Worcester Hazard Mitigation Plan Update

[Last Revised – March 8, 2019]

Tatnuck area of the City, December 2017

Adopted by the City Council February 26, 2019

Prepared by the **Central Massachusetts Regional Planning Commission**
1 Mercantile Street, Suite 520
Worcester, MA 01608
www.cmrpc.org

&

Local Hazard Mitigation Team
City of Worcester, Massachusetts

Acknowledgements

The Worcester City Council extends its thanks to participants in the Local Hazard Mitigation Team:

Meghan Gomes, Emergency Management
Michelle Smith, Executive Office Economic Development
Robert Pezzella, Public School Dept.
Francis Sena Jr., Inspectional Services
Sandy Mawdsley, Emergency Management
Chris Rutigliano, Technical Services
George Sherrill, MCPHS
Joseph Fitman, Emergency Management Intern
Dan George, Police Dept.
Robert Mansfield, Fire Dept.
Jonathan Gervais, DPW&P
Christine Dixon, St. Vincent Hospital
John Coyne, St. Vincent Hospital
Tony Penny, Clark University
Stefanie Covino, Mass. Audubon
Roger Clinton, Water Dept.
Alissa Errede, Dept. Public Health
Doug Courville, Worcester Fire Department
James Kempton, DPW&P
David Horne, Inspectional Services
Richard Fiske, Emergency Management
Luba Zhaurova, Energy & Asset Management
Richard Cavalieri, DPW&P, Streets
Steve Roberts, MassDOT
Josh Watkins, Public School Dept.
Raymond Binette, Police Dept.

The Council likewise offers thanks to the Massachusetts Emergency Management Agency (MEMA) for guidance and feedback regarding this plan.

In addition, thanks are extended to the staff of the Central Massachusetts Regional Planning Commission for process facilitation and preparation of this document.

Central Massachusetts Regional Planning Commission

Adam Menard, Assistant Planner
Andrew Loew, Principal Planner
Derrick Mathieu, Assistant Planner
Trish Settles, Regional Collaboration & Community Planning Manager
Matthew Franz, GIS Analyst
Leah Stanley, GIS Intern

cm2019feb19043034

CITY OF WORCESTER

A RESOLUTION ADOPTING THE CITY OF WORCESTER'S HAZARD MITIGATION PLAN UPDATE

WHEREAS: the City of Worcester established a Committee to prepare the Hazard Mitigation Plan; and

WHEREAS: the City of Worcester participated in the development of the Hazard Mitigation Plan; and

WHEREAS: the Hazard Mitigation Plan contains several potential future projects to mitigate potential impacts from natural hazards in the City of Worcester, and

WHEREAS: a duly-noticed public meeting is being held by the Worcester City Council on February, 26, 2019 for the public and municipality to review prior to consideration of this resolution; and

WHEREAS: the City of Worcester authorizes responsible departments and/or agencies to execute their responsibilities demonstrated in the plan.

NOW THEREFORE BE IT RESOLVED:

1. The Worcester City Council formally approves and adopts the Hazard Mitigation Plan update, as approved, pending local adoption, by the Federal Emergency Management Agency (FEMA) and in accordance with MGL Ch. 40; and
2. That the City Manager be and is hereby authorized to provide such documentation as is required for plan adoption by FEMA through its grantee, the Central Massachusetts Regional Planning Commission (CMRPC); and
3. That the City Manager be and is hereby authorized to take other such actions as deemed necessary to carry out the terms, purposes, and conditions of the FEMA grant that is funding this planning process through the CMRPC; and
4. That this resolution shall take effect upon passage.

In City Council **February 26, 2019**

Resolution adopted by a yea and nay vote of Ten Yeas and No Nays

Susan M Ledoux

A Copy. Attest: **Susan M. Ledoux**
City Clerk

Contents

1.0 INTRODUCTION

1.1 Disaster Mitigation Plan

Congress enacted the Disaster Mitigation Act of 2000 (DMA 2000) on October 10, 2000. Also known as the Stafford Act Amendments, the bill was signed into law by President Clinton on October 30, 2000, creating Public Law 106-390. The law established a national program for pre-disaster mitigation and streamlined the federal administration of disaster relief. Specific rules on the implementation of DMA 2000 were published in the Federal Register in February 2002 and required that all communities must have a Hazard Mitigation Plan in place in order to qualify for future federal disaster mitigation grants following a Presidential disaster declaration; each plan must be updated every five years to remain valid. The Hazard Mitigation Plan emphasizes measures that can be taken to reduce or prevent future disaster damages caused by natural hazards. In the context of natural hazard planning, hazard mitigation refers to any action that permanently reduces or eliminates long-term risks to human life and property.

1.2 Plan Purpose

New England weather is renowned for its mercurial and dramatic nature. Late summer hurricanes, major winter blizzards, and summer droughts are all part of climactic atmosphere in Central Massachusetts. These occur frequently enough to be familiar scenes to residents of Worcester. The intersection of these natural hazards with the built environment can transition these routine events into classified natural disasters. Since many cities and towns historically developed along waterways as a corridor for transportation and power, much development is present in riverine floodplains. Such historical development patterns of Central Massachusetts make the likelihood of a devastating impact of a natural disaster more likely.

This plan identifies the natural hazards facing the City of Worcester, assesses the vulnerabilities of the area's critical facilities, infrastructure, residents, and businesses, and presents recommendations on how to mitigate the negative effects of typical natural hazards.

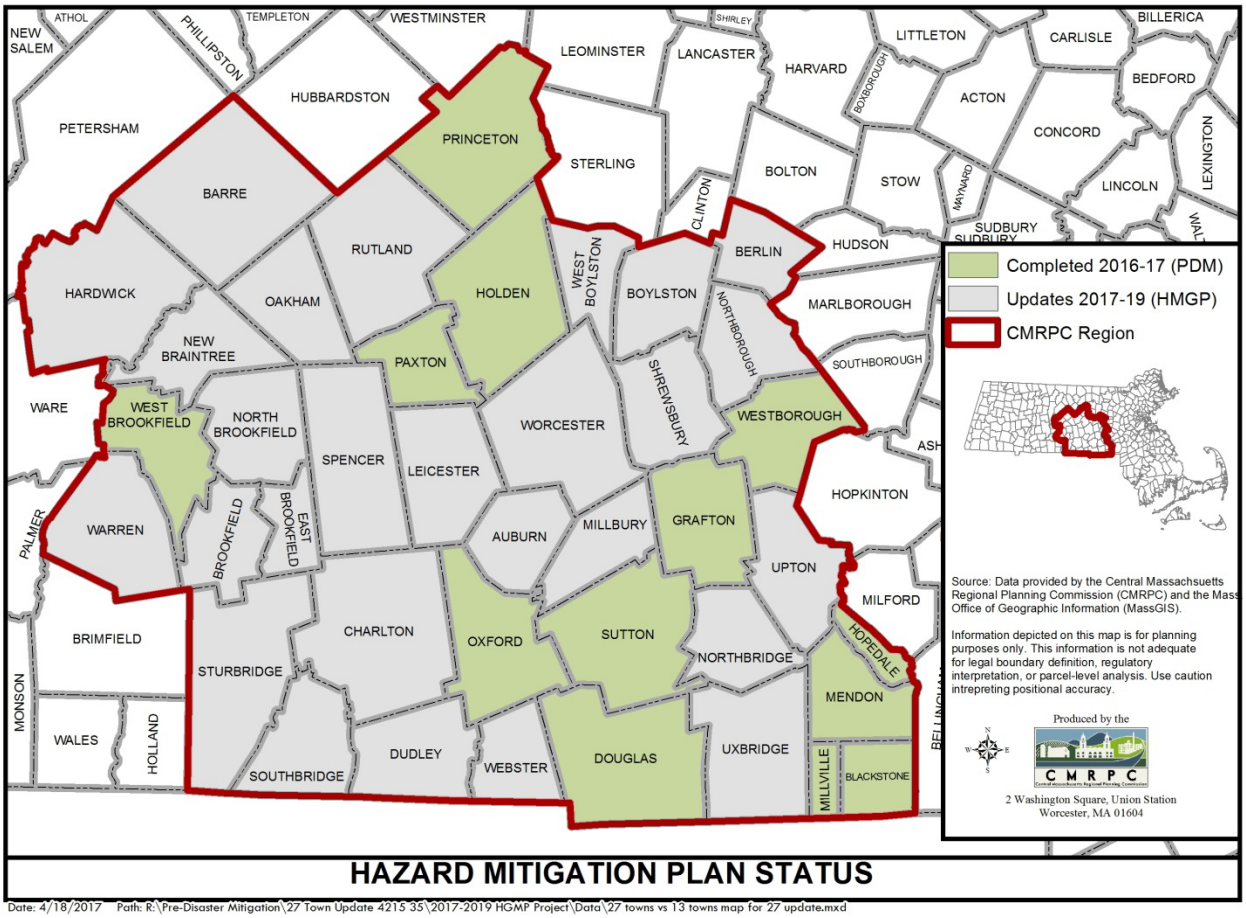
This effort has drawn from the knowledge of local municipal officials and residents, and the recommendations presented are intended to be realistic and effective steps for mitigating natural hazards. Implementation of these actions will translate into savings for the community, fewer lives lost, less property destroyed, and less disruption to essential services.

2.0 PLANNING PROCESS

This Plan is funded by a Fiscal Year 2017 Hazard Mitigation Grant Program (HMGP) grant to CMRPC from the Federal Emergency Management Agency (FEMA) through the Massachusetts Emergency Management Agency (MEMA). Twenty-seven Central Massachusetts communities

are participating in this effort, which involves community-specific updates to a regional plan adopted in March of 2013. Aside from Worcester, the twenty-six other communities are Auburn, Barre, Berlin, Boylston, Brookfield, Charlton, Dudley, East Brookfield, Hardwick, Leicester, Millbury, New Braintree, North Brookfield, Northborough, Northbridge, Oakham, Rutland, Shrewsbury, Southbridge, Spencer, Sturbridge, Upton, Uxbridge, Warren, Webster and West Boylston.

Figure 1



The planning process in each community was composed of two distinct but related phases – data collection and technical review, planning, and public input. Identification of natural hazards impacting participating communities was accomplished through review of available information from various sources. These included federal and state reports and datasets, existing plans, and in some cases engineering documents. An assessment of risks and vulnerabilities was performed primarily using geographic information systems (GIS) to identify the infrastructure (critical facilities, public buildings, roads, homes, businesses, etc.) at the highest risk for being damaged by hazards, particularly flooding. Local knowledge as imparted by city officials, staff, emergency management volunteers and others was a critical element of this phase.

The second phase of the process was focused on outreach, public participation and input, and planning. This phase was critical to ensuring awareness of the planning process among a wide range of local officials, coordinating plan elements with other sectors of the community, and providing opportunities for public comment and input from a representative base of residents and other stakeholders in each community. Through this engagement, CMRPC was better able to gauge community priorities for mitigation and to understand local resources and existing policies and procedures. With this information in hand, the planning team was able to develop an informed and community-specific list of mitigation strategies for each participating town.

In Worcester, a planning team of local staff and volunteers led by Meghan Gomes, Preparedness Specialist, Worcester Emergency Management met four times on the following dates to discuss hazard areas, critical infrastructure and other assets, and plan priorities and strategies: February 22, 2017, April 6, 2017 June 6, 2017 and February 8, 2018. Participants included Meghan Gomes, Emergency Management, Michelle Smith, DPRS, Robert Pezzlla, Worcester Public Schools, Doug Courville Fire Dept., and many others, (see sign-in sheets in appendix D for all participants). Between meetings and during development of the draft and final plans, information and comments were shared among the local team and CMRPC. Additionally, in late 2017 to early 2018, a public survey to gauge residents' concerns about (and experiences with) hazards was distributed on the City's website, as well as CMRPC's, sent electronically to targeted groups (e.g. stakeholders at lake and watershed associations, etc.), and on various city entity social media platforms (e.g. Facebook, etc.). 117 participated to the survey, offering opinions on hazards and vulnerabilities, preferred means of emergency communication, and priorities and suggestions for future mitigation action. (Appendix C) Survey responses were discussed by the planning team at its February 2018 meeting and informed development and prioritization of mitigation strategies.

As planning activities progressed, a public presentation was made by CMRPC at the May 8, 2018 meeting of the Worcester Local Emergency Planning Committee to provide a summary of key aspects of the draft Plan report then being finalized. The opportunity for public comment was emphasized. Materials and notes from the presentation and subsequent public discussion are included in the appendix. A full draft Plan was provided to the City for distribution and made available online at CMRPC's website for public comment for two weeks starting on May 8, 2018. No comments by the public were received. In addition, the final draft Plan was distributed to officials in all neighboring communities for review and input regarding shared hazards. No comments were received.

The final draft Plan was submitted to MEMA for review on June 14, 2018 and was then relayed to FEMA for federal review. After receipt of FEMA's revisions on August 30,2018, a presentation of the final plan was made by CMRPC at the February 26, 2019 meeting of the City Council. At the meeting, the plan was formally adopted by vote of the Council.

The Worcester Planning Board one of the primary city agency responsible for permitting development in the city. The Planning Board is staffed by the Division of Planning and Regulatory Services and the Department of Inspectional Services representatives of which each participated on the local hazard planning team. In addition, CMRPC, the State-designated regional planning authority for Worcester, works with all agencies that regulate development in its region, including the municipal entities listed above and state agencies, such as Department of Conservation and Recreation and MassDOT. This regular involvement ensured that during the development of the Worcester Hazard Mitigation Plan, the operational policies and any mitigation strategies or identified hazards from these entities were incorporated.

See Appendix D for additional documentation of local stakeholder involvement and public participation in the planning process.

3.0 REGIONAL AND COMMUNITY PROFILE

The Central Massachusetts Regional Planning Commission (CMPRC) region occupies roughly 1,000 square miles 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 New England, with a population of 183,382 as of the 2015 American Community Survey (five-year estimate). Nearly 563,000 people live in the CMRPC Region.

The CMRPC area is framed on the west by the Central Massachusetts uplands, on the south by Rhode Island and Connecticut, on the east by the Boston metropolitan area, and on the north by the Montachusett region in northern Worcester County. The forty-community region has been divided for planning purposes into six sub-regions, determined by shared characteristics and roadway corridors. Worcester is located in the Central sub-region which consists solely of the city and lies within the Blackstone River Valley.

Massachusetts has a humid continental climate, with maritime influences increasing from northwest to southeast. The Worcester area, as represented by National Weather Service data collected from 2000 through 2016, sees monthly mean temperatures ranging from 24.4 degrees in January to 71 in July. Precipitation is relatively high at 49.15 inches annually, including 78 inches of snowfall. With a temperate climate and a location some 40 miles from the Atlantic coast, Worcester and its neighboring communities are subject to a variety of severe weather, including hurricanes, nor'easters, thunderstorms, and blizzards. All of these are discussed more fully in Chapter 4.

The City of Worcester, Massachusetts was incorporated in 1848. Worcester is located on I-290, I-190, Route 9, Route 146, and Route 20 and is a dense urban area with variety of industries and residential neighborhoods. Most of Worcester lies within the Blackstone River Basin except for

the northern most tip which lies in the Nashua River Valley. Worcester is bordered by Holden and West Boylston to the north, Shrewsbury on the east, Grafton, Millbury and Auburn on the south, and Leicester and Paxton on the west.

Worcester has a total area of 38.6 square miles and a population of 183,382 (2015 American Community Survey). While the number of city residents has grown from 169,759 in the 1990 US Census to 172,648 in 2000 to the currently (2018) estimated 183,382. According to the Central Massachusetts Regional Planning Commission's (CMRPC) Long Range Transportation Plan, Mobility 2040, the City of Worcester is expected to experience low population growth, similar to the CMRPC region, over the next 25 years. [1]

Worcester, being the second largest city in New England, is a very diverse community. White residents make up 57.9% of the population. Latinos or Hispanics of all races are the largest minority group, at 20.8%. There is a large foreign born population in the city- approximately 22%. The age breakdown is similar to Massachusetts state splits, with children under 19 (25.5%) and seniors 65 or over (12.5%) state rates are 24% and 14.7% respectively. Median age is 33.8, much lower than the state median of 39.3. At $56,221, median household annual income is somewhat below the state ($68,563) and Worcester County ($65,313) medians. Poverty is high at 22.4 %, or more than the state rate (11.6%) and county rate (11.8%). Housing costs are relatively low, with a median owner-occupied home valued at $205,200, compared to $333,100 for Massachusetts and $252,600 for the county. Approximately 38% of occupied homes are detached or semi-detached single family houses; the remainder is multi-unit structures. At 9.4%, vacant housing units are below the state average (9.8%) and above county average (8.4%) numbers. Much of the housing stock is relatively old, with 47.7% structures built before 1940, compared to 34% for Massachusetts and 32.5% for Worcester County.

4.0 NATURAL HAZARD IDENTIFICATION AND ANALYSIS

The following section includes a summary of disasters that have affected or could affect Worcester. Historical research, discussions with local officials and emergency management personnel, available hazard mapping and other weather-related databases were used to develop this list. The most significant identified hazards are the following:

- Dam Failure
- Drought
- Earthquakes
- Extreme Temperatures
- Flooding

[1] http://cmrpc.org/sites/default/files/Documents/Trans/Study_and_Plan/2016%20RTP/Final%20PDF/5.%20RTP%20Chapter%20I%20-%20Introduction%20and%20Background.pdf

- Hurricanes
- Severe Snowstorms/Ice Storms/Nor'easter
- Severe Thunderstorms/Tornadoes/Wind
- Wildfire/Brushfire
- Other hazards

4.1 Overview of Hazards and Impacts

This section examines the hazards in the Massachusetts State Hazard Mitigation Plan which are identified as likely to affect Worcester. The analysis is organized into the following sections: Hazard Description, Location, Extent, Previous Occurrences, Probability of Future Events, Impact, and Vulnerability. A description of each of these analysis categories is provided below.

Hazard Description

The natural hazards identified for Worcester are: Dam Failure, Drought, Earthquakes, Extreme Temperatures, Flooding, Hurricanes, Severe Snowstorms / Ice Storms / Nor'easters, Severe Thunderstorms / Tornadoes / Wind, and Wildfire / Brushfire Many of these hazards result in similar impacts to a community and some are interconnected. For example, hurricanes, tornadoes, and severe snowstorms may cause wind-related damage. Severe thunderstorms may cause flooding, etc.

Location

Location refers to the geographic areas within the planning area that are affected by the hazard. Some hazards affect the entire planning area universally, while others apply to a specific portion, such as a floodplain or area that is susceptible to wild fires. Classifications are based on the area that would potentially be affected by the hazard, on the following scale:

Table 1

Percentage of City Impacted by Natural Hazard	
Land Area Affected by Occurrence	**Percentage of City Impacted**
Large	More than 50% of the city affected
Medium	10 to 50% of the city affected
Small	Less than 10% of the city affected

Extent

Extent describes the strength or magnitude of a hazard. Where appropriate, extent is described using an established scientific scale or measurement system. Other descriptions of extent include water depth, wind speed, and duration.

Previous Occurrences

Previous hazard events that have occurred are described. Depending on the nature of the hazard, events listed may have occurred on a local, state-wide, or regional level.

Probability of Future Events

The probability of future occurrences is estimated by the number of past events. The likelihood of a future event for each natural hazard was classified according to the following scale:

Table 2

Frequency of Occurrence and Annual Probability of Given Natural Hazard	
Frequency of Occurrence	**Probability of Future Events**
Very High	70-100% probability in the next year
High	40-70% probability in the next year
Moderate	10-40% probability in the next year
Low	1-10% probability in the next year
Very Low	Less than 1% probability in the next year

Impact

Impact refers to the effect that a hazard may have on the people and property in the community, based on the assessment of extent described above. Impacts are classified according to the following scale:

Table 3

Impacts, Magnitude of Multiple Impacts of Given Natural Hazard	
Impacts	**Magnitude of Multiple Impacts**
Catastrophic	Multiple deaths and injuries possible. More than 50% of property in affected area damaged or destroyed. Complete shutdown of facilities for 30 days or more.
Critical	Multiple injuries possible. More than 25% of property in affected area damaged or destroyed. Complete shutdown of facilities for more than 1 week.
Limited	Minor injuries only. More than 10% of property in affected area damaged or destroyed. Complete shutdown of facilities for more than 1 day.
Minor	Very few injuries, if any. Only minor property damage and minimal disruption on quality of life. Temporary shutdown of facilities.

Vulnerability

Based on the above metrics, a hazard index rating was determined for each hazard. The hazard index ratings are based on a scale of 1 through 5 as follows:

1 – Highest risk
2 – High risk
3 – Medium risk
4 – Low risk
5 – Lowest risk

The ranking is qualitative and is based, in part, on local knowledge of past experiences with each type of hazard. The size and impacts of a natural hazard can be unpredictable. However; many of the mitigation strategies currently in place and many of those proposed for implementation can be applied to the expected natural hazards, regardless of their unpredictability.

Table 4

Hazard Identification and Analysis for the City of Worcester				
Type of Hazard	**Location of Occurrence**	**Probability of Future Events**	**Impact**	**Hazard Risk Index Rating**
Dam Failure	Small	Very Low	Limited	4
Drought	Large	Very Low	Minor	4
Earthquakes	Large	Very Low	Minor	5
Extreme Temperatures	Large	Moderate	Limited	4
Flooding	Medium	Moderate	Minor	2
Hurricanes	Large	Low	Limited	3
Severe Snowstorms / Ice Storms/ Nor'easter	Large	Very High	Limited	2
Severe Thunderstorms	Small	High	Minor	2
Tornadoes	Small	Very Low	Limited	4
Wildfire / Brushfire	Medium	Moderate	Minor	4
Winds	Small	Moderate	Limited	2

Source: based on Massachusetts State Hazard Mitigation Plan, 2013; modified to reflect conditions in Worcester

4.2 Dam Failure

Hazard Description

Dams and their associated impoundments provide many benefits to a community, such as water supply, recreation, hydroelectric power generation, and flood control. However, they also pose a potential risk to lives and property. Dam failure is not a common occurrence, but dams do represent a potentially disastrous hazard. When a dam fails, the potential energy of the stored water behind the dam is released rapidly. Most dam failures occur when extreme floodwaters overtop dams, causing rapid deterioration through erosion of upper dam surfaces. Often dam breeches lead to catastrophic consequences as the water rushes in a torrent downstream flooding an area engineers refer to as an "inundation area." The number of casualties and the amount of

property damage will depend upon the timing of the warning provided to downstream residents, the number of people living or working in the inundation area, and the number of structures in the inundation area.

Many dams in Massachusetts were built during the 19th century without the benefit of modern engineering design and construction oversight. Dams of this age can fail because of structural problems due to age and/or lack of proper maintenance, as well as from structural damage caused by an earthquake or flooding.

The Massachusetts Department of Conservation and Recreation Office of Dam Safety is the agency responsible for regulating dams in the state (M.G.L. Chapter 253, Section 44 and the implementing regulations 302 CMR 10.00). To be regulated, these dams must be in excess of 6 feet in height (regardless of storage capacity) and have more than 15 acre-feet of storage capacity (regardless of height). Dam safety regulations enacted in 2005 transferred significant responsibilities for dams from the Commonwealth of Massachusetts to dam owners, including the responsibility to conduct dam inspections.

Extent

Dams in Massachusetts are assessed according to their risk to life and property. The state has three hazard classifications for dams:

Extent

- High Hazard: Dams located where failure or improper operation will likely cause loss of life and serious damage to homes, industrial or commercial facilities, important public utilities, main highways, or railroads.

- Significant Hazard: Dams located where failure or improper operation may cause loss of life and damage to homes, industrial or commercial facilities, secondary highways or railroads or cause interruption of use or service of relatively important facilities.

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

Location

According to the Massachusetts Office of Dam Safety, there are 25 dams in Worcester, 16 of which are owned by a government entity and 9 by private owners. 6 are High Hazard and 12 are Significant Hazard. The names and hazard levels of dam structures within Worcester are:

Table 5

National ID	Dam Name	Owner Type	Hazard Potential	Notes
MA02938	Ansila Pond Dam	Private	N/A	
MA03330	Bear Book Dam	City of Worcester	Significant Hazard	
MA00148	Bell Pond Dam	City of Worcester	Significant Hazard	2011 report: poor condition; dam in poor level of upkeep, very little maintenance, no O&M manual
MA02346	Burncoat Park Pond Dam	City of Worcester	Low Hazard	
MA02937	Charles Johnson Pond Dam	Private	N/A	
MA01660	Coes Lower Pond Dam	City of Worcester	Significant Hazard	
MA00120	Coes Reservoir Dam	City of Worcester	High Hazard	
MA00123	Cook's Pond Dam	Private Association or other non-profit	High Hazard	
MA00140	Curtis Ponds Dam	Private-National Grid	Significant Hazard	
MA01661	Duffy Mill Pond Dam	Private	Significant Hazard	
MA02347	Green Hill Duck Pond Dam	City of Worcester	N/A	
MA00149	Green Hill Pond Dam	City of Worcester	High Hazard	
MA00125	Indian Lake Dam	DOT - Dept. of Transportation	Significant Hazard	
MA01662	Kiver Pond Dam	Private Association or other non-profit	Significant Hazard	
MA00141	Leesville Pond Dam	Town of Auburn	Significant Hazard	
MA01659	Old Cider Mill Pond Dam	City of Worcester	Significant Hazard	
MA02348	Parsons Reservoir Dam	City of Worcester	Significant Hazard	

National ID	Dam Name	Owner Type	Hazard Potential	Notes
MA03341	Patch Pond Dam	City of Worcester	High Hazard	2011 report; poor condition, dam in disrepair, no evidence of maintenance, no O&M manual
MA00122	Patch Reservoir Dam	City of Worcester	High Hazard	
MA00139	Quinsigamond Pond Dam	City of Worcester	High Hazard	2011 report; in poor condition, Dam in disrepair, no evidence of maintenance, no O&M manual
MA01663	Rice Street Pool Dam	Private	N/A	
MA00124	Salisbury Pond Dam	City of Worcester	Significant Hazard	
MA02936	Smith Mill Pond Dam	Political Subdivision	Significant Hazard	
MA01664	Tatnuck Country Club Dam	Private	N/A	
MA00121	Williams Mill Pond Dam	City of Worcester	Low Hazard	

Note: this list does NOT include City-owned dams and other dams outside Worcester proper.

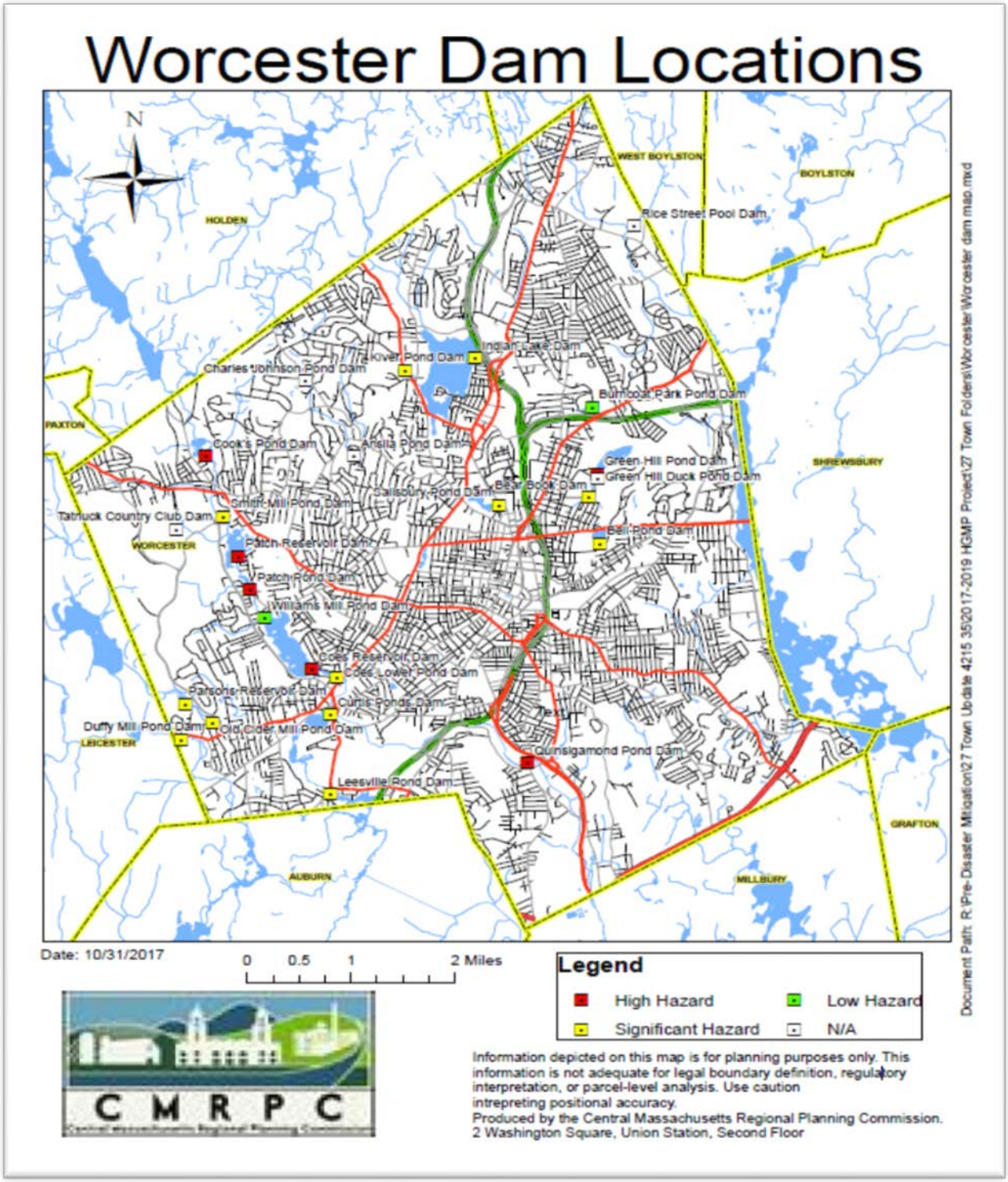


Figure 2 – Worcester Dam Locations

Inundation areas for these dams cover less than 10% of the city, or a “small” portion of its area.

Previous Occurrences

To date, there have been no catastrophic dam failures in Worcester. However, extreme weather led to dams in neighboring towns to breach in the past. Nearly every dam along the French River was destroyed in 1955, which led to flooding in the Webster Square area of the City. Lynde Brook Dam in Leicester breached after two successive Hurricanes in 1876, which led to downstream flooding of Kettle Brook in Worcester.

Probability of Future Events

While Worcester has a fairly high number of High and Significant Hazard dams, there are no reported previous dam failure events in the 150-plus years that dams have been present. Probability for future failure events is therefore "very low" with less than 1 percent chance of a dam bursting in any given year.

Impact

The city faces a "limited" impact from failure of dams, with 10 to 25 percent of the affected area likely to see damage.

It is not possible to estimate the property loss impacts of dam failure quantitatively given the large number of variables involved in failure events. Qualitatively, losses from failure of an individual dam could be significant but would be geographically limited to portions of the dam's inundation zone.

Vulnerability

In accordance with the Massachusetts Hazard Mitigation Plan, a quantitative vulnerability analysis could not be completed to estimate potential losses from a dam failure event. Based on a mostly qualitative assessment, Worcester has a hazard index rating of "4 – limited" from dam failure.

4.3 Drought

Hazard Description

Drought is a normal, recurrent feature of climate. It occurs almost everywhere, although its features vary from region to region. In the most general sense, drought originates from a deficiency of precipitation over an extended period of time, resulting in a water shortage for some activity, group, or environmental sector. Reduced crop, rangeland, and forest productivity; increased fire

hazard; reduced water levels; increased livestock and wildlife mortality rates; and damage to wildlife and fish habitat are a few examples of the direct impacts of drought. These impacts can have far-reaching effects throughout the region and even the country.

Most of Worcester is served by the Worcester Water Treatment Plant (Public Works Department) processing 50 Million Gallons Per Day. The plant utilizes a series of ten surface water reservoirs located in Leicester, Paxton, Rutland, Holden and Princeton, holding over 7 billion gallons of water.

Location

Because of this hazard's regional nature, a drought would likely impact the entire community, meaning the location of occurrence is "large" or over 50 percent of the city.

Extent

The severity of a drought determines the scale of the event. Most of Worcester is served by the Worcester Water Operations Division of Worcester's Department of Public Works & Parks. A small area around Mountain Street West is supplied with water purchased from the Town of Holden. There are also approximately 50 houses in the area using private wells. The U.S. Drought Monitor also records information on historical drought occurrence based on its categorization of drought on a D0-D4 scale as shown below.

Table 6

U.S. Drought Monitor		
Classification	**Category**	**Description**
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies

Source: US Drought Monitor, http://droughtmonitor.unl.edu/.

Previous Occurrences

In Massachusetts, seven major droughts have occurred statewide between 1930 and the recently-notable 2016 event, though the Worcester area has been spared the most severe impacts in each case according to USGS Water Supply Paper for Massachusetts #2375. These historic major droughts range in severity and in length, lasting from three to eight years. In many of these droughts, water-supply systems around the state were found to be inadequate. Water was piped into urban areas, and water-supply systems were modified to permit withdrawals at lower water levels. The following table displays peak drought severity since 2000, from the US Drought Monitor:

Table 7

Annual Drought Status in Worcester County, Mass.	
Year	**Maximum Severity**
2000	No drought
2001	D2 conditions in 7% of the county
2002	D2 conditions in 100% of the county
2003	No drought
2004	D0 conditions in 96% of the county
2005	D0 conditions in 100% of the county
2006	D0 conditions in 100% of the county
2007	D1 conditions in 87% of the county
2008	D0 conditions in 98% of the county
2009	D0 conditions in 76% of the county
2010	D1 conditions in 43% of the county
2011	No drought
2012	D2 conditions in 70% of the county
2013	D1 conditions in 91% of the county
2014	D1 conditions in 79% of the county
2015	D1 conditions in 100% of the county
2016	D3 conditions in 57% of the county
2017 (to Sept. 19)	D2 conditions in 77% of the county

Source: US Drought Monitor, 2017.

In Worcester, the last drought event with substantial impacts occurred in 2016.

Probability of Future Events

In Worcester, as in the rest of the state, extreme and exceptional droughts occur at a "very low" probability (1 to 10 percent in the next year). Based on past events and current criteria outlined in the Massachusetts Drought Management Plan, it appears that central Massachusetts may be slightly more vulnerable than parts of eastern Massachusetts to severe drought conditions. However, many factors, such as water supply sources, population, economic factors (i.e., agriculture based economy), infrastructure and climate change, may affect the severity and length of a drought event. When evaluating the region's risk for drought on a national level, utilizing a measure called the Palmer Drought Severity Index from the National Drought Mitigation Center at the University of Nebraska, Massachusetts is historically in the lowest percentile for severity and risk of drought.

As with all communities in normally precipitation-rich Massachusetts, Worcester is unlikely to be adversely affected by anything other than a major, extended drought. While such a drought would require water saving measures to be implemented, foreseeable damage to structures or loss of life resulting from the hazard would likely be very limited, with modest increased risk of damaging forest or brush fires.

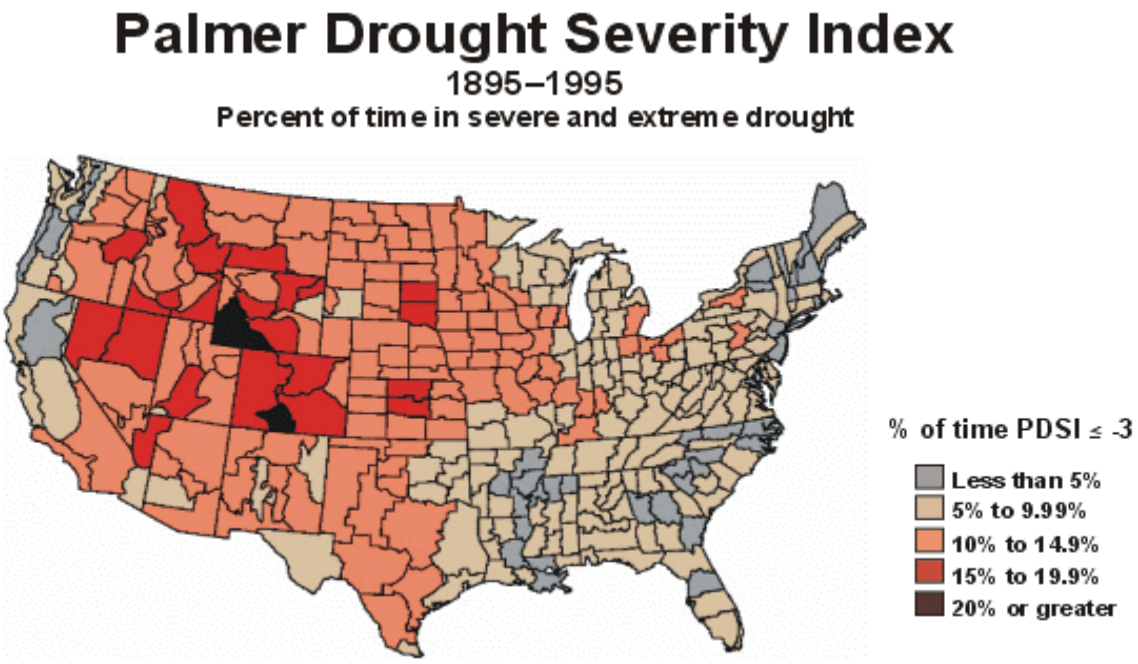


Figure 3

Impact

The impact of droughts is categorized by the U.S. Drought Monitor include:

- Slowing or loss of crops and pastures
- Water shortages or restrictions
- Minor to significant damage to crops, pastures;
- Low water levels in streams, reservoirs, or wells

Impacts in Worcester vary based on the severity and duration of drought. A comprehensive Drought and Water Emergency Plan combined with the ability to supplement reservoir capacity through emergency connections alleviate impacts. While the impact of drought can be assessed as 'minor" overall, with very little damage to people or property likely to occur, impacts may be higher based on the severity and duration of the drought event.

Agricultural impacts due to drought are generally not substantial in the area, because agriculture is a relatively insignificant industry in Worcester. On a county-wide scale, the extreme drought of 2016 caused crop failures on roughly 0.4% of all harvested cropland based on USDA loss claims and the Massachusetts Agricultural Census.

Vulnerability

Based on the above assessment, Worcester has a hazard index rating of “4 – low risk” from drought. Minimal or no loss of property, or damage to people or property is expected due to this hazard. Vulnerability is higher in areas outside the municipal water service area (see Figure 4).

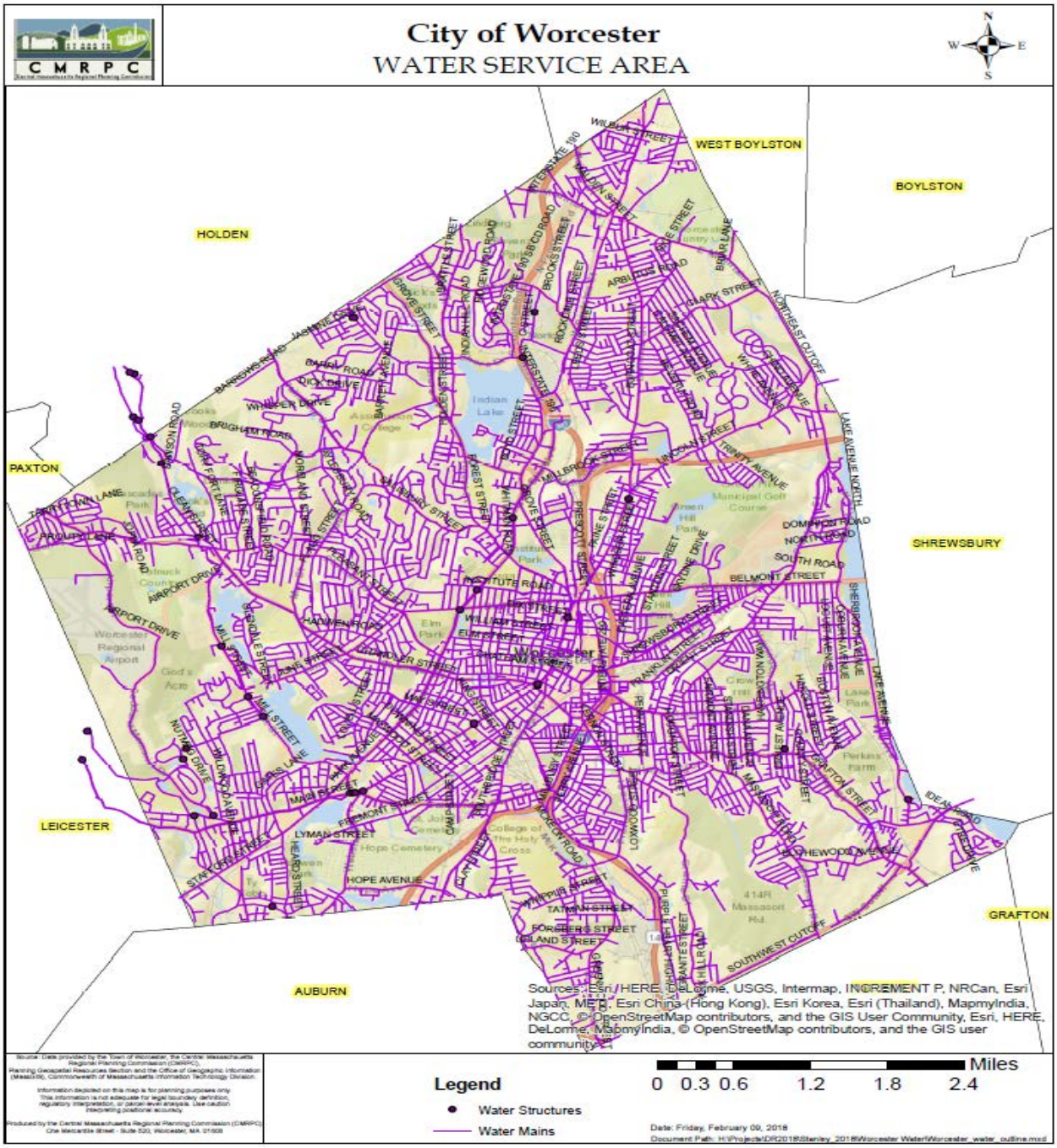


Figure 4 City of Worcester Water Service

4.4 Earthquakes

Hazard Description

An earthquake is a sudden, rapid shaking of the ground that is caused by the breaking and shifting of rock beneath the Earth's surface. Earthquakes can occur suddenly, without warning, at any time

of the year. Ground shaking from earthquakes can rupture gas mains and disrupt other utility service, damage buildings, bridges and roads, and trigger other hazardous events such as avalanches, flash floods (dam failure) and fires. Un-reinforced masonry buildings, buildings with foundations that rest on filled land or unconsolidated, unstable soil, and mobile homes not tied to their foundations are at risk during an earthquake.

Location

Because of the regional nature of the hazard, the entire City of Worcester is susceptible to earthquakes. This makes the location of occurrence "large," or over 50 percent of the total area.

Extent

The magnitude of an earthquake is measured using the Richter Scale, which measures the energy of an earthquake by determining the size of the greatest vibrations recorded on the seismogram. On this scale, one step up in magnitude (from 5.0 to 6.0, for example) increases the energy more than 30 times.

Table 8

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

The intensity of an earthquake is measured using the Modified Mercalli Scale. This scale quantifies the effects of an earthquake on the Earth's surface, humans, objects of nature, and man-made structures on a scale of I through XII, with I denoting a weak earthquake and XII denoting an earthquake that causes almost complete destruction.

Table 9

Modified Mercalli Intensity Scale for and Effects			
Scale	**Intensity**	**Description of Effects**	**Corresponding Richter Scale Magnitude**
I	Instrumental	Detected only on seismographs.	
II	Feeble	Some people feel it.	< 4.2
III	Slight	Felt by people resting; like a truck rumbling by.	
IV	Moderate	Felt by people walking.	
V	Slightly Strong	Sleepers awake; church bells ring.	< 4.8
VI	Strong	Trees sway; suspended objects swing, objects fall off shelves.	< 5.4
VII	Very Strong	Mild alarm; walls crack; plaster falls.	< 6.1
VIII	Destructive	Moving cars uncontrollable; masonry fractures, poorly constructed buildings damaged.	
IX	Ruinous	Some houses collapse; ground cracks; pipes break open.	< 6.9
X	Disastrous	Ground cracks profusely; many buildings destroyed; liquefaction and landslides widespread.	< 7.3
XI	Very Disastrous	Most buildings and bridges collapse; roads, railways, pipes and cables destroyed; general triggering of other hazards.	< 8.1
XII	Catastrophic	Total destruction; trees fall; ground rises and falls in waves.	> 8.1

Source: U.S. Federal Emergency Management Agency

Previous Occurrences

Although New England has not experienced a damaging earthquake since 1755, seismologists state that a serious earthquake occurrence is possible. There are five seismological faults in Massachusetts, but there is no discernible pattern of previous earthquakes along these fault lines. Earthquakes occur without warning and may be followed by aftershocks. Most older buildings and infrastructure were constructed without specific earthquake resistant design features.

The most recent notable (Magnitude or Intensity 4 or greater) earthquakes to affect Massachusetts since 1900 are shown in the table below:

Table 10

Notable Earthquakes in Massachusetts 1900 – 2007			
Location	**Date**	**Magnitude**	**MMI**
Nantucket, MA	October 25, 1965	4.7	5.0
Wareham, MA	April 25, 1924	4.0	5.0
Cape Ann, MA	January 7, 1925	4.0	5.0
Newbury, MA	June 10, 1951	4.0	5.0

Source: Northeast States Emergency Consortium website, *http://nesec.org/massachusetts-earthquakes/*

Additionally, a table showing historic incidences of earthquakes for the six New England states are shown in the table below:

Table 11

New England States Record of Historic Earthquakes		
State	**Years of Record**	**Number of Earthquakes**
Connecticut	1668 - 2007	137
Maine	1766 - 2007	544
Massachusetts	1668 - 2007	355
New Hampshire	1638 - 2007	360
Rhode Island	1776 - 2007	38
Vermont	1843 - 2007	73
Total Number of Earthquakes within the New England states between 1638 and 2007 is 1,507.		

Source: Northeast States Emergency Consortium website, *http://nesec.org/massachusetts-earthquakes/*

Probability of Future Events

One measure of earthquake activity is the Earthquake Index Value. It is calculated based on historical earthquake events data using USA.com algorithms. It is an indicator of the earthquake activity level in a region. A higher earthquake index value means a higher chance of earthquake events. Data was used for Worcester County to determine the Earthquake Index Value as shown in the table below:

Table 12

Earthquake Index for Worcester County	
Worcester County	0.34
Massachusetts	0.70
United States	1.81

Source: *USA.com*

The local Hazard Mitigation Team reports that no earthquakes have been felt in Worcester. Based upon existing records, there is a "very low" frequency (less than 1 percent probability in any given year) of an earthquake in Worcester.

Impact

Massachusetts introduced earthquake design requirements into their building code in 1975 and improved building code for seismic reasons in the 1980s. However, these specifications apply only to new buildings or to extensively-modified existing buildings. Buildings, bridges, water supply lines, electrical power lines and facilities built before the 1980s may not have been designed to withstand the forces of an earthquake. The first edition of the Massachusetts State Building Code went into effect on January 1, 1975, and 47.7% percent of the city's 75,724 occupied housing units was constructed in 1979 or earlier (American Communities Survey, 2015 5-year estimate). The seismic standards were upgraded with the 1997 revision of the State Building Code. Despite its older housing stock, Worcester faces a "minor" impact from earthquakes, with little damage likely to occur due to the extreme rarity of damaging events.

Vulnerability

Based on the above analysis, Worcester has a hazard index rating of "5- lowest risk" from earthquakes. HAZUS- MH (multiple-hazards) is a computer program developed by FEMA to estimate losses due to a variety of natural hazards. The HAZUS earthquake module allows users to define an earthquake magnitude and model the potential damages caused by that earthquake as if its epicenter had been at the geographic center of the study area. For the purposes of this plan, a magnitude 5.0 earthquake was selected for analysis. Historically, major earthquakes are rare in New England, although a magnitude 5 event occurred in 1963.

Table 13 - Estimated Damages from an Earthquake

	Magnitude 5.0
Building Characteristics	
Estimated total number of buildings	44,752
Estimated total building replacement value (2010 $)	$ 23,021,000,000
Building Damages	
# of buildings sustaining slight damage	12,551
# of buildings sustaining moderate damage	7,488
# of buildings sustaining extensive damage	2,467
# of buildings completely damaged	678
Population Needs	
# of households displaced	4,519
# of people seeking public shelter	3,326
Debris	
Building debris generated (tons)	940,000
# of truckloads to clear debris (@ 25 tons/truck)	37,520
Value of Damages (dollars)	
Total property damage	$165,510,000
Total losses due to business interruption	$17,820,000

For more information on the HAZUS-MH software, visit www.fema.gov/hazus-software.

In addition to the general impacts identified by HAZUS, the planning team noted that the City Hall historic brick clock tower may be vulnerable to a substantial earthquake.

4.5 Extreme Temperatures

Hazard Description

As per the Massachusetts Hazard Mitigation Plan, 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. There is no universal definition for extreme temperatures, with the term relative to local weather conditions. For Massachusetts, extreme temperatures can be defined as those that are far outside the normal ranges. Wind chill can also play an important factor in defining an extreme temperature. 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 at www.weather.gov/box/criteria.

Location

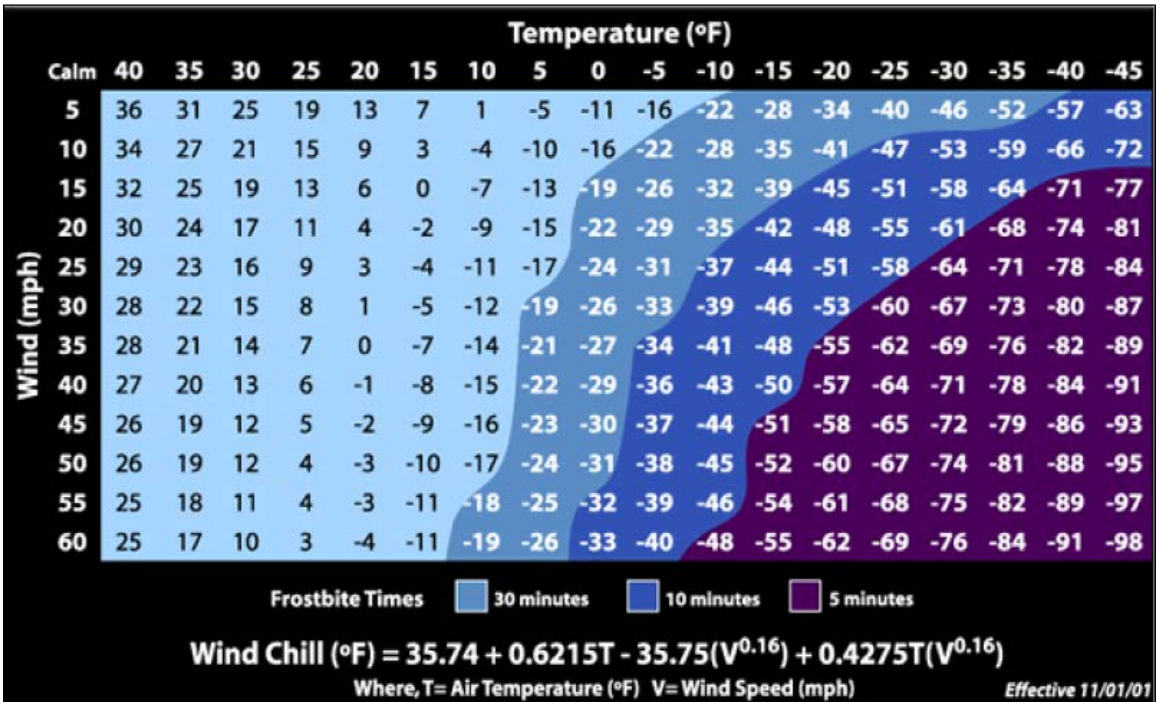
Extreme temperatures can be expected to be fairly uniform across Worcester during a given weather event, due to the city's lack of extreme elevations and coastal areas. Therefore, this hazard is of "large" geographic coverage.

Extent

As per the Massachusetts Hazard Mitigation Plan, 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. 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.

Extreme temperatures would affect the whole community.

Wind Chills



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

Frostbite Times: 30 minutes; 10 minutes; 5 minutes

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

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

Effective 11/01/01

Figure 5

For extremely hot temperatures, the heat index scale is used, which combines relative humidity with actual air temperature to determine the risk to humans. 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 chart indicates the relationship between heat index and relative humidity:

Heat Index

Table 14

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

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.

Previous Occurrences

Worcester's annual average temperature range is 56° for the high and 39.6°for the low. There are areas of the city that likely have differing daily or extreme temperatures due to elevation and the heat island effect of the city. The following are some of the lowest temperatures recorded in parts of 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: –24°F

The following are some of the highest temperatures recorded for the period from 1895 to present (NOAA):

- Blue Hills, MA: 101°F
- Boston, MA: 102°F
- Worcester, MA: 102°F

Probability of Future Events

The probability of future extreme heat and extreme cold is considered to be "moderate," or between 10 and 40 percent in the next year.

In summer, buildings, roads, and other structures in cities absorb heat from sunshine and slowly release it. As a result, urban areas are typically several degrees warmer than greener and less densely developed areas that surround them. The difference can be especially noticeable at night, when cities are much slower to cool off. This phenomenon is called the urban heat-island effect.

Impact

The impact of extreme heat or cold in Worcester is considered to be "limited," with no property damage and very limited effect on humans. Extreme temperatures are of some concern for the local Hazard Mitigation Team due to health threats to the very young and very old and the homeless. Bursting pipes with extreme cold and air quality issues with extreme heat could impact emergency responders.

Vulnerability

Worcester's vulnerability to extreme heat and cold is considered to be, "4 - Low Risk."

4.6 Flooding

Hazard Description

Flooding was the most prevalent natural hazard identified by local officials in Worcester. Flooding is generally caused by hurricanes, nor'easters, severe rainstorms, and thunderstorms. Global climate change has the potential to exacerbate these issues over time with the predicted potential for more severe and frequent storm and rainfall events. In the Northeast, we are already seeing 71% more rainfall in large storms during the years 1958-2012. Since 1991, the amount of rain falling in very heavy precipitation events, defined as the heaviest 1% of all daily events from 1901-2012, has been significantly above average compared to historic rainfall events from 1901-1960.[2] There are several different types of flood hazards – from stormwater inundation and poor drainage infrastructure to riverine flooding and storm surges to dam failures. The most extensive damage would result from dam failure. However, the most frequent flood threat is due to riverine and stormwater flooding.

[2] https://nca2014.globalchange.gov/report/our-changing-climate/heavy-downpours-increasing

Location

Flooding and flood-prone areas in Worcester are closely associated with the course of the Blackstone River and its tributary water bodies and waterways. According to a GIS analysis performed by CMRPC, there are 1,465 parcels in Worcester that are susceptible flooding during a 100-year or base flood events, with 896 of these parcels containing structures. Due to the hilly nature of the city, much of Worcester is upland, away from rivers and ponds and as a result, the location of this hazard is relatively "small". Map 2 in Appendix A illustrates the FEMA FIRM 100-year flood zones in the city, as well as other locally-identified flooding areas. Despite much of the city being upland, the urban environment, and extensive network of imperviousness combined with inadequate drainage systems and steep slopes often leads to localized flooding due to excessive surface water runoff. Known hazard areas are noted in the "previous Occurrences" section below.

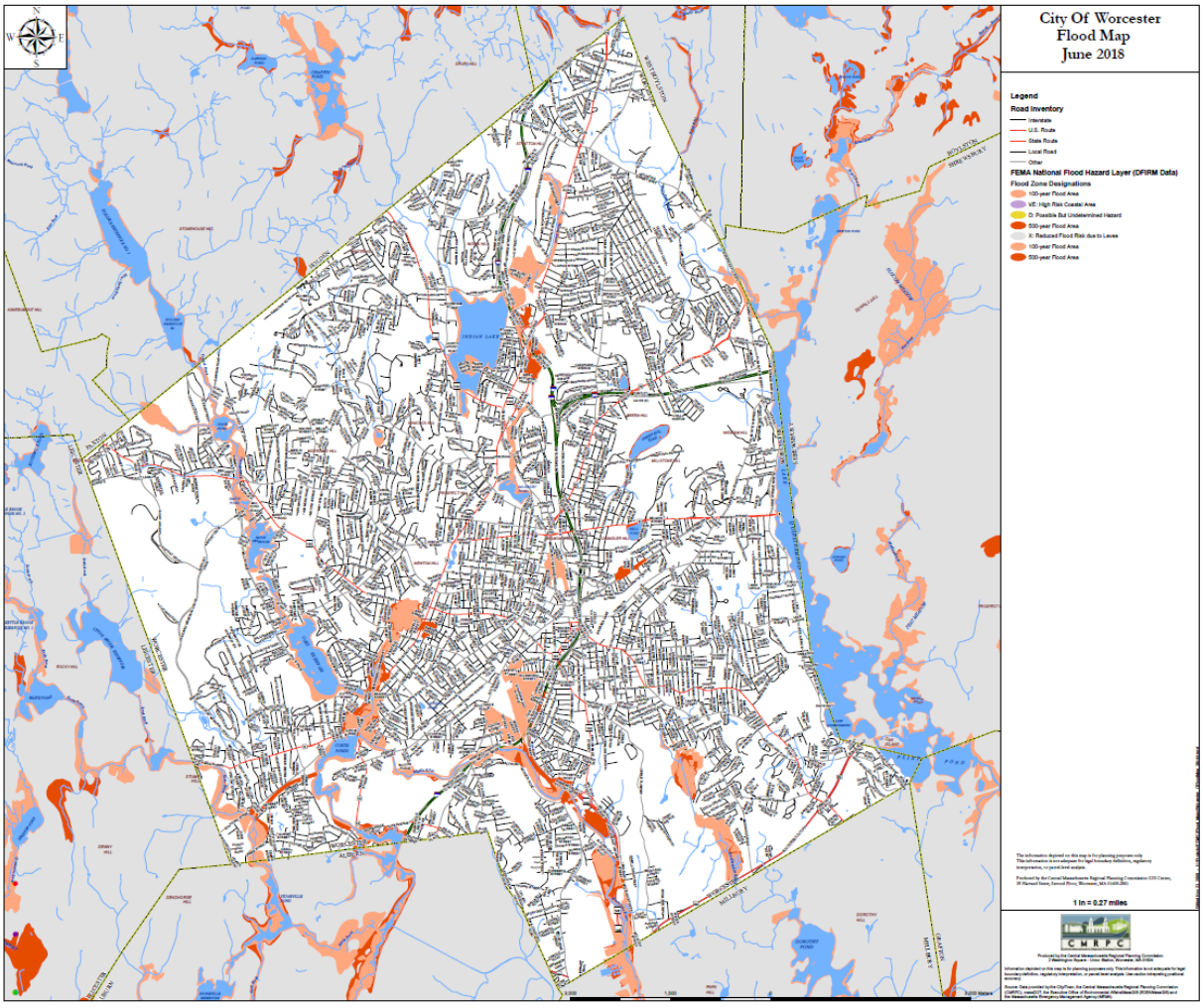


Figure 6 - Worcester Map of FEMA 100 & 500-year flood zone, 2018

Extent

The average annual precipitation for Worcester and surrounding areas in central Massachusetts is 48.1 inches.

Water levels in Worcester's rivers, streams, and wetlands rise and fall seasonally and during heavy rainfall events. High water levels are typical in spring, due to snowmelt and ground thaw combined with rainfall. This is a period when flood hazards are normally expected. Low water levels occur in summer due to high evaporation and plant uptake (transpiration). At any time, heavy rainfall may create conditions that raise water levels in rivers and streams above bank full stage, which then overflow to adjacent land.

Based on past records and the knowledge and experience of members of the Worcester Hazard Mitigation team and residents, the extent of the impact of localized flooding would be considered "minor".

Previous Occurrences

In addition to the floodplains mapped by FEMA for the 100-year and 500-year flood, Worcester often experiences minor flooding at isolated locations due to drainage problems, or problem culverts. The following specific flooding locations were identified by the Worcester Hazard Mitigation Team based on knowledge of past flood events:

- The entire Green Island Area, including Brosnihan Square and ramp to Route 146 at the south, north to Ellsworth street, has been subject to recurrently flooding, with severe instances as recently as October of 2016.
- Washington Street, Green Island, area has repeated historical flooding for more than 100 years. An instance of flooding occurred recently, in October of 2016, resulting in 2 feet of water.
- Elsworth Street, Green Island area, was severely flooded in 1991 & 2011.
- Quinsigamond Avenue has recurrently flooded most recently in 2014 & 2016. The neighborhoods in this area experience flooding, and the WRTA Maintenance Facility has been affected by flooding. The flooding of this property could impact the Ambubus, a mass casualty vehicle which is stored at the WRTA's 40 Quinsigamond Facility, if needed for emergency response.
- Cambridge Street area has flooded regularly during heavy rain events notably impacting the railroad tracks and local businesses
- Southbridge Street and Hammond Street has experienced severe isolated flooding
- Southbridge Street, at College Square, in 2010, flooded along the Blackstone River

- Millbury Street along the Blackstone River
- Shrewsbury Street has flooded in extreme rain events notably in 2011 & 2013
- Southgate Street (under the Rail Road Bridge near its intersection with Southbridge Street) has flooded in the past, 2009, 2012, 2013; the location is outside of the flood zone.
- MA-20 floods under the Grafton Street overpass, a catch basin was added but the location still floods
- Major Taylor Blvd near the DCU Center area flooded in 2016, St. Vincent Hospital was also impacted by this flooding event.

Additionally, undersized culverts and the surface sewer system are a problem citywide.

Detailed study areas in the City of Worcester, though representing small watersheds, have in the past caused severe flooding problems. Much of the floodplain in Worcester is extensively urbanized, which has contributed to the flooding problems[3]

Hurricane Diane, and the accompanying flood of August 19 and 20, 1955, was the most severe flood in the history of the City of Worcester. An Excerpt of the 2011 effective Flood Insurance Study discusses other extents of flooding experience in the city:
"In Webster Square, near the confluence of Beaver and Kettle Brooks, flooding was approximately 12 feet deep. Flooding would have been more severe in the Square had the two Holden Reservoirs not been approximately 3 feet below their normal water surface elevations. The additional 3 feet of storage delayed runoff, which may otherwise have reached Webster Square at the peak of the flood. On Middle River, the Freemont Street Bridge was overtopped by 1 foot, and the Southbridge Street Bridge was overtopped by approximately 1 foot.

Also, there was severe flooding associated with the Mill Brook Conduit in the August 1955 flood. Lamartine, Gold, and Washington Streets were under 2 to 3 feet of water, and Brosnihan Square was under 5 feet of water. At the intersection of Madison and Washington streets, there was 3 feet of water, and at the intersection of Madison and Gold Streets there was 4 feet. The Shrewsbury Street Brook Conduit, which is a large lateral storm drain connected to the Mill Brook Conduit, surcharged and flooded Shrewsbury Street to a depth of approximately 2 feet. Between Washington Square and Lincoln Square on Central Street, the surcharged Mill Brook Conduit flooded Central Street to a depth of approximately 3 feet.

Weasel Brook in the City of Worcester, overbank flooding is caused by inadequate capacity of culverts. North of Brooks Street, floodwaters again pond upstream of an inadequately sized culvert. This culvert conveys the brook underneath a factory which extends into the overbank areas

[3] https://msc.fema.gov/portal/search?AddressQuery=worcester%20ma#searchresultsanchor

on both sides of the brook. Once the pond elevation is higher than the railroad embankment to the east of the factory, flood waters flow down West Boylston Street to join the downstream pond at Brooks Street. The depth of flooding will be less than 3 feet, and the product of depth (in feet) and velocity (in feet per second) will be less than 15."

In addition to the locations listed here (and mapped in Appendix A, Map 2), there are many areas with no record of previous known flood incidents that could be affected in the future by heavy rain and runoff.

Since 1979, there have been 88 loss claims in Worcester paid out by FEMA by National Flood Insurance Program (NFIP) participants, totaling $2,311,943.51. As of January 2017, Worcester has 31 repetitive loss properties. As defined by the NFIP, a repetitive loss property is any property which the NFIP has paid for two or more flood claims of $1,000 or more in any given 10-year period since 1978. Of the 31 structures with losses, 16 are residences and 15 are commercial.

Probability of Future Events

Based upon previous data, there is "moderate" probability of localized flooding occurring in Worcester. It is anticipated that this will be exacerbated by the impacts of climate change, which are already resulting in more rainfall during precipitation events, and by continued development, and re-development of the city.

Impact

With less than 10% of total city area likely to be affected by a flood event, according to the effective flood maps, the city faces a potential "minor" impact.

Utilizing the GIS analysis noted above, the total value of the structures, as of February 2017, on the 1,465 parcels that are susceptible to a 100-year flood is approximately $408,634,300.

HAZUS- MH (multiple-hazards) is a computer program developed by FEMA to estimate losses due to a variety of natural hazards. The HAZUS (4.2) software was used to model potential damage to the community from a 100-year flood event, assuming a 1 square mile data resolution.

Table 15

Estimated Damages from Flood

	100 Year flood event
Building Characteristics	
Estimated total number of buildings	44,752
Estimated total building replacement value (2010 $)	$ 23,021,000,000
Building Damages	
# of buildings sustaining minor damage (1-10%)	126
# of buildings sustaining moderate damage (11-40%)	85
# of buildings sustaining severe damage (41-50%)	4
# of buildings destroyed	0
Population Needs	
# of households displaced	2805
# of people seeking public shelter	217
Value of Damages	
Total property damage (buildings and content)	$ 224,370,000
Total losses due to business interruption	$211,410, 000

Historically there are a number of recorded instances of flood events of the 100-year size. This model was included in order to help planners and emergency personnel quantify the impact scale of a plausible and increasingly likely flood event as we observe increasing frequency of severe weather events due to climate change.[4]

Vulnerability

Based on this HAZUS-MH analysis, Worcester faces a hazard index rating of "2 - high risk" from flooding.

Further vulnerability results from the location of certain critical infrastructure. The Webster Square Fire Station is located within the 100-year flood zone. Additionally, sections of evacuation routes including Routes 9, 122A/146 and I-290 are located in or adjacent to areas prone to flooding. Other Critical Facilities include, the Electrical Substation at Webster Sq. and the WRTA Administrative Building Headquarters. St. Vincent Hospital has flooded in recent years. A vulnerable population (elderly residents) residing in 256 units at the Webster Sq. Towers, (East & West), is located in

[4] For more information on the HAZUS-MH software, go to http://www.fema.gov/hazus-software.

the flood plain. If evacuation routes and critical facilities such as those listed above are flooded, emergency response and/or evacuations could be hampered.

4.7 Hurricanes

Hazard Description

Hurricanes are classified as cyclones and defined as any closed circulation developing around a low-pressure center in which the winds rotate counter-clockwise in the Northern Hemisphere (or clockwise in the Southern Hemisphere) and whose diameter averages 10 to 30 miles across. The primary damaging forces associated with these storms are high-level sustained winds and heavy precipitation. Hurricanes are powerful rainstorms with strong winds that can reach speeds of up to 200 miles per hour and generate large amounts of precipitation. Hurricanes generally occur between June and November and can result in flooding and wind damage to structures and above-ground utilities.

Location

Because of the hazard's regional nature, the entire City of Worcester is at risk from hurricanes, meaning the location of occurrence is "large." Ridgetops are more susceptible to wind damage while areas susceptible to flooding are likely to be affected by heavy rainfall.

Extent

As an incipient hurricane develops, barometric pressure (measured in millibars or inches) at its center falls and winds increase. If the atmospheric and oceanic conditions are favorable, it can intensify into a tropical depression. When maximum sustained winds reach, or exceed 39 miles per hour, the system is designated a tropical storm, given a name, and is closely monitored by the National Hurricane Center in Miami, Florida. When sustained winds reach or exceed 74 miles per hour the storm is deemed a hurricane. Hurricane intensity is further classified by the Saffir-Simpson Hurricane Wind Scale, which rates hurricane wind intensity by category on a scale of 1 to 5, with 5 being the most intense.

Table 16

Saffir-Simpson Scale	
Hurricane Category	**Maximum Sustained Wind Speed (MPH)**
1	74–95
2	96–110
3	111–129
4	130–156
5	157 +

Source: National Hurricane Center, 2012

Previous Occurrences

Hurricanes that have affected the region in which Worcester is located through 2017 are shown in the following table:

Table 17

Major Hurricanes and Tropical Storms Affecting the region		
Hurricane/Storm Name	**Year**	**Saffir/Simpson Category (when reached MA)**
Great Hurricane of 1938	1938	3
Great Atlantic Hurricane	1944	1
Hurricane Dog	1950	Unclear
Carol	1954	3
Edna	1954	1
Diane & Connie	1955	Tropical Storms, 5 days apart
Donna	1960	Unclear, 1 or 2
Belle	1976	Minor Storm
Gloria	1985	1
Bob	1991	2
Floyd	1999	Tropical Storm
Irene	2011	Tropical Storm
Sandy	2012	Tropical Storm

Source: National Oceanic and Atmospheric Administration

Probability of Future Events

Worcester's location, approximately 40 miles inland, in central Massachusetts reduces the risk of extremely high winds that are associated with hurricanes, although it can still experience some high wind events. Based upon past occurrences, it is reasonable to say that there is a "low" probability (1 percent to 10 percent in any given year) of hurricanes in Worcester. Climate change is projected to result in more severe weather, including increased occurrence and intensity of hurricanes and tropical storms. Because of this, the occurrence of hurricanes in Worcester will increase in the future.

Impact

A description of the damages that could occur due to a hurricane is described by the Saffir-Simpson scale, as shown below:

Table 18

Hurricane Damage Classifications			
Storm Category	**Damage Level**	**Description of Damages**	**Wind Speed (MPH)**
1	MINIMAL Very dangerous winds will produce some damage	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Also, some coastal flooding and minor pier damage. An example of a Category 1 hurricane is Hurricane Dolly (2008).	74-95
2	MODERATE Extremely dangerous winds will cause extensive damage	Some roofing material, door, and window damage. Considerable damage to vegetation, mobile homes, etc. Flooding damages piers and small craft in unprotected moorings may break their moorings. An example of a Category 2 hurricane is Hurricane Francis in 2004.	96-110
3	EXTENSIVE Devastating damage will occur	Some structural damage to small residences and utility buildings, with a minor amount of curtain wall failures. Mobile homes are destroyed. Flooding near the coast destroys smaller structures, with larger structures damaged by floating debris. Terrain may be flooded well inland. An example of a Category 3 hurricane is Hurricane Ivan (2004).	111-129
4	EXTREME Catastrophic damage will occur	More extensive curtain wall failures with some complete roof structure failure on small residences. Major erosion of beach areas. Terrain may be flooded well inland. An example of a Category 4 hurricane is Hurricane Charley (2004).	130-156
5	CATASTROPHIC Catastrophic damage will occur	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Flooding causes major damage to lower floors of all structures near the shoreline. Massive evacuation of residential areas may be required. An example of a Category 5 hurricane is Hurricane Andrew (1992).	157+

The city faces a “limited” impact from hurricanes, with 10 percent or less of Worcester affected.

Vulnerability

Based on the above analysis, Worcester has a hazard index rating of “3 – medium risk” from hurricanes.

HAZUS- MH (multiple-hazards) is a computer program developed by FEMA to estimate losses due to a variety of natural hazards. The HAZUS software was used to model potential damages to the community from a 100-year and 500-year hurricane event; storms that are 1% and .02% likely to happen in a given year, and roughly equivalent to a Category 2 and Category 4 hurricane. The damages caused by these hypothetical storms were modeled as if the storm track passed directly through the city, bringing the strongest winds and greatest damage potential.

Table 19

Estimated Damages from Hurricanes

	100 Year	500 Year
Building Characteristics		
Estimated total number of buildings	44,752	
Estimated total building replacement value (2014 $)	$ 23,021,000,000	
Building Damages		
# of buildings sustaining minor damage	1,020	5,985
# of buildings sustaining moderate damage	139	1,321
# of buildings sustaining severe damage	5	67
# of buildings destroyed	0	11
Population Needs		
# of households displaced	74	744
# of people seeking public shelter	20	211
Debris		
Building debris generated (tons)	10,580	48,340
Tree debris generated (tons)	4,717	15,442
# of truckloads to clear building debris	425	1,927
Value of Damages (thousands of dollars)		
Total property damage (buildings and content)	$74,082.53	$362,252.91
Total losses due to business interruption	$ 5,720.83	$41,912.05

Though there are no recorded instances of a hurricane equivalent to a 500-year storm passing through Massachusetts, this model was included in order to present a reasonable "worst case scenario" that would help planners and emergency personnel evaluate the impacts of storms that may be more likely in the future, as we enter into the climate change era. For more information on the HAZUS-MH software visit: http://www.fema.gov/hazus-software.

4.8 Severe Snowstorms / Ice Storms / Nor'easters

Hazard Description

Severe winter storms can pose a significant risk to property and human life. Severe snowstorms and ice storms can involve rain, freezing rain, ice, snow, cold temperatures and wind. Heavy snowfall and extreme cold can immobilize an entire region. Even areas that normally experience mild winters can be hit with a major snowstorm or extreme cold. Winter storms can result in flooding, storm surge, closed highways, blocked roads, downed power lines and hypothermia. 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.

Location

The entire City of Worcester is susceptible to severe snowstorms, which means the location of occurrence is "large." Because these storms occur regionally, they would impact the entire city. The Worcester Regional Airport is especially vulnerable to severe snow storms due to its high elevation.

Extent

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: Extreme, Crippling, Major, Significant, and Notable. 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.

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 around one for smaller storms to over ten for extreme storms. The raw score is then 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.

Table 20

Northeast Snowfall Impact Scale Categories		
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

Source : http://www.ncdc.noaa.gov/snow-and-ice/rsi/nesis

Previous Occurrences

The 2011 Halloween Nor'easter produced unusually early snowfall on trees that were often still in leaf, adding extra weight, with the ground in some areas still soft from a preceding warm, rainy period that increased the possibility trees could be uprooted. Based on data available from the National Oceanic and Atmospheric Administration (NOAA), there are 62 high-impact snowstorms, according to the NESIS scale, since 1958 which affected the Northeast Corridor. Of these, 36 storms resulted in snowfalls in Worcester of at least 10 inches. These storms are listed in the table below:

Table 21

Winter Storms Producing Over 10 Inches of Snow in Worcester, 1958-2018			
Date	**NESIS Value**	**NESIS Category**	**NESIS Classification**
3/11/2018	3.16	2	Significant
3/05/2018	3.45	2	Significant
1/03/2018	1.71	1	Notable
3/12/2017	5.03	3	Major
2/8/2015	1.32	1	Notable
1/29/2015	5.42	3	Major
1/25/2015	2.62	2	Significant
2/11/2014	5.28	3	Major
3/4/2013	3.05	2	Significant
2/7/2013	4.35	3	Major

Winter Storms Producing Over 10 Inches of Snow in Worcester, 1958-2018			
10/29/2011	1.75	1	Notable
1/26/2011	2.17	1	Notable
1/9/2011	5.31	3	Major
2/23/2010	5.46	3	Major
2/12/2006	4.1	3	Major
1/21/2005	6.8	4	Crippling
2/15/2003	7.5	4	Crippling
3/31/1997	2.29	1	Notable
1/6/1996	11.78	5	Extreme
2/2/1995	1.43	1	Notable
2/8/1994	5.39	3	Major
3/12/1993	13.2	5	Extreme
2/10/1983	6.25	4	Crippling
4/6/1982	3.35	2	Significant
2/5/1978	5.78	3	Major
1/19/1978	6.53	4	Crippling
2/18/1972	4.77	3	Major
12/25/1969	6.29	4	Crippling
2/22/1969	4.29	3	Major
2/8/1969	3.51	2	Significant
2/5/1967	3.5	2	Significant
2/2/1961	4.04	3	Major
1/18/1961	4.04	3	Major
12/11/1960	4.53	3	Major
3/2/1960	8.77	4	Crippling
2/14/1958	6.25	4	Crippling

Source : http://www.ncdc.noaa.gov/snow-and-ice/rsi/nesis

Probability of Future Events

Based upon the availability of records for Worcester County, the likelihood that a severe snow storm will affect Worcester is “very high” (greater than 70 percent in any given year).

Research on climate change indicates that there is great potential for stronger, more frequent storms as the global temperature increases. The Massachusetts State Climate Change Adaptation Report says that predicted changes in the amount, frequency, and timing of precipitation, and the

shift toward more rainy and icy winters would have significant implications. By the end of the century, under the high-emissions scenario, annual precipitation is expected to increase by 14%, with a slight decrease in the summer, and a 30% increase in the winter. Additionally, it is predicted that most of the winter precipitation will be in the form of rain rather than snow [5]

Impact

The city faces a "limited" impact or less than 10 percent of total property damaged, from snowstorms.

The weight from multiple snowfall events can test the load ratings of building roofs and potentially cause significant damage. Multiple freeze-thaw cycles can also create large amounts of ice and make for even heavier roof loads and lead to ice dams and both interior and exterior structural damage.

Other impacts from snowstorms and ice storms include:

- Disrupted power, internet, and phone service
- Damage to telecommunications structures and utility infrastructure
- Infrastructure and other property are also at risk from severe winter storms and the associated flooding that can occur following heavy snow melt.
- Tree damage and fallen branches that cause utility line damage and roadway blockages – particularly during ice, sleet, or heavy snow storms
- Unsafe driving conditions and increased traffic accidents
- Reduced ability of emergency officials to respond promptly to medical emergencies or fires

Vulnerability

Based on the above assessment, Worcester has a hazard index rating of "2 — high risk" from snowstorms and ice storms.

Utilizing the city's total value of all property, $11,236,881,245 (Massachusetts Department of Revenue, 2016), and an estimated 5 percent of damage to 10 percent of residential structures, approximately $56,184,406 worth of damage could occur from a severe snowstorm. This is a rough estimate and likely reflects a worst-case scenario. The cost of repairing or replacing the roads, bridges, utilities, and contents of structures is not included in this estimate.

[5] https://www.mass.gov/service-details/climate-change-in-massachusetts-and-its-impacts

4.9 Severe Thunderstorms / Wind / Tornado

Hazard Description

A thunderstorm is a storm with lightning and thunder produced by a cumulonimbus cloud, usually producing gusty winds, heavy rain, and sometimes generating 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).

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.

Tornadoes are swirling columns of air that typically form in the spring and summer during severe thunderstorm events. In a relatively short period of time and with little or no advance warning, a tornado can attain rotational wind speeds in excess of 250 miles per hour and can cause severe devastation along a path that ranges from a few dozen yards to over a mile in width. The path of a tornado may be hard to predict because they can stall or change direction abruptly. Within Massachusetts, tornadoes have occurred most frequently in the Connecticut River Valley and in western Worcester County, with Worcester some 20 miles east of the zone of most frequent past occurrence. High wind speeds, hail, and debris generated by tornadoes can result in loss of life, downed trees and power lines, and damage to structures and other personal property.

Location

As per the Massachusetts Hazard Mitigation Plan, the entire City is at risk of high winds, severe thunderstorms, and tornadoes. The plan identifies Worcester and its surrounding communities as having a moderate frequency of tornado occurrence within the Massachusetts context. However, the actual area affected by thunderstorms, wind, or tornadoes is "small," with less than 10 percent of the city generally affected.

Extent

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. Thunderstorms can cause hail, wind, and flooding.

Tornadoes are measured using the enhanced F-Scale, shown with the following categories and corresponding descriptions of damage:

Table 22

Enhanced Fujita Scale Levels and Descriptions of Damage			
EF-Scale Number	**Intensity Phrase**	**3-Second Gust (MPH)**	**Type of Damage Done**
EF0	Gale	65–85	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages to sign boards.
EF1	Moderate	86–110	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
EF2	Significant	111–135	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
EF3	Severe	136–165	Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.
EF4	Devastating	166–200	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.

Table 23 - Extent Scale for Hail

CONVERTING TRADITIONAL HAIL SIZE DESCRIPTIONS

Traditional object-to-size conversion for assessment and translation of severe hail reports. We encourage *measurement*, not estimation, of hail size.

HAIL SIZE (in.)	OBJECT ANALOG REPORTED
.50	Marble, moth ball
.75	Penny
.88	Nickel
1.00	Quarter
1.25	Half dollar
1.50	Walnut, ping pong
1.75	Golf ball
2.00	Hen egg
2.50	Tennis ball
2.75	Baseball
3.00	Tea cup
4.00	Grapefruit
4.50	Softball

Previous Occurrences

Because thunderstorms and wind affect the city regularly on an annual basis, there are not significant records available for these events. As per the Massachusetts Hazard Mitigation Plan, there are approximately 10 to 30 days of thunderstorm activity in the state each year.

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:

Figure 7- Photo: MEMA 2011

- In 1953, a F4 tornado struck Worcester. The event resulted in at least 90 fatalities, and more than 1,200 injured. There was extensive property damage. On the same date, a F3 tornado began in the Town of Sutton, South of Worcester.
- In 1981 a F3 tornado struck, resulting in just 3 injuries and very little reported property damage.

- In June 2011, a F3 tornado struck Massachusetts. Few deaths were reported, all in Hampden County. No deaths were reported in Worcester County.

Figure 8 - Above: NASA released this image of part of the 39-mile-long tornado track through south-central Mass. The image was captured June 5, 2011 by Landsat 5 satellite.

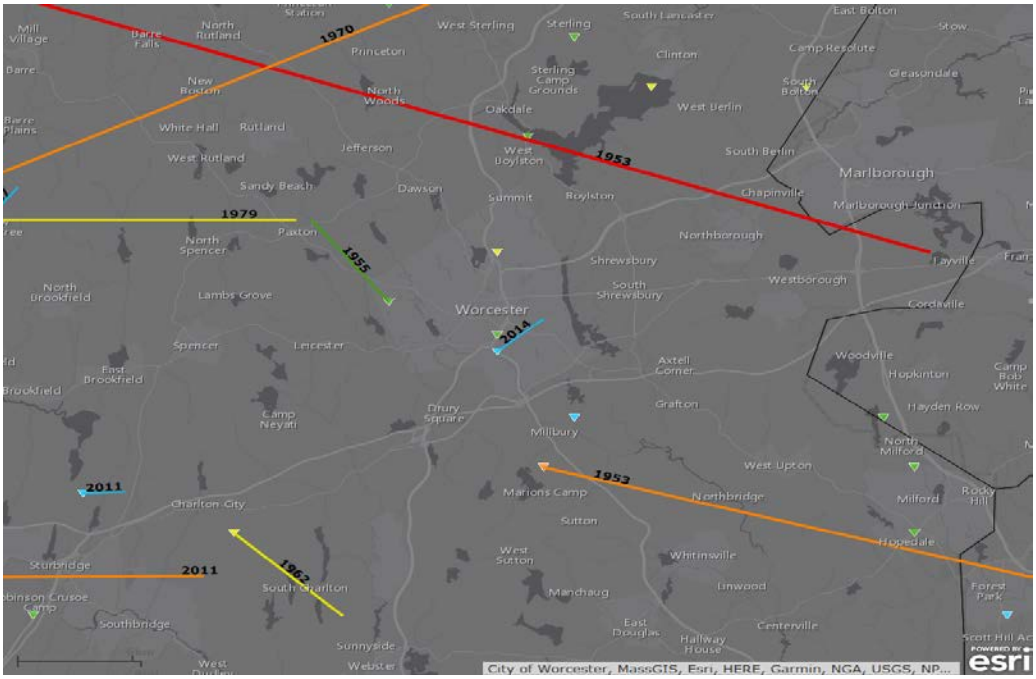


Figure 9 - Tornado Tracks, 1950-2016 in the Worcester area. ***http://mrcc.isws.illinois.edu/gismaps/cntytorn.htm***

Probability of Future Events

One measure of tornado activity is the tornado index value. Activity is calculated based on historical tornado events data using USA.com algorithms. The index is an indicator of the relative tornado activity level in a region. A higher tornado index value means a higher chance of tornado events. Index values for Worcester and its surroundings are shown below.

Table 24

Tornado Index Value	
City of Worcester	131.72
Worcester County	120.35
Massachusetts	87.60
United States	136.45

Source : http://www.usa.com/massachusetts-state-natural-disasters-extremes.htm

Based upon the available historical record, as well as Worcester's location in a moderate-density cluster of tornado activity for Massachusetts, there is a "very low" probability (less than 1 percent chance in any given year) of a tornado affecting the city, and a moderate (10 percent to 40 percent chance in any given year) probability of a severe thunderstorm and/or high winds.

Impact

Overall, Worcester faces a "minor" impact from severe thunderstorms, and a "limited" impact from severe winds, or tornados, with 10 percent or less of the city likely to be affected.

As indicated as part of the Enhanced Fujita Scale Levels for tornados, the following impacts can result from a tornado:

- EF0 - Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages to sign boards.
- EF1 - The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
- EF2 - Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.

- EF3 - Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.

- EF4 - Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large projectiles generated.

Vulnerability

Based on the above assessment, Worcester has a hazard index rating of "2- high risk" from severe thunderstorms and winds, and a "4 – low risk" from tornadoes.

The potential for locally catastrophic damage is a factor in any tornado, severe thunderstorm, or wind event. In Worcester, a tornado that hit residential areas would leave much more damage than a tornado with a travel path that ran along the city's uplands, where less settlement has occurred. Most buildings in the city have not been built to Zone 1, Design Wind Speed Codes. The first edition of the Massachusetts State Building Code went into effect on January 1, 1975, and 80.6% percent of the city's 75,724 occupied housing units were constructed in 1979 or earlier (American Communities Survey, 2015 5-year estimate. Private homes and city facilities are vulnerable to strong winds and tornados.. Utility lines throughout the City are also vulnerable, particularly where trees have not been trimmed recently.

Utilizing the city's total value of all property, $11,236,881,245 (Massachusetts Dept. of Revenue, 2016), and an estimated 10 percent of damage to 5 percent of all structures, the estimated amount of damage from a tornado is $56,184,406. The cost of repairing or replacing the roads, bridges, utilities, and contents of structures is not included in this estimate.

4.10 Wildfires / Brush Fires

Hazard Description

Wildfires are typically fires triggered by lightning or accidents, involving full-sized trees as well as meadows and scrublands. Brushfires are uncontrolled fires that occur in meadows and scrublands, but do not involve full-sized trees. Typical causes of brushfires and wildfires are lightning strikes, human carelessness, and arson.

FEMA has classifications for 3 different classes of wildfires:

- Surface fires are the most common type of wildfire, with the surface burning slowly along the floor of a forest, killing or damaging trees.

- Ground fires burn on or below the forest floor and are usually started by lightening
- Crown fires move quickly by jumping along the tops of trees. A crown fire may spread rapidly, especially under windy conditions.

Potential vulnerabilities to wildfires include damage to structures and other improvements, and impacts on natural resources. 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.

Location

Worcester County has approximately 645,000 acres of forested land, which accounts for 64% of total land area (Massachusetts Office of GIS, 2007). In Worcester, an estimated 21% of the land is forested. Worcester is developed in a mostly dense urban pattern and few uninterrupted tracts of forest are present, the tree coverage does present some risk for wildfires and brush fires. The total amount of the city that could be affected by a wildfire is categorized as "small," or less than 10 percent of the total area.

Extent

Wildfires can cause widespread damage. They can spread very rapidly, depending on local wind speeds and can be very difficult to get under control. Fires can last for several hours up to several days.

In Worcester, approximately 21% percent of the city's total land area is forested, and is therefore at risk of fire. This forested area is generally scattered throughout the community, with developed areas, rivers and major transportation corridors (I-290, I-190 and Route 9) breaking up the forest. In drought conditions, a brushfire or wildfire would be a matter of concern. As noted in the next section describing previous occurrences of wildfire, there have not been any major wildfires recorded in Worcester in recent decades. Based on historic data for 2006-2015, it is estimated that a brush fire might destroy 499 acres of forested area (Massachusetts Fire Incident Reporting System).

Rating of wildfires is shown in the table below:

Table 25 - Extent of Wildfires

Rating	Basic Description	Detailed Description
CLASS 1: Low Danger (L) Color Code: Green	Fires not easily started	Fuels do not ignite readily from small firebrands. Fires in open or cured grassland may burn freely a few hours after rain, but wood fires spread slowly by creeping or smoldering and burn in irregular fingers. There is little danger of spotting.
CLASS 2: Moderate Danger (M) Color Code: Blue	Fires start easily and spread at a moderate rate	Fires can start from most accidental causes. Fires in open cured grassland will burn briskly and spread rapidly on windy days. Woods fires spread slowly to moderately fast. The average fire is of moderate intensity, although heavy concentrations of fuel – especially draped fuel -- may burn hot. Short-distance spotting may occur, but is not persistent. Fires are not likely to become serious and control is relatively easy.
CLASS 3: High Danger (H) Color Code: Yellow	Fires start easily and spread at a rapid rate	All fine dead fuels ignite readily and fires start easily from most causes. Unattended brush and campfires are likely to escape. Fires spread rapidly and short-distance spotting is common. High intensity burning may develop on slopes or in concentrations of fine fuel. Fires may become serious and their control difficult, unless they are hit hard and fast while small.
CLASS 4: Very High Danger (VH) Color Code: Orange	Fires start very easily and spread at a very fast rate	Fires start easily from all causes and immediately after ignition, spread rapidly and increase quickly in intensity. Spot fires are a constant danger. Fires burning in light fuels may quickly develop high-intensity characteristics - such as long-distance spotting - and fire whirlwinds, when they burn into heavier fuels. Direct attack at the head of such fires is rarely possible after they have been burning more than a few minutes.
CLASS 5: Extreme (E) Color Code: Red	Fire situation is explosive and can result in extensive property damage	Fires under extreme conditions start quickly, spread furiously and burn intensely. All fires are potentially serious. Development into high-intensity burning will usually be faster and occur from smaller fires than in the Very High Danger class (4). Direct attack is rarely possible and may be dangerous, except immediately after ignition. Fires that develop headway in heavy slash or in conifer stands may be unmanageable while the extreme burning condition lasts. Under these conditions, the only effective and safe control action is on the flanks, until the weather changes or the fuel supply lessens.

Previous Occurrences

Worcester has a full-time fire department with professional firefighters. There have not been any major wildfires in Worcester in recent decades. During the period 2006-2015, there were 1,442 total forest and brush fire incidents, with 499 total acres burned (Massachusetts Fire Incident Reporting System).

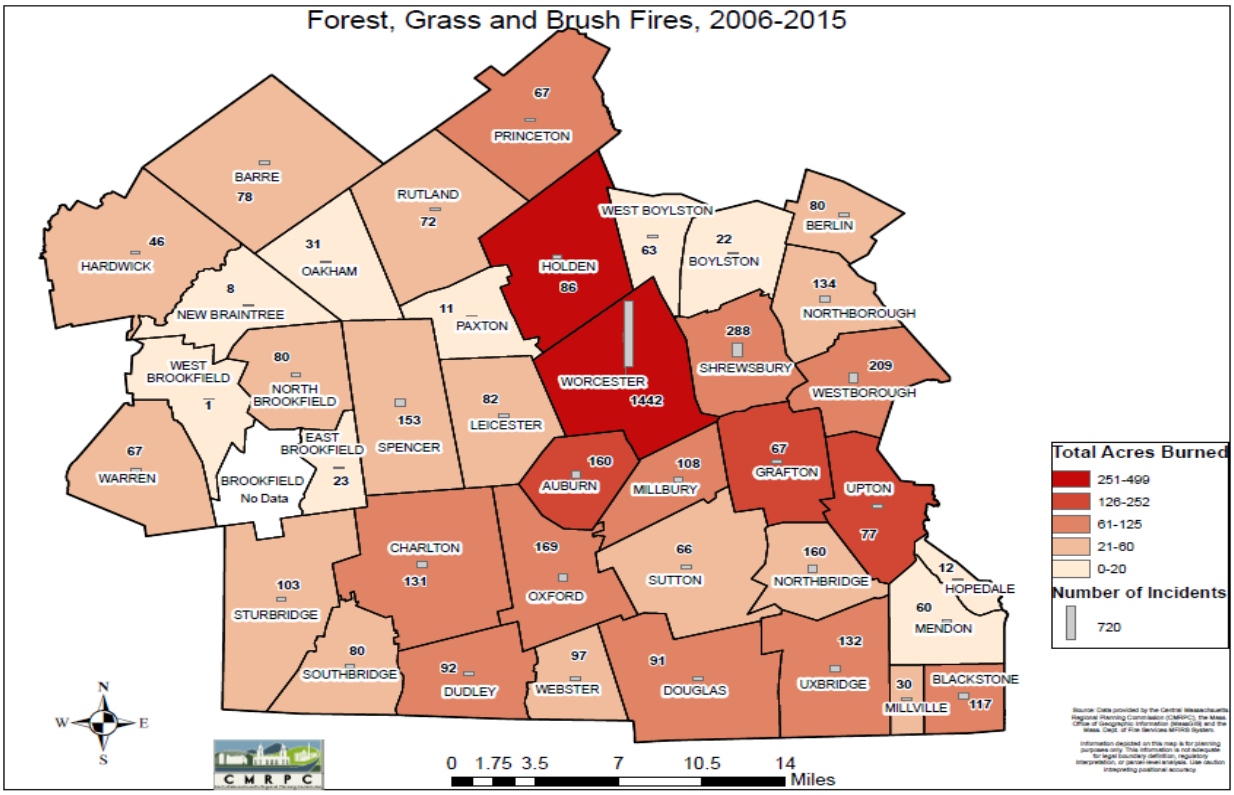


Figure 10 - Forest, Grass and Brush Fires, 2006-2015

Probability of Future Events

In accordance with the Massachusetts Hazard Mitigation Plan, the Worcester Hazard Mitigation Team found it is difficult to predict the likelihood of wildfires in a probabilistic manner because the number of variables involved. However, based on regular previous occurrences of minor brush fires, the planning team determined the probability of future damaging wildfire events to be "moderate" (10 percent to 40 percent probability in the next year).

Climate scenarios project summer temperature increases between 2º C and 5º C 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.

Climate change is also predicted to bring increased wind damage from major storms, as well as new types of pests to the region. Both increased wind and the introduction of new pests could potentially create more debris in wooded areas and result in a larger risk of fires.

Impact

While a large wildfire could in theory damage much of the landmass of Worcester, most forested areas are sparsely developed, meaning that wildfire affected areas are not likely to cause damage to personal property. For this reason, the city faces a "minor" impact from wildfires, with little damage likely to occur.

Both wildfires and brush fires can consume homes, other buildings and/or agricultural resources. The impact of wildfires and brush fires are as follows:

- Impact to benefits that people receive from the environment, such as food/water and the regulation of floods and drought
- Impact on local heritage, through the destruction of natural features
- Impact to the economy, due to damage to property and income from land following a wildfire
- Impact through the destruction of people and property

Vulnerability

Based on the above assessment, Worcester has a hazard risk index of "4 – low risk" from wildfires.

There are several areas considered vulnerable in the City, Worcester Regional Airport, Crow Hill Conservation Area and the EcoTarium, Newton Hill and Elm Park, Bovenzi Conservation Park and God's Acre and surrounding woods. Utilizing the City's total value of all property, $11,236,881,245 (Massachusetts Dept. of Revenue, 2016), and an estimated 5 percent of damage to 1 percent of all structures, the estimated amount of damage from a wildfire is $56,184,406. The cost of repairing or replacing the roads, bridges, utilities, and contents of structures is not included in this estimate.

4.11 Other Hazards

In addition to the hazards identified in previous sections, the Hazard Mitigation Team reviewed the other hazards listed in the Massachusetts Hazard Mitigation Plan: coastal hazards, atmospheric

hazards, ice jams, coastal erosion, sea level rise, nor'easters, and tsunamis. It was determined that these hazards are either irrelevant to Worcester due to the city's location, or in the case of nor'easters, that the hazard is already included within another hazard described above (severe winter storms). The Hazard Mitigation Team noted the major impact of invasive species to Worcester, notably the Asian Longhorned Beetle which severely damaged forested areas and led to the cutting of approximately 35,000 trees.

Invasive Species

The Asian Longhorned Beetle (ALB, *Anoplophora glabripennis*) is a destructive wood-boring pest of maple and other hardwoods. ALB is believed to have been introduced into the United States from wood pallets and other wood packing material accompanying cargo shipments from Asia. The tree species preferred as hosts by the Asian Longhorned Beetle are hardwoods including several maple species (Norway, sugar, silver, and red maple), box elder, horse chestnut, buckeye, elm, London plane, birch, and willow. All of Worcester and several neighboring towns have been impacted by the infestation. A quarantine remains in place and public education efforts should be continued. Trees weakened by the infestation could be further damaged and impacted by natural hazards such as snowstorms and severe rain/wind events. Weakened limbs could in turn damage power lines and other infrastructure. Continued monitoring of trees should occur, especially in August, as adult beetles are most active during the summer and early fall and is the time of year when beetles are most active and mobile. The larvae that spent the previous year maturing and eating through their host trees emerge as adults and look for a new place to colonize and start the next generation.

Landslides

An additional hazard that can affect Worcester is landslides. Landslides occur in all U.S. states and territories. In a landslide, masses of rock, earth, or debris move down a slope. Landslides may be small or large, slow or rapid. They are generally activated by:

- storms
- earthquakes
- volcanic eruptions
- fires
- alternate freezing or thawing
- steepening of slopes by natural erosion or by human modification

Debris and mud flows are rivers of rock, earth, and other debris saturated with water. They develop when water rapidly accumulates in the ground, during heavy rainfall or rapid snowmelt, changing

the earth into a flowing river of mud or "slurry." They can flow rapidly, striking with little or no warning at avalanche speeds. They also can travel several miles from their source, growing in size as they pick up trees, boulders, cars, and other materials.

There are no documented previous occurrences of significant landslides in Worcester. The city is relatively hilly but, the risk of landslides is minimal. Most of the City's rivers are slow moving, albeit "flashy" during heavy rain events, and frequently dammed, which can minimize landslide risk. Roadways are not generally built close to river channels, reducing undercutting risk from stormwater-induced bank erosion. High slope terrain (defined as 15 to 25% grade) cover 3,142 acres, or 14.3% of the city; very high slopes (higher than 25% grade) cover 1,005 acres, or slightly more than 4% of the city's area. Development is present in these areas and, should a landslide occur in the future in Worcester, the type and degree of impacts would likely be highly localized. Vulnerabilities could include damage to structures, damage to transportation and other infrastructure, and localized road closures, though our data review and the local planning team noted no specific concerns. Injuries and casualties, while possible, would be unlikely given the low extent and impact of landslides in Worcester.

Worcester, like nearly all communities in the CMRPC region, is categorized in the Massachusetts Natural Hazard Mitigation Plan as a low incidence/low susceptibility area for landslide hazards based on review of past occurrences. Landslides are therefore considered low frequency events that may occur once in 50 to 100 years (a 1% to 2% chance of occurring per year).

4.12 Impacts of Climate Change on Hazards

Over the next several decades, climate change can be expected to exacerbate many of the hazards described previously in this chapter. This section identifies the impacts that a changing climate may have on Worcester's hazard risk profile going forward. Sources for this section include:

- Northeast Climate Impacts Assessment (NECIA) (2007)
- Massachusetts Climate Change Adaptation Report (2011)
- Massachusetts Multi-Hazard Mitigation Plan (2013)

Expected Changes

The NECIA and state Climate Change Adaptation Report offer Massachusetts state-level predictions for temperature and precipitation for upcoming decades, which show dramatic increases in both measures:

Table 26

Category	Current (1961-1990 avg.)	Predicted Change 2040-2069	Predicted Change 2070-2099
Average Annual Temperature (°F)	46°	50°to 51°	51° to 56°
Average Winter Temperature (°F)	23°	25.5° to 27°	31° to 35°
Average Summer Temperature (°F)	68°	69.5° to 71.5°	74° to 82°
Days over 90 °F	5 to 20 days	-	30 to 60 days
Days over 100 °F	0 to 2 days	-	3 to 28 days
Annual Precipitation	41 inches	43 to 44 inches	44 to 47 inches
Winter Precipitation	8 inches	8.5 to 9 inches	9 to 10.4 inches
Summer Precipitation	11 inches	10.9 to 10.7 inches	10.9 to 11 inches

Flooding

A warming climate is expected to lead to higher precipitation throughout the region. The Massachusetts Multi-Hazard Mitigation Plan estimates that precipitation will increase 6 to 14% by volume by mid-century, with an increased frequency of floods meeting current 10-year flood levels. Much of the winter precipitation increase is projected to be in the form of rain rather than snow, which may actually reduce peak spring flooding but could lead to more frequent winter runoff events. Overall, the frequency of flooding events and their impacts on people and property can be expected to increase over time, largely in locations that are already of flood concern. Public health may be impacted through increased mosquito populations, which depend on the availability of standing water.

Severe Snowstorms/Ice Storms/Nor'easters

The Massachusetts Multi-Hazard Mitigation Plan estimates that as the climate warms, winter snowfall will be reduced and will generally fall later in the winter season. The Climate Change Adaptation Report predicts that snowfall events will decline over time from around 5 per month during winter to 1 – 3, but that the frequency of the strongest winter storms may actually increase until winter average temperatures warm above the freezing point late in the century. Ice storms are expected to increase as temperatures warm, risk of extreme ice storms like the December 2008 storm which impacted millions with one million residents in Massachusetts without power for days. Massachusetts received $49.2 million from FEMA in emergency relief to help the fund recovery from this storm So, while long-term, the risk of winter storms to people and property can be expected to decline, short- and mid-term events will likely continue to result in damage to property.

Hurricanes

The Massachusetts Multi-Hazard Mitigation Plan notes that there is still a great deal of uncertainty about the impacts of climate change on hurricanes and tropical storms, but that the limited evidence available indicates that stronger storms (Category 4 and 5) are becoming more frequent. Overall, the risk from hurricanes and their associated flooding can be expected to increase overtime.

Severe Thunderstorms/Wind/Tornado

Evidence shows that severe weather including thunderstorms, damaging wind and tornados is already increasing as temperatures rise. The Massachusetts Multi-Hazard Mitigation Plan notes that smaller storm events are becoming less frequent, while more severe storms are becoming more common. Overall, the risk from severe storms, including related effects such as flooding, etc., can be expected to increase overtime.

Wildfire/Brush Fire

The Massachusetts Multi-Hazard Mitigation Plan projects summer rainfall to decrease as much as 15% in the next decades. In combination with higher temperatures and winds, this drop in precipitation would contribute to additional fire risk. Forest response to increased atmospheric carbon dioxide – the so-called "fertilization effect" – could also contribute to more tree growth and thus provide more fuel for wildfires. Climate change may increase winds that spread fires. Faster fires are harder to contain, and thus are more likely to expand into residential neighborhoods.. Overall, the risk of wildfires to people and property can be expected to increase.

Earthquake

Climate change is not expected to significantly impact the risk of earthquakes. The state Multi-Hazard Mitigation Plan notes that there may be additional earthquake risk in conjunction with other hazards such as higher rainfall (which can contribute to soil liquefaction during earthquakes), but that research is not yet mature. At this time, overall risk from earthquake to people and property can be expected to stay around the same as the current risk level.

Dam Failure

The Massachusetts Multi-Hazard Mitigation Plan does not note major concerns about catastrophic dam failure due to climate change. It does, however, mention that increased heavy rainfall events may lead to more frequent dam design failures, in which spillways overflow due to flow rates exceeding design capacity. This type of failure may have a secondary result of increased riverine flooding below dams. Overall, the risk of dam failure to people and property can be expected to

stay around the same as the current risk level, but could become increasingly likely if required maintenance and monitoring are not conducted to existing aging dam infrastructure.

Drought

While the projections noted above show overall increases in precipitation going forward, summer rainfall is actually expected to decline slightly as the climate warms, raising the risk of seasonal droughts. According to the Massachusetts Multi-Hazard Mitigation Plan, droughts are expected to increase in frequency, severity and length. The Massachusetts Climate Change Adaptation Report finds that by the end of the century, under a high carbon emissions scenario, the occurrence of droughts lasting one to three months could go up by as much as 75% over existing conditions. Secondary to drought, wildfire risk can be expected to rise. Overall, the risk of drought to people and property can be expected to increase.

Extreme Temperatures

According to records of the US Historical Climatology Network, average temperatures in the region have increased about 0.2 degrees C (0.5°F) per decade since 1970. These higher average temperatures have primarily been the result of warmer winters (December through March), during which there has been an increase of 1.3°F per decade since 1970. In addition to average temperature increases, the number of extremely hot and record heat days has also increased: the number of days with temperatures of 90°F and higher throughout the Northeast has doubled during the past 45 years. As noted in the table elsewhere in this section, the number of days exceeding 90 degrees is expected to surge several times over, presenting a health risk to young children, the elderly, and to persons with various health conditions. Overall, the risk of extreme temperatures to people and property can be expected to increase.

5.0 CRITICAL FACILITIES & VULNERABLE POPULATIONS

Critical Infrastructure provides the essential services to the City of Worcester and serve as the backbone to the City's security and health. The systems and networks that make up the infrastructure would be disrupted by a natural disaster and would impact response to the disaster and safety of the City.

A Critical Facility is defined as a building, structure, or location which:

- Is vital to the hazard response effort.
- Maintains an existing level of protection from hazards for the community.
- Would create a secondary disaster if a hazard were to impact it.

5.1 Critical Facilities within Worcester

The Critical Facilities List for the City of Worcester has been identified utilizing the knowledge and expertise of the team and several sources, such as:

- Team knowledge of the content of Worcester's Comprehensive Emergency Management Plan
- MassGIS data
- Critical infrastructure mapping undertaken by CMRPC under contract with the Central Region Homeland Security Advisory Council, which is charged by the Executive Office of Public Safety and Security to administer and coordinate the State Homeland Security Grant for central Massachusetts.

Worcester's Hazard Mitigation Team has broken up this list of facilities into four categories:

- Emergency Response Facilities needed in the event of a disaster
- Non-Emergency Response Facilities that have been identified by the Team as non-essential. These are not required in an emergency response event, but are considered essential for the everyday operation of Worcester
- Dams
- Facilities/Populations that the Team wishes to protect in the event of a disaster

Critical infrastructure and facilities are mapped in Appendix A.

Category 1 – Emergency Response Facilities

The City of Worcester has identified the Emergency Response Facilities and Services as the highest priority in regards to protection from natural and man-made hazards.

1. **Emergency Operations Center and Regional Emergency Communications**
   2 Coppage Drive, Worcester, MA
   To be constructed at 50 Skyline Drive, Worcester, MA

2. **Police Station**
   Worcester Police Dept. HQ 9-11 Lincoln Square, Worcester, MA

3. **Fire Station**
   Fire Headquarters 141 Grove Street, Worcester, MA
   Burncoat Street 19 Burncoat Street, Worcester, MA

Franklin Street	266 Franklin Street, Worcester, MA
Greendale	438 W. Boylston Street, Worcester, MA
McKeon Road	80 McKeon Road, Worcester, MA
Park Avenue	424 Park Avenue, Worcester, MA
Southeast Station	745 Grafton Street, Worcester, MA
South Division	180 Southbridge Street, Worcester, MA
Tatnuck Square	1067 Pleasant Street, Worcester, MA
Webster Square	40 Webster Street, Worcester, MA

4. Communications Facilities

Back up Communications Center	80 McKeon Rd, Worcester, MA
Mack Truck Radio Site	422 SW Cutoff, Worcester, MA
Mill Stone Radio Site	50 Skyline Drive, Worcester, MA
Worcester Regional Airport Radio Site	375 Airport Drive, Worcester, MA
Worcester PD Back Up Servers	9-11 Lincoln Square, Worcester, MA
Worcester Tech HS Backup Servers	1 Skyline Drive, Worcester, MA

5. Highway Department

DPW Headquarters, 20 East Worcester Street, Worcester, MA

6. Primary Evacuation Routes

I-290
I-190
MA-9
MA-122
MA-146
US-20

7. EMS Response

Worcester EMS	100 Providence Street, Worcester, MA
Worcester EMS	23 Wells Street, Worcester, MA
Vital EMS	1013 Main Street, Worcester, MA
Vital EMS	53 Glennie Street, Worcester, MA
Medstar Ambulance Service	62 Washington Street, Worcester, MA
Eascare	140 Prescott Street, Worcester, MA
Lifeline Ambulance Service	165 Southbridge Street, Worcester, MA
Access Ambulance	74 Grafton Street, Worcester, MA

8. Disaster Response and Recovery

National Guard Facility	50 Skyline Drive, Worcester, MA
National Guard Facility	701 Plantation Street, Worcester, MA
National Guard Facility	640 Plantation Street, Worcester, MA
WRTA Maintenance Facility	54 Quinsigamond Avenue, Worcester, MA

Category 2 – Non-Emergency Response Facilities

The city has identified these facilities as non-emergency facilities; however, they are considered essential for the everyday operation of Worcester.

1. Water and Sewer System

Worcester Water Treatment Plant	71 Stonehouse Hill Road, Holden MA
Pump Station/Filtration	Olean Street, Worcester, MA
Combined Sewer Overflow Treatment Facility	Quinsigamond Avenue
Asnebumskit Pond	Paxton, MA
Coal Mine Brook Well	Worcester, MA
Holden Reservoir No. 1	Holden, MA
Holden Reservoir No. 2	Holden, MA
Home Farm Well	Worcester, MA
Kendall Reservoir	Holden, MA
Kettle Brook Reservoir No. 1	Leicester, MA
Kettle Brook Reservoir No. 2	Leicester, MA
Kettle Brook Reservoir No. 3	Leicester, MA
Kettle Brook Reservoir No. 4	Leicester, MA
Lynde Brook Reservoir	Leicester, MA
Pine Hill Reservoir	Holden, MA
Quinapoxet Reservoir	Holden, MA

2. City Facilities

City Hall	455 Main Street, Worcester, MA
Dept. of Inspectional Services & Fire Prevention Div.	25 Meade Street, Worcester, MA
DPW&P Customer Service	76 E. Worcester Street, Worcester, MA
DPW&P Administration Building	20 East Worcester Street, Worcester, MA
DPW&P Central Garage	29 Albany Street, Worcester, MA
DPW&P Water Operations	16-18 East Worcester Street, Worcester, MA
DPW&P Water Operations – Reservoir HQ	50-55 Moy Ranch Rd, Holden
Frances Perkins Branch Library	470 W. Boylston Street, Worcester, MA
Great Brook Valley Branch Library	89 Tacoma Street, Worcester, MA

Parks, Rec. & Cemetery Division	50 Skyline Drive, Worcester, MA
Public School Administration	20 Irving Street, Worcester, MA
School Administration Parent Info Center	768 Main Street, Worcester, MA
Union Station	2 Washington Square, Worcester, MA
Worcester Public Library	3 Salem Square, Worcester, MA

3. Utilities

Cable Access/WCCA	415 Main Street, Worcester, MA
CSX Railroad Depot	271 Franklin Street, Worcester, MA
Providence Worcester Railroad Depot	Southbridge Street, Worcester, MA
National Grid Substation	Bancroft Street, Worcester, MA
National Grid Substation	Bloomingdale, Worcester, MA
National Grid Substation	Brooks Street, Worcester, MA
National Grid Substation	Cambridge Street, Worcester, MA
National Grid Substation	Chandler Street, Worcester, MA
National Grid Substation	Cooks Pond, Worcester, MA
National Grid Substation	Faraday Street, Worcester, MA
National Grid Substation	Grafton Street, Worcester, MA
National Grid Substation	Greendale, Worcester, MA
National Grid Substation	Byron Street, Worcester, MA
National Grid Substation	Marion Avenue, Worcester, MA
National Grid Substation	Millbrook Street, Worcester, MA
National Grid Substation	Rena Street, Worcester, MA
National Grid Substation	Salisbury Street, Worcester, MA
National Grid Substation	Squantum Street, Worcester, MA
National Grid Substation	Stearns Street, Worcester, MA
National Grid Substation	Tory Fort Lane, Worcester, MA
National Grid Substation	Gloucester Road, Worcester, MA
National Grid Substation	Webster Road, Worcester, MA
Transfer Station	1065 Millbury Street, Worcester, MA

Category 3 – Dams

A list of dams in Worcester is included in Chapter 4 under Dam Failure.

Category 4 – Facilities/Populations to Protect

1. Shelters

The City has several warming and overnight shelters, such as the Senior Center, some of its high

school buildings, and more. These public buildings have been selected based on a number of criteria, such as size, ADA accessibility, availability of showers, floor plan flow, generators, and more. In case of a disaster, the appropriately assigned emergency shelter for that particular disaster is announced by the Emergency Operations team, via such communication methods such as ALERTWorcester, the city's Emergency Notification System.

2. **Special Needs Population/Elderly Housing/Assisted Living**

St. Vincent Hospital	123 Summer Street, Worcester, MA
UMass Memorial Hospital	119 Belmont Street, Worcester, MA
UMass Memorial Medical Center	55 N. Lake Avenue, Worcester, MA

See Appendix B for more facilities

3. **Public Buildings/Areas**

DCU Center	50 Foster Street, Worcester, MA
Hanover Theatre	561 Main Street, Worcester, MA
Mechanics Hall	321 Main Street, Worcester, MA
The Palladium	261 Main Street, Worcester, MA
Tuckerman Hall	10 Tuckerman Street, Worcester, MA
Worcester Senior Center	128 Providence Street, Worcester, MA

4. **Schools/Daycare**

(Please note: The EMD has a list of current daycare facilities but these can change locations and addresses frequently, so this list should be revisited periodically.)

See complete list of Schools and Daycares in Appendix B

5. **Other Facilities**

See list in Appendix B

6. **Historic Buildings/Sites**

According to the Massachusetts Cultural Resources Information System (MACRIS) online database accessed in March 2018, within Worcester there are 47 Districts, two Multiple Resources Areas/Surveys, approximately 910 Buildings, 57 Objects, and 16 Structures listed on the National Register of Historic Places, and two National Historic Landmarks. It should be noted that MACRIS records are not up to date, and therefore do

not reflect the total number of resources that are no longer extant. The Local Team noted three Local Historic Districts – Massachusetts Avenue, Montvale, and Crown Hill. These, as well as significant municipal and commercial buildings concentrated around Main Street, have been identified as areas of priority to protect from natural hazards

7. Employment Centers

Based on data obtained from the Massachusetts Executive Office of Labor and Workforce Development (EOLWD), the following table shows the largest employers in Worcester:

Table 27

Largest Employers in Worcester - April 2017		
Company	**Location**	**No. of Employees**
UMass Memorial Medical Center	Belmont Street	5,000-9,999
College of the Holy Cross	College Street	1,000-4,999
Community Healthlink	Jaques Avenue #72	1,000-4,999
Hanover Insurance Group Inc	Lincoln Street	1,000-4,999
New England Financial	Chestnut Street	1,000-4,999
Saint-Gobain Abrasives	New Bond Street	1,000-4,999
Saint-Gobain Ceramic Materials	New Bond Street	1,000-4,999
St. Vincent Hospital	Summer Street	1,000-4,999
UMass Memorial Group Practice	Lake Avenue N	1,000-4,999
VNA Care Network	Thomas Street	1,000-4,999

Source: EOLWD

8. Environmental Justice and Vulnerable Populations

The US Environmental Protection Agency defines Environmental Justice (EJ) as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Within the context of natural hazards and their mitigation, potential EJ concerns may arise from income-related factors, discrimination (overt or institutional), cultural isolation and barriers, language isolation, lack of transportation access, and disability (especially among the elderly).

In 2015, as part of its Mobility 2040 long range transportation plan, CMRPC identified

disproportionate concentrations of EJ and other vulnerable populations at the US Census block group level throughout Central Massachusetts. Thresholds used in this identification process included various metrics from the 2010 Census and 2013 American Community Survey:

- Lower income households (median income below $50,259/year); or
- Minority residents (20.3% or more of population); or
- Hispanic or Latino residents (14.0% or more of population); or
- Language isolated households (9.45% or more of population); or
- Zero vehicle households (12.75% or more of population); or
- Households with persons 75+ years of age (18.8% or more of population); or

Worcester is a diverse city with a number of concentrations of environmental justice populations. Worcester is home to an estimated 37,970 immigrants from 85 countries, which make up 21 percent of the city's total population. This compares to 15 percent statewide.[6] More than half of immigrants in Worcester have low English proficiency. The two most predominant foreign languages in the City are Spanish and Vietnamese, outreach was made to these populations in the planning process by means of translated surveys and seeking out organizations which seek to serve these demographics, such as the South East Asian Coalition and Centro, Inc. Worcester's diversity trends reflect forecasts for US population growth overall.

Effective communication regarding hazard mitigation to these populations should occur through active outreach efforts with the public, the academic community, other agencies, and non-federal governmental entities, to anticipate, understand, and resolve specific issues of concern. The City should provide resources and assistance to threatened neighborhoods, such as the Green Island Neighborhood which historically has flooded for 100 years and vulnerable populations to enhance their resilience during and after a disaster.

[6] http://www.sevenhills.org/uploads/ForeignBornStudy.pdf

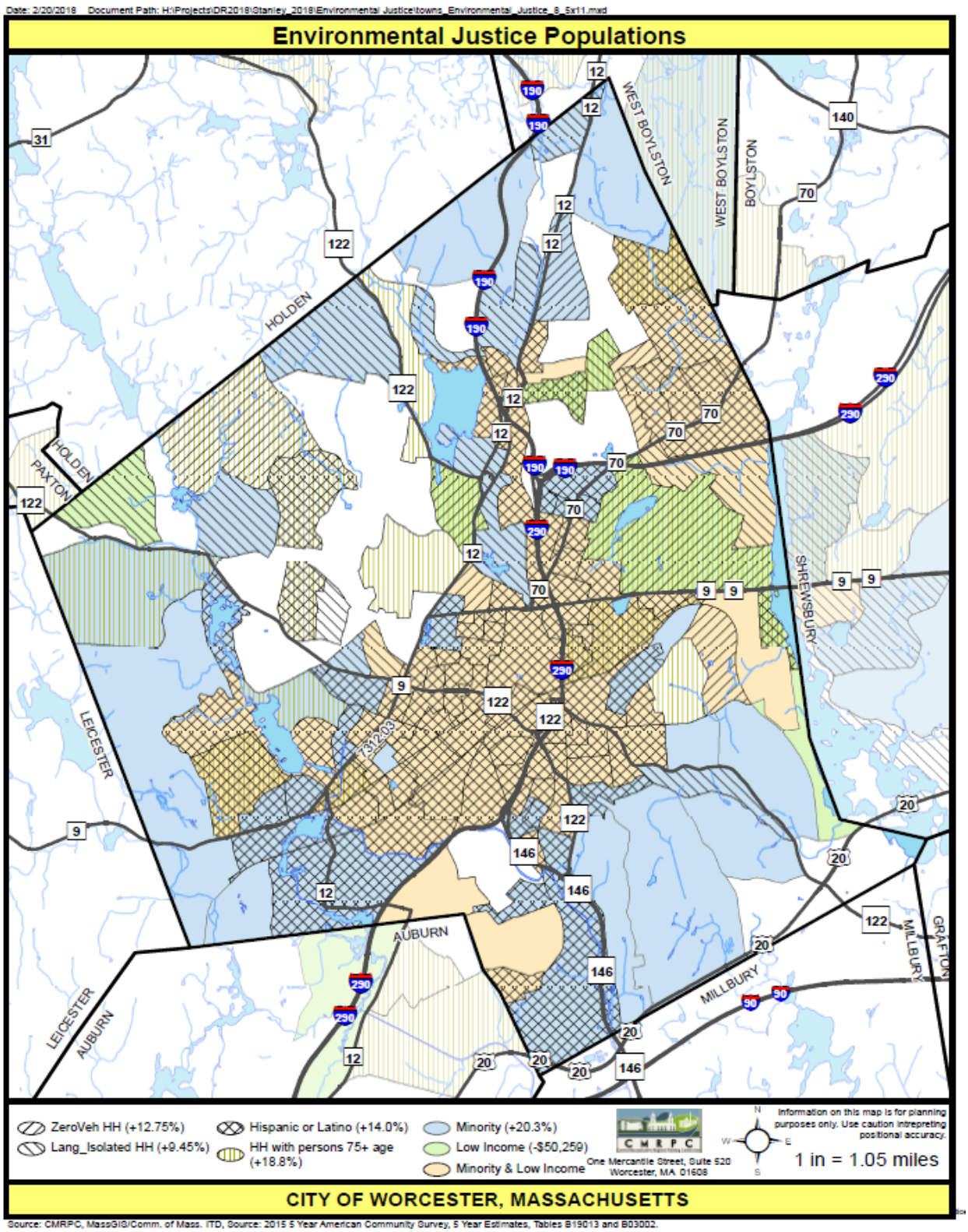


Figure 11- Environmental Justice Areas in the City of Worcester, 2015

More information regarding the identification of Environmental Justice and Vulnerable populations in the Central Massachusetts region can be found online. [7]

9. Development

Worcester is the second largest city in New England, with an estimated 2016 population of 184,508 (US Census). Development activity has increased considerably in recent years, particularly in the residential sector. While a number or larger projects have been concentrated downtown and in nearby centrally located neighborhoods, development is occurring throughout the city.

While the City of Worcester is a mostly developed urban environment, the city continues to have development in previously undeveloped areas and redevelop, often with higher density, in existing developed areas. The topography of Worcester is unique with many hills and rivers, thus development has and continues to occur in floodplains, near waterways and on steep slopes. The industrial revolution led many factories, and related workforce housing, to be built along the city's waterways and in adjacent hazard prone areas. While new construction and re-development are generally more resilient to hazards, due to increasingly stringent building codes and stormwater management requirements, much of the city's existing housing stock is older and often vulnerable to natural hazards. Additionally, the city's industrial and manufacturing past has left many sites with challenging developments constraints in the form of environmental pollutants - often increasing the costs and challenges associated with re-development. Despite such constraints, many hazard prone areas continue to be re-developed - often resulting in the removal of non-elevated structures in the floodplain and installation of new more resilient, elevated, construction in its place. Examples of such re-development sites are the DCR Blackstone Visitor's Center, under construction along McKeon Road, which is intended to promote and protect the Blackstone River Watershed, various right of way infrastructure and drainage improvements made in the Green Island areas, and the newly constructed Worcester Regional Transit authority (WRTA) Maintenance facility on Quinsigamond Avenue.

In addition to more resilient construction, there are numerous other mechanisms that the City of Worcester has established that help prevent or mitigate hazards. These include pre-development consultations (Interdepartmental Review Team, or - IRT), which are available free of charge to developers and offer an opportunity to meet with building, zoning, planning, fire and public works officials to review potential issues early in the project development process. City regulations such as the Zoning Ordinance, Wetlands Protection Ordinance, and Subdivision regulations each include measures intended to prevent or reduce the risk of various hazards. They also establish

[7] www.cmrpc.org/mobility2040

board review processes, such as site plan review, which provide an opportunity to review development plans to ensure that the basic safety and welfare of the people of Worcester are protected. These reviews include specific evaluation criteria that are relevant to natural hazards – including requirements for preventing and mitigating flooding and stormwater impacts. Further, a recently adopted complete streets policy encourages street trees which help decrease heat island effects. In 2015, the City adopted a Commercial Corridors Overlay District (CCOD) which, in part, reduces parking requirements and prevents the creation of new small parking lots in many commercial areas of the city - in turn reducing new impervious surfaces and related stormwater runoff. Meanwhile, efforts to permanently protect sensitive natural resources - both within and outside of the mapped floodplains - through open space acquisition are continually underway. Such efforts, including the protection of over 10 acres along Kettle Brook and over 50 acres of land tributary to Tatnuck Brook by the Greater Worcester Land Trust (GWLT), help ensure that the natural functions of the existing floodplains in city remain intact long-term.

As the population of Worcester continues to grow and additional development occurs, officials should seek to further integrate hazard mitigation practices into planning and development processes. It is imperative that the city consider how to address the effects of continued new and redevelopment on the city's landscape as well as predicted increases in extreme storm events, due to climate change. The City of Worcester intends to begin updating its Master Plan in 2018, this will provide an opportunity to re-examine existing policies and initiatives, to better understand identified threats, and to create and prioritize strategies to address vulnerabilities. While current efforts are important, recognition and first steps toward adapting to a changing natural environment, it will be critical for the city to find additional ways to mitigate and adapt to anticipated long-term climatic changes in order to protect people and property in the city from such related vulnerabilities.

6.0 EXISTING PROTECTION

The City of Worcester currently makes use of most available locally-controlled tools to mitigate the consequences of natural hazards such as zoning and wetlands protection regulations and and physical infrastructure improvements. The City does participate in federal programs such as StormReady certification and Community Rating System, and it does plan to research the utility of more public awareness and education programs as a result of this planning process.

Worcester already has most of the no-cost or low-cost hazard mitigation capabilities in place. Land use zoning, subdivision regulations and an array of specific policies and regulations that include hazard mitigation best practices, such as limitations on development in floodplains, stormwater management, tree maintenance, etc. Worcester also has appropriate staff dedicated to hazard mitigation-related work for a community of its size, including a City Manager, an Emergency

Management Director, a Department of Public Works, a Facilities Director, and a Tree Warden. Worcester has several relevant plans in place, including a Comprehensive Emergency Management Plan, a Drought Plan, and it is working now to create a DPW&P's Integrated Water Resources Management Plan and update the city's overall Master Plan. Not only does Worcester have these capabilities in place, but they are also deployed for hazard mitigation, as appropriate. The City also has very committed and dedicated volunteers who serve on Boards, Commissions and Committees and in other volunteer positions. The City collaborates closely with surrounding communities and larger institutions and utility providers through its Local Emergency Planning Committee (LEPC) and has opted in to fire protection mutual aid agreements through MEMA.

Worcester is an active member community of the Central Massachusetts Regional Planning Commission (CMRPC) and can take advantage of no cost local technical assistance as needed provided by the professional planning staff at CMRPC.

The table below describes existing mitigation protections in Worcester. It includes a brief description of each activity as well as a subjective evaluation of its effectiveness and of any need for modifications.

6.1 Existing Protection Matrix

Table 28

Existing Measure	Description	Action	Effectiveness & Recommendations
Participation in National Flood Insurance Program (NFIP)	Provides flood insurance for structures located in flood-prone areas. Also, communities participating in the NFIP have adopted and enforce ordinances, and regulations that meet or exceed FEMA requirements to reduce the risk of flooding.	Worcester monitors building activity within the flood plain to ensure compliance with provisions of state building code.	Effective There are 31 repetitive loss properties in Worcester. Of these 31 properties 16 are residences and 15 are commercial properties, the city should engage with the property owners and tenants to reduce the socio-economic impact of flooding. Worcester should seek to further limit development in the 100-year flood zones. It should continue to score in the Community Rating System (CRS) under NFIP to enable its residents to obtain lower flood insurance rates. Worcester should educate its residents and staff about NFIP.
Floodplain Zoning District Ordinance in place	Requires all development to be in compliance with state building code requirements for construction in floodplains	Worcester has a Floodplain Overlay District (Article VI) in its Zoning Ordinances	Very effective Investigate actions to limit development or imperviousness and require flood storage.

Existing Measure	Description	Action	Effectiveness & Recommendations
Stormwater Management policy and regulations in place	Planning Boards or Conservation Commissions review projects for consistency with MA DEP standards. This helps ensure adequate on site retention and recharge.	Worcester does not have a Stormwater Management Ordinance however, Zoning, Subdivision and Wetlands Regulations have different requirements for Stormwater Management.	Effective Seek increase in compliance with stormwater regulations for redevelopment projects.
StormReady	StormReady is a National Weather Service voluntary program with a focus on communication and community preparedness for community's increasing vulnerability to extreme weather and water events.	Worcester should continue participation in the program and renew every three years to ensure the city continues to meet program standards	Effective No changes recommended
Community Rating System (CRS)	The goals of the CRS are to reduce flood damages to insurable property, strengthen and support the insurance aspects of the NFIP, and encourage a comprehensive approach to floodplain management.	Worcester participates in CRS and maintains a class rating of 9 earning NFIP policy holders a discount.	Effective Worcester should continue participation in CRS and work to better its class rating.

Existing Measure	Description	Action	Effectiveness & Recommendations
Local Open Space and Recreation Plan	Local plan identifying significant natural resources and identifying mechanisms to ensure their protection. Following Mass. Department of Conservation and Recreation guidance for development of OSRPs, this document does not focus on specific hazards. Open Space Plans can provide many tools. Towns must commit to making the land acquisitions and regulatory changes, giving increased attention to preserving undeveloped flood-prone areas and associated lands	Worcester's Open Space and Recreation Plan Update was issued in 2013.	Effective Plan will expire in 2020. Worcester should prepare plan update as per Mass. DCR guidance. Where allowable, Worcester should use the update to integrate hazard mitigation activities and recommendations, including those identified herein, to further and implement these strategies .
Combined Sewer Overflow (CSO) upgrade program	Upgrade of municipal sewer systems to reduce or eliminate CSO's, which compromise water quality and can increase flood risk during heavy storm events	Combined Sewer System covers some 4 square miles of the City including downtown, Shrewsbury Street, Green Island and parts of Main South. Some of the oldest pipes in the City are combined sewers with many constructed of brick in the mid to late 1800's.	Effective Continue options identified in the 2004 CSO Long-term Control Plan. Update the Plan when necessary. Follow recommendations of the Integrated Plan. Identify ways to mitigate flooding in the Green Island area.

Existing Measure	Description	Action	Effectiveness & Recommendations
Local wetlands protection ordinance and regulations in place (Mass. Assoc. of Conservation Commissions, 2006 data)	Local ordinances build upon the State's Wetlands Protection Act and Regulations. These add regulatory oversight provisions for development within the jurisdictional buffer zone, adding increased attention to alteration of wetlands and the opportunity to preserve capacity and quality.	Worcester has a Wetlands Protection Ordinance and Wetlands Protection Regulations enacted in 1990 and amended in 2007 and 2016	Very effective Worcester should examine enhanced development controls at wetlands to sustain natural barriers to flooding Request more detailed hydraulic and hydrologic calculations for new development proposing new stream crossings to avoid creation of restrictions and new flooding areas. Institute more than the 1:1 compensatory storage required for floodplain impacts. Require on-site mitigation and re-charge for other development in the city to prevent additional stormwater entering many overtaxed city drainage systems. Consider regulation of development in the 500 year floodplain. Affirm requirements of the NFIP for work any work in the floodway.
Drainage system maintenance and repair program	Plan to keep municipal drainage facilities (storm drains, culverts, etc.) in good order	Worcester performs catch basin cleaning every two years, problem locations more frequently	Effective Worcester should examine a public education program for residents on storm drain clearance and other best practices

Existing Measure	Description	Action	Effectiveness & Recommendations
Tree Trimming	Plan to ensure routine maintenance of trees to reduce likelihood of vegetative debris in response to storm events	Worcester conducts roadside mowing from April-November to remove juvenile trees. Tree trimming (take-downs and clearing dead branches) takes place as needed.	Effective Worcester should work with its electrical utility to coordinate a more systematic tree trimming program
Street Sweeping	Sweep streets to increase stormwater management capacity; capture a dispose of debris appropriately.	Arterial Roads swept once a week. Central Business District swept 6 times a week. All Residential roads swept twice a year	Very Effective No changes recommended
Culvert Maintenance and Replacement	Maintain existing culverts through regular maintenance and (in some cases) beaver controls; replace/expand culverts where needed to allow for adequate stormwater flow.	Culverts are repaired or upgraded on an as needed basis. An inventory of problem culverts is maintained.	Somewhat effective Worcester should develop a policy to prepare for expected climate change related precipitation increase by upsizing culverts, especially in known problematic areas. Seek external financial support. Planning must comply with 2014 Mass. Wetlands Protection Act update; culverts may not be replaced in-kind.

Existing Measure	Description	Action	Effectiveness & Recommendations
ALERTWorcester/ CodeRED System	Emergency warning system that sends voicemail/text/email alerts to residents (text/email alerts are optional).	ALERTWorcester enables the city to provide residents with critical information quickly in a variety of situations, such as severe weather, unexpected road closures, missing persons and evacuation of buildings or neighborhoods.	Very effective Promote ALERTWorcester more extensively so that all residents are familiar with the program.

7.0 MITIGATION STRATEGY

The Worcester hazard mitigation planning team developed a list of mitigation strategies (both new and previously identified by local officials) and prioritized them using the criteria described below. This list of factors is broadly derived from FEMA's STAPLE+E feasibility criteria.

7.1 Impact

The team's consideration of each strategy included an analysis of the mitigation impact each can provide, regardless of cost, political support, funding availability, and other constraints. The intent of this step is to separately evaluate the theoretical potential benefit of each strategy to answer the question: If cost were no object, what strategies have the most benefit? Factors considered in this analysis include the number of hazards each strategy helps mitigate (more hazards equal higher impact), the estimated benefit of the strategy in reducing loss of life and property (more benefit equals higher impact) based on the relevant hazard(s) as assessed in Chapter 4, and the geographic extent of each strategy's benefits (other factors being equal, a larger area equals higher impact).

- **High Impact** – Actions that help mitigate several hazards, substantially reduce loss of life and property (including critical facilities and infrastructure), and/or aid a relatively large portion of the community
- **Medium Impact** – Actions that help mitigate multiple hazards, somewhat reduce loss of life and property (including critical facilities and infrastructure), and/or aid a sizeable portion of the community
- **Low Impact** – Actions that help mitigate a single hazard, lead to little or no reduction in loss of life and property (including critical facilities and infrastructure), and/or aid a highly-localized area

7.2 Priority

Following the ranking of each strategy for its mitigation impact, real world considerations were brought back into the analysis to inform the priority ranking process. Factors considered in this step include costs and cost effectiveness (including eligibility and suitability for outside funding), timing, political and public support, and local administrative burden.

Costs and cost effectiveness – In order to maximize the effect of mitigation efforts using limited funds, priority is given to low-cost strategies. For example, regular tree maintenance is a relatively low-cost operational strategy that can significantly reduce the length of time of power outages during a winter storm. Strategies that have clear and viable potential funding streams, such as FEMA's Hazard Mitigation Grant Program (HMGP), are also given higher priority.

Time required for completion - Projects that are faster to implement, either due to short work duration, current or near-term availability of funds, and/or ease of permitting or other regulatory procedures, are given higher priority.

Political and public support - Strategies that have demonstrated political and/or public support through positive involvement by the public or prioritization in previous regional and local plans and initiatives that were locally initiated or adopted are given higher priority.

Administrative burden – Strategies that are realistically within the administrative capacity of the City and its available support network (CMRPC, Worcester local emergency planning committee, etc.) are prioritized. Considerations include grant application requirements, grant administrative requirements (including audit requirements), procurement, and staff time to oversee projects.

- **High Priority** – Strategies that have obvious mitigation impacts that clearly justify their costs and to a large degree can be funded, can be completed in a timely fashion, can be administered effectively, and are locally supported
- **Medium Priority** – Strategies that have some clear mitigation impacts that generally justify their costs and generally can be funded, can be completed in a timely fashion, can be administered effectively, and are locally supported
- **Low Priority** – Strategies that have relatively low mitigation impacts that do not necessarily justify their costs and that may have difficulty being funded, completed in a timely fashion, administered effectively, and locally supported

7.3 Estimated Cost

Each implementation strategy is provided with a rough cost estimate based on available third-party or internal estimates and past experience with similar projects. Each includes hard costs (construction and materials), soft costs (engineering design, permitting, etc.), and where appropriate City staff time (valued at appx. $25/hour for grant applications, administration, etc.). Projects that already have secured funding are noted. Detailed and current estimates were not generally available, so costs are summarized within the following ranges:

- **Low** – less than $50,000
- **Medium** – between $50,000 – $100,000
- **High** – over $100,000

Timeline

Each strategy is provided with an estimated length of time it will take for implementation. Where funding has been secured for a project, a specific future date is provided for when completion is expected. However, most projects do not currently have funding and thus it is difficult to know exactly when they will be completed. For these projects, an estimate is provided for the amount of time it will take to complete the project once funding becomes available. Strategies are grouped by 1-2-year timeframe, 3-5-year timeframe, 5+ year timeframe, and ongoing items.

Strategy Types

Mitigation strategies were broken into four broad categories to facilitate local implementation discussions, especially regarding budget considerations and roles/responsibilities:

Structure and Infrastructure Projects - Construct "bricks & mortar" infrastructure and building improvements in order to eliminate or reduce hazard threats, or to mitigate the impacts of hazards. Examples include drainage system improvement, dam repair, and generator installation. Structure and infrastructure improvements tend to have the greatest level of support at the local level, but are highly constrained by funding limits.

Preparedness, Coordination and Response Actions - Ensure that a framework exists to facilitate and coordinate the administration, enforcement and collaboration activities described in this plan. Integrate disaster prevention/mitigation and preparedness into every relevant aspect of city operations, including Police, Fire, EMD, EMS, DPW, City Manager's Office, Planning Board, Conservation Commission and City Council; coordinate with neighboring communities where appropriate. Recommendations in this category tend toward standardizing and memorializing generally-practiced activities.

Education and Awareness Programs - Integrate education and outreach into the community to raise awareness of overall or hazard-specific risk and generate support for individual or community-wide efforts to reduce risk.

Awareness and education seek to affect broad patterns of behavior, essentially altering a culture. Awareness-building activity tends to have a fairly slow effect, although in the end it can provide extraordinary benefits with relatively little cash outlay.

Local Plans and Regulations - Review and propose updates to local ordinances and regulations to protect vulnerable resources and prevent further risk to those resources. Formally adopt these updates into the local regulatory framework. Review the effectiveness of past

mitigation projects, programs procedures and policies. Incorporate mitigation planning into master plans, open space plans, capital improvement plans, facility plans, and other planning.

Planning and regulatory activity tends to provide extraordinary benefits with relatively little cash outlay. However, political support may be difficult to achieve for some planning and regulatory measures, especially those that place new constraints on land use.

In addition to describing action items in each of these categories, for each strategy we also identify what hazard(s) it is intended to address, as described in Chapter 4 of this plan. Each strategy also identifies the lead organization who serves as the primary point of contact for coordinating efforts associated with that item, and identifies potential funding sources for implementation. See Chapter 8 for more information on potential funding.

City of Worcester
Mitigation Strategies

OVERALL GOAL: Facilitate activities within the City of Worcester that reduces the loss, and risk of loss, to persons and property

Mitigation Strategy Description	**Hazard(s) Addressed**	**Who? Agencies Involved**	**Potential Funding Sources**	**Priority** (Political & economic viability: High/Med/Low)	**Impact Mitigation** (Impact: High/Med/Low)	**Estimated Cost** (High ($100k+)/ Med ($50k-100k)/ Low (<$50k))	**Timeline** (Time needed to complete)
A. Structure & Infrastructure Strategies							
Weasel Brook becomes restricted at an improper culvert inlet causing restrictions. Not under City control. Work with stakeholders to upgrade culvert	FL, HU, ST	Private, State, DPW&P	Private, State, Local	Low	High	High	1-3 years
Maintain street sweeping policy effectiveness to increase stormwater management.	FL, HU, ST	DPW&P, State	Local	High	High	Med	Ongoing
Clean Catch Basins at least every two years or more often as needed.	FL, HU, ST	DPW&P, State	Local	High	High	Med	Ongoing
Continue and expand Rain Barrel Program, especially target, educate and make available to lower income residents	DR	DPW&P	Local, Grant	High	Med	Low	Yearly
Update at the Senior Center Lightening Surge Protection for the building Electrical Distribution system	ST	Local, EAM	Local, State	High	High	Med	1 year
At the Senior Center install an Auxiliary Fuel tank for Emergency Generator (to increase from 2 to 7+ day supply for emergency shelter needs)	All	Local, EAM	Local, State, Federal	High	Med	High	1 year
Repair/replace City Hall Roof	All	Local, EAM	Local, State Federal	High	High	High	1-2 years
At Dept. of Inspectional Services design and install Fire Alarm radio box and resolve ground fault issue with Fire Alarm Panel	WF	Local, EAM	Local, State, Federal	High	High	Low	1 year

Mitigation Strategy Description	**Hazard(s) Addressed**	**Who? Agencies Involved**	**Potential Funding Sources**	**Priority** (Political & economic viability: High/Med/Low)	**Impact Mitigation** (Impact: High/Med/Low)	**Estimated Cost** (High ($100k+)/ Med ($50k-100k)/ Low (<$50k))	**Timeline** (Time needed to complete)
Integrate disaster mitigation into transportation projects.	All	DPW&P, State, DOT	Local, State, Federal	High	Med	Med	Ongoing
Develop rockfall protection system for McKeon Rd. Fire Station to be capable of absorbing the impact of the falling rocks	OT	Fire, EM	Local, State, Federal	Low	Med	High	2-3 years
Upgrade Kettle Brook #4 control structure, repair gates	FL, HU, ST	Local, State	Local, State, Federal	Med	High	High	1-2 years
Investigate Johnson Tunnel, upgrade drainage	FL, HU, ST	DPW&P, State	Local, State, Federal	Low	Med	High	2-3 years
Shaft 3/ Quinapoxet pipeline Rehabilitation Project	Water Supply Emergency/ Drought	DPW&P	Local, Grant	High	High	High	2-3 years
Shaft 3 Pump Station Upgrades	Water Supply Emergency/ Drought	DPW&P	Local, Grant	Med	Med	Med	5 Years
Wachusett Pump Station Upgrades	Water Supply Emergency/ Drought	DPW&P	Local, Grant	Low	Med	High	10 Years

Mitigation Strategy Description	**Hazard(s) Addressed**	**Who? Agencies Involved**	**Potential Funding Sources**	**Priority** (Political & economic viability: High/Med/Low)	**Impact Mitigation** (Impact: High/Med/Low)	**Estimated Cost** (High ($100k+)/ Med ($50k-100k)/ Low (<$50k))	**Timeline** (Time needed to complete)
Wachusett Pipeline Investigation/ Rehabilitation	Water Supply Emergency/ Drought	DPW&P	Local, Grant	Low	Med	High	10 Years
Storage Tank upgrade (Indian Hill)	Water Supply Emergency/ Drought	DPW&P	Local, Grant	High	Med	High	2-5 Years
Olean Street Pump Station upgrades	Water Supply Emergency	DPW&P	Local, Grant	Low	Med	High	5 Years
Worcester Diversion Project- repairs to dam, tunnel, morning glory, channel	FL, HU, ST	DPW&P	Local, Grant	Med	Med	High	2 Years
Green Island Flood Mitigation	FL, HU, ST	DPW&P	Local, Grant	Med	Med	High	10 Years
Headworks Dam located in Holden, MA, tree removal needed	FL, HU, ST, DF	DPW&P	Local, State	Med	Low	Med	1-2 Years
Holden Reservoir Dam #1 needs spillway maintenance	FL, HU, ST, DF	DPW&P	Local, State	Med	Low	Med	1-2 years
Holden Reservoir Dam #2 needs trees to be removed	FL, HU, ST, DF	DPW&P	Local, State	Med	Low	Med	1-2 Years
Kettle Brook Reservoir #1 Dam needs spillway maintenance	FL, HU, ST, DF	DPW&P	Local, State	Med	Low	Med	1-2 Years

Mitigation Strategy Description	Hazard(s) Addressed	Who? Agencies Involved	Potential Funding Sources	Priority (Political & economic viability: High/Med/Low)	Impact Mitigation (Impact: High/Med/Low)	Estimated Cost (High ($100k+)/ Med ($50k-100k)/ Low (<$50k))	Timeline (Time needed to complete)
Kettle Brook Reservoir #2 Dam needs spillway maintenance	FL, HU, ST, DF	DPW&P	Local, State	Med	Low	Med	1-2 Years
Kettle Brook Reservoir #3 Dam needs spillway maintenance	FL, HU, ST, DF	DPW&P	Local, State	Med	Low	Med	1-2 Years
Pine Hill Reservoir Dam needs to be repaired	FL, HU, ST, DF	DPW&P	Local, State	Med	Low	High	1-2 Years
Coes Reservoir Dam spillway needs repair	FL, HU, ST, DF	DPW&P	Local, State	Med	Low	Med	1-2 Years
Patch Pond Dam needs to be rehabilitated	FL, HU, ST, DF	DPW&P	Local, State	Med	Low	High	1-2 Years
Patch Reservoir Dam needs repair	FL, HU, ST, DF	DPW&P	Local, State	Med	Low	Med	1-2 Years
Poor Farm Pond Dam needs to be decommissioned	FL, HU, ST, DF	DPW&P	Local, State	Med	Low	High	1-3 Years
B. Preparedness, Coordination & Response Action Strategies							
Develop a comprehensive interdepartmental record-keeping system of all hazards and disasters happening in the city – past and present.	All	All	Local, State, Federal	Med	Med	Low	1-2 years
Parsons Reservoir Dam- seek funds for a decommissioning study	DF, FL, ST, HU	DPW&P, DCR	Local, State, Federal	Low	Med	Med	10 years
Create/review citywide processes for data collection, sharing during and after hazard events. Create evaluation process post-event to improve responses/issues resulting from the event and share effective strategies/best practices going forward. Evaluate status quo relative to Best Practices.	All	EM, State	Local	Med	Med	Low	1 year

Mitigation Strategy Description	**Hazard(s) Addressed**	**Who? Agencies Involved**	**Potential Funding Sources**	**Priority** (Political & economic viability: High/Med/Low)	**Impact Mitigation** (Impact: High/Med/Low)	**Estimated Cost** (High ($100k+)/ Med ($50k-100k)/ Low (<$50k))	**Timeline** (Time needed to complete)
Seek grants relating to hazard mitigation, collaborate with planning agencies	All	All	Local	High	Med	Low	Ongoing
Continuing to build strong relationships with feds/state/county by hosting trainings/meetings in our facility as well as attending all other related meetings with intentions of strengthening networks. Participate in drills with outside partners.	All	EM, LEPC	Local	Low	Low	Low	Ongoing
Continue to actively engage with utilities community liaison. Continue to allow space for National Grid and other utilities as needed at EOC	All	EM	Local	Low	Low	Low	Ongoing
Upgrade notification/warning system upgrade to current software, as needed. Improve updates on social media before, during and post storm events	All	EM	Local, State, Federal	Med	Med	Low	Ongoing
Develop a formal Shelter Plan. Inventory shelter/emergency resources. Identify what services are available at the different shelters (e.g. food preparation, potable water, back-up electrical power, heat, showers, etc.) and whether the location of different shelters will be impacted by different hazards (i.e. whether flooding will make the shelter inaccessible to some residents). This would help ensure that suitable shelters are available for different types of natural hazards	All	EM	Local, State	Med	Low	Low	1 year
Develop policy to locate generators on city owned buildings on roofs, when possible.	All	All	EAM, Schools, EM	Med	Med	Med	1 year
Develop program to monitor properties and known flood areas for impacts after major flood events.	FL, ST, HU	DPW&P, DPRS, EM	Local	Low	Low	Low	1-2 years

Mitigation Strategy Description	Hazard(s) Addressed	Who? Agencies Involved	Potential Funding Sources	Priority (Political & economic viability: High/Med/Low)	Impact Mitigation (Impact: High/Med/Low)	Estimated Cost (High ($100k+)/ Med ($50k-100k)/ Low (<$50k))	Timeline (Time needed to complete)
C. Education & Awareness Strategies							
Improve information available to residents regarding flood hazards (e.g. in retro-fitting structures); make information available at all permit offices throughout the City.	FL, ST, HU	DPW&P, DPRS,	Local, State, Federal	High	Med	Low	Ongoing
Improve accessibility of existing and new information about protection from hazards (flooding, water conservation, etc.) on the City's website. Include cross-references/links to similar pages (e.g. stormwater/flooding on DPW&P page, all other hazards on EM page).	All	All	Local	High	Med	Low	Ongoing
Create guidance and information to help educate property owners and residents about the benefits of wetlands to increase compliance with regulations	FL, ST, HU	CC, DPRS	Local	High	Med	Low	1 year
Attend pertinent community meetings with stakeholder groups (e.g. watershed/way groups) to provide education and information about flood hazards and wetland protection.	FL, ST, HU	DPW&P, DPRS	Local	High	Med	Low	Ongoing
Improve education about and reporting of illegal dumping in storm drains, wetlands and waterways. Create awareness of connection of storm drains to natural resource areas. Storm drain stenciling projects, signage of how to report illegal dumping near storm drains (especially in CSO areas)	FL, ST, HU	DPW&P, DPRS, DCR	Local, State	High	High	Low	Ongoing
Evaluate existing mechanisms for information sharing with residents/owners and streamline and harness these to share additional information regarding hazards. Explore ability to use electronic permitting processes to flag permits sought in flood hazard areas to help facilitate sharing of information with property owners (e.g. information on flood insurance and/or mitigating properties, etc.).	All	All	Local	High	High	Low	1-2 years

Mitigation Strategy Description	Hazard(s) Addressed	Who? Agencies Involved	Potential Funding Sources	Priority (Political & economic viability: High/Med/Low)	Impact Mitigation (Impact: High/Med/Low)	Estimated Cost (High ($100k+)/ Med ($50k-100k)/ Low (<$50k))	Timeline (Time needed to complete)
Create new "Natural Hazard Mitigation" webpage; Post maps and plan on the City's Website.	All	EM	Local	Med	Med	Low	1 year
Continue and expand outreach programs including National Preparedness Month, National Night Out, social media, community presentation, and various community meetings, and other events	All	EM	Local, State	High	High	Low	Ongoing
Maintain and improve educational outreach as part of CRS including, educating residents in flood prone area and repetitive loss properties.	FL, ST, HU	DPRS	Local, State, Federal	High	Med	Low	Ongoing
Educate community about water conservation; continue including information on water bills and NPDES permits.	DR, FL, ST, HU	DPW&P, CC	Local	High	High	Low	Ongoing
Encourage utilization of low cost training opportunities and harness existing resources, such as FEMA brochures, to help educate resident and property owners in the City regarding hazards.	All	All	Local, State, Federal	High	High	Low	Ongoing
Educate renters on actions they can take to mitigate and prepare for disaster.	All	All	Local	Med	Med	Low	Ongoing
Ensure Unified Incident Command program remains up to date.	All	All	Local	High	High	Low	Ongoing
D. Local Planning & Regulatory Strategies							
Update/implement relevant recommendations into the Open Space & Recreation Plan. Use Mass Audubon's Mapping and Prioritizing Parcels for Resilience to prioritize conservation areas and overlay with flood prone areas and soils able to infiltrate. Note these as critical for restoration and implementation of LID BMPs.	All	DPRS, DPW&P, CC	Local, State	Med	Med	Low	1-2 years

Mitigation Strategy Description	**Hazard(s) Addressed**	**Who? Agencies Involved**	**Potential Funding Sources**	**Priority (**Political & economic viability: High/Med/Low)	**Impact Mitigation** (Impact: High/Med/Low)	**Estimated Cost (**High ($100k+)/ Med ($50k-100k)/ Low (<$50k))	**Timeline (**Time needed to complete)
Update the Wetlands Protection Ordinance/Zoning Ordinance to address establish clear stormwater requirements for all projects (e.g. requirements for re-charge - new and re-development; clarify "maximum extent practical" as defined in 310 CMR 10. Outline clear requirements for creation/use of LID/Green Infrastructure improvements). Consider adoption of minor exemptions where there are public benefits from such activities. Investigate requiring preliminary plans to ensure LID is incorporated early on and can be adjusted based on Conservation Commission recommendation	DR, FL, ST, HU	CC, DPRS	Local	Med	Med	Low	1-2 years
Develop open space property acquisition prioritization matrix. Use MAPPR to prioritize conservation areas and overlay with flood prone areas and soils able to infiltrate. Note these as critical for restoration and implementation of LID BMPs.	All	DPRS	Local	Low	Low	Low	1-2 years
Incorporate Hazard Mitigation Planning recommendations and elements in the Master Plan and ensure Master Plan process evaluates HMP concerns	All	DPRS	Local	High	Med	Med	2-3 years
Update/implement relevant recommendations in the Climate Action Plan	All	DPRS	Local, State	High	High	Med	1-2 years
Consider updates to Subdivision Regulations to encourage LID use, design standards, and cluster developments to protect open-space, reduce imperviousness, and increase buffers to wet areas. Potentially require preliminary plans to ensure LID is incorporated early on and can be adjusted based on PB recommendations. Cluster Development changes: Increase required minimum amount of OS protected. Connect to city's OS plan. Change from cluster to OSRD to include 4-step design process.	All	DPRS	Local	High	Med	Low	1-2 years
Consider adopting additional limitations on imperviousness into zoning and/or wetland regulations.	FL, ST, HU	DPRS	Local	High	High	Low	2-3 years

Mitigation Strategy Description	**Hazard(s) Addressed**	**Who? Agencies Involved**	**Potential Funding Sources**	**Priority** (Political & economic viability: High/Med/Low)	**Impact Mitigation** (Impact: High/Med/Low)	**Estimated Cost** (High ($100k+)/ Med ($50k-100k)/ Low (<$50k))	**Timeline** (Time needed to complete)
Update Zoning Ordinance to modernize parking requirements in order to reduce impervious surfaces through means such as shared parking, mixed-use credits, lower parking minimums, parking maximums, and flexible parking requirements.	FL, ST, HU	DPRS	Local	High	High	Low	1-2 years
Evaluate best-practices for hazard mitigation regulations for new and re-development. Create "resiliency" review checklists for new/re-development projects relative to hazard mitigation best practices for use in zoning, planning, and conservation permitting reviews. Identify ways to incorporate requirements of resiliency BMP's into regulations/ordinances.	All	DPRS	Local	High	High	Low	1 year
Further partnerships with and support for local land protection and management of open space specific to protection from natural hazards (e.g. GWLT, Mass Audubon, etc.). Develop prevention and monitoring programs to avoid illegal dumping in wetlands on such entity owned protected spaces.	FL, ST, HU	DPRS, DCR, non-profits	Local, State	Med	Med	Low	Ongoing
Develop zoning regulations pertaining to land clearing and/or alteration of steep grades to prevent off-site adverse impacts with regard to stormwater/flooding and erosion. Include best practices and requirements for working with natural land form and topography to avoid the creation of steep slopes and use of large retaining walls. Minimize clearing/grading MEP. Create standards within SPR for >15% slope such as setbacks and limiting drop offs; consider reducing to 10% slope.	FL, ST, HU, OT	DRPS	Local	High	High	Low	1-2 years
Implement additional requirements for stormwater management (create storage capacity) for substantial improvement/re-development of existing flood prone properties.	FL, ST, HU	DPW&P, DPRS	Local	High	High	Med	1-2 years
Evaluate feasibility of requiring all new utility service infrastructure to be underground (includes putting underground: Power/cable/fiber optics).	All	Utilities, DPW&P, ISD	Local	Med	Med	Low	1-2 years

Mitigation Strategy Description	**Hazard(s) Addressed**	**Who? Agencies Involved**	**Potential Funding Sources**	**Priority** (Political & economic viability: High/Med/Low)	**Impact Mitigation** (Impact: High/Med/Low)	**Estimated Cost** (High ($100k+)/ Med ($50k-100k)/ Low (<$50k))	**Timeline** (Time needed to complete)
Explore the feasibility of converting existing aerial utility infrastructure (includes putting underground: Power/cable/fiber optics) when streets are resurfaced or work is conducted on city-owned property.	All	Utilities, DPW&P	Local	Med	Med	Low	1-2 years
Develop formal process for providing feedback on MEPA projects.	All	DPRS, DPW&P, Fire	Local	Med	Med	Low	1 year
Consider use of Zoning (e.g. existing floodplain district) to evaluate the extent of appropriate uses for new development located in the floodplain.	FL, ST, HU	DPRS	Local	Med	Med	Low	1-2 years
Investigate opportunities to create restoration requirements for re-development projects in the floodplain/riverfront areas to provide additional storage capacity and riparian zones.	FL, ST, HU	DPW&P, DPRS	Local	Med	Med	Low	Ongoing
Consider development regulations that would require adding flood storage capacity/mitigation measures (e.g. rain gardens, drywells, etc.) in susceptible areas, such the Green Island and Beaverbrook areas of the City.	FL, ST, HU	DPW&P, DPRS	Local	High	High	Med	1-2 years
Investigate feasibility of buy-back programs for high-risk or Repetitive Loss residential structures.	FL, ST, HU	DPW&P, DPRS	Local	Med	Med	Low	1-2 years
Actively monitor and enforce all aspects of the state building code for all construction activities	All	Bldg. Inspector	Local	High	High	Low	Ongoing
Work to actively enforce the Massachusetts Wetlands Protection Act & City of Worcester Wetlands Protection Ordinance and require oversight of projects located in close proximity to storm-drain inlet components.	FL, ST, HU	CC	Local	High	High	Low	Ongoing

Mitigation Strategy Description	**Hazard(s) Addressed**	**Who? Agencies Involved**	**Potential Funding Sources**	**Priority (**Political & economic viability: High/Med/Low)	**Impact Mitigation** (Impact: High/Med/Low)	**Estimated Cost (**High ($100k+)/ Med ($50k-100k)/ Low (<$50k))	**Timeline (**Time needed to complete)
Review best practices and identify those that could be implemented in Worcester, update HMP priorities annually,	All	EM, DPW&P., DPRS	Local	Med	Med	Low	Ongoing
Update Hazard Mitigation Plan on a 5-year basis	All	All	Local, State, Federal	High	High	Low	1 year
Work with CMRPC to maintain up to date evacuation routes, expand on evacuation planning.	All	EM, CMRPC	Local, State, Federal	Med	Med	Low	1-2 years
Take part in the Municipal Vulnerability Preparedness Program and become certified.	All	All	Local, State	High	High	Low	1 year

'Hazards Addressed' abbreviations:

DF	Dam Failure	DR	Drought
EQ	Earthquake	FL	Flooding
HU	Hurricane	OT	Other
SS	Severe Snowstorm/Ice storm/Nor'easter	ST	Severe Thunderstorm/Wind/Tornado
WF	Wildfire/Brushfire	XT	Extreme Temperatures

'Who? Agencies Involved' abbreviations:

CMRPC	Central Mass. Regional Planning Commission	CC	Conservation Commission
DCR	Mass. Department of Conservation & Recreation	DOT	Mass. Department of Transportation
DPRS	Department of Planning & Regulatory Services	DPW&P	Department of Public Works & Parks
ISD	Information Services Department	EAM	Electrical and Mechanical
EM	Emergency Management	LEPC	Local Emergency Planning Committee

8. PLAN ADOPTION, IMPLEMENTATION, AND MAINTENANCE

8.1 Plan Adoption

A public meeting was held on May 8, 2018 as part of the LEPC meeting in order detail the planning process to date and to solicit comments and feedback from the public on the Worcester Hazard Mitigation Plan then being finalized. The draft plan was provided to the City for distribution and posted on CMRPC's website from May 8 for public review and input. The Plan was then submitted to the Massachusetts Emergency Management Agency (MEMA) and the Federal Emergency Management Agency (FEMA) for their review. Upon receiving conditional approval of the plan by FEMA, the final plan was presented to the Worcester City Council and adopted on February 26, 2019.

8.2 Plan Implementation

The implementation of this plan began upon its formal adoption by the City Council and approval by MEMA and FEMA. Those City departments and boards responsible for ensuring the development of policies, ordinance revisions, and programs as described in Sections 5 and 6 of this plan will be notified of their responsibilities immediately following approval. The Hazard Mitigation Team will oversee the implementation of the plan.

Incorporation with Other Planning Documents

Existing plans, studies, reports and municipal documents were incorporated throughout the planning process. This included a review and incorporation of significant information from the following key documents:

- ***Worcester Comprehensive Emergency Management Plan*** (particularly the Critical Infrastructure Section) – The Critical Infrastructure section was used to help identify infrastructure components in city that have been identified as crucial to the function of the city; this resource was also used to identify potentially vulnerable populations and potential emergency response shortcomings.

- ***Worcester Open Space and Recreation Plan Update*** **(2013) –** This Plan was used to identify the natural context within which mitigation planning would take place. This proved useful insofar as it identified water bodies, rivers, streams, infrastructure components (i.e. water and sewer, or the lack thereof), as well as population trends. This was incorporated to ensure that the City's mitigation efforts would be sensitive to the surrounding environment. It should be noted that this plan will expire in 2018 and will need to be updated.

- ***Worcester Zoning Ordinance*** –Zoning was used to gather and identify those actions that the City is already taking that are reducing the potential impacts of a natural hazard (i.e. floodplain regulations) to avoid duplicating existing successful efforts.

- ***Worcester Master Plan*** – The City is currently going through a Master Planning process, which is scheduled to be completed in 2019. We encourage the Master Plan committee to include the recommendations provided by the Worcester Local Hazard Mitigation Team in this Plan be incorporated into the final Worcester Master Plan.

- ***Massachusetts State Hazard Mitigation Plan (2013)*** - This plan was used to ensure that the city's HMP was consistent with the State's Plan.

After the Worcester Hazard Mitigation Plan has been approved by both FEMA and the local government, links to the plan will be emailed to all city staff, boards, and committees, with a reminder to review the plan periodically and work to incorporate its contents, especially the action plan, into other planning processes and documents. In addition, during annual monitoring meetings for the Hazard Mitigation Plan implementation process, the Hazard Mitigation Team will review whether any of these plans are in the process of being updated and if any of the strategies identified in the plan have newly begun, continue to make progress, or have been completed. If so, the Hazard Mitigation Team will remind people working on these plans, policies, etc., of the Hazard Mitigation plan, and urge them to incorporate the Hazard Mitigation plan into their efforts. The Hazard Mitigation Team will also review current city programs and policies to ensure that they are consistent with the mitigation strategies described in this plan. The Hazard Mitigation Plan will also be incorporated into updates of the City's Comprehensive Emergency Management Plan.

8.3 Plan Monitoring and Evaluation

The City's Emergency Management Director will call annual monitoring meetings to review plan progress at a bi-annual meeting of the LEPC, and may also call additional monitoring meetings on an as needed basis based on the occurrence of hazard events. At such monitoring meetings attendance, will be requested or all responsible parties and the Hazard Mitigation Team. Responsible parties identified for specific mitigation actions will be asked to submit their monitoring reports, relative to strategies outlined in the plan, in advance of the meeting.

The public will be notified of these meetings, as the LEPC meetings are public meetings with agendas posted by the City Clerk, and the results of the monitoring meetings and various monitoring reports will be transmitted to City Council via an annual monitoring progress report. in advance through a posting of the agenda at City Hall.

Meetings will involve evaluation and assessment of the plan, regarding its effectiveness at

achieving the plan's goals and stated purpose. The following questions will serve as the criteria that is used to evaluate the plan:

Plan Mission and Goal

- Is the Plan's stated goal and mission still accurate and up to date, reflecting any changes to local hazard mitigation activities?
- Are there any changes or improvements that can be made to the goal and mission?

Hazard Identification and Risk Assessment

- Have there been any new occurrences of hazard events since the plan was last reviewed? If so, these hazards should be incorporated into the Hazard Identification and Risk Assessment.
- Have any new occurrences of hazards varied from previous occurrences in terms of their extent or impact? If so, the stated impact, extent, probability of future occurrence, or overall assessment of risk and vulnerability should be edited to reflect these changes.
- Is there any new data available from local, state, or Federal sources about the impact of previous hazard events, or any new data for the probability of future occurrences? If so, this information should be incorporated into the plan.

Existing Mitigation Strategies

- Are the current strategies effectively mitigating the effect of any recent hazard events?
- Has there been any damage to property since the plan was last reviewed?
- How could the existing mitigation strategies be improved upon to reduce the impact from recent occurrences of hazards? If there are improvements, these should be incorporated into the plan.

Proposed Mitigation Strategies

- What progress has been accomplished for each of the previously identified proposed mitigation strategies?
- How have any recently completed mitigation strategies affected the city's vulnerability and impact from hazards that have occurred since the strategy was completed?
- Should the criteria for prioritizing the proposed mitigation strategies be altered in any way?
- Should the priority given to individual mitigation strategies be changed, based on any recent changes to financial and staffing resources, or recent hazard events?

Review of the Plan and Integration with Other Planning Documents

- Is the current process for reviewing the Hazard Mitigation Plan effective? Could it be improved?

- Are there any city plans in the process of being updated that should have the content of this Hazard Mitigation Plan incorporated into them?
- How can the current Hazard Mitigation Plan be better integrated with other city planning tools and operational procedures, including the zoning ordinance, the Comprehensive Emergency Management Plan, and the Capital Improvement Plan?

Following these discussions, it is anticipated that the planning team may decide to reassign the roles and responsibilities for implementing mitigation strategies to different city departments and/or revise the goals and objectives contained in the plan. Any such changes would be reflected in annual monitoring progress report which will be transmitted to the City Council. The team will fully review and update the Hazard Mitigation Plan every five years, following he FEMA and MEMA required update process.

Public participation will be a critical component of the Hazard Mitigation Plan maintenance process. The Hazard Mitigation Team will hold all meetings in accordance with Massachusetts open meeting laws and the public invited to attend. The public will be notified of any changes to the Plan via the meeting notices board at City Hall, and copies of the revised Plan will be made available to the public at City Hall.

8.4 Potential Federal and State Funding Sources

Federal Funding Sources

The FEMA web pages identify a number of funding opportunities. Please refer to https://www.fema.gov/grants. Some programs are described briefly below:

Hazard Mitigation Assistance

The HMA grant programs provide funding opportunities for pre- and post-disaster mitigation. While the statutory origins of the programs differ, all share the common goal of reducing the risk of loss of life and property due to Natural Hazards. Brief descriptions of the HMA grant programs can be found below. For more information on the individual programs, or to see information related to a specific Fiscal Year, please click on one of the program links.

Hazard Mitigation Grant Program (HMGP)

HMGP assists in implementing long-term hazard mitigation measures following Presidential disaster declarations. Funding is available to implement projects in accordance with State, Tribal, and local priorities. Please refer to: http://www.fema.gov/hazard-mitigation-grant-program for additional information.

HMGP funds may be used to fund projects that will reduce or eliminate the losses from future disasters. Projects must provide a long-term solution to a problem, for example, elevation of a

home to reduce the risk of flood damages as opposed to buying sandbags and pumps to fight the flood. In addition, a project's potential savings must be more than the cost of implementing the project. Funds may be used to protect either public or private property or to purchase property that has been subjected to, or is in danger of, repetitive damage. Examples of projects include, but are not limited to:

- Acquisition of real property for willing sellers and demolition or relocation of buildings to convert the property to open space use
- Retrofitting structures and facilities to minimize damages from high winds, earthquake, flood, wildfire, or other natural hazards
- Elevation of flood prone structures
- Development and initial implementation of vegetative management programs
- Minor flood control projects that do not duplicate the flood prevention activities of other Federal agencies
- Localized flood control projects, such as certain ring levees and floodwall systems, that are designed specifically to protect critical facilities
- Post-disaster building code related activities that support building code officials during the reconstruction process

Pre-Disaster Mitigation Grant Program (PDM)

The PDM Program, authorized by Section 203 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, is designed to assist States, U.S. Territories, Federally-recognized tribes, and local communities in implementing a sustained pre-disaster natural hazard mitigation program. The goal is to reduce overall risk to the population and structures from future hazard events, while also reducing reliance on Federal funding in future disasters. This program awards planning and project grants and provides opportunities for raising public awareness about reducing future losses before disaster strikes. Please refer to http://www.fema.gov/pre-disaster-mitigation-grant-program for additional information.

Flood Mitigation Assistance (FMA)

Flood Mitigation Assistance (FMA) provides funds on an annual basis so that measures can be taken to reduce or eliminate risk of flood damage to buildings insured under the National Flood Insurance Program. Please refer to the FMA website: http://www.fema.gov/flood-mitigation-assistance-grant-program.

Three types of FMA grants are available to States and communities:

- **Planning Grants** to prepare Flood Mitigation Plans. Only NFIP-participating communities with approved Flood Mitigation Plans can apply for FMA Project grants
- **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; these include structures with 2 or more losses each with a claim of at least $1,000 within any ten-year period since 1978.

- **Technical Assistance Grants** for the State to help administer the FMA program and activities. Up to ten percent (10%) of Project grants may be awarded to States for Technical Assistance Grants

Repetitive Flood Claims (RFC)

The Repetitive Flood Claims (RFC) grant program was authorized by the Bunning-Bereuter-Blumenauer Flood Insurance Reform Act of 2004 (P.L. 108–264), which amended the National Flood Insurance Act (NFIA) of 1968 (42 U.S.C. 4001, et al). Please refer to: https://www.fema.gov/repetitive-flood-claims-grant-program-fact-sheet

RFC provides funds on an annual basis to reduce the risk of flood damage to individual properties insured under the NFIP that have had one or more claim payments for flood damages. RFC provides up to 100% federal funding for projects in communities that meet the reduced capacity requirements.

Severe Repetitive Loss (SRL)

The Severe Repetitive Loss (SRL) grant program was authorized by the Bunning-Bereuter-Blumenauer Flood Insurance Reform Act of 2004, which amended the National Flood Insurance Act of 1968 to provide funding to reduce or eliminate the long-term risk of flood damage to severe repetitive loss (SRL) structures insured under the National Flood Insurance Program (NFIP). Please refer to: https://www.fema.gov/media-library/resources-documents/collections/14

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. SRL provides up to 90% federal funding for eligible projects.

Definition**:** The definition of severe repetitive loss as applied to this program was established in section 1361A of the National Flood Insurance Act, as amended (NFIA), 42 U.S.C. 4102a. An SRL property is defined as a residential property that is covered under an NFIP flood insurance policy and:

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 ten-year period, and must be greater than 10 days apart.

Purpose: To reduce or eliminate claims under the NFIP through project activities that will result in the greatest savings to the National Flood Insurance Fund (NFIF).

Federal / Non-Federal cost share: 75/25%; up to 90% Federal cost-share funding for projects approved in States, Territories, and Federally-recognized Indian tribes with FEMA-approved Standard or Enhanced Mitigation Plans or Indian tribal plans that include a strategy for mitigating existing and future SRL properties.

Disaster Assistance

Disaster assistance is money or direct assistance to individuals, families and businesses in an area whose property has been damaged or destroyed and whose losses are not covered by insurance. It is meant to help with critical expenses that cannot be covered in other ways. This assistance is not intended to restore damaged property to its condition before the disaster. While some housing assistance funds are available through our Individuals and Households Program, most disaster assistance from the Federal government is in the form of loans administered by the Small Business Administration.

Disaster Assistance Available from FEMA

In the event of a Declaration of Disaster, assistance from FEMA is grouped in 3 categories:

A. Housing Needs
B. Other than Housing Needs
C. Additional Services

A. Housing Needs

- **Temporary Housing** (a place to live for a limited period of time): Money is available to rent a different place to live, or a government provided housing unit when rental properties are not available.
- **Repair**: Money is available to homeowners to repair damage from the disaster to their primary residence that is not covered by insurance. The goal is to make the damaged home safe, sanitary, and functional.
- **Replacement**: Money is available to homeowners to replace their home destroyed in the disaster that is not covered by insurance. The goal is to help the homeowner with the cost of replacing their destroyed home.
- **Permanent Housing Construction**: Direct assistance or money for the construction of a home. This type of help occurs only in insular areas or remote locations specified by FEMA, where no other type of housing assistance is possible.

B. Other than Housing Needs

Money is available for necessary expenses and serious needs caused by the disaster, including:

- Disaster-related medical and dental costs.
- Disaster-related funeral and burial cost.
- Clothing; household items (room furnishings, appliances); tools (specialized or protective clothing and equipment) required for your job; necessary educational materials (computers, school books, supplies)
- Fuels for primary heat source (heating oil, gas).
- Clean-up items (wet/dry vacuum, dehumidifier).
- Disaster damaged vehicle.
- Moving and storage expenses related to the disaster (moving and storing property to avoid additional disaster damage while disaster-related repairs are being made to the home).
- Other necessary expenses or serious needs as determined by FEMA.
- Other expenses that are authorized by law.

C. Additional Services

- Crisis Counseling
- Disaster Unemployment Assistance
- Legal Services
- Special Tax Considerations

Assistance to Firefighters Grants

The FEMA Assistance to Firefighters Grants (AFG) program provides funds to equip and train emergency personnel to recognized standards, enhance operations efficiencies, foster interoperability, and support community resilience. Under AFG, funds may be available for equipment, vehicles and/or training that can be used to mitigate and/or respond to wildfire-related hazards. AFG also has a Fire Prevention and Safety (FPS) component which funds public outreach programs and prevention activities, which can emphasize wildfire mitigation. Please refer to: https://www.fema.gov/welcome-assistance-firefighters-grant-program.

Disaster Loans Available from the Small Business Administration

The U.S. Small Business Administration (SBA) can make federally subsidized loans to repair or replace homes, personal property or businesses that sustained damages not covered by insurance. The Small Business Administration can provide three types of disaster loans to qualified homeowners and businesses:

- Home disaster loans to homeowners and renters to repair or replace disaster- related damages to home or personal property (please refer to: https://www.disasterassistance.gov/get-assistance/forms

- Business physical disaster loans to business owners to repair or replace disaster- damaged property, including inventory, and supplies (please refer to: https://www.sba.gov/loans-grants/see-what-sba-offers/sba-loan-programs/disaster-loans/disaster-loan-data); and

- Economic injury disaster loans, which provide capital to small businesses and to small agricultural cooperatives to assist them through the disaster recovery period (please refer to): https://www.sba.gov/funding-programs/disaster-assistance

For many individuals, the SBA disaster loan program is the primary form of disaster assistance.

Disaster Assistance from Other Organizations and Entities

The website https://www.disasterassistance.gov/ is a secure, user-friendly U.S. Government web portal that consolidates disaster assistance information in one place. If you need assistance following a presidentially declared disaster— which has been designated for individual assistance— you can now to go to DisasterAssistance.gov to register online. Local resource information to help keep citizens safe during an emergency is also available. Currently, 17 U.S. Government agencies, which sponsor almost 60 forms of assistance, contribute to the portal.

DisasterAssistance.gov speeds the application process by feeding common data to multiple online applications. Application information is shared only with those agencies you identify and is protected by the highest levels of security. DisasterAssistance.gov will continue to expand to include forms of assistance available at the federal, state, tribal, regional and local levels, with a projected completion date of 2014. Through www.DisasterAssistance.gov you have the ability to:

- Determine the number and forms of assistance you may be eligible to receive by answering a brief series of questions or start the individual assistance registration process immediately
- Apply for FEMA assistance and be referred to the Small Business Administration for loans through online applications
- Choose to have your Social Security benefits directed to a new address
- Access your federal student loan account information
- Receive referral information on forms of assistance that do not yet have online applications
- Access a call center in the event you do not have Internet access to ensure you can still register for assistance
- Check the progress and status of your applications online.
- Identify resources and services for individuals, families and businesses needing disaster

assistance during all phases of an emergency situation
- Identify resources to help locate family members and pets
- Access assistance from the Department of State if you are affected by a disaster while traveling abroad
- Find information on disaster preparedness and response

Federal Funding Summary Table

The following is a summary of the programs which are the primary source for federal funding of hazard mitigation projects and activities in Massachusetts:

Table 29

Program	Type of Assistance	Availability	Managing Agency	Funding Source
National Flood Insurance Program (NFIP)	Pre-Disaster Insurance	Any time (pre & post disaster)	DCR Flood Hazard Management Program	Property Owner, FEMA
Community Rating System (CRS) (Part of the NFIP)	Flood Insurance Discounts	Any time (pre & post disaster)	DCR Flood Hazard Management Program	Property Owner
Flood Mitigation Assistance (FMA) Program	Cost share grants for pre- disaster planning & projects	Annual pre-disaster grant program	MEMA	75% FEMA/ 25% non- federal
Hazard Mitigation Grant Program (HMGP)	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
Assistance to Firefighters Grants (AFG)	Training & equipment for wildfire-related hazards	Annual	FEMA	FEMA
Small Business Administration (SBA) Mitigation Loans	Pre- & Post- disaster loans to qualified applicants	Ongoing	MEMA	Small Business Administration

Program	Type of Assistance	Availability	Managing Agency	Funding Source
Public Assistance	Post-disaster aid to state & local governments	Post Disaster	MEMA	FEMA/ plus a non-federal share

For a list of additional potential funding sources, please refer to Table 17-7 on Pages 545-8 of the 2013 State Hazard Mitigation Plan:
http://www.mass.gov/eopss/docs/mema/resources/plans/state-hazard-mitigation-plan/massachusetts-state-hazard-mitigation-plan.pdf.

State Funding Sources

The Commonwealth of Massachusetts provides matching FEMA assistance. This means that, following Presidential disaster declarations, the state may contribute a portion of the 25% non-federal share for federal Infrastructure Support funds. Since 1991, the state has contributed nearly $20 million to match FEMA's funding following declared Presidential disasters. Other State funding sources include the following:

Special Appropriations and Legislative Earmarks

Although there is no separate state disaster relief fund in Massachusetts, the state legislature may enact special appropriations for those communities sustaining damages following a natural disaster that are not large enough for a Presidential disaster declaration. Since 1991, Massachusetts has issued 20 major disaster declarations. Additionally, individual legislators may seek specific project funding for projects through the legislative budgeting and appropriations process.

State Revolving Fund

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

Chapter 90 Funds

This statewide program reimburses communities for roadway projects, such as resurfacing and related work and other work incidental to the above such as preliminary engineering including State Aid/Consultant Design Agreements, right-of-way acquisition, shoulders, side road approaches, landscaping and tree planting, roadside drainage, structures (including bridges), sidewalks, traffic control and service facilities, street lighting (excluding operating costs), and for such other purposes as the Department may specifically authorize. Maintaining and upgrading critical infrastructure and evacuation routes is an important component of hazard mitigation.

MVP Program

Launched in 2017, the Municipal Vulnerability Preparedness (MVP) program provides support for

cities and towns to begin or to supplement the process of planning for resiliency. The state awards communities with funding to complete vulnerability assessments and to develop action-oriented resiliency plans, with a special emphasis on the impacts climate change. Communities will be able to define extreme weather and natural and climate related hazards, identify existing and future vulnerabilities and strengths, develop and prioritize actions for the community, and identify opportunities to take action to reduce risk and build resilience. MVP activities can easily be integrated with updates to the local hazard mitigation plan. More information is available online here:www.mass.gov/eea/air-water-climate-change/climate-change/massachusetts-global-warming-solutions-act/municipal-vulnerability-preparedness-program.html

Community Development Block Grant (CDBG)

CDBG remains the principal source of revenue for communities to use in identifying solutions to address physical, economic, and social deterioration in lower-income neighborhoods and communities. While primarily a housing and community development program administered through the Executive Office of Housing and Community Development (EOHCD), the program can also fund the rehabilitation of municipal buildings such as town halls, which in many cases, also serve as Emergency Operations Centers for their communities.

State Land Acquisition & Conservation Program

Through the Massachusetts Executive Office of Energy and Environmental Affairs, this annual program purchases private property for open space, wetland protection and floodplain preservation purposes. For instance, in 1998, the state set an ambitious goal of protecting 200,000 acres of open space in the Commonwealth by 2010. In August 2001, less than three years later, the state 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 the website of the Executive Office of Energy and Environmental Affairs Open Space Protection program at: https://www.mass.gov/orgs/executive-office-of-energy-and-environmental-affairs

Dams & Levees Program

EEA funds projects for the repair and removal of dams, levees, seawalls, and other forms of inland and coastal flood control. In FY 2016, the maximum award for any one application was $1,000,000 for dams and levees and $3,000,000 for seawalls and other coastal foreshore protection. A minimum financial match of 25% of total funds requested is required. For additional information, please refer to http://www.mass.gov/eea/waste-mgnt-recycling/water-resources/preserving-water-resources/water-laws-and-policies/water-laws/draft-regs-re-dam-and-sea-wall-repair-or-removal-fund.html.

Major Flood Control Projects

The state 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

Natural Resource Conservation Service (NRCS), manages the Flood Control Dams Program, (PL566), which funds states in the operation and maintenance of the 25 PL566 flood control dams located 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 state provides the 25% non-federal share for FEMA's funding under the Community Assistance Program - State Support Services Element (CAP-SSSE). CAP-SSSE funding, and the state match supports the Flood Hazard Management Program (FHMP) within the Department of Conservation and Recreation. The FHMP works with FEMA to coordinate the National Flood Insurance Program throughout Massachusetts, providing technical assistance to participating communities and professionals.

MassWorks Infrastructure Program

The MassWorks Infrastructure Program provides a one-stop shop for municipalities and other eligible public entities seeking public infrastructure funding to support economic development and job creation. Although not specific to natural hazards per se, these infrastructure enhancements under MassWorks could also address identified needs for hazard mitigation. The MassWorks Infrastructure Program is administered by the Executive Office of Housing and Economic Development, in cooperation with the Department of Transportation and Executive Office for Administration & Finance. Please refer to: http://www.mass.gov/hed/economic/eohed/pro/infrastructure/massworks/ for additional information.

Weatherization Assistance Program

The Weatherization Assistance Program is funded each year by the U.S. Department of Energy's Office of Energy Efficiency & Renewable. 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. Please refer to http://energy.gov/eere/wipo/weatherization-assistance-program for additional information.

APPENDICES

A. Maps
B. Critical Infrastructure
C. Public Survey Results
D. Planning Team & Public Meetings
E. Glossary
F. Repetitive Loss Properties
G. 2012/2018 Priority Comparison