# Massachusetts State Hazard Mitigation and Climate Adaptation Plan

## **Chapter 3: Introduction to Risk Assessment**

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Prepared for:



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## **Table of Contents**

Acr	onyr	ms and Abbreviations	ii
3.	Intr	roduction to Risk Assessment	
	3.1	Natural Hazard Identification Process	3-1
	3.2	Climate Change and Natural Hazard Taxonomy	3-4
	3.3	Sectors Assessed	3-6
		3.3.1 Populations	3-6
		3.3.2 Government	3-9
		3.3.3 Built Environment	3-9
		3.3.4 Natural Resources and Environment	
		3.3.5 Economy	
	3.4	Methodologies Used	
		3.4.1 Data Choices and Limitations	
		3.4.2 General Inventories	
		3.4.3 Techniques and Approaches	
	3.5	Hazard Profile Organization and Key Terms	

#### **Figures**

#### **Tables**

Table 3-1: Climate Change and Natural Hazard Taxonomy	.3-5
Table 3-2: Populations Vulnerable to Natural Hazards and Climate Change	.3-7

#### Appendix

Appendix A: Risk Assessment Methodology

## **Acronyms and Abbreviations**

DCAMM	Division of Capital Asset Management and Maintenance			
EMAP	Emergency Management Accreditation Program			
FEMA	Federal Emergency Management Agency			
GIS	Geographic Information System			
HIRA	Hazard Identification and Risk Assessment			
MassDOT	Massachusetts Department of Transportation			
MEMA	Massachusetts Emergency Management Agency			
NE CASC	Northeast Climate Adaptation Science Center			
NOAA	National Oceanic and Atmospheric Administration			
PMT	Project Management Team			
SHMCAP	State Hazard Mitigation and Climate Adaptation Plan			
SHMP	State Hazard Mitigation Plan			



# 3. Introduction to Risk Assessment

## 3.1 Natural Hazard Identification Process

To identify natural hazards of concern for the Hazard Identification and Risk Assessment (HIRA), the Project Management Team (PMT) and its consulting team reviewed the 2013 State Hazard Mitigation Plan (SHMP), the 2017 Massachusetts Threat and Hazard Identification and Risk Assessment, and the 2017 Commonwealth of Massachusetts Comprehensive Emergency Management Plan. Natural hazards are natural events that threaten lives, property, and other assets. Often, natural hazards can be predicted. They tend to occur repeatedly in the same geographical locations because they are related to weather patterns or physical characteristics of an area. The assessment conducted for the 2013 SHMP recognized the following 11 natural hazards that could potentially impact the Commonwealth of Massachusetts:

- Coastal Erosion
- Dam Failure
- Earthquake
- Fire
- Flood
- Hurricane

- Landslide
- Nor'easter
- Severe Weather
- Severe Winter
- Tsunami

All of the hazards identified and assessed in the 2013 SHMP were determined to be relevant for the HIRA for the 2018 State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) through a PMT kickoff meeting and subsequent risk assessment methodology development. However, some of these hazards were reclassified and/or regrouped (for example, "flood" was broken out into separate "inland flooding" and "coastal flooding" hazard profiles), and a new hazard—invasive species—was added. The natural hazards assessed in this 2018 SHMCAP are identified on the following page.

A key distinction between the 2013 HIRA and the 2018 HIRA is the inclusion of an additional lens through which natural hazards were assessed: climate change, or the statistically significant variation in climate data or patterns over multiple decades due to climate variability or human activity. The Northeast Climate Adaptation Science Center (NE CASC) developed downscaled climate data that were used in the development of this plan and risk assessment, and form a new basis and format for the categorization of natural hazards as they relate to the primary climate change interactions discussed in Section 3.2.

The 2018 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. As part of the SHMCAP planning process, the Massachusetts Emergency Management Agency (MEMA) undertook a review of more than 20 recently approved local hazard mitigation plans, and identified and synthesized common vulnerabilities from these plans for each hazard recognized in the SHMCAP (see *Chapter: 10 Coordination of Local Hazard Mitigation and Climate Adaptation Planning* for additional detail). This information from local plans was also considered in development of the hazard profiles. The primary data collection window for this plan was from May 1 through August 18, 2017. In some sections, supplemental data were integrated into the plan for the purpose of capturing some of the significant weather events that occurred in the winter of 2017-2018, as well as other data that became available following the primary data collection window.

State facilities data used in the risk assessment were provided by Division of Capital Asset Management and Maintenance (DCAMM). The PMT asked that each hazard profile be revised to include significant hazard events that have occurred since the last plan update, include new hazard zone maps, incorporate the likely impacts of climate change on each hazard, and update other information as necessary. Subject-matter experts from various disciplines provided relevant data, including updated studies and reports, and reviewed and updated the completed hazard profiles. This expert review enhanced the accuracy and relevance of information; validated the criteria used to assess vulnerability; and enabled conformity with federal requirements. Extensive geographic information system (GIS) data from state, regional, and local sources were used. These data sources are detailed in the risk assessment methodology provided in Appendix A.

### **Natural Hazards Assessed**



**Inland Flooding** 



Drought



Landslide



**Coastal Flooding** 



**Coastal Erosion** 



Tsunami



Average/Extreme Temperatures



Wildfires



**Invasive Species** 



**Hurricanes/Tropical Storms** 



Severe Winter Storm



Tornadoes



**Other Severe Weather** 



Earthquake

## 3.2 Climate Change and Natural Hazard Taxonomy

The HIRA is organized based on primary climate change interactions. A categorization of traditional natural hazards, within the context of climate change, was included to demonstrate the connections between traditional natural hazard analysis and climate change projections. This categorization also aligns with the four climate change categories included on the Commonwealth's resilient MA Climate Change Clearinghouse website (http://www.resilientma.org/). Those categories are illustrated as follows.



**Changes in Precipitation:** Changes in the amount, frequency, and timing of precipitation—including both rainfall and snowfall—are occurring across the globe as temperatures rise and other climate patterns shift in response.



**Sea Level Rise:** Climate change will drive rising sea levels, and rising seas will have wide-ranging impacts on communities, natural resources, and infrastructure along the Commonwealth's 1,519 tidal shoreline miles.



**Rising Temperatures:** Average global temperatures have risen steadily in the last 50 years, and scientists warn that the trend will continue unless greenhouse gas emissions are significantly reduced. The 9 warmest years on record all occurred in the last 20 years (2017, 2016, 2015, 2014, 2013, 2010, 2009, 2005, and 1998), according to the U.S. National Oceanographic and Atmospheric Administration (NOAA).



**Extreme Weather:** Climate change is expected to increase extreme weather events across the globe, as well as right here in Massachusetts. There is strong evidence that storms—from heavy downpours and blizzards to tropical cyclones and hurricanes—are becoming more intense and damaging, and can lead to devastating impacts for residents across the state.

The hazards presented in this risk assessment, and the order in which they appear, are based on the taxonomy presented in Table 3-1.

Primary Climate Change Interaction	Natural Hazard	Other Climate Change Interactions	Representative Climate Change Impacts
<b>+</b> 1	Inland Flooding	Extreme Weather	Flash flooding, urban flooding, drainage system impacts (natural and human-made), lack of groundwater recharge, impacts to
<u>. ï.ll</u>	Drought	Rising Temperatures, Extreme Weather	drinking water supply, public health impacts from mold and worsened indoor air quality, vector-borne diseases from stagnant water, episodic drought, changes in snow-rain
Changes in Precipitation	Landslide	Rising Temperatures, Extreme Weather	ratios, changes in extent and duration of snow cover, degradation of stream channels and wetland
ራራራ	Coastal Flooding	Extreme Weather	
	Coastal Erosion	Changes in Precipitation, Extreme Precipitation	Increase in tidal and coastal floods, storm surge, coastal erosion, marsh migration, inundation of coastal and marine
Sea Level Rise	Tsunami	Rising Temperatures	ecosystems, loss and subsidence of wetlands
≈∥≈	Average/Extreme Temperatures	N/A	Shifting in seasons (longer summer, early spring, including earlier timing of spring peak flow), increase in length of growing season,
©	Wildfires	Changes in Precipitation	increase of invasive species, ecosystem stress, energy brownouts from higher energy demands, more intense heat waves, public health impacts from high heat
Rising Temperatures	Invasive Species	Changes in Precipitation, Extreme Weather	exposure and poor outdoor air quality, drying of streams and wetlands, eutrophication of lakes and ponds
_	Hurricanes/Tropical Storms	Rising Temperatures, Changes in Precipitation	
	Severe Winter Storm / Nor'easter	Rising Temperatures, Changes in Precipitation	Increase in frequency and intensity of extreme weather events, resulting in greater
Extreme Weather	Tornadoes	Rising Temperatures, Changes in Precipitation	damage to natural resources, property, and infrastructure, as well as increased potential for loss of life
	Other Severe Weather (Including Strong Wind and Extreme Precipitation)	Rising Temperatures, Changes in Precipitation	
Non-Climate- Influenced Hazards	Earthquake	Not Applicable	There is no established correlation between climate change and this hazard

#### Table 3-1: Climate Change and Natural Hazard Taxonomy

## **3.3 Sectors Assessed**

Five key sectors were evaluated as part of the risk assessment. These sectors are introduced in the following sections, and risk assessment findings for each sector are included in the hazard profiles in *Chapter: 4 Risk Assessment*.

#### 3.3.1 Populations



For each hazard, and to the extent practicable for this plan update, the impacts on human health, particularly vulnerable populations, were evaluated and incorporated into each hazard profile. Federal Emergency Management Agency's (FEMA's) GIS-based Hazus program was used for the analysis of several hazards in the risk

assessment, and Hazus calculates data for a population located within a hazard extent. These Hazus analysis results are included in a hazard profile when applicable. The Hazus analysis results are supplemented by information regarding vulnerable populations (including but not limited to disabled, low-income, communities of color, and low English proficiency populations) that could potentially be more severely impacted by each hazard under current and future conditions. Among other factors, these populations may require extra time or outside assistance during evacuations or during events that cause power outages or isolation, and are considered to be more likely to seek or require emergency services. They are also more likely to live in risk-prone areas with poor infrastructure and higher levels of air pollution.

As discussed in *Chapter 2: Planning Context* vulnerability is influenced by three factors: exposure or contact with the hazard; sensitivity or degree to which people or communities are affected by the exposure to the hazard; and capacity to adapt or the ability of communities, institutions, or people to adjust and respond to and recover from potential hazards. As summarized in Table 3-2, the major health impacts from natural hazards and climate change include:

- Heat-related illnesses and death from an increase in extreme temperatures and poor air quality (USGCRP, 2016; DPH, 2017).
- Increases in food- and waterborne illnesses and other infectious diseases from altering geographic and seasonal distributions of existing vectors and vector-borne diseases (USGCRP, 2016).
- **Injuries and accidental premature death** associated with extreme weather events. Extreme weather events can result in acute health impacts, such as injuries and accidental premature death during an event (e.g., drowning during floods). In addition, health impacts can also occur during disaster preparation and post-event cleanup. Other impacts include damage to property, destruction of assets, loss of infrastructure and public services, social and economic impacts, environmental degradation, and other factors (USGCRP, 2016).

Vulnerability Category	Vulnerable Population	Heat-related illnesses	Changes in the prevalence and geographical distribution of food- and waterborne illnesses and other infectious diseases	Injuries and accidental premature death	Exacerbation of chronic diseases (respiratory and cardiovascular diseases, diabetes)	Mental health and stress- related disorders
Age	Individuals over 65	х	Х	х	Х	Х
	Individuals over 65 and living alone	х		х	х	х
	Children under 5	х	Х	х		
Socioeconomic	People living in poverty	Х	Х	Х	Х	Х
Status	The homeless	х	Х	х	х	х
	People with limited English proficiency	х	Х	х	х	х
	People lacking access to air conditioning	х			х	х
Race	Communities of color	Х	Х	Х	Х	Х
Place	People living in an urban area with limited green space	Х			х	х
	People living near high-traffic roadways				х	х
Current Health Status	Adults with chronic diseases (e.g., respiratory and cardiovascular diseases; compromised immune systems)	Х	Х	Х	Х	Х
	Children with respiratory disease (e.g., asthma)	х			х	х
	Individuals using electricity-dependent medical equipment and/or medications that need refrigeration	Х		х	Х	х
	Individuals with disabilities or mobility problems	Х	X	х	x	х
	Individuals with mental health challenges	х		Х		х

Table 3-2: Populations Vulnerable to Natural Hazards and Climate Change

- Exacerbation of chronic diseases (USGCRP, 2016; DPH, 2017).
- Mental health and stress-related disorders ranging from minimal stress and distress symptoms to clinical disorders such as anxiety, depression, post-traumatic stress, and suicidality. Specific groups of people who are at higher risk for distress and other adverse mental health consequences from exposure to climate-related or weather-related disasters include children, the elderly, women (especially pregnant and post-partum women), people with preexisting mental illness, the economically disadvantaged, the homeless, and first responders. Populations living in areas most susceptible to specific climate change events are at increased risk for adverse mental health outcomes (Neria and Shultz, 2012; Neria, Nandi, and Galea, 2008; USGCRP, 2016).

Table 3-2 also identifies the vulnerable populations for each of the major health impacts associated with natural hazards and climate change.

Figure 3-1 illustrates the need for adaptation strategies to consider the multiple and complex risks to the health and well-being of vulnerable populations that are posed by natural and climate-related hazards.



#### Figure 3-1: Potential Impacts of Climate Change on Physical, Mental, and Community Health

Source: USGCRP, 2016

#### 3.3.2 Government

The government sector includes such State-owned assets as transportation (e.g., roads, bridges, and rail), buildings, landholdings, and other infrastructure, such as pump stations and dams. The Commonwealth of Massachusetts owns and operates more than 13,000 parcels and 6,000 structures. 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. There are more than 190 types of facilities in the DCAMM database that are included in this risk and vulnerability assessment.

#### 3.3.3 Built Environment



The built environment sector includes critical facilities owned by the Commonwealth and critical infrastructure sectors that provide or link to key lifeline services, social welfare, and economic development. The State-owned critical facilities assessed were derived from the State's property infrastructure

and critical facilities inventory data set provided by DCAMM. The DCAMM data were more accurate in terms of location and more current than the default critical facility inventories in Hazus. The facility types used include military facilities, police facilities, fire facilities, hospitals, emergency operation centers, and colleges/universities. Critical infrastructure sectors that were qualitatively assessed when applicable and where information was available include:

- Agriculture (including farms, land, crops, livestock, and operations)
- Energy (production, transmission, storage, and distribution, including power plants, substations, electric lines, natural gas systems, and fuel systems)
- Public safety (including public safety facilities and communications)
- Public health (including public health facilities and services provided)
- Transportation (including roads, highways, bridges, tunnels, subways, commuter and commercial rail, ferries, buses, airports, and ports)
- Water infrastructure (including water sources, pump stations, storage tanks or reservoirs, distribution systems, and drinking water)

#### 3.3.4 Natural Resources and Environment



The natural resources and environment sector includes land-based assets owned by the State. It also includes key habitats and natural landscapes documented in the State's BioMap 2 (Conserving the Biodiversity of Massachusetts in a Changing World) and Areas of Critical Environmental Concern, as well as

species identified in the State's Wildlife Action Plan.

#### 3.3.5 Economy

The components in the economy sector include economic loss resulting from damage to critical state assets, the built environment, municipal resources, natural resources, and other sectors. Many sectors of the economy are dependent on the integrity of natural resources. For example, if a coastal resource such as a beach is damaged beyond repair by a storm, that beach will no longer attract tourists and the local and state economy may

experience a loss of revenue from tourism and recreation.

## 3.4 Methodologies Used

#### 3.4.1 Data Choices and 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 next update cycle to be a technical partner in enhancing this project.
- The DCAMM facility database was used to generate critical facility counts in the exposure areas for various hazards; however, this data set only includes State-owned facilities. Therefore, private critical facilities, such as hospitals, or critical facilities managed at the local level, such as K-12 schools, are not included in these counts.
- Hazard data for some hazards, such as coastal erosion and coastal flooding, were limited. The Massachusetts Office of Coastal Zone Management and Department of Transportation (MassDOT) are currently developing more detailed models for each of these hazards, and these models should be used in future plan updates. This item is listed in the strategy portion of the plan as a 2018 new project.
- Throughout this risk assessment, climate data were derived from emerging research conducted by NE CASC at the University of Massachusetts, Amherst. The results of NE CASC analysis will ultimately be published as a formal report, and data will be

accessible using the <u>resilient MA Climate Change Clearinghouse</u>. These resources will likely contain additional information that will be useful for future plan updates.

• Information from Tribal Hazard Mitigation Plans was not included in the risk assessment, but it is incorporated in Chapter 10.

#### 3.4.2 General Inventories

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. The following are key information sources used:

- Historical disaster records and documents, including, but not limited to, reports and spreadsheets maintained by MEMA as they relate to assistance made available following disasters
- Literature developed by state and national hazard experts containing the best available science and most current knowledge of hazards
- Current hazard zone maps, including new ShakeMaps, SLOSH (Sea, Lake and Overland Surges from Hurricanes) models, and Digital Flood Data
- Written and oral communication from state and national hazard experts
- State facilities inventory developed by DCAMM, with information provided by state agencies
- FEMA
- Hazard Research Laboratory, Department of Geography, University of South Carolina
- National Drought Mitigation Center, University of Nebraska-Lincoln
- NOAA and its agencies/programs (National Climatic Data Center and National Weather Service)
- U.S. Forest Service
- U.S. Census 2010
- U.S. Department of Agriculture
- U.S. Geological Survey, U.S. Department of the Interior
- U.S. Army Corps of Engineers

• Other state offices, including Agriculture, Commerce/Economic Development, Health, Ecology, and Social and Health Services agencies

#### 3.4.3 Techniques and Approaches

A 2018 SHMCAP Risk Assessment Methodology document was developed and finalized in October 2017, and was subsequently revised as needed over the course of the project (Appendix A). The document was considered a "living" document throughout much of the plan update process, because the methodologies required refinement on receipt and application of referenced data sets. For many of the hazards addressed, some data used in the analysis have not changed significantly since the 2013 SHMP update. For those hazards whose underlying data has not changed, updates were primarily limited to data interpretation, inclusion of climate change analysis, and the addition of any recent hazard occurrences, as appropriate. Asset data required for exposure and vulnerability analysis were provided by state agencies, as well as the State Agency Vulnerability Assessment Survey Tool developed as part of this effort.

For the purposes of climate change analysis, the assumption made was that the baseline year would be defined as 2017. For those identified hazards likely to be impacted by climate change, it was assumed that vulnerability and risk would be looked at for the following time horizons, as data permitted: 2030, 2050, 2070, and 2100.

Details of the methodologies executed for each hazard as part of the risk assessment update are presented in Appendix A. Applicable state mitigation planning requirements and Emergency Management Accreditation Program (EMAP) standards for each hazard are identified in this appendix.

## 3.5 Hazard Profile Organization and Key Terms

Each hazard profile section included in Chapter 4 varies slightly, based on the nature of each individual hazard; but in general, each section includes background information for that hazard, secondary hazards, exposure and vulnerability, impacts to key sectors, and other areas of concern as appropriate. A summary sheet is also provided for each hazard that presents key information and findings from the risk assessment conducted for that hazard, including identification of areas and jurisdictions that are most at risk to the hazard.

The hazard profile sections examine the natural hazards that have the potential to impact the Commonwealth, identify counties and populations that are most vulnerable to each hazard, and estimate potential losses from the hazards at the state and local levels.

Extensive GIS analysis and Hazus modeling were performed, integrating information from federal, state, and local sources. Each hazard profile contains updated maps or data, where

applicable; and presents risks, in addition to areas most vulnerable to the hazard. The vulnerability of various jurisdictions of the state to each hazard was addressed depending on the available data and other information that were used for the statewide risk assessment. All hazard profiles were updated for the 2018 SHMCAP with any new available information, and data from the 2013 SHMP were retained where it was appropriate and still deemed current.

The following definitions apply for terms used in the risk assessment:

- Climate adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.
- Climate change: A change in the state of the climate that can be identified by statistical changes of its properties that persist for an extended period, whether due to natural variability or as a result of human activity.
- Climate change impact: Consequences of climate change on natural and human systems.
- Consequence: The effect of a hazard occurrence. Consequence is demonstrated by the impact on population, physical property (e.g., state facilities, local jurisdiction assets and general building stock, and critical facilities), responders, operations, the environment, the economy, and public confidence in state governance. A consequence analysis meets the EMAP standard for hazards identified in state plans.
- Exposure: The extent to which something is in direct contact with natural hazards or their related climate change impacts. Exposure is often determined by examining the number of people or assets that lie within a geographic area affected by a natural hazard, or by determining the magnitude of the climate change impact. For example, measurements of flood depth outside a building or number of heat waves experienced by a county are measurements of exposure.
- 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 in 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, because it can impact the entire Commonwealth.
- Natural hazard: Natural hazards are natural events that threaten lives, property, and other assets. Often, natural hazards can be predicted. They tend to occur repeatedly in the same geographical locations because they are related to weather patterns or physical characteristics of an area.
- Natural resources: These are components of natural systems that exist without human involvement. For the purpose of this survey, key natural resource categories include forested

ecosystems, aquatic ecosystems, coastal ecosystems, wetland ecosystems, and old field ecosystems.

- 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 the actual demonstrated impact, such as through the use of the Hazus model. In other cases, dollar losses are demonstrated through exposure analysis due to the inability to determine the extent to which a structure is impacted.
- Probability: Probability is used as a synonym for likelihood, or the estimated potential for an incident to occur.
- Sensitivity: Sensitivity refers to the impact on a system, service, or asset when exposed to natural hazards. For example, if a facility is exposed to storm surge, how will its ability to function be affected? The level of sensitivity indicates how much or to what extent the occurrence of a hazard would exceed a critical threshold (if known) for something such that it would disrupt the ability of the system, service, or asset to continue normal operation. If the critical threshold is not exceeded, then the sensitivity to a certain hazard is low, even if it is exposed.
- Severity/Extent: The extent or magnitude of a hazard, as measured against an established indicator (e.g., Richter Scale, Saffir-Simpson Hurricane Scale, or Regional Snowfall Index).
- Vulnerability: The propensity or predisposition to be adversely affected; for example, as applied to building performance (functionality), damage, or the number of people injured. Vulnerability is a function of exposure, sensitivity, and adaptive capacity.