities and groundwater yields.
- The Lake Communities (Hanson, Halifax, Pembroke, and Plympton). The Lake region has a range of tight wetlands soils and porous areas of sand and gravel, with many lakes and ponds and fewer major streams.

- The South Coastal Area (Kingston and Plymouth). The South Coastal area of the region has typically porous sandy soils and many ponds. It supports very few streams of any size since the coarse soils and irregular terrain absorb much rainfall before it can run off. Instead, the major surface waters consist of the frequent ponds and lakes, many of them consisting of exposed groundwater.

Residential growth is estimated to occur at a fast rate in the less populated communities in the region. There has been recent growth in commercial and retail development in the region. Though most is not in or near the floodplain, there are some developments in or near the scrub oak and pitch pine forest, which could increases wildfire risk.

Currently the City of Brockton accounts for approximately 28% of the region's population and continues to have the region's highest population density as well, with approximately 4,356 persons per square mile. Brockton, along with Abington, Stoughton and Whitman, the three other early urbanizing communities with population densities over 1,000 persons per square mile, collectively account for 45% of the region's population. While the population density is highest in the northern part of the region, the past decade has seen much of the region's growth occur in the southeastern half of the region, where many communities grew by over 6 percent. Communities in the northwestern half experienced substantially less growth during this same time period. Areas in the southeastern half of the region generally have had more available developable land, where a substantial amount of subdivisions and low-density, large-lot development has occurred.

The total number of housing units in the region increased from 118,300 in 2000 to 128,081 units in 2010, an increase of 9,781 units or 8.7%. The City of Brockton accounted for the largest share of housing units in the region, however, its percentage share of the total housing units in the region decreased slightly from 29.5% in 2000 to 27.8% in 2010. In 2010, 6.7% of the total housing units were vacant in the region, with Plymouth having the highest rate of vacant units at 14.2%. In terms of housing unit density, the communities of Abington, Brockton, Stoughton and Whitman were the only communities in 2010 that had more than 600 housing units per square mile.

Between 2010 and 2035, each community in the region is expected to increase in population, but none more so than the towns of Plympton and Plymouth, whose population is expected to increase 37.45% and 25.84% respectively. For those communities that are much more developed, such as Avon, Brockton, Stoughton and Whitman, less dramatic population growth is expected to occur in the next twenty-five years. Overall, the rate of growth rates for the remaining communities range between 5.61% (Brockton) to 23.19% (Hanson).

The number of housing units in the region is expected to increase from 119,437 in 2010 to 138,700 in 2035, an increase of 16.1%. The principal areas of household growth will be in Plympton (50.3%), Hanson (32.5%) and Plymouth (26.3%). The more developed communities of Avon (4.9%), Brockton (6.5%) and Whitman (9.2%) will experience more restrained household growth between 2010 and 2035.

Based on review of the hazards of concern addressed within the profiles and risk assessment portions of the Regional Hazard Mitigation Plan, flood is the number one hazard of concern, with five (5) of the seven hazards occurring within the planning region during the time period 2001-2011 resulting in FEMA disaster declarations.

Review of analysis conducted by the Commonwealth demonstrates that Plymouth County filed 9,677 NFIP claims, with sums of dollars expended reaching in excess of $115 million (losses and premiums paid).

PIONEER VALLEY PLANNING COMMISSION

This region consists of 43 towns and cities, has a total population of 608,000, and has a density of 506 persons per square mile. Growth is defined as being fairly stable with minor urban sprawl around Springfield, Northampton, and Westfield in the form of residential development. The Pioneer Valley is experiencing a unique form of growth called "sprawl without population growth," due to a variety of factors. Undeveloped farmland conversion rose at a rate of 48%, but this rate of development is not sustainable due to the nearly stable population in the region.

Hampden County is the most populous county in western Massachusetts. It has a strong industrial and commercial employment base. Hampden County's largest city, Springfield, is the third largest community in the Commonwealth. The County is called "the Crossroads of New England" and features rail service in all directions, as well as several exchanges of the Massachusetts Turnpike and I-91. The leading employers in the County include the following: Baystate Health, Big Y Supermarkets, Friendly Ice Cream Corp., Hasbro Games, Holyoke Community College, Holyoke Medical Center, Mass Mutual Financial Group, Mercy Medical Center, Monson Development Center, and Springfield Technical Community College.

Hampshire County is bisected by the Connecticut River and is located in the middle of western Massachusetts. The County has a mix of rural and urban areas and is becoming a popular residential and recreational area. Hampshire County contains several state parks and the Quabbin Reservoir, a man-made reservoir that serves Boston. I-91 is the County's primary highway and has an extensive network of public bus service links. Passenger rail service via Amtrak is available in Northampton. There are two general hospitals and one veteran's hospital. The County also contains several state parks and forests. The leading employers in the County include the following: Amherst College, Berry Tubed Products, C&S Wholesale Grocers, Inc., Cooley Dickinson Hospital, Delivery Express, Hampshire College, InteliCoat Technologies, Mount Holyoke College, Smith College, and the University of Massachusetts.

Hazard Mitigation Plan: *(Multiple Single Jurisdiction Plans Expiration ranging from 2/14/13 to 3/5/17).*

Agawam
Amherst
Belchertown
Blandford
Brimfield
Chester
Chesterfield
Chicopee
Cummington
East Longmeadow
Easthampton
Goshen
Granby
Granville
Hadley
Hampden
Hatfield
Holland
Holyoke
Huntington
Longmeadow
Ludlow
Middlefield
Monson
Montgomery
Northampton
Palmer
Pelham
Plainfield
Russell
South Hadley
Southampton
Southwick
Springfield
Tolland
Wales
Ware
West Springfield
Westfield
Westhampton
Wilbraham
Williamsburg
Worthington

West Springfield LHMP Review

The West Springfield LHMP was adopted on December 20, 2010. West Springfield in Western Massachusetts' is a diverse community with both suburban and rural qualities, and a historic downtown. The town is comprised of over 17 square miles, located on the western bank of the Connecticut River. West Springfield is bordered by Holyoke to the north, and Chicopee and Springfield to the east. Westfield lies to West Springfield's west, and Agawam to the south. Zoning is the primary land use tool that the town uses to manage development and direct growth to suitable and desired areas while also protecting critical resources and ensuring that development is in keeping with the town's character. While relying primarily on zoning as the tool to mitigate potential impacts to disaster incidents, the town also has four districts which are specifically relevant to natural hazard mitigation: the River

Protection District, Water Supply Protection District, Flood Hazard District, and Age Restricted Housing District. Each of these promotes sustainability and incorporates mitigation into the intent behind the intended purpose to the district. More information on these specific districts can be obtained within the 2010 West Springfield LHMP, beginning at page 7.

Table 38 identifies the hazard ranking index as established by the planning committee during the 2010 plan update process.

TABLE 38.
WEST SPRINGFIELD HAZARDS OF CONCERN

Type of Hazard	Location	Extent	Previous Occurrences	Probability of Future Events	Hazard Risk Index Rating
Flooding (100-year)	Large	Catastrophic	Yes	Very Low	5
Flooding (localized)	Medium	Limited	Yes	Very High	1
Severe Snow/Ice Storms	Large	Minor	Yes	Very High	5
Hurricanes/Severe Wind	Medium	Limited	Yes	Low	3
Tornado/Microburst	Small	Catastrophic	Yes	Low	3
Wildfire/Brushfire	Medium	Limited	Yes	Low	3
Earthquake	Large	Catastrophic	No	Very Low	5
Dam Failure	Small	Minor	Yes	Low	4
Drought	Small	Minor	No	Very Low	5
Man-Made Hazard: Hazardous Materials	Large	Critical	Yes	Low	3

Data utilized to determine dollar losses were based on Community Information System (CIS) of FEMA, and is based on 2005 data. Vulnerability for a 100-year flood event was estimated at approximately $1.7 million of damages, with 22 individuals impacted. The plan indicates that at the time of the update, there were no repetitive loss properties identified. Review of the 2013 data utilized to update the Commonwealth's HMP confirms this information to be accurate for data collected within Hampden County through December 31, 2012. The plan identifies Hurricanes and Severe Wind to be a low risk, but indicates that all of West Springfield is at risk. Loss estimations were also provided for hurricane wind damage, but the methodology used to determine those figures is unclear. The plan identifies critical facilities, but states that "all critical facilities fall into the hazard area" as the hazards identified in the plan are regional risks (Springfield, 2010, p. 25).

Mitigation strategies remain consistent with the remaining planning area, as do the goals and capabilities assessment. That information is captured in the overall general data for the State's review previously contained in this section.

Town of Palmer LHMP Review:

Palmer reviewed involved the LHMP adopted December 2010. The Town of Palmer is located in eastern Hampden County in Western Massachusetts, where the confluence of the Ware, Quaboag, and Swift Rivers form the headwaters of the Chicopee River. Palmer is made up of four villages: Bondsville, Depot Village (or Palmer Center), Thorndike, and Three Rivers. It has a total land area of just over 32 square miles, and is bordered by Monson to the south, Wilbraham and Ludlow to the west, Belchertown and Ware to the north, and Warren and Brimfield to the east. Palmer lies seventeen miles from downtown Springfield, and seventy-three miles from the metropolitan center of Boston.

Palmer spans the Ware, Quaboag, and Swift River Valleys from the Wilbraham Hills in the west, to the Warren and Brimfield mountains in the east. With these major river courses and multiple hills, the Town's landscape is very irregular. The valley plains along the riverbanks are the most populated areas for industry and commercial activity as well as residential living. At the time of the writing of the 2010 plan, the "vast majority (68%) of the total acreage of Palmer is undeveloped forestland, at approximately 14,260 acres" (Palmer, 2010, p. 6). The 2010 plan identifies that "the vast majority of Palmer's 32.7 square miles is undeveloped land, totaling close to 14,260 acres. Residential land is the second most prolific land use, at approximately 3,110 acres, followed by agricultural land at approximately 1,295 acres. Land used for industry constitutes a relatively large 470 acres, with commercial use occupying just 142 acres. Land characterized as urban open/public land constitutes 243 acres, and there are 111 acres of outdoor recreational land throughout Town. Water in the town of Palmer comprises over 470 acres" (ibid).

Table 39 shows the hazard profiling and risk index worksheet.

TABLE 39.
PALMER HAZARD PROFILING AND RISK INDEX WORKSHEET

Type of Hazard	Previous Occurrences	Location of Occurrence	Extent of Impacts (Damage)	Probability of Future Events	Hazard Risk Index Rating
Flooding (100-year)	Yes	Large	Critical	Low	3
Flooding (localized)	Yes	Medium	Critical	Very High	1
Severe Snow/Ice Storms	Yes (minimal)	Large	Limited	Very High	2
Hurricanes/Severe Wind	Yes	Large	Critical	Very Low	4
Tornado/Microburst	Micrburst only	Small	Catastrophic	Low	4
Wildfire/Brushfire	Yes	Medium	Limited	Moderate	3
Earthquake	No	Large	Catastrophic	Low	4
Dam Failure	Yes	Large	Catastrophi	Very Low	5
Drought	No	Small	Minor	Very Low	5
Man-Made Hazard: Hazardous Materials	No	Medium	Minor	Low	3

Loss estimates are based on 2006 total value of all structures and median home value, with an average household size of 2.4 persons/household. Loss estimates are based on exposure analysis, "assuming 100% damage to 100% of the structures" within the hazard area (ibid, p. 13). No Hazus analysis was conducted. Flood is rated at high risk for the planning area, while severe snow/ice storms are rated as medium-high risk. Along with the natural hazards, the town also identifies hazardous materials at medium risk as there

are 21 facilities within Palmer, 17 of which are Tier II facilities. The plan references no repetitive loss properties; review of the 2013 State plan update data does not reveal any RL properties within the township.

The plan identifies a well-established list of critical facilities, including what are referred to as "Category 3—Facilities/Populations to Protect," which focuses on special needs populations, elderly and assisted living areas, among others (ibid, p. 35).

Goals remain consistent with those of the state; capabilities are also consistent with other local and state initiatives. One of the action items identified by the town is the establishment of an Emergency Operations Center, and to equip the Community Emergency Response Team response trailer. The town also has zoning ordinances in place to help reduce impervious surfaces, allowing more groundwater infiltration (p. 42).

Town of Brimfield LHMP Review

Review for this analysis stems from the January 31, 2011 Brimfield LHMP. Brimfield is a small, rural town located in the southeastern corner of Hampden County in western Massachusetts. Comprised of five villages—Brimfield Center, East and West Brimfield, Fentonville, and Dingley Dell—it has managed to remain a rural, residential community of approximately 3,400 residents. Native woodlands are the principle vegetation type in Brimfield. Woodlands cover 17,803 acres of Brimfield, approximately 80 percent of the Town's land area. As of the writing of the plan, the community was "home to approximately 3,400 residents. The majority of Brimfield's 22,588 acres is undeveloped land, totaling nearly 18,569 acres. Residential land totaling 1,601 acres and agricultural land totaling 1,586 acres account for the majority of the remaining Town area" Brimfield, 2011, p. 7).

Table 40 lists the hazard profiles and risk index portion of the plan. Localized flooding and severe snow/ice storms, as well as wildfire/brushfire are the highest hazards of concern. Loss estimations are based on 2006 valuation for all structures within the planning area ($406,673,450), with a 2007 valuation for median home values ($192,450), and 2.4 persons per household.

Analysis states that there "are approximately 1,678 acres of land within the FEMA mapped 100-year floodplain and 715 acres of land within the 500-year floodplain within the Town of Brimfield. According to the Community Information System (CIS) of FEMA, there were 23 structures (all residential) located within the Special Flood Hazard Area in Brimfield as of July 1999, the most current records in the CIS for the Town of Brimfield" (ibid, p. 11). The vulnerability assessment for a 100-year flood equals approximately $4,426,350 million of damage, with approximately 57 people impacted. The plan indicates no repetitive loss properties, but review of the State's 2013 data indicates the town has one.

The plan identifies a well-established list of critical facilities, again including what are referred to as "Category 3—Facilities/Populations to Protect," which focuses on special needs populations, elderly and assisted living areas, among others.

TABLE 40.
BRIMFIELD HAZARD PROFILING AND RISK INDEX WORKSHEET

Type of Hazard	Location	Extent	Previous Occurrences	Probability of Future Events	Hazard Risk Index Rating
Flooding (100-year)	Large	Limited	Yes	Low	2
Flooding (localized)	Medium	Minor	Yes(extensive)	Very High	1
Severe Snow/Ice Storms	Large	Limited	Yes	Very High	1
Hurricanes/Severe Wind	Large	Minor	Yes (minimal)	Very Low	4
Tornado/Microburst	Small	Catastrophic	No	Very Low	4
Wildfire/Brushfire	Small	Minor	Yes (minimal)	Very High	3
Earthquake	Large	Catastrophic	No	Very Low	4
Dam Failure	Small	Minor	No	Very Low	5
Drought	Small	Minor	No	Very Low	5
Man-Made Hazard: Hazardous Materials	Large	Limited	No	Very Low	3

SOUTHEASTERN REGIONAL PLANNING AND ECONOMIC DEVELOPMENT DISTRICT

While the Southeastern Regional Planning and Economic Development District plan expired in January 2010, in an effort to maintain a statewide assessment of information, the State Hazard Mitigation Team determined it would be valuable to capture the planning commission's risk assessment for statewide continuity. The information from the expired plan is incorporated below.

Link to local plan:
http://www.srpedd.org/zoning/Final%20PDM%20Regional%20Plan%2004.pdf Expired 1/28/10: Mansfield Expires 2/12/14; Middleborough to FEMA 11/12.

Acushnet
Attleboro
Berkley
Carver
Dartmouth
Dighton
Fairhaven
Fall River
Freetown
Lakeville
Mansfield
Marion
Mattapoisett
Middleborough
New Bedford
North Attleborough
Norton
Plainville
Raynham
Rehoboth
Rochester
Seekonk
Somerset
Swansea
Taunton
Wareham
Westport

The regional population is 600,000 with the population being dispersed from the smallest community—Rochester with 4,581 persons—to New Bedford with 93,768. There are 765.5 people per square mile in this region. The 6 coastal communities have an increased summer population due to tourism. From 1990-2000 the population's growth percentage was 6.1%, less than the national average of 13.2%. In a 1999, 42.7% of the region is considered urbanized or built out, 20.6% is considered developable, and 37% is not developable or protected. The four urban areas have 47.5 % of the regional population and have population densities in the range of 2,254—4,655 persons per square mile. This contrasts with the more rural areas of the region where the densities are generally less than 300 persons per square mile. New Bedford stands out in the region because it has the greatest population and is a significant outlier in terms of density. The topography includes many basin areas that are generally wetlands and marshes that provide recharge to the local aquifers. Approximately 22.1% of the region is classified as wetland areas according to Mass GIS. Within the region, there is a total of approximately 348 miles of tidal shoreline.

The 800 square mile southeastern region covers most of the expanse of southeastern Massachusetts below greater Boston and before Cape Cod. It is bounded along the west and southwest by the Rhode Island border, to the north and northeast by the greater Boston region, and to the south and southeast by open water. It stretches for over 35 miles from the shoreline of Wareham, to its northern interior in Plainville. This region includes 27 communities, 23 of which are towns and four (4) are cities, which can be divided into subregions of communities grouped by geographically dominant characteristics:

- South Coastal—seven communities with coastline along Buzzards Bay: Acushnet, Dartmouth, Fairhaven, Marion, Mattapoisett, New Bedford, Wareham, and Westport;
- Cranberry Country—four low density communities with large areas of cranberry bogs: Carver, Rochester, Lakeville and Middleborough;
- Greater Fall River—five communities in the Fall River urban area: Fall River, Freetown, Somerset and Swansea;
- Greater Taunton—four communities in the Taunton urban area: Berkley, Dighton, Raynham and Taunton;
- Greater Attleboro—seven communities in the Attleboro urban area: Attleboro, Mansfield, Norton, North Attleborough, Plainville, Seekonk, and Rehoboth.

Geologists classify the southeastern Massachusetts area as part of the Northeast Coastal Lowlands/Coastal Plain region. The area is characterized by the conditions created over 12,000 years ago when massive glaciers receded. These characteristics include: low hills; highly porous soils; deposits of sand and gravel; multiple swamps, lakes, rivers and ponds; and a high water table. The glaciers left behind glacial till that contains thick deposits of both sand and gravel, lying over bedrock. There are occasionally boulders, known as glacial erratics, of different rock types that were carried from northern regions and left behind as the glaciers receded.

It is not uncommon for flooding to occur in the spring as some of the rivers in the region overflow their banks. In particular, rivers that are in more developed areas are problematic. These rivers have typically been channeled or covered, and receive heavy influxes of point and non-point run-off from impervious surfaces such as roadways and parking lots. It is worth noting that of the entire region, 17% or approximately 141 square miles are within the 100-year floodplain and an additional 4% in the five-hundred year flood plain.

The hazards within the Southeastern region 2004 plan are divided into four groups: flood related hazards, wind related hazards; fire-related hazards, and geologic hazards. Review of the hazards profiles reveals that the Southeastern region plan also places the highest emphasis of hazard risk to those associated to flooding. However, within their analysis, several hazards fall into the flood category, specifically: Riverine, Coastal, Erosion, Dam Failures, Thunderstorms, Winter Storms, Coastal Storms/Nor'easters, and Hurricanes.

Within the same concept of risk ranking, the jurisdictions again utilizes Hurricanes, Coastal Storms/Nor'easter and Winter Storms to determine risk ranking for Wind Related Hazards, as well as Flooding to determine the risk ranking for the Fire-Related Hazards.

The breakdown of hazards is shown in Table 41 and Table 42.

TABLE 41.
SOUTHEAST REGION HAZARD MATRIX

Natural Hazard	Likelihood/ Frequency	Impact Area Assessment	Severity/ Magnitude	Hazard Index
FLOOD RELATED HAZARDS ➢ Riverine ➢ Coastal ➢ Erosion ➢ Dam Failures ➢ Thunderstorms ➢ Winter Storms ➢ Coastal Storms/ Nor'easters ➢ Hurricanes	Highly Likely (3)	Medium (2)	Limited (1)	6 Pts.* Rank #1
WIND RELATED HAZARDS ➢ Hurricanes ➢ Coastal Storms/ Nor'easters ➢ Winter Storms ➢ Downspouts ➢ Tornadoes	Highly Likely (3)	Medium (2)	Limited (1)	6 Pts.* Rank #1
FIRE-RELATED HAZARDS ➢ Drought ➢ Wildfires ➢ Urban Fires ➢ Flooding	Highly Likely (3)	Medium (2)	Limited (1)	6 Pts.* Rank #1
GEOLOGIC HAZARDS ➢ Earthquakes ➢ Landslides ➢ Sink Holes ➢ Subsidence	Possible (1)	Small (1)	Limited (1)	3 Pts. Rank #4
				* equally ranked

TABLE 42.
POINT VALUES USED IN SOUTHEAST REGION HAZARD MATRIX

FREQUENCY/ LIKELIHOOD		
POINT VALUE	**CATEGORY**	**CHARACTERISTICS**
3	Highly Likely	Near 100% Probability in the next year
2	Likely	Between 10 – 100% probability in the next year; or at least one chance in 10 years
1	Possible	Between 1- 10% probability in the next year; or at least one chance in the next 100 years
0	Unlikely	Less than 1% probability in the next 100 years

IMPACT ASSESSMENT		
POINT VALUE	**CATEGORY**	**CHARACTERISTICS**
3	Large	Relative to total land area and concentrations of population/structures and critical facilities
2	Medium	Relative to total land area and concentrations of population/structures and critical facilities
1	Small	Relative to total land area and concentrations of population/structures and critical facilities

MAGNITUDE/SEVERITY		
POINT VALUE	**CATEGORY**	**CHARACTERISTICS**
3	Catastrophic	Multiple Deaths. Complete shutdown of facilities for 30 days or more. Property severely damaged >50%.
2	Critical	Injuries and/or illness result in permanent disability. Complete shutdown of critical facilities for at least two weeks. Property severely damaged <50%, >25%.
1	Limited	Injuries and/or illness do not result in permanent disability. Complete shutdown of critical facilities for more than one week. Property severely damaged <25%, >10%.
0	Negligible	Injuries and/or illnesses are treatable with first aid Minor quality of life loss. Shutdown of critical facilities and services for 24 hours or less. Property severely damaged <10%.

(Source: State of North Carolina Emergency Management Agency)

APPENDIX G.
STAPLEE RESULTS

Good=3, Average=2, Poor=1 , N/A	S Social		T Technical			A Administrative			P Political			L Legal			E Economic				E Environmental			
Actions	Community Acceptance	Effects on Segement of Population	Technical Feasiability	Long Term Solution	Secondary Impacts	Staffing	Funding Allocated	Maintainence/ Operations	Political Support	Local Support	Public Support	State Authority	Existing Local Authority	Potential Legal Challenge	Benefit of Action	Cost of Action	Contributes to Economic Goals	Outside Funding Required	Effects on Land/Water	Effects of HAZMAT/ Waste Sites	Consistent with Community Envirlnmental Goals	Constistent with Federal Laws
1. Evaluate and analyze vulnerability in order to guide and promote sound mitigation activities through integrated																						
a. Complete a standard State Hazard Mitigation Plan Update and submit for FEMA review and approval prior to the October 2013 deadline per DMA 2000. The state has written the plan to enhanced status, with the hopes of gaining that status with the submission of the 2013 plan.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	2	n/a	3	3
b. Perform a statewide risk analysis for all hazards to include in future updates to this state hazard mitigation plan and other related plans	3	3	2	3	3	3	3	3	3	2	3	3	3	3	3	2	3	3	3	3	2	3
c. Develop Enhanced State Hazard Mitigation Plan and submit to FEMA for approval.	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	2	3	3	3	n/a	3	3
d. Work with the SHMIC to resesarch and develop a more realistic set of criteria by which to prioritize mitigation actions that captures timely and relevant mitigaiton needs throughout the State.	3	2	3	3	2	3	3	3	3	n/a	2	3	n/a	n/a	2	3	2	2	n/a	n/a	3	2
e. Partner with regional planning agencies and other groups in Massachusetts to develop and implement regional and local multi-hazard mitigation plans by providing technical assistance.	3	3	3	3	3	2	3	2	3	3	3	2	3	3	3	3	2	3	3	n/a	3	2
f. Apply for available federal funding to implement and update the completed and approved multi-jurisdictional and local hazard	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	n/a	3	3
g. Continue to incorporate new data and recommendations from the FEMA-approved regional and local mitigation plans into the State Mitigation Plan, especially locations of critical facilities and assessments of vulnerability and estimates of potential losses by jurisdiction.	3	3	3	2	1	3	3	3	3	3	3	3	3	3	3	3	3	3	2	n/a	3	3
h. Track potential hazard mitigation projects and strategies statewide in a database, using new information provided by the multi-jurisdictional plans with local annexes and state agencies.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	n/a	3	2
i. Coordinate data collection and sharing with other statewide planning initiatives, such as the Statewide Homeland Security Planning process.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	2
j. Continue to support existing statewide mitigation planning, especially the Community Assistance Program-State Support Element Floodplain Management Plan, including activities under the National Flood Insurance Program, and the Risk MAP Business Plan.	3	3	3	3	3	3	3	2	3	3	3	3	2	3	3	3	3	3	2	n/a	3	3
k. Address data deficiencies and improve analysis, when available, by partnering with Federal, State, local, and other subject matter experts.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
l. Create a statewide Threat and Hazard Identification and Risk Assessment (THIRA) as described in FEMA's April, 2012 Threat and Hazard Identification and Risk Assessment Guide (CPG 201). In conjunction with the development of the THIRA conduct a statewide capabilities gap assessment. The THIRA will be the man-made portion of the risk assessment in the SHMP	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3

Good=3, Average=2, Poor=1 , N/A	S Social		T Technical			A Administrative			P Political			L Legal			E Economic				E Environmental			
Actions	Community Acceptance	Effects on Segement of Population	Technical Feasiability	Long Term Solution	Secondary Impacts	Staffing	Funding Allocated	Maintainence/ Operations	Political Support	Local Support	Public Support	State Authority	Existing Local Authority	Potential Legal Challenge	Benefit of Action	Cost of Action	Contributes to Economic Goals	Outside Funding Required	Effects on Land/Water	Effects of HAZMAT/ Waste Sites	Consistent with Community Envirinmental Goals	Constistent with Federal Laws
2. Increase awareness of the benefits of hazard mitigation through outreach and education.																						
a. Develop and implement a statewide hazard mitigation training program, including educational materials for federal and state agencies	3	2	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
b. Conduct hazard mitigation community outreach and educational programs for the general public, such as programs in schools and at home improvement stores and events.	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
c. Continue to hold hazard mitigation grant workshops for state agencies and local governments after natural disasters, especially immediately following Presidential Disaster Declarations.	3	3	3	3	3	3	2	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3
d. Utilize the Internet to develop more consistent and timely tools for distributing information about current hazard mitigation programs and success stories in Massachusetts to other government agencies, the private sector, and the general public.	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	2
e. Provide improved outreach to all eligible applicants for mitigation projects and planning.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
3. Increase coordination and cooperation between state agencies in implementing sound Hazard Mitigation planning a																						
a. Investigate the possibility of creating a standardized format or model for local hazard mitigation plans to create consistency among all plans statewide.	3	3	3	3	3	3	2	3	3	2	3	3	3	3	3	2	3	3	3	3	3	2
b. Develop a strategy to reduce the overlap between Comprehensive Emergency Management Plans and Hazard Mitigation Plans	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
c. Build 'non-traditional' partners in mitigation by encouraging colleges and universities, non-governmental organizations, private non-profits, and the private sector to use their resources to study hazard vulnerability and implement mitigation projects and by prioritizing project applications for traditional funding sources that leverage funding and contributions from these non-traditional sources.	3	3	2	3	3	3	2	3	3	3	2	3	3	3	3	3	3	3	3	3	2	3
d. Educate all communities, state agencies, and the private sector specifically, building and insurance industries to the benefits of mitigating against natural hazards by participating in planning and projects.	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3
e. Continue to make recommendations to the Board of Building Regulations and Standards as the Massachusetts State Building Code is updated to include updated NFIP Standards and other building standards related to natural hazards, such as wind, snow, seismic loads and others. hazards.	3	3	3	2	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3

Good=3, Average=2, Poor=1 , N/A	S Social		T Technical			A Administrative			P Political			L Legal			E Economic				E Environmental			
Actions	Community Acceptance	Effects on Segement of Population	Technical Feasiability	Long Term Solution	Secondary Impacts	Staffing	Funding Allocated	Maintainence/ Operations	Political Support	Local Support	Public Support	State Authority	Existing Local Authority	Potential Legal Challenge	Benefit of Action	Cost of Action	Contributes to Economic Goals	Outside Funding Required	Effects on Land/Water	Effects of HAZMAT/ Waste Sites	Consistent with Community Envirlnmental Goals	Constistent with Federal Laws
f. Encourage project granting agencies in the state, such as the Massachusetts Department of Housing and Community Development's review of CDBG Grants, to include the analysis of hazard impacts when reviewing applications for funding	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
g. Recruit additional state agencies to become involved in the State Hazard Mitigation Interagency Committee.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
h. Continue working with other state agencies, especially those on the State Hazard Interagency Committee, to ensure that all the necessary permits and requirements are being met before the execution of all hazard mitigation projects through the Hazard Mitigation Assistance Programs.	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	2	3	3	3	3	3	3
4. Promote cost-effective hazard mitigation actions that protect and promote public health and safety from all-hazard.																						
a. Research the potential for implementing a state hazard mitigation program that more effectively includes involvement with all state agencies and the possible source for a state investment in mitigation	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2
b. Enhance the effectiveness of 406 funding by working to further integrate mitigation into the FEMA Public Assistance Program.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
c. Apply for available federal hazard mitigation project grants through pre-disaster and post-disaster mitigation programs and other federal mitigation programs as the funding becomes available and explore.	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
d. Notify all eligible applicants of available hazard mitigation project grant programs for mitigation projects, including available funding through the Unified Hazard Mitigation Assistance programs and other mitigation opportunities	3	3	3	3	3	2	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3
e. Work with state agencies that own state facilities believed to be at high or medium flood risk or Overland Tidal Surge (as identified in Section 4) to further evaluate the flood and surge risk and to identify and implement appropriate mitigation strategies.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
f. Develop a methodology for collecting and assessing the natural hazard risks, especially flooding, erosion, and storm damage, for all current and future state owned facilities and properties, to be used by agencies to identify and implement appropriate mitigation strategies.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
g. Work with state agencies to fully identify all potential hazards to facilities before major repairs, or the construction of new facilities, to minimize future impacts from natural hazards, particularly flooding, storm damage and erosion.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	n/a	3	2
h. Work with communities to implement cost-effective, environmentally sound, and feasible mitigation projects to severe repetitive loss properties.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

Good=3, Average=2, Poor=1 , N/A	S Social		T Technical			A Administrative			P Political			L Legal			E Economic				E Environmental			
Actions	Community Acceptance	Effects on Segement of Population	Technical Feasiability	Long Term Solution	Secondary Impacts	Staffing	Funding Allocated	Maintainence/ Operations	Political Support	Local Support	Public Support	State Authority	Existing Local Authority	Potential Legal Challenge	Benefit of Action	Cost of Action	Contributes to Economic Goals	Outside Funding Required	Effects on Land/Water	Effects of HAZMAT/ Waste Sites	Consistent with Community Envirinmental Goals	Constistent with Federal Laws
5. Monitor, evaluate and disseminate information on the effectiveness of Hazard Mitigation actions implemented by																						
a. Develop a process to track all completed mitigation projects in Massachusetts, including 406 mitigation and privately funded mitigation projects.	2	3	3	2	3	3	3	3	2	3	3	3	2	3	3	3	3	3	2	3	3	3
b. Evaluate the feasibility of maintaining a database of potential mitigation projects across the state, taken from local hazard mitigation plans, Project Worksheets from the Public Assistance Process, and other sources.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3
c. Prepare hazard mitigation best practices and case studies on a regular basis.	3	3	2	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	2	2
d. Implement a standard information sharing procedure on disaster damage data collected by FEMA, PDA, Community Relations and Infrastructure Inspectors to use in local hazard mitigation planning efforts and identifying potential hazard mitigation projects.	3	2	3	3	2	3	3	3	2	3	2	3	2	3	3	3	3	2	n/a	n/a	3	3
e. Improve the states capability assessment by intergrating the locally administered capabilities and the state level capabilities in order to show how mitigation at various levels is implemented and integrated. This will also show us any gaps or areas we can improve either state or local efforts to increase mitigation potential.	3	2	3	3	2	3	3	3	3	3	2	3	3	n/a	3	3	3	2	n/a	n/a	3	2
f. Research best practices and then work with RPC's and local communities through outreach and education to help local communities strengthen the ownership of the planning process.	3	3	3	3	3	3	3	2	3	2	2	3	3	3	3	3	3	3	n/a	n/a	3	3

APPENDIX H.
PARTICIPATING TEAM MEMBERS

APPENDIX H.
STATE HAZARD MITIGATION PLAN UPDATE PROCESS PARTICIPANTS

AGENCIES

State Agencies Involved in Upate Process

- Massachusetts Animal Response Team
- Massachusetts Bay Transit Authority
- Massachusetts Board of Building Regulation & Standards
- Massachusetts Board of Library Commissioners
- Massachusetts Bureau of Animal Health
- Massachusetts CFC
- Massachusetts Commission for Deaf and Hard of Hearing
- Massachusetts Department of Agricultural Resources
- Massachusetts Department of Conservation and Recreation
- Massachusetts Department of Environmental Protection (MassDEP)
- Massachusetts Department of Fire Services
- Massachusetts Department of Fish and Game (Several Divisions)
- Massachusetts Historical Commission
- Massachusetts Department of Housing & Economic Development
- Massachusetts Department of Mental Health
- Massachusetts Department of Public Education
- Massachusetts Department of Public Health
- Massachusetts Department of Transportation
- Massachusetts Division of Capital Asset Management and Maintenance (DCAMM)
- Massachusetts Division of Energy Resources
- Massachusetts Emergency Management Agency
- Massachusetts Executive Office of Energy and Environmental Affairs
- Massachusetts Executive Office of Public Safety and Security
- Massachusetts Fire Services/ Hazardous Materials Response
- Massachusetts Information Technology Division
- Massachusetts Major City Police Chiefs Association Massachusetts State Police
- Massachusetts National Guard
- Massachusetts Office of Coastal Zone Management
- Massachusetts Office of Chief Medical Examiner
- Massachusetts Office of Disability
- Massachusetts State Fusion Center
- Massachusetts State Homeland Security Advisory Council
- Massachusetts State Police
- Massachusetts Statewide Interoperability Executive Committee
- Massachusetts USDA
- Massachusetts Voluntary Organizations Active in Disaster

Federal Agencies

- Federal Emergency Management Agency
- National Oceanic and Atmospheric Administration (NOAA) (new in 2013)
- National Weather Service
- Natural Resource Conservation Service
- U.S. Army Corp of Engineers, New England District
- U.S. Geologic Survey
- U.S. Coast Guard

Other Agencies

(Includes planning partners and stakeholders, agencies to which presentations were made, or from which information was gathered):

- American Red Cross
- Boston Civil Engineers (new in 2013)
- Boston Regional Intelligence Center
- Civil Engineers Society (new in 2013)
- Climate Change Adaptation Workshop (new in 2013)
- Climate Change and Coastal Hazard Committee (new in 2013)
- Franklin Regional Council of Governments
- Massachusetts Association of Regional Planning Agencies
- Massachusetts Fire Chiefs Association
- Massachusetts Geological Survey
- Massport
- Massachusetts' River Alliance (new in 2013)
- Metro Boston Homeland Security Region (new in 2013)
- Metro Boston Urban Areas Security Initiative (UASI) region
- New England Disaster Recovery Exchange
- Northeast States Emergency Consortium
- Regional Homeland Security Councils
- Salvation Army
- State Fusion Center (new in 2013)
- State Homeland Security Advisory Council (new in 2013)
- University of Massachusetts (Various departments)
- Weston Observatory at Boston College
- Woods Hole Oceanographic Institute

State Agency Survey Participants

- Board of Building Regulation & Standards
- Board of Building Regulation & Standards
- Coastal Zone Management
- Coastal Zone Management
- Dam Maintenance
- DCR Bureau of Forest Fire Control
- DCR Bureau of Forest Fire Control
- DCR Division of Planning and Engineering
- DCR Office of Water Resources
- Department of Environmental Protection, Bureau of Resource Protection
- Department of Environmental Protection, Bureau of Resource Protection
- Division of Agricultural Development

- Division of Capital Asset Management, Office of Facilities Management
- Division of Fisheries & Wildlife
- Massachusetts Board of Library Commissioners
- Massachusetts Department of Transportation
- Massachusetts Division of Marine Fisheries
- Massachusetts Historical Commission
- Massachusetts Historical Commission
- Massachusetts Water Resource Authority
- MassDEP
- Northeast States Emergency Consortium
- University of Massachusetts
- University of Massachusetts
- Weston Observatory

APPENDIX I.
NATIONAL FLOOD INSURANCE PROGRAM CLAIMS

APPENDIX I. NATIONAL FLOOD INSURANCE PROGRAM CLAIMS

The National Flood Insurance Program data is a useful tool to determine the location of areas vulnerable to flood and severe storm hazards. Table I-1 summarizes the NFIP policies, claims, repetitive loss and severe repetitive loss properties in each Massachusetts county and municipality. The majority of the repetitive loss and severe repetitive loss properties are located in eastern Massachusetts, with the largest number along the coast in the counties of Barnstable, Essex, Middlesex, Norfolk, Plymouth and Suffolk.

TABLE I-1.
NFIP POLICIES, CLAIMS AND REPETITIVE LOSS STATISTICS BY MUNICIPALITY

Community Name	Policies in Force	Claims	Total Loss Payment	Repetitive Losses	Severe Repetitive Losses
Barnstable County					
Barnstable	1,101	283	$2,951,965	19	—
Bourne	1,129	478	$5,495,466	15	1
Brewster	91	16	$33,895	—	—
Chatham	428	135	$2,773,056	7	—
Dennis	1,084	227	$1,436,080	18	1
Eastham	176	65	$393,040	7	—
Falmouth	2,191	639	$9,114,164	33	—
Harwich	580	46	$446,015	3	—
Mashpee	533	67	$221,641	3	—
Orleans	196	53	$668,572	6	—
Provincetown	918	169	$1,307,622	9	1
Sandwich	394	135	$1,198,335	15	—
Truro	268	26	$79,360	—	—
Wellfleet	175	33	$308,068	—	—
Yarmouth	1,303	236	$953,259	14	1
Berkshire County					
Adams	46	19	$116,948	1	—
Alford	3	1	$1,629	—	—
Becket	31	7	$46,615	—	—
Cheshire	16	11	$50,157	1	—
Clarksburg	9	1	$2,255	—	—
Dalton	20	11	$46,552	—	—
Egremont	16	8	$34,052	2	—
Great Barrington	25	45	$244,355	4	—
Hancock	6	1	$4,353	—	—
Hinsdale	3	2	$2,032	—	—
Lanesborough	10	3	$86,049	—	—
Lee	72	12	$42,035	2	—
Lenox	17	6	$63,254	1	—
Monterey	24	26	$558,688	5	—
New Ashford	1	—	—	—	—
New Marlborough	23	9	$52,819	1	—
North Adams	15	15	$284,140	1	—

TABLE I-1.
NFIP POLICIES, CLAIMS AND REPETITIVE LOSS STATISTICS BY MUNICIPALITY

Community Name	Policies in Force	Claims	Total Loss Payment	Repetitive Losses	Severe Repetitive Losses
Otis	28	4	$32,005	—	—
Pittsfield	520	129	$728,165	11	—
Richmond	14	1	$0	—	—
Sandisfield	22	4	$13,676	—	—
Sheffield	38	9	$156,263	—	—
Stockbridge	47	16	$91,740	1	—
Tyringham	5	—	—	—	—
West Stockbridge	24	11	$28,457	1	—
Williamstown	125	21	$125,138	—	—
Bristol County					
Acushnet	14	1	$14,622	—	—
Attleboro	163	58	$1,070,635	6	—
Berkley	55	13	$62,562	1	—
Dartmouth	590	139	$814,670	4	—
Dighton	109	73	$888,479	5	—
Easton	98	23	$120,300	3	—
Fairhaven	793	416	$3,336,336	17	—
Fall River	79	19	$93,645	1	—
Freetown	122	43	$257,181	1	—
Mansfield	47	8	$8,068	—	—
New Bedford	241	55	$645,971	—	—
North Attleborough	152	36	$153,438	—	—
Norton	99	55	$311,383	5	—
Raynham	24	1	$8,696	—	—
Rehoboth	27	11	$103,607	1	—
Seekonk	33	13	$126,528	1	—
Somerset	198	64	$116,072	3	—
Swansea	416	144	$522,545	5	—
Taunton	470	90	$1,152,966	11	—
Westport	337	136	$1,403,385	6	—
Dukes County					
Aquinnah	11	2	$13,463	1	—
Edgartown	478	51	$608,103	4	—
Gosnold	7	1	$2,215	—	—
Oak Bluffs	220	73	$723,875	9	—
Tisbury	147	35	$257,609	3	—
West Tisbury	31	44	$809,161	—	—
Essex County					
Amesbury	124	192	$7,967,768	6	—
Andover	460	141	$1,457,192	28	3
Beverly	339	10	$40,439	17	—
Boxford	28	42	$464,185	1	—
Danvers	258	—	—	5	—
Essex	48	80	$1,134,688	8	—
Georgetown	65	20	$257,362	4	—
Gloucester	482	306	$5,079,488	27	2
Groveland	30	16	$57,276	—	—

TABLE I-1.
NFIP POLICIES, CLAIMS AND REPETITIVE LOSS STATISTICS BY MUNICIPALITY

Community Name	Policies in Force	Claims	Total Loss Payment	Repetitive Losses	Severe Repetitive Losses
Hamilton	38	12	$58,467	2	—
Haverhill	528	102	$2,212,446	15	—
Ipswich	92	40	$393,456	3	—
Lawrence	394	307	$12,053,281	28	1
Lynn	441	159	$1,110,612	18	1
Lynnfield	64	28	$169,274	2	—
Manchester-By-The-Sea	126	82	$1,039,607	19	—
Marblehead	245	215	$1,984,230	20	2
Merrimac	26	6	$15,571	—	—
Methuen	200	124	$1,198,737	16	—
Middleton	18	11	$137,868	2	—
Nahant	202	365	$4,391,045	46	2
Newbury	431	208	$1,320,036	16	—
Newburyport	573	229	$1,998,820	20	—
North Andover	172	55	$1,493,911	7	—
Peabody	603	327	$7,153,279	44	2
Rockport	294	268	$3,855,784	17	1
Rowley	8	—	—	—	—
Salem	242	128	$993,074	15	—
Salisbury	1,183	347	$4,552,046	34	2
Saugus	446	286	$1,368,693	30	1
Swampscott	249	339	$3,266,973	44	—
Topsfield	41	24	$440,206	5	—
Wenham	15	2	$724	—	—
West Newbury	18	3	$103,188	1	—
Franklin					
Ashfield	6	2	$63,936	—	—
Bernardston	12	—	—	—	—
Buckland	19	12	$248,502	—	—
Charlemont	11	5	$48,624	—	—
Colrain	8	3	$10,992	—	—
Conway	6	8	$179,061	—	—
Deerfield	32	8	$96,379	1	—
Erving	2	1	$0	—	—
Gill	4	1	$0	—	—
Greenfield	48	49	$3,023,959	1	—
Hawley	7	2	$1,451	—	—
Heath	1	—	—	—	—
Leverett	6	3	$16,978	1	—
Montague	11	2	$1,208	—	—
Northfield	9	—	—	—	—
Orange	11	1	$8,300	—	—
Shelburne	11	—	—	—	—
Sunderland	12	2	$14,045	—	—
Whately	3	—	—	—	—
Hampden County					
Agawam	290	47	$132,345	—	—

TABLE I-1.
NFIP POLICIES, CLAIMS AND REPETITIVE LOSS STATISTICS BY MUNICIPALITY

Community Name	Policies in Force	Claims	Total Loss Payment	Repetitive Losses	Severe Repetitive Losses
Brimfield	16	4	$41,432	1	—
Chester	54	11	$57,189	2	—
Chicopee	127	7	$1,494	—	—
East Longmeadow	16	6	$30,134	—	—
Granville	4	1	$3,202	—	—
Hampden	23	18	$469,760	2	—
Holland	47	6	$19,457	—	—
Holyoke	22	12	$47,890	1	—
Longmeadow	35	2	$1,036	—	—
Ludlow	24	5	$14,992	—	—
Monson	12	6	$236,347	1	—
Palmer	34	4	$59,488	—	—
Russell	28	3	$1,771	—	—
Southwick	18	13	$12,290	—	—
Springfield	86	14	$6,829	—	—
Wales	7	—	—	—	—
West Springfield	41	26	$118,442	—	—
Westfield	272	45	$1,050,099	1	—
Wilbraham	29	7	$37,651	1	—
Hampshire County					
Amherst	34	4	$15,469	—	—
Belchertown	11	5	$13,500	—	—
Chesterfield	3	—	—	—	—
Cummington	10	3	$22,862	1	—
Easthampton	26	27	$467,359	6	—
Goshen	2	—	—	—	—
Granby	22	2	$0	—	—
Hadley	114	15	$96,283	1	—
Hatfield	50	5	$25,834	—	—
Huntington	27	10	$100,995	—	—
Middlefield	4	4	$44,692	—	—
Northampton	116	60	$603,374	8	1
South Hadley	61	23	$124,608	4	—
Southampton	11	7	$57,123	—	—
Ware	32	7	$13,249	—	—
Westhampton	6	—	—	—	—
Williamsburg	14	10	$57,817	1	—
Worthington	12	2	$4,091	—	—
Middlesex County					
Acton	136	43	$227,605	5	—
Arlington	648	435	$1,546,122	29	—
Ashby	6	—	—	—	—
Ashland	57	21	$51,322	1	—
Ayer	31	3	$7,783	—	—
Bedford	148	108	$999,460	11	1
Belmont	48	22	$107,573	2	—
Billerica	235	355	$2,822,726	50	2

TABLE I-1.
NFIP POLICIES, CLAIMS AND REPETITIVE LOSS STATISTICS BY MUNICIPALITY

Community Name	Policies in Force	Claims	Total Loss Payment	Repetitive Losses	Severe Repetitive Losses
Boxborough	11	—	—	—	—
Burlington	122	40	$180,482	8	—
Cambridge	231	53	$1,932,976	2	—
Carlisle	17	1	$0	—	—
Chelmsford	272	71	$548,171	7	2
Concord	150	60	$368,841	5	—
Dracut	54	22	$349,249	2	—
Dunstable	6	—	—	—	—
Everett	14	10	$63,613	3	—
Framingham	834	205	$1,203,372	17	1
Groton	36	2	$12,395	—	—
Holliston	87	24	$102,801	3	—
Hopkinton	20	1	$0	—	—
Hudson	55	13	$8,444	—	—
Lexington	96	50	$183,841	5	—
Lincoln	19	12	$60,919	1	—
Littleton	19	13	$85,915	—	—
Lowell	1,116	240	$4,762,068	24	—
Malden	195	77	$216,157	5	—
Marlborough	34	10	$19,579	—	—
Maynard	19	6	$7,105	—	—
Medford	69	35	$184,265	5	—
Melrose	317	86	$726,683	10	—
Natick	79	32	$257,496	4	—
Newton	483	369	$1,817,651	42	2
North Reading	83	116	$769,433	20	1
Pepperell	34	20	$186,126	2	—
Reading	37	21	$63,750	2	—
Sherborn	6	5	$22,209	—	—
Shirley	14	13	$159,634	1	—
Somerville	38	22	$831,053	2	—
Stoneham	18	3	$2,443	—	—
Stow	19	1	$0	—	—
Sudbury	68	19	$55,867	3	—
Tewksbury	114	69	$369,446	8	—
Townsend	30	16	$43,801	2	—
Tyngsborough	130	28	$2,167,315	8	—
Wakefield	109	76	$436,898	12	1
Waltham	186	142	$1,145,587	15	—
Watertown	93	18	$788,690	2	—
Wayland	62	26	$96,514	5	—
Westford	99	13	$76,521	—	—
Weston	90	30	$206,398	3	—
Wilmington	79	35	$166,198	3	—
Winchester	433	137	$3,822,529	29	3
Woburn	47	44	$803,486	7	—

TABLE I-1.
NFIP POLICIES, CLAIMS AND REPETITIVE LOSS STATISTICS BY MUNICIPALITY

Community Name	Policies in Force	Claims	Total Loss Payment	Repetitive Losses	Severe Repetitive Losses
Nantucket County					
Nantucket	896	414	$12,222,739	49	—
Norfolk County					
Avon	15	2	$717	—	—
Bellingham	64	19	$68,215	—	—
Braintree	278	157	$1,958,022	18	—
Brookline	89	23	$373,417	3	—
Canton	80	33	$111,810	2	—
Cohasset	165	114	$1,104,789	10	—
Dedham	302	54	$230,706	1	—
Dover	37	12	$77,889	—	—
Foxborough	48	7	$13,928	—	—
Franklin	56	31	$139,373	5	—
Holbrook	84	44	$487,942	5	—
Medfield	38	3	$24,676	—	—
Medway	122	5	$98,387	1	—
Millis	26	14	$17,152	—	—
Milton	124	66	$543,533	6	—
Needham	91	38	$92,017	4	—
Norfolk	45	52	$163,673	3	—
Norwood	70	28	$600,610	2	—
Plainville	20	2	$5,929	—	—
Quincy	3,396	1487	$7,974,301	169	11
Randolph	103	27	$100,110	2	—
Sharon	64	33	$93,871	—	—
Stoughton	158	33	$64,926	1	—
Walpole	70	15	$60,325	—	—
Wellesley	110	48	$167,319	4	—
Westwood	60	37	$144,246	4	—
Weymouth	667	233	$1,111,111	25	1
Wrentham	19	2	$7,000	—	—
Plymouth County					
Abington	26	12	$27,649	—	—
Bridgewater	74	26	$63,287	2	—
Brockton	470	314	$1,855,891	38	1
Carver	7	9	$24,692	—	—
Duxbury	278	333	$3,953,145	42	1
East Bridgewater	31	8	$50,651	1	—
Halifax	20	5	$7,922	1	—
Hanover	61	14	$69,319	—	—
Hanson	3	8	$13,078	—	—
Hingham	249	118	$682,459	10	—
Hull	2,231	2179	$13,798,651	238	16
Kingston	66	18	$72,912	—	—
Lakeville	71	36	$654,958	1	—
Marion	527	177	$2,893,696	6	—
Marshfield	1,389	1324	$14,356,303	158	7

TABLE I-1.
NFIP POLICIES, CLAIMS AND REPETITIVE LOSS STATISTICS BY MUNICIPALITY

Community Name	Policies in Force	Claims	Total Loss Payment	Repetitive Losses	Severe Repetitive Losses
Mattapoisett	831	479	$6,756,475	13	—
Middleborough	47	20	$181,503	1	—
Norwell	37	12	$51,230	2	—
Pembroke	49	11	$21,591	—	—
Plymouth	441	370	$4,486,532	37	—
Plympton	8	6	$64,937	—	—
Rochester	10	1	$0	—	—
Rockland	69	9	$28,635	—	—
Scituate	1,473	3296	$53,894,031	490	82
Wareham	2,049	869	$11,607,645	19	—
West Bridgewater	32	6	$6,192	—	—
Whitman	15	17	$210,736	1	—
Suffolk County					
Boston	1,011	261	$1,028,241	23	—
Chelsea	19	24	$74,283	1	—
Revere	2,021	2499	$14,625,217	293	17
Winthrop	1,107	1130	$5,842,323	140	5
Worcester County					
Ashburnham	19	2	$5,199	—	—
Athol	16	2	$22,247	—	—
Auburn	63	22	$82,921	1	—
Barre	13	2	$6,340	—	—
Berlin	6	—	—	—	—
Blackstone	21	7	$12,380	—	—
Bolton	16	4	$12,916	1	—
Boylston	5	3	$9,553	—	—
Brookfield	24	23	$604,099	4	—
Charlton	50	1	$0	—	—
Clinton	123	29	$385,448	3	—
Douglas	15	3	$4,886	—	—
Dudley	22	4	$15,816	—	—
East Brookfield	12	2	$8,308	—	—
Fitchburg	72	31	$379,453	4	—
Gardner	5	—	—	—	—
Grafton	48	17	$121,752	1	—
Harvard	11	—	—	—	—
Holden	11	3	$2,225	—	—
Hopedale	7	1	$4,854	—	—
Hubbardston	4	—	—	—	—
Lancaster	47	34	$327,171	5	1
Leicester	32	13	$141,075	3	—
Leominster	105	25	$98,077	4	—
Lunenburg	21	2	$2,538	—	—
Mendon	9	—	—	—	—
Milford	46	20	$64,559	1	—
Millbury	53	17	$119,916	1	—
Millville	6	4	$9,859	—	—

TABLE I-1.
NFIP POLICIES, CLAIMS AND REPETITIVE LOSS STATISTICS BY MUNICIPALITY

Community Name	Policies in Force	Claims	Total Loss Payment	Repetitive Losses	Severe Repetitive Losses
New Braintree	1	—	—	—	—
North Brookfield	9	2	$7,063	—	—
Northborough	83	6	$22,415	—	—
Northbridge	48	29	$647,568	2	—
Oakham	3	1	$4,690	—	—
Oxford	17	5	$16,742	—	—
Paxton	1	—	—	—	—
Petersham	1	—	—	—	—
Princeton	3	1	$6,722	—	—
Royalston	1	—	—	—	—
Rutland	7	—	—	—	—
Shrewsbury	65	14	$28,356	—	—
Southborough	31	1	$0	—	—
Southbridge	70	27	$1,016,688	1	—
Spencer	20	1	$0	—	—
Sterling	9	1	$6,546	—	—
Sturbridge	36	10	$32,149	2	—
Sutton	23	4	$19,524	1	—
Templeton	5	—	—	—	—
Upton	10	—	—	—	—
Uxbridge	40	19	$463,653	1	—
Warren	5	1	$40,072	—	—
Webster	15	6	$1,471	—	—
West Boylston	68	3	$46,497	1	—
West Brookfield	22	2	$5,341	—	—
Westborough	39	8	$30,890	—	—
Westminster	19	6	$7,895	1	—
Winchendon	19	2	$420	—	—
Worcester	519	228	$4,195,670	29	—
Total	**58,673**	**30,123**	**$324,863,088**	**3,062**	**177**

APPENDIX J.
ICE JAM TABLE

APPENDIX J. TABLE OF HISTORICAL ICE JAM EVENTS

The CRREL database was queried for all ice jam events that occurred in Massachusetts from 1913 through 2012. Based on review of the CRREL database, 226 ice jam events have occurred in the Commonwealth, between 1913 and 2010. These events are listed in Table J-1. Information regarding losses associated with these reported ice jams was limited. No events have occurred since 2010, and the data is current as of the 2013 update.

TABLE J-1.
ICE JAM EVENTS IN MASSACHUSETTS BETWEEN 1913 AND 2012

Event Date	River / Location	County	Losses	Event Write-Up
February 28, 1913	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
March 2, 1914	Ware River	Worcester	N/A	No reference and/or no damage reported.
January 7, 1915	Quaboag River	Hampden	N/A	No reference and/or no damage reported.
February 26, 1916	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
February 26, 1916	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
January 14, 1917	West Branch Farmington River	Middlesex	N/A	No reference and/or no damage reported.
February 28, 1917	Ware River	Worcester	N/A	No reference and/or no damage reported.
February 20, 1918	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
March 21, 1918	Deerfield River		N/A	No reference and/or no damage reported.
March 14, 1920	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
March 23, 1923	Deerfield River		N/A	No reference and/or no damage reported.
February 12, 1925	Deerfield River		N/A	No reference and/or no damage reported.
February 12, 1925	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
February 12, 1925	Quaboag River	Hampden	N/A	No reference and/or no damage reported.
February 12, 1925	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
February 13, 1925	Moss Brook	Franklin	N/A	No reference and/or no damage reported.
February 17, 1930	Deerfield River		N/A	No reference and/or no damage reported.
February 5, 1934	Deerfield River		N/A	No reference and/or no damage reported.
March 5, 1934	Quaboag River	Hampden	N/A	No reference and/or no damage reported.
March 5, 1934	Ware River	Worcester	N/A	No reference and/or no damage reported.
March 7, 1934	Taunton River	Bristol	N/A	No reference and/or no damage reported.
January 10, 1935	Millers River		N/A	No reference and/or no damage reported.
March 12, 1936	Deerfield River		N/A	No reference and/or no damage reported.

TABLE J-1.
ICE JAM EVENTS IN MASSACHUSETTS BETWEEN 1913 AND 2012

Event Date	River / Location	County	Losses	Event Write-Up
March 12, 1936	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
March 12, 1936	Millers River		N/A	House damage and injured people
March 12, 1936	Quaboag River	Hampden	N/A	No reference and/or no damage reported.
March 12, 1936	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
March 13, 1936	Connecticut River		N/A	flooding, river-bank corrosion, scour of agricultural land
December 26, 1937	Priest Brook		N/A	No reference and/or no damage reported.
January 25, 1938	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
January 25, 1938	Millers River		N/A	No reference and/or no damage reported.
January 25, 1938	Quaboag River	Hampden	N/A	No reference and/or no damage reported.
March 31, 1940	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
April 2, 1940	Priest Brook		N/A	No reference and/or no damage reported.
February 8, 1941	Deerfield River		N/A	No reference and/or no damage reported.
February 8, 1941	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
February 8, 1941	Mill River	Hampshire	N/A	No reference and/or no damage reported.
February 8, 1941	North River		N/A	No reference and/or no damage reported.
February 8, 1941	Quaboag River	Hampden	N/A	No reference and/or no damage reported.
February 8, 1941	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
February 8, 1941	West Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
February 11, 1941	Millers River		N/A	No reference and/or no damage reported.
February 12, 1941	Charles River		N/A	No reference and/or no damage reported.
March 9, 1942	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
March 9, 1942	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
March 9, 1942	Westfield River	Hampshire	N/A	No reference and/or no damage reported.
January 9, 1943	Millers River		N/A	No reference and/or no damage reported.
March 7, 1943	Aberjona River		N/A	No reference and/or no damage reported.
January 2, 1945	Mill River	Hampshire	N/A	No reference and/or no damage reported.
January 27, 1945	Quinebaug River		N/A	No reference and/or no damage reported.
December 7, 1945	Aberjona River		N/A	No reference and/or no damage reported.
December 21, 1945	Connecticut River		N/A	No reference and/or no damage reported.
January 6, 1946	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
March 1, 1946	Connecticut River		N/A	No reference and/or no damage reported.

TABLE J-1.
ICE JAM EVENTS IN MASSACHUSETTS BETWEEN 1913 AND 2012

Event Date	River / Location	County	Losses	Event Write-Up
March 10, 1946	Connecticut River		N/A	No reference and/or no damage reported.
January 31, 1947	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
January 31, 1947	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
March 1, 1947	Connecticut River		N/A	No reference and/or no damage reported.
March 17, 1948	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
January 6, 1949	North Nashua River		N/A	No reference and/or no damage reported.
March 9, 1950	Mill River	Hampshire	N/A	No reference and/or no damage reported.
February 7, 1951	Rocky Brook	Worcester	N/A	No reference and/or no damage reported.
February 9, 1951	Priest Brook		N/A	No reference and/or no damage reported.
February 9, 1951	Ware River	Worcester	N/A	No reference and/or no damage reported.
December 20, 1951	Ware River	Worcester	N/A	No reference and/or no damage reported.
December 21, 1951	Millers River		N/A	No reference and/or no damage reported.
February 2, 1953	Rocky Brook	Worcester	N/A	No reference and/or no damage reported.
January 10, 1956	Merrimack River		N/A	No reference and/or no damage reported.
January 10, 1956	Quaboag River	Hampden	N/A	No reference and/or no damage reported.
January 23, 1957	Aberjona River		N/A	No reference and/or no damage reported.
January 23, 1957	Deerfield River		N/A	No reference and/or no damage reported.
January 23, 1957	Green River		N/A	No reference and/or no damage reported.
January 23, 1957	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
January 23, 1957	Mill River	Hampshire	N/A	No reference and/or no damage reported.
January 23, 1957	Millers River		N/A	No reference and/or no damage reported.
January 23, 1957	North River		N/A	No reference and/or no damage reported.
January 23, 1957	Quaboag River	Hampden	N/A	No reference and/or no damage reported.
January 23, 1957	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
January 23, 1957	West Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
January 24, 1957	Connecticut River		N/A	No reference and/or no damage reported.
January 24, 1957	Millers River		N/A	No reference and/or no damage reported.
January 24, 1957	Sykes Brook	Hampshire	N/A	No reference and/or no damage reported.
January 24, 1957	Ware River	Worcester	N/A	No reference and/or no damage reported.
January 25, 1957	Moss Brook	Franklin	N/A	No reference and/or no damage reported.
January 26, 1958	Aberjona River		N/A	No reference and/or no damage reported.
February 18, 1958	Swift River	Hampshire	N/A	No reference and/or no damage reported.
February 20, 1958	Millers River		N/A	No reference and/or no damage reported.
January 6, 1959	Quinebaug River		N/A	No reference and/or no damage reported.

TABLE J-1.
ICE JAM EVENTS IN MASSACHUSETTS BETWEEN 1913 AND 2012

Event Date	River / Location	County	Losses	Event Write-Up
January 21, 1959	Green River		N/A	No reference and/or no damage reported.
January 22, 1959	Deerfield River		N/A	No reference and/or no damage reported.
January 22, 1959	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
January 22, 1959	Mill River	Hampshire	N/A	No reference and/or no damage reported.
January 22, 1959	Quaboag River	Hampden	N/A	No reference and/or no damage reported.
January 24, 1959	Millers River		N/A	No reference and/or no damage reported.
March 6, 1959	Hop Brook	Franklin	N/A	No reference and/or no damage reported.
March 6, 1959	Sykes Brook	Hampshire	N/A	No reference and/or no damage reported.
March 6, 1959	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
April 3, 1959	Priest Brook		N/A	No reference and/or no damage reported.
March 31, 1960	Rocky Brook	Worcester	N/A	No reference and/or no damage reported.
December 12, 1960	North Nashua River		N/A	No reference and/or no damage reported.
December 15, 1960	Ware River	Worcester	N/A	No reference and/or no damage reported.
February 24, 1961	Quaboag River	Hampden	N/A	No reference and/or no damage reported.
February 25, 1961	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
February 26, 1961	Millers River		N/A	No reference and/or no damage reported.
February 26, 1961	Sevenmile River	Worcester	N/A	No reference and/or no damage reported.
February 27, 1961	Millers River		N/A	No reference and/or no damage reported.
January 7, 1962	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
January 11, 1962	Wading River	Bristol	N/A	No reference and/or no damage reported.
January 5, 1963	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
February 16, 1963	Wading River	Bristol	N/A	No reference and/or no damage reported.
March 7, 1963	Moose Brook	Worcester	N/A	No reference and/or no damage reported.
March 7, 1963	Sevenmile River	Worcester	N/A	No reference and/or no damage reported.
March 14, 1963	Dry Brook	Berkshire	N/A	No reference and/or no damage reported.
March 23, 1963	Marsh Brook	Berkshire	N/A	No reference and/or no damage reported.
January 21, 1964	Hop Brook	Franklin	N/A	No reference and/or no damage reported.
January 21, 1964	Hop Brook	Franklin	N/A	No reference and/or no damage reported.
January 21, 1964	Moss Brook	Franklin	N/A	No reference and/or no damage reported.
January 21, 1964	Rocky Brook	Worcester	N/A	No reference and/or no damage reported.
January 21, 1964	Sevenmile River	Worcester	N/A	No reference and/or no damage reported.
January 21, 1964	Sykes Brook	Hampshire	N/A	No reference and/or no damage reported.
January 22, 1964	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
January 23, 1964	Mill River	Hampshire	$3,571	No reference and/or no damage reported.

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ICE JAM EVENTS IN MASSACHUSETTS BETWEEN 1913 AND 2012

Event Date	River / Location	County	Losses	Event Write-Up
January 23, 1964	Millers River	Worcester	$3,571	No reference and/or no damage reported.
January 23, 1964	West Branch Farmington River	Berkshire/ Hampden	$3,571	No reference and/or no damage reported.
January 25, 1964	Mill River	Hampshire	N/A	No reference and/or no damage reported.
January 26, 1964	Millers River	Franklin	N/A	No reference and/or no damage reported.
January 29, 1964	Wading River	Bristol	N/A	No reference and/or no damage reported.
March 5, 1964	Marsh Brook	Berkshire	N/A	No reference and/or no damage reported.
January 1, 1965	Sevenmile River	Worcester	N/A	No reference and/or no damage reported.
January 18, 1965	Swift River	Hampshire	N/A	No reference and/or no damage reported.
February 7, 1965	Moss Brook	Franklin	N/A	No reference and/or no damage reported.
February 8, 1965	Dry Brook	Berkshire	N/A	No reference and/or no damage reported.
February 8, 1965	Green River	Berkshire	N/A	No reference and/or no damage reported.
February 8, 1965	Hoosic River	Berkshire	N/A	No reference and/or no damage reported.
February 8, 1965	Marsh Brook	Berkshire	N/A	No reference and/or no damage reported.
February 8, 1965	Mill River	Hampshire	N/A	No reference and/or no damage reported.
February 8, 1965	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
February 9, 1965	Bassett Brook	Hampshire	N/A	No reference and/or no damage reported.
February 9, 1965	Kearney Brook	Hampshire	N/A	No reference and/or no damage reported.
February 9, 1965	Middle Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
February 9, 1965	Moose Brook	Worcester	N/A	No reference and/or no damage reported.
February 11, 1965	Otter River	Worcester	N/A	No reference and/or no damage reported.
February 25, 1965	East Meadow River	Essex	$35,714	No reference and/or no damage reported.
February 25, 1965	Hop Brook	Franklin	$35,714	No reference and/or no damage reported.
February 25, 1965	Rocky Brook	Worcester	$35,714	No reference and/or no damage reported.
February 25, 1965	Sykes Brook	Hampshire	$35,714	No reference and/or no damage reported.
March 12, 1965	Green River	Berkshire	N/A	No reference and/or no damage reported.
December 1, 1965	West Branch Westfield River	Hampshire	N/A	No reference and/or no damage reported.
December 2, 1965	Hoosic River	Berkshire	N/A	No reference and/or no damage reported.
January 9, 1966	Dorcester Brook	Plymouth	N/A	No reference and/or no damage reported.
January 17, 1966	Swift River	Hampshire	N/A	No reference and/or no damage reported.
February 13, 1966	Bassett Brook	Hampshire	N/A	No reference and/or no damage reported.
February 13, 1966	Marsh Brook	Berkshire	N/A	No reference and/or no damage reported.
February 13, 1966	Sykes Brook	Hampshire	N/A	No reference and/or no damage reported.
February 15, 1966	Taunton River	Bristol	N/A	No reference and/or no damage reported.
February 16, 1966	East Meadow River	Essex	N/A	No reference and/or no damage reported.

TABLE J-1.
ICE JAM EVENTS IN MASSACHUSETTS BETWEEN 1913 AND 2012

Event Date	River / Location	County	Losses	Event Write-Up
February 8, 1967	Swift River	Hampshire	N/A	No reference and/or no damage reported.
March 17, 1967	Marsh Brook	Berkshire	N/A	No reference and/or no damage reported.
January 9, 1968	Swift River	Hampshire	N/A	No reference and/or no damage reported.
March 18, 1968	Bassett Brook	Hampshire	N/A	No reference and/or no damage reported.
March 18, 1968	Cadwell Creek	Hampshire	N/A	No reference and/or no damage reported.
March 18, 1968	Dry Brook	Berkshire	N/A	No reference and/or no damage reported.
March 18, 1968	Marsh Brook	Berkshire	N/A	No reference and/or no damage reported.
March 19, 1968	Nashua River	Middlesex	N/A	No reference and/or no damage reported.
March 19, 1968	Priest Brook	Worcester	N/A	No reference and/or no damage reported.
March 19, 1968	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
December 26, 1968	Swift River	Hampshire	N/A	No reference and/or no damage reported.
January 3, 1969	Millers River	Worcester	N/A	No reference and/or no damage reported.
January 3, 1969	Ware River	Worcester	N/A	No reference and/or no damage reported.
January 28, 1969	Marsh Brook	Berkshire	N/A	No reference and/or no damage reported.
February 9, 1969	Moose Brook	Worcester	$357,143	No reference and/or no damage reported.
February 10, 1969	Moose Brook	Worcester	N/A	No reference and/or no damage reported.
January 15, 1970	Millers River	Worcester	N/A	No reference and/or no damage reported.
January 22, 1970	Swift River	Hampshire	N/A	No reference and/or no damage reported.
February 3, 1970	Moose Brook	Worcester	N/A	No reference and/or no damage reported.
February 3, 1970	West Branch Farmington River	Berkshire/ Hampden	$55,556	No reference and/or no damage reported.
February 4, 1970	Mill River	Hampshire	N/A	No reference and/or no damage reported.
February 4, 1970	Millers River	Worcester	N/A	No reference and/or no damage reported.
February 4, 1970	Otter River	Worcester	N/A	No reference and/or no damage reported.
February 4, 1970	Sevenmile River	Worcester	N/A	No reference and/or no damage reported.
February 5, 1970	Moss Brook	Franklin	N/A	No reference and/or no damage reported.
February 5, 1970	Wading River	Bristol	N/A	No reference and/or no damage reported.
February 7, 1970	Charles River	Norfolk	N/A	No reference and/or no damage reported.
February 12, 1970	Green River	Hampden	N/A	No reference and/or no damage reported.
January 18, 1971	Swift River	Hampshire	N/A	No reference and/or no damage reported.
January 24, 1971	Millers River	Worcester	N/A	No reference and/or no damage reported.
February 14, 1971	Hop Brook	Franklin	N/A	No reference and/or no damage reported.
February 14, 1971	Wading River	Bristol	N/A	No reference and/or no damage reported.
February 15, 1971	Moose Brook	Worcester	N/A	No reference and/or no damage reported.
February 15, 1971	Old Swamp River	Norfolk	N/A	No reference and/or no damage reported.
February 28, 1971	Quaboag River	Hampden	N/A	No reference and/or no damage reported.
March 1, 1971	Schenob Brook	Berkshire	N/A	No reference and/or no damage reported.
March 3, 1971	Marsh Brook	Berkshire	$357,143	No reference and/or no damage reported.

TABLE J-1.
ICE JAM EVENTS IN MASSACHUSETTS BETWEEN 1913 AND 2012

Event Date	River / Location	County	Losses	Event Write-Up
March 4, 1971	Marsh Brook	Berkshire	N/A	No reference and/or no damage reported.
March 3, 1972	Sevenmile River	Worcester	N/A	No reference and/or no damage reported.
March 4, 1972	Maple Meadow Brook	Middlesex	N/A	No reference and/or no damage reported.
March 17, 1972	Marsh Brook	Berkshire	N/A	No reference and/or no damage reported.
March 18, 1972	Moss Brook	Franklin	N/A	No reference and/or no damage reported.
March 18, 1972	Nashoba Brook	Middlesex	N/A	No reference and/or no damage reported.
January 7, 1973	Wading River	Bristol	N/A	No reference and/or no damage reported.
January 10, 1973	Millers River	Worcester	N/A	Maximum annual gage height, 7.10 feet due to backwater from ice. Discharge 400 cubic feet per second (cfs)
February 2, 1973	Cadwell Creek	Hampshire	$3,571	No reference and/or no damage reported.
February 2, 1973	Hop Brook	Franklin	$3,571	No reference and/or no damage reported.
February 3, 1973	Marsh Brook	Berkshire	N/A	No reference and/or no damage reported.
February 3, 1973	Moss Brook	Franklin	N/A	No reference and/or no damage reported.
February 3, 1973	Sykes Brook	Hampshire	N/A	No reference and/or no damage reported.
February 3, 1973	West Branch Farmington River	Berkshire/ Hampden	N/A	No reference and/or no damage reported.
December 19, 1973	Parker River	Essex	N/A	No reference and/or no damage reported.
January 13, 1974	Marsh Brook	Berkshire	N/A	No reference and/or no damage reported.
December 24, 1974	Ipswich River	Essex	N/A	No reference and/or no damage reported.
February 3, 1976	Charles River at Waltham, MA	Middlesex	N/A	USGS Water Resources Data for Massachusetts WY 2007 reported an annual maximum peak stage of 6.54 feet on 03-FEB-1976 due to release of water stored behind an ice jam upstream at USGS gaging station 01104500 Charles River at Waltham, MA. The annual maximum peak stage was 4,150 cfs.
January 1, 1979	Saugus and Pines Rivers	Essex	N/A	Saugus and Pines River ice broke up and moved downstream, accumulating near General Edwards Bridge. The river is tidal, and broken ice moving in from Lynn Harbor added to the problem; Fishing boats unable to leave harbor

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Event Date	River / Location	County	Losses	Event Write-Up
January 1, 1994	Middle Branch Westfield River	Hampshire	N/A	An ice jam on the Middle Branch Westfield River in Middlefield, MA. The ice jammed in the Middle Branch Westfield River during the last week of January, 1994, forming at a bend in the river, and backing-up about 1000 feet long. The ice floes destroyed a steel foot/snowmobile bridge about 800 feet upstream of the toe. River flows went out of banks and flooded the home at the toe of the jam occupied by Earnest Robinson (about a 8 to 10 foot rise in river stage). Tree scars were observed about 3 feet above the current ice cover elevation. Most of the out-of-bank flow from the river ran down the driveway of the private home and re-entered the river about 200 feet below the jam. On Feb. 18, 1994 the jam appeared to be frozen in place and about 6 feet thick. The most feasible options discussed to alleviate flooding were dusting of the ice cover and the mechanical removal of the broken ice pieces. foot/snowmobile bridge destroyed, home flooded
January 21, 1994	Buck River in Sandisfield, MA	Berkshire	N/A	An ice jam on the Buck River in Sandisfield, MA. The ice jammed in the Buck River on Jan. 21, 1994. “The jam formed where a tree (about 24-inch diameter) was blocking the 30-foot wide river channel perpendicular to flow. Ice backed-up and a jam about 0.5 mile long formed. River flows went out of banks and flooded two homes just upstream of the toe of the jam (about a 10-12 foot rise in river gage).” The town declared a local emergency and the tree was removed. On Feb. 18, 1994 the jam appeared to be frozen in place and 6 to 8 feet thick. The most feasible option discussed to alleviate flooding was the mechanical removal of the broken ice pieces.
January 1, 1996	Millers River	Worcester	N/A	The largest ice jam is located near Morton Meadows. The toe of the jam is located near the wastewater treatment plant and extends upstream 2000 feet to 300 feet below the Main Street Bridge. The jam was made up of broken ice cover about 3-4 feet thick. Flow is passing the jam and there are no signs of grounding. The other two jams are located upstream. The larger of the two is about 1000 feet long, 2-3 ft. thick, and is located at the Starrett Co. Dam
January 22, 1999	West Branch of the Westfield River between Huntington and Chester, MA	Hampshire	N/A	At 1:30 PM EST on Friday, January 22, 1999, an ice jam was reported on the West Branch of the Westfield River between Huntington and Chester, MA. At 12:30 on the 24th, the ice jam remained in place, and the water levels were being affected by a combination of melting snow and expected heavy rains.

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Event Date	River / Location	County	Losses	Event Write-Up
January 24, 1999	vicinity of Fitchburg and Westminster, MA along a portion of the Nashua River	Worcester	N/A	At 5:30 PM EST on Sunday, January 24, 1999 an ice jam was reported in the vicinity of Fitchburg and Westminster, MA along a portion of the Nashua River. The ice jam was not quite one-half mile, and was in place at the Route 12 bridge in Westminster. It extended approximately 1,500 feet downstream of the bridge and was about 750 feet upstream of the bridge. Localized flooding was predicted above the ice jam, but the heaviest rainfall causing the flooding had moved out of Worcester County at this time. Water was flowing beneath the jam and through the jam at the bridge, so flooding was not too much of a threat.
January 17, 2004	Millers River	Worcester	N/A	The last two severe cold spells resulted in backyard flooding, with the most significant being on the weekend of 17 January. Measurements of the ice thickness indicated two layers of ice from the two flooding events. The first event left an ice thickness of 0.7 foot frozen to the existing ground. The second cold event added an additional 1.8 feet of water with a 0.6 feet thick floating ice sheet on top.
January 24, 2005	Millers River	Worcester	$100,000	Water in the Millers River had risen 20 inches overnight due to freeze up jamming. Water was flooding basements and parking lots, and beginning to enter roadways. Flooding was affecting the area from the Tully River confluence up to the next dam on the Millers River. Although flow was estimated at less than 1-year recurrence interval, stages reached about 500-year flood levels.
December 15, 2005	Millers River, downstream of the South Main Street Bridge, in Athol MA	Worcester	N/A	A freeze-up jam was reported, located on Millers River, downstream of the South Main Street Bridge, in Athol MA. The jam has reduced the river's flow near Shore Drive, resulting in frazil ice jammed in that location. This is upstream from the location of the 2004 and 2005 ice jams.
February 13, 2008	Millers River, in Athol MA	Worcester	$10,000	A somewhat loosely-formed jam was noted on Millers River, in Athol MA, on 13 Feb 2008. The freeze-up accumulation was located upstream of the waste water treatment plant, continuing to about 1000 feet upstream of Main St. bridge. The water was flowing freely, carrying small chunks of ice down to the jam.
February 14, 2008	Priest Brook near Winchendon, MA	Worcester	N/A	5.22 feet water rise due to backwater from an ice at USGS gaging station 01162500 Priest Brook near Winchendon, MA. The average daily discharge was 275 cfs.
February 17, 2008	Nashoba Brook near Acton, MA	Middlesex	N/A	7.24 feet water rise due to backwater from an ice jam at USGS gaging station 01097300 Nashoba Brook near Acton, MA. The average daily discharge was 60 cfs.
February 20, 2008	Otter River at Otter, MA	Worcester	N/A	3.42 feet water rise due to backwater from ice at USGS gaging station 01163200 Otter River at Otter, MA. The average daily discharge was 364 cfs.

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ICE JAM EVENTS IN MASSACHUSETTS BETWEEN 1913 AND 2012

Event Date	River / Location	County	Losses	Event Write-Up
February 21, 2008	Millers River	Franklin	N/A	An ice jam located near Rodney Hunt Co. was about 1500 feet long, with the downstream edge 1-2 feet thick. It is thought to be the remainder of the jam that had been in Athol, which released due to the runoff from snowmelt, rain, and spring-like temperatures in the region. No flooding was observed.
March 14, 2010	West Branch of the Farmington River	Berkshire/ Hampden	N/A	Precipitation totals across the Berkshires from March 12 - 13 ranged from 1 1/2 to 3 1/2 inches. The heavy rain, combined with snowmelt, resulted in minor flooding of urban areas and small streams. Route 8 in North Otis was reported closed due to ice chunks in the road left over from an ice jam that broke on the West Branch of the Farmington River. The road was reopened after the ice chunks were cleared.

APPENDIX K.
GLOSSARY

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ABBREVIATIONS

BBRS	Massachusetts Board of Building Regulations and Standards
BRPC	Berkshire Regional Planning Commission
CCC	Cape Cod Commission
CDBG	Community Development Block Grant
CEMP	Comprehensive Emergency Management Plan
CFR	Code of Federal Regulations
cfs	Cubic feet per second
CHC	Office for Coastal Zone Management Coastal Hazards Commission
CMI	Crop Moisture Index
CMR	Code of Massachusetts Regulations
CMRPC	Central Massachusetts Regional Planning Commission
COSTEP-MA	Coordinated Statewide Emergency Preparedness in Massachusetts
CRREL	U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory
CRS	Community Rating System
CZM	Massachusetts Office for Coastal Zone Management
DCAMM	Division of Capital Asset Management and Maintenance
DCR	Massachusetts Department of Conservation and Recreation (formerly Department of Environmental Management)
DEM	Massachusetts Department of Environmental Management ***or*** Digital elevation model
DFIRM	Digital Flood Insurance Rate Map
DHS	Department of Homeland Security
DLTA	District Local Technical Assistance Program
DMA 2000	Disaster Mitigation Act of 2000
DPS	Department of Public Safety
DR	Identification code for federally declared major disasters
EF	Enhanced Fujita (tornado scale)
EM	Identification code for federally declared emergency events
EMAP	Emergency Management Accreditation Program
EOEA	Massachusetts Executive Office of Environmental Affairs

EOEEA	Massachusetts Executive Office of Energy and Environmental Affairs (formerly Executive Office of Environmental Affairs)
EOPSS	Massachusetts Executive Office of Public Safety and Security
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FM	Identification code for fire management assistance events
FMA	Flood Mitigation Assistance Program
FRCOG	Franklin Regional Council of Governments
GAR	Governor's Authorized Representative
GIS	Geographic Information System
HMA	Hazard Mitigation Assistance
HMGP	Hazard Mitigation Grant Program
IFG	Individual and Family Grant Program
IHP	Individual Household Program
IPCC	Intergovernmental Panel on Climate Change
JFO	Joint Field Office
KBDI	Keetch-Byram Drought Index
LiMWA	Limit of Moderate Wave Action
MAPC	Metropolitan Area Planning Council
MassDEP	Massachusetts Department of Environmental Protection
MassDOT	Massachusetts Department of Transportation
MassGIS	Massachusetts Geographic Information System
MBTA	Massachusetts Bay Transportation Authority
MEMA	Massachusetts Emergency Management Agency
MEMT	Massachusetts Emergency Management Team
MEPA	Massachusetts Environmental Policy Act
MGL	Massachusetts General Law
MHC	Massachusetts Historical Commission
MHHW	Mean higher high water
MRP	Mean return period
MRPC	Montachusett Regional Planning Council
MSA	Metropolitan Statistical Area

MVC	Martha's Vineyard Commission
MVPC	Merrimack Valley Regional Planning Commission
MWRA	Massachusetts Water Resources Authority
NAICS	North American Industry Classification System
NAVD	North American Vertical Datum
NCDC	National Climatic Data Center
NEHRP	National Earthquake Hazards Reduction Program
NESIS	Northeast Snowfall Impact Scale
NFIP	National Flood Insurance Program
NGDC	National Geophysical Data Center
NMCOG	Northern Middlesex Council of Governments
NOAA	National Oceanic and Atmospheric Administration
NP&EDC	Nantucket Planning & Economic Development Commission
NRCS	Natural Resource Conservation Service
OCPC	Old Colony Planning Council
PA	Public Assistance
PDM	Pre-Disaster Mitigation Program
PDM/C	Pre-Disaster Mitigation Program Competitive Grants National competitive program
PDSI	Palmer Drought Severity Index
PVPC	Pioneer Valley Planning Commission
Q3	Quality 3 (refers to a level of flood mapping data quality)
RFC	Repetitive Flood Claims
Risk MAP	Risk Mapping, Assessment and Planning
RPA	Regional Planning Agency
RSI	Regional Snowfall Index
SBA	Small Business Administration
SFHA	Special Flood Hazard Area
SHMIC	State Hazard Mitigation Interagency Committee
SHMO	State Hazard Mitigation Officer
SHMP	State Hazard Mitigation Plan
SHMT	State Hazard Mitigation Team
SLOSH	Sea, Lake and Overland Surge from Hurricanes
SPI	Standardized Precipitation Index
SRL	Severe repetitive loss
SRPEDD	Southeastern Regional & Economic Development District

STAPLEE	Social, technical, administrative, political, legal, economic, environmental
TACCEI	Technical Advisory Committee on Coastal Construction and Environmental Issues
TBHA	The Boston Harbor Association
THIRA	Threat Hazard Identification and Risk Assessment
UMC	Uniform Minimum Credit
USC	United States Code
USGS	U.S. Geological Survey
WCT	Wind Chill Temperature
WUI	Wildland Urban Interface

DEFINITIONS

Blizzard—Issued for sustained or frequent gusts to 35 mph or more, accompanied by falling and/or blowing snow reducing visibility to or below ¼ mile. These conditions must be the predominant condition over a 3 hour period. Extremely cold temperatures are often associated with blizzard conditions, but are not a formal part of the definition. The hazard created by the combination of snow, wind and low visibility significantly increases, however, with temperatures below 20 degrees.

Blizzard warning—Sustained winds or frequent gusts of 35 mph occurring in combination with considerable falling and/or blowing snow for a period of at least three hours. Visibilities will frequently be reduced to less than one-quarter mile and temperatures will often remain extremely cold in a blizzard.

Blowing snow—Wind driven snow that reduces visibility to six 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.

Conflagrations—A large destructive fire; which attains such intensity that it creates and sustains its own wind system. It is most commonly a natural phenomenon, created during some of the largest bushfires, forest fires, and wildfires.

Drifting snow—Uneven distribution of snowfall caused by strong surface winds. Drifting snow does not reduce visibility.

Exposure—refers to the people, property, systems, or functions that could be lost to a hazard. Generally exposure includes what lies in the area the hazard could affect.

Flurries—Light snow falling for short durations. No accumulation or just a light dusting is all that is expected.

Freeze—Occurs when the surface air temperature is expected to be 32 degrees Fahrenheit or below over a widespread area for a significant period of time.

Freezing rain or drizzle—Occurs when rain or drizzle freezes on surfaces such as trees, cars and roads, forming a coating or glaze of ice. Temperatures above the ground are warm enough for rain to form, but surface temperatures are below 32 degrees Fahrenheit, causing the rain to freeze on impact. Even small accumulations of ice can be a significant hazard.

Frost—the formation of thin ice crystals on the ground or other surfaces. Frost develops when the temperature of the earth's surface falls below 32 degrees Fahrenheit, but because frost is primarily an

event that occurs as the result of radiational cooling, it frequently occurs with air temperatures in the middle 30s.

Graupel—Small pellets of ice created when super-cooled water droplets coat, or rime, a snowflake. The pellets are cloudy or white, not clear like sleet, and often are mistaken for hail.

Gustnado—A whirl of dust or debris at or near the ground with no condensation funnel

Hail—a form of precipitation that occurs when updrafts in thunderstorms carry raindrops upward into extremely cold areas of the atmosphere where they freeze into ice.

Heavy snow—This definition depends on the region of the USA. In Massachusetts, heavy snow means that six or more inches of snow have fallen in 12 hours, or at least 8 inches in 24 hours. The exception is in Berkshire County, where heavy snow equates to 7 or more inches of snow in 12 hours, or at least 9 inches in 24 hours. Across the Commonwealth, heavy snow is also observed when snow is falling at a rate of one inch per hour.

Heavy snow warning—Snow accumulations are expected to approach or exceed six inches in 12 hours but will not be accompanied by significant wind. A heavy snow warning could also be issued if eight inches or more of accumulations are expected in a 24 hour period. In addition, during a heavy snow warning, freezing rain and sleet are not expected.

Hurricane—An intense tropical weather system of strong thunderstorms with a well-defined surface circulation and a maximum sustained winds of 75 mph or higher.

Ice storm—An ice storm is used to describe occasions when damaging accumulation of ice are expected during a freezing rain situation. Significant accumulations of ice are defined as one-quarter inch or greater. This can cause trees, utility and power lines to fall down causing the loss of power and communication.

Ice storm warning—A significant coating of ice, one-quarter inch or more, is expected.

Mitigation—the process of reducing the severity of the impact of natural hazards through planning. Each hazard requires a specific type of mitigation. In some cases, we can use engineering solutions (such as an earthquake-resistant building) to at least temporarily reduce the impact of a natural hazard. In other cases, the only form of mitigation that is guaranteed to be successful is to limit or not allow human activities where the hazard occurs (such as in floodplains). Natural Hazard an unexpected or uncontrollable natural event of unusual magnitude that threatens the activities of people or people themselves.

Natural disaster—a natural hazard event, such as a flood or tornado, which results in widespread destruction of property or caused injury and/or death.

Natural hazard—an act or phenomenon that has the potential to produce harm or other undesirable consequences to a person or thing.

Risk—depends on all three factors: hazard, vulnerability, and exposure. Risk is the estimated impact that a hazard would have on people, services, facilities, and structures in a community. It refers to the likelihood of a hazard event resulting in an adverse condition that causes injury or damage.

Sleet—Rain drops that freeze into ice pellets before reaching the ground. Sleet usually bounces when hitting a surface and does not stick to objects. However, it can accumulate like snow and cause a hazard to motorists. Heavy sleet occurs when a half of an inch of sleet accumulates

Snow showers—Snow falling at varying intensities for brief periods of time. Some accumulation is possible.

Snow squalls—Intense, but of limited duration, periods of moderate to heavy snowfall, accompanied by strong, gusty surface winds and possible lightning.

Storm surge—A huge dome of water pushed on-shore by hurricane and tropical storm winds. Storm surges can reach 25' high and 50-100 miles wide. This can cause severe erosion, major flooding and extensive damage to coastal areas

Sustained winds—One-minute average wind measured at about 33 feet above the surface.

Technological disaster—A disaster that results from a technological or man-made hazard event.

Technological hazard—A hazard that originates in accidental or intentional human activity (oil spill, chemical spill, building fires, terrorism, etc.)

Tropical depression—An organized system of clouds and thunderstorms with a defined surface circulation and maximum sustained winds of 38 mph or less.

Tropical storm—An organized system of strong thunderstorms with a defined surface circulation and maximum sustained winds of 39-73 mph.

Vulnerability—susceptibility to physical injury, harm, damage, or economic loss. It depends on an asset's construction, contents, and economic value of its functions. Vulnerability assessment provides the extent of injury and damages that may result from a hazard event of a given intensity in a given area.

Warning/advisory—These products are issued when a hazardous weather event is occurring, is imminent or has a very high probability of occurrence. A warning is used for conditions posing a threat to life or property. Advisories are for less serious conditions that cause significant inconvenience and, if caution is not exercised, could lead to situations that may threaten life and property.

Watch—A watch is used when the risk of a hazardous weather event has increased significantly, but the occurrence, location and timing are still uncertain.

Whiteout—A condition caused by falling and/or blowing snow that reduces visibility to nothing or zero miles; typically only a few feet. Whiteouts can occur rapidly often blinding motorists and creating chain-reaction crashes involving multiple vehicles. Whiteouts are most frequent during blizzards.

Wind chill—The wind chill is based on the rate of heat loss from exposed skin caused by the combined effects of wind and cold. As the wind increases, heat is carried away from the body at an accelerated rate, driving down the body temperature. This temperature is the reading the body "feels" given the combination of wind and air temperature. At wind speeds of four mph or less, the wind chill temperature is the same as the actual air temperature. The threshold for potentially dangerous wind chill conditions is about minus 20 degrees Fahrenheit.

Wind chill warning—Life-threatening wind chills reach minus 50 or lower. Criteria varies across the nation.

Winter storm warning—Issued when severe winter weather conditions are occurring, imminent or likely. A warning is used for winter weather conditions posing a threat to life and property. In Massachusetts, with the exception of Berkshire County, a Winter Storm Warning is issued when one of the following is expected: an average 6 inches of snow/sleet in 12 hours, average 8 inches snow/sleet in 24 hours, or one half inch accumulation of freezing rain. In Berkshire County, a Winter Storm Warning is issued when one of the following is expected: an average of 7 inches of snow/sleet in 12 hours, average 9 inches of snow/sleet in 24 hours, or one half inch accumulation of freezing rain. A Winter Storm Warning may be issued based on significant public impacts when the above criteria are not quite expected to be met. For instance, a Winter Storm Warning may be issued if a mixture of heavy wet snow and freezing rain may not separately meet warning criteria, but the snow and ice combined will significantly impact transportation, commerce and public safety.

Winter storm watch—A significant winter storm may affect your area, but its occurrence, location and timing are still uncertain. A winter storm watch is issued to provide 12 to 36 hours' notice of the possibility of severe winter weather. A watch will often be issued when neither the path of a developing winter storm nor the consequences of the weather event are as yet well defined. Ideally, the winter storm watch will eventually be upgraded to a warning when the nature and location of the developing weather event becomes more apparent. A winter storm watch is intended to provide enough lead time so those who need to set plans in motion can do so.

APPENDIX L.
BIBLIOGRAPHY

APPENDIX L. BIBLIOGRAPHY

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