APPENDIX A. HAZARD ANALYSIS AND RISK ASSESSMENT

The Hazard Analysis and Risk Assessment provides an in-depth study of natural hazard risks for the Town of Fairhaven. It is presented in the following distinct sections:

A.1 Overview
A.2 Hazard Identification
A.3 Hazard Profiles
A.4 Vulnerability Assessment
A.5 Summary Findings and Conclusions

A.1. OVERVIEW

The purpose of the Hazard Analysis and Risk Assessment is to identify, analyze, and assess the Town of Fairhaven's overall risk to natural hazards. It helps determine the potential impacts of hazards to the people, economy, and built and natural environments of the community as well as specific vulnerabilities or problem areas. It is a critical element that serves as the foundation to the entire mitigation planning process, which is focused on identifying and prioritizing actions to reduce risk to hazards. In addition to informing the Mitigation Strategy included in this plan, the Hazard Analysis and Risk Assessment can also be used to establish local emergency preparedness and response priorities, for land use and community development planning, and for decision making by elected officials, Town staff, businesses, and organizations in the community.

The Hazard Analysis and Risk Assessment completed for the Town of Fairhaven builds on available historical data and information on past hazard occurrences, and projections for anticipated future occurrences. It includes hazard-by-hazard profiles for those hazards deemed to pose significant risk, a geospatial-based exposure and risk assessment for those hazards with geographically-defined boundaries, and culminates in a hazard risk ranking based on the findings and conclusions about the location, probability, potential impact, warning time, and duration of each hazard. The process is designed to assist the Town of Fairhaven seek the most appropriate mitigation actions to pursue and implement—focusing its efforts on those hazards of greatest concern and those community assets facing the greatest risk.

Specific information on the methods and data sources used to complete the Hazard Analysis and Risk Assessment are incorporated throughout this section and will be refined as necessary through future updates to this plan.

A.2. HAZARD IDENTIFICATION

This section provides a summary of the Town's initial hazard identification and screening process. The first step in completing a comprehensive risk assessment for mitigation planning purposes is the identification of all natural hazards that can affect the people, economy, and built and natural environments in the planning area. The primary purpose of this step is to ensure that all potential natural hazard threats are considered for inclusion in the plan and to determine which are significant enough to carry forward for more detailed hazard analysis and risk assessment tasks.

Fairhaven is vulnerable to a wide range of natural hazards that threaten life and property which can be defined or categorized in a variety of ways. The hazard identification process completed for this plan began with capturing early input from the Hazard Mitigation Planning Committee (HMPC) and other community stakeholders through public outreach as described in Section 2. This was followed by an extensive evaluation and classification of all potential hazards based on a review of the Massachusetts State Hazard Mitigation Plan (2013), past major disaster and emergency declarations for Bristol County, historical and anecdotal data on previous hazard events, and the hazard mitigation plans for neighboring jurisdictions. Readily available information from other official and reputable data sources was also evaluated to supplement information provided through these primary sources.

Table A-1 identifies the 13 definitive types of natural hazards considered for this plan, listed in alphabetical order, and summarizes the rationale for why each was or was not recommended for further study in the risk assessment. While descriptive profiles and vulnerability assessments are to be completed only for the 9 hazards identified as posing significant risk for Fairhaven, the Town shall not be precluded from considering mitigation actions for others if deemed appropriate. It should also be noted that hazards not currently identified for inclusion in the risk assessment may be further studied and/or included during the plan maintenance process as required.

Table A-1: Hazard Identification and Screening Summary

Natural Hazard	Significant Risk for Fairhaven?	Rationale for Inclusion or Exclusion from Risk Assessment
Coastal Erosion and Sea Level Rise	Yes	• Chronic condition along most shoreline areas in the planning area • Frequency of rapid, episodic erosion caused by storm events • Coastal properties are becoming more exposed to flood hazards due to long-term erosion and projected sea level rise
Coastal Storm *(includes hurricanes, tropical storms, nor'easters, etc.)*	Yes	• Priority concern for the HMPC • Frequency and severity of previous occurrences in planning area, including multiple major disaster and emergency declarations • High probability of future events, with potential to cause severe, extensive loss, damage and disruption to the entire planning area
Dam Failure	No	• No significant or high hazard dams are located within or immediately upstream from the planning area • No record of significant previous occurrences in planning area • Very low probability of future events
Drought	Yes	• History of previous occurrences • Potential for increased frequency, duration and severity of drought events due to climate change • Potential impacts to groundwater and private well supplies, the farming community, and other agribusinesses in planning area
Earthquake	Yes	• Previous occurrences – moderately damaging earthquakes strike somewhere in the region every few decades • Expected probability of ground shaking at damaging levels is extremely low but older, unreinforced masonry buildings or structures not constructed to code could still be at risk • Potential local impacts caused by ground liquefaction in low-lying areas near water bodies

Natural Hazard	Significant Risk for Fairhaven?	Rationale for Inclusion or Exclusion from Risk Assessment
Extreme Temperatures	Yes	• History of previous occurrences • Potential for increased frequency, duration and severity of extreme heat events due to climate change • Potential life/safety impacts to vulnerable populations in the planning area that could be disproportionately affected
Fire *(includes urban fire and wildfire)*	Yes	• Previous occurrences in planning area that have resulted in property damage and destruction • Locally confirmed wildfire hazard areas in planning area with increasing fuel loads and susceptibility to offshore winds • Potential for increased frequency and severity of wildfire events due to climate change
Flood *(includes riverine, coastal, and urban drainage flooding)*	Yes	• Priority concern for the HMPC • Frequency and severity of previous occurrences in planning area, including multiple major disaster and emergency declarations • High probability of future events, with potential to cause severe, extensive loss, damage and disruption to the entire planning area
Landslide	No	• No record of significant previous occurrences in planning area • No indication of risk for planning area per the State Hazard Mitigation Plan and Massachusetts Geological Survey • Low probability of future events
Severe Weather *(includes high winds, severe thunderstorms, tornadoes, etc.)*	Yes	• Frequency and severity of previous occurrences in planning area, including major disaster declarations • High probability of future events, with potential to cause extensive damage and disruption to the entire planning area
Severe Winter Storm *(includes snow, blizzards, ice storms, etc.)*	Yes	• Priority concern for the HMPC • Frequency and severity of previous occurrences in planning area, including multiple major disaster and emergency declarations • High probability of future events, with potential to cause extensive damage and disruption to the entire planning area
Soil Hazards *(includes sinkholes, subsidence, expansion or collapse, etc.)*	No	• Identified as potential hazard in 2004 regional hazard mitigation plan, but with limited severity/magnitude • No record of significant previous occurrences in planning area • Low probability of future events
Tsunami	No	• No record of previous occurrences in the planning area • Very low probability of future events

The 13 natural hazards identified above are consistent with all the hazards of concern for the Commonwealth of Massachusetts as identified in the State Hazard Mitigation Plan. Some of the hazards are interrelated (for example, hurricanes may cause flooding, or drought conditions may increase the likelihood of wildfires), but for hazard identification purposes these individual hazards are distinguished separately. More information on the interrelationship between hazards, potential secondary hazards resulting from a hazard event, and opportunities to mitigate multiple hazard-related risks through common mitigation techniques are addressed in subsequent sections of this plan.

A.3. HAZARD PROFILES

This section provides descriptive information on each of the nine (9) hazards identified as posing significant risk for Fairhaven, including the following key sub-sections:

- **General Description** – Provides brief descriptions of the hazard, its characteristics and potential effects.
- **Location** – Provides information on the geographic areas within the planning area that are susceptible to occurrences of the hazard.
- **Severity/Extent** – Provides information on the potential strength or magnitude of the hazard.
- **Previous Occurrences** – Provides information on the history of previous hazard events in the planning area, including their impacts on people and property.
- **Probability of Future Occurrences** – Describes the likelihood of future hazard occurrences in the planning area, including a qualitative classification (Unlikely, Possible, Likely, or Highly Likely) as defined in the Priority Risk Index provided on page A-79. Narrative descriptions include a summary of any anticipated effects that climate change may have on the frequency, duration and intensity of future hazard events. A summary of these effects in the Northeast region and specifically Massachusetts is provided below.

This section concludes with an overall summary of the key findings on the characteristics of each hazard and their potential impacts to the planning area. This information was used to measure relative risk each hazard poses to Fairhaven and helped the HMPC in ranking and generally prioritizing the hazards for purposes of mitigation strategy development.

Natural Hazards and the Anticipated Effects of a Changing Climate

One of the most important factors in assessing natural hazard risk is the consideration of climate change and its potential effects on future events. Traditionally, hazard risk assessments have relied heavily on historical data and information along with the assumption of stationarity – that natural systems will not change with time – in predicting future climate and hazard conditions. However, best available science now tells us that hazard risk will change and, in many cases, will accelerate rapidly. Risk assessments must therefore embrace the reality of non-stationarity and address how climate change may affect natural hazards. As mentioned above, this has been done for all applicable hazards throughout this section and is specifically summarized in the discussion on the *probability of future occurrences*. A more general overview of the anticipated effects of climate change for the Northeast and specifically Massachusetts is provided below.

<u>Climate Change Impacts in the Northeast</u>
Annual average temperatures in the Northeast has increased by 2°F since 1970, with winter temperatures rising twice this much. This warming has resulted in many other climate-related changes including more frequent very hot days, a longer growing season, an increase in heavy downpours (an observed increase of 71 percent since 1958), less winter precipitation falling as snow and more as rain, reduced snowpack, earlier break-up of winter ice on lakes and rivers, earlier spring snowmelt resulting in earlier peak river flows, rising sea surface temperatures, and rising sea level. These trends are projected to continue, with more dramatic changes under higher greenhouse gas emissions scenarios

compared to lower emissions scenarios. The key messages from the latest (2014) National Climate Assessment on the Northeast include the following:[1]

- Heat waves, coastal flooding, and river flooding will pose a growing challenge to the region's environmental, social, and economic systems. This will increase the vulnerability of the region's residents, especially its most disadvantaged populations.
- Infrastructure will be increasingly compromised by climate-related hazards, including sea level rise, coastal flooding, and intense precipitation events.
- Agriculture, fisheries, and ecosystems will be increasingly compromised over the next century by climate change impacts. Farmers can explore new crop options, but these adaptations are not cost- or risk-free. Moreover, adaptive capacity, which varies throughout the region, could be overwhelmed by a changing climate.
- While a majority of states and a rapidly growing number of municipalities have begun to incorporate the risk of climate change into their planning activities, implementation of adaptation measures is still at early stages.

Massachusetts Climate Change Projections

In 2017, researchers from the Northeast Climate Science Center at the University of Massachusetts Amherst developed downscaled projections for changes in temperature, precipitation, and sea level rise for Massachusetts. These projections are provided at three geographic scales: statewide; county; and major basins. Regardless of geographic scale, it is clear from the latest research for Massachusetts that rising temperatures, changing precipitation, and extreme weather will continue to affect the people and resources of the Commonwealth throughout the 21st century. An overall summary of the anticipated statewide impacts for Massachusetts is provided below.

Impacts from Increasing Temperatures

- Temperatures are projected to increase significantly over the next century. Winter average temperatures are likely to increase more than those in summer, with major impacts on everything from winter recreation to increased pests and challenges to harvesting for the forestry industry.
- Warmer temperatures and extended heat waves could have very significant impacts on public health, as well as the health of plants, animals and ecosystems like forests and wetlands. Rising temperatures will also affect important economic sectors like agriculture and tourism, and infrastructure like the electrical grid.
- Even what seems like a very small rise in average temperatures can cause major changes in other factors, such as the relative proportion of precipitation that falls as rain or snow.
- Beyond this general warming trend, Massachusetts will experience an increasing number of days with extreme heat in the future. Extreme heat can be especially damaging in urban areas, where there is often a concentration of vulnerable populations, and where more impervious surfaces such as streets and parking lots and less vegetation cause a "heat island" effect that makes them hotter compared to neighboring rural areas.
- Urban residents in Massachusetts – especially those who are very young, ill, or elderly, and those who live in older buildings without air conditioning – will face greater risks of serious heat-

[1] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

related illnesses when extreme heat becomes more common. Extreme heat and dry conditions or drought could also be detrimental to crop production, harvest and livestock.

- While warmer winters may reduce burdens on energy systems, more heat in the summer may put larger demands on aging systems, creating the potential for power outages. The number of cooling degree days is expected to increase significantly by the end of the century adding to this strain. In addition, heat can directly stress transmission lines, substations, train tracks, roads and bridges, and other critical infrastructure.

Impacts from Changing Precipitation Conditions

- Rainfall is expected to increase in spring and winter months, with increasing consecutive dry days in summer and fall. More total rainfall can have an impact on the frequency of minor but disruptive flooding events, especially in areas where storm water infrastructure has not been adequately sized to accommodate higher levels. Increased total rainfall will also affect agriculture, forestry and natural ecosystems.
- More intense downpours often lead to inland flooding as soils become saturated and stop absorbing more water, river flows rise, and the capacity of urban storm water systems is exceeded. Flooding may occur as a result of heavy rainfall, snowmelt, or coastal flooding associated with high wind and wave action, but precipitation is the strongest driver of flooding in Massachusetts. Winter flooding is also common in the state, particularly when the ground is frozen.
- The climate projections suggest that the frequency of high-intensity rainfall events will trend upward. Overall, it is anticipated that the severity of flood-inducing weather events and storms will increase, with events that produce sufficient precipitation to present a risk of flooding likely increasing. A single intense downpour can cause flooding and widespread damage to property and critical infrastructure. The coast will experience the greatest increase in high-intensity rainfall days, but some level of increase will occur in every area of Massachusetts.
- Climate projections for Massachusetts indicate that in future decades, winter precipitation could increase, but by the end of the century most of this precipitation is likely to fall as rain instead of snow due to warmer winters. There are many human and environmental impacts that could result from this change including reduced snow cover for winter recreation and tourism, less spring snow melt to replenish aquifers, higher levels of winter runoff, and lower spring river flows for aquatic ecosystems.
- A small projected decrease in average summer precipitation in Massachusetts could combine with higher temperatures to increase the frequency of episodic droughts, like the one experienced across the Commonwealth in the summer of 2016.
- Droughts will create challenges for local water supply by reducing surface water storage and the recharge of groundwater supplies, including private wells. More frequent droughts could also exacerbate the impacts of flood events by damaging vegetation that could otherwise help mitigate flooding impacts. Droughts may also weaken tree root systems, making them more susceptible to toppling during high wind events.

For purposes of this plan, the Town of Fairhaven relied on the climate projections downscaled to the Buzzards Bay basin. These projections were considered and addressed in the hazard profiles for each relevant hazard (including sea level rise, drought, extreme temperatures, and flood), and specifically under descriptions of the "probability of future occurrences."

Summary of Major Disaster and Emergency Declarations

Prior to delving into hazard-specific profiles, it is important to review past major disaster and emergency declarations that have included Bristol County. Major disaster and emergency declarations are issued by the President of the United States at a county level when an event has been determined to be beyond the capabilities and resources of state and local governments to respond and recover. A major disaster declaration is issued when a disaster or catastrophic event requires broader authority and resources to help states and local communities, as well as families and individuals, recover from the damage caused by the event. An emergency declaration is issued to protect property and public health and safety and to lessen or avert the imminent threat of a major disaster or catastrophe.

Since 1953, when presidential declarations first became issued, Bristol County has been included in 16 major disaster declarations and 11 emergency declarations as listed in **Table A-2**. Many additional emergencies and disasters have occurred that were not severe enough to require federal disaster relief through a presidential declaration.

Table A-2: Major Disaster and Emergency Declarations for Bristol County, Since 1953

Declaration Date	Incident Type	Declaration Type	Description
4/13/2015	Severe Storm(s)	Major Disaster	Severe Winter Storm, Snowstorm, and Flooding
4/19/2013	Severe Storm(s)	Major Disaster	Severe Winter Storm, Snowstorm, and Flooding
4/17/2013	Terrorist	Emergency	Explosions
12/19/2012	Hurricane	Major Disaster	Hurricane Sandy
10/28/2012	Hurricane	Emergency	Hurricane Sandy
9/3/2011	Hurricane	Major Disaster	Tropical Storm Irene
8/26/2011	Hurricane	Emergency	Hurricane Irene
9/2/2010	Hurricane	Emergency	Hurricane Earl
3/29/2010	Severe Storm(s)	Major Disaster	Severe Storms and Flooding
12/13/2008	Severe Storm(s)	Emergency	Severe Winter Storm
11/10/2005	Severe Storm(s)	Major Disaster	Severe Storms and Flooding
10/19/2005	Severe Storm(s)	Emergency	Severe Storms and Flooding
9/13/2005	Hurricane	Emergency	Hurricane Katrina Evacuation
2/17/2005	Snow	Emergency	Record and/or Near Record Snow
1/15/2004	Snow	Emergency	Snow
3/11/2003	Snow	Emergency	Snow
4/10/2001	Severe Storm(s)	Major Disaster	Severe Storms and Flooding
6/23/1998	Flood	Major Disaster	Heavy Rains and Flooding
1/24/1996	Snow	Major Disaster	Blizzard of ‘96
3/16/1993	Snow	Emergency	Blizzards, High Winds and Record Snowfall

Declaration Date	Incident Type	Declaration Type	Description
8/26/1991	Hurricane	Major Disaster	Hurricane Bob
10/28/1985	Hurricane	Major Disaster	Hurricane Gloria
2/10/1978	Flood	Major Disaster	Coastal Storms, Flood, Ice and Snow
9/28/1972	Fishing Losses	Major Disaster	Toxic Algae in Coastal Waters
8/20/1955	Hurricane	Major Disaster	Hurricane and Floods
9/2/1954	Hurricane	Major Disaster	Hurricanes
6/11/1953	Tornado	Major Disaster	Tornado

Source: FEMA

A.3.1. COASTAL EROSION AND SEA LEVEL RISE

A.3.1.1 General Description

Coastal erosion may be generally defined as a gradual, chronic but natural condition of losing shoreline sediments (mostly beach sand and dune systems) due to wind, waves, tides, currents, and other natural coastal processes. Other long-term influences may include subsidence and sea level rise (further described below). Rapid coastal erosion exacerbates the long-term threat and typically results from episodic natural hazard events such as hurricanes, nor'easters, and storm surge which can flatten dunes and create massive erosion in only hours or days. Erosion may also be worsened by human activities such as boat wakes, shoreline hardening, and offshore dredging.

As coastal erosion continues the shoreline moves landward, posing an increased threat of damages to adjacent property and infrastructure – particularly when development is sited close to the shoreline, in unstable or low-lying areas. Natural recovery from episodic erosion events can take months or years. If a beach and dune system does not recover quickly enough naturally, coastal and upland property may be exposed to further damage in subsequent events. Erosion can result in significant economic and emotional loss in a system of fixed property lines. Shoreline hardening techniques such as seawalls, revetments, bulkheads, groins and jetties may stave off coastal erosion but, in most cases, they worsen or shift the problem to adjacent, downdrift property owners to similar or greater losses.

Sea level rise refers to an increase in mean sea level over time. There is strong scientific evidence that global sea level is now rising at an increased rate and will continue to rise during this century. Climate change, including the continued increase in global temperature, is projected to result in an acceleration of observed rates of sea level rise. The Intergovernmental Panel on Climate Change (IPCC) estimates that global average sea level will rise between 1.4 to 3.2 feet by 2100.[2] However, climate models, satellite data, and hydrographic observations demonstrate that sea level is not rising uniformly around the world. Depending on the region, sea level might be projected to rise several times the global mean rise or can fall.

[2] Intergovernmental Panel on Climate Change. *Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. 2013.

The two major causes of global sea level rise are thermal expansion caused by the warming of the oceans (since water expands as it warms) and the loss of land-based ice (such as glaciers and polar ice caps) due to increased melting. Local sea level change, which is of more direct concern to coastal communities, is a combination of the rise in sea level and the change in land elevation. Areas experiencing coastal erosion and land subsidence accelerate the rate of sea level rise occurring locally. Coastal communities experiencing increases in mean sea level are at greater risk to the effects of coastal flood hazards as natural, protective buffers such as coastal wetlands and dunes are lost and property and infrastructure become more exposed to the frequency and severity of coastal flood and storm surge inundation.

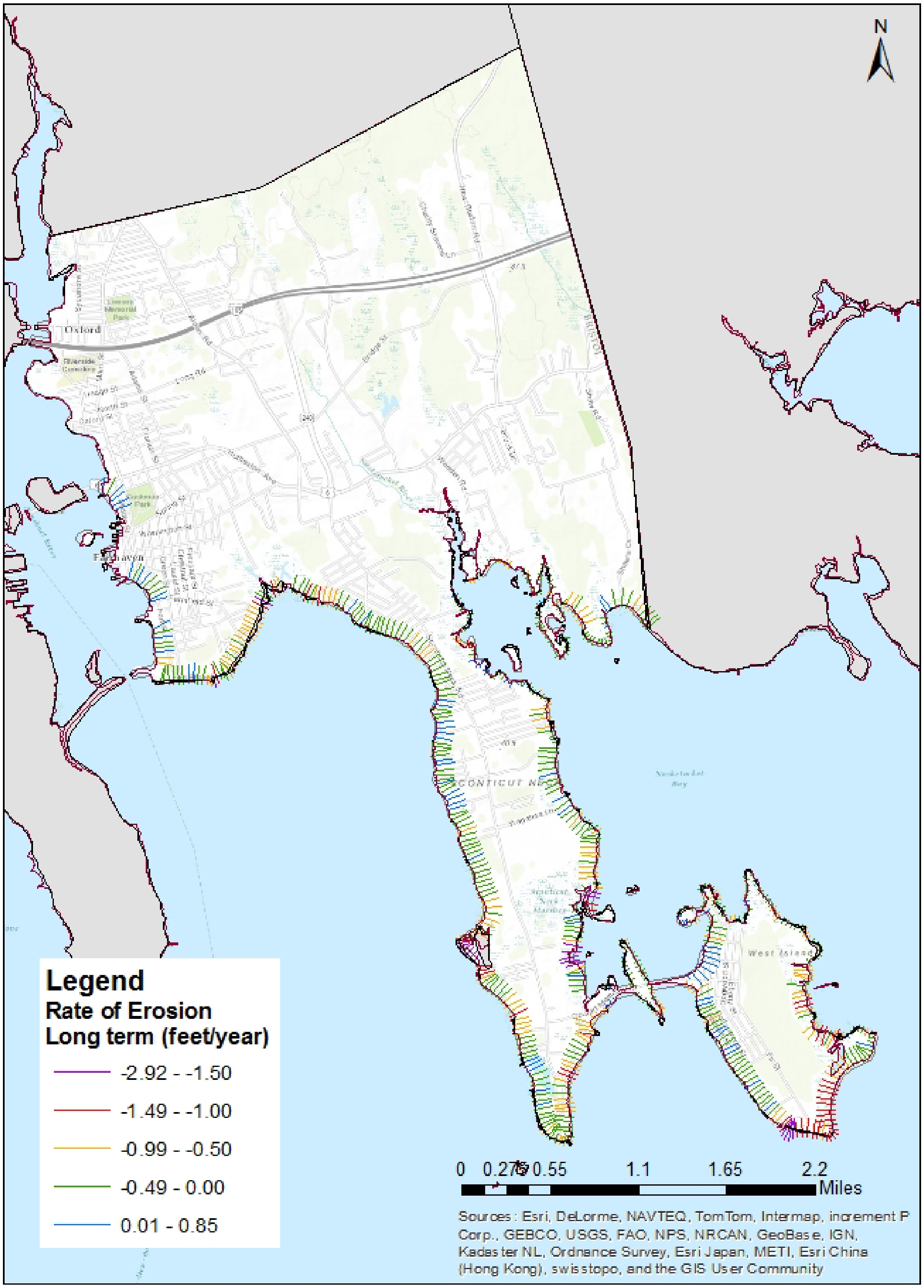
A.3.1.2 Location

Coastal Erosion

Most shoreline areas in Fairhaven are susceptible to the occurrence of long-term and storm-induced coastal erosion, though the rates of erosion vary for different locations and shoreline types. Through its *Shoreline Change Project*, the Massachusetts Office of Coastal Zone Management (CZM) has studied and documented the rate of change of all ocean-facing shorelines in the state with the goal of developing and distributing scientific data to support local land-use decisions. As part of this project, historic shorelines for Fairhaven have been delineated and evaluated using shore-perpendicular transects at 50-meter intervals to demonstrate trends from the mid-1800s to 2009. This data allows for the computation of long-term (approximately 150-year) and short-term (approximately 30-year) rates of shoreline change, including both erosion and accretion. In a broad sense, this information provides useful insight into the historical migration of shorelines and the identification of erosional hot spots.

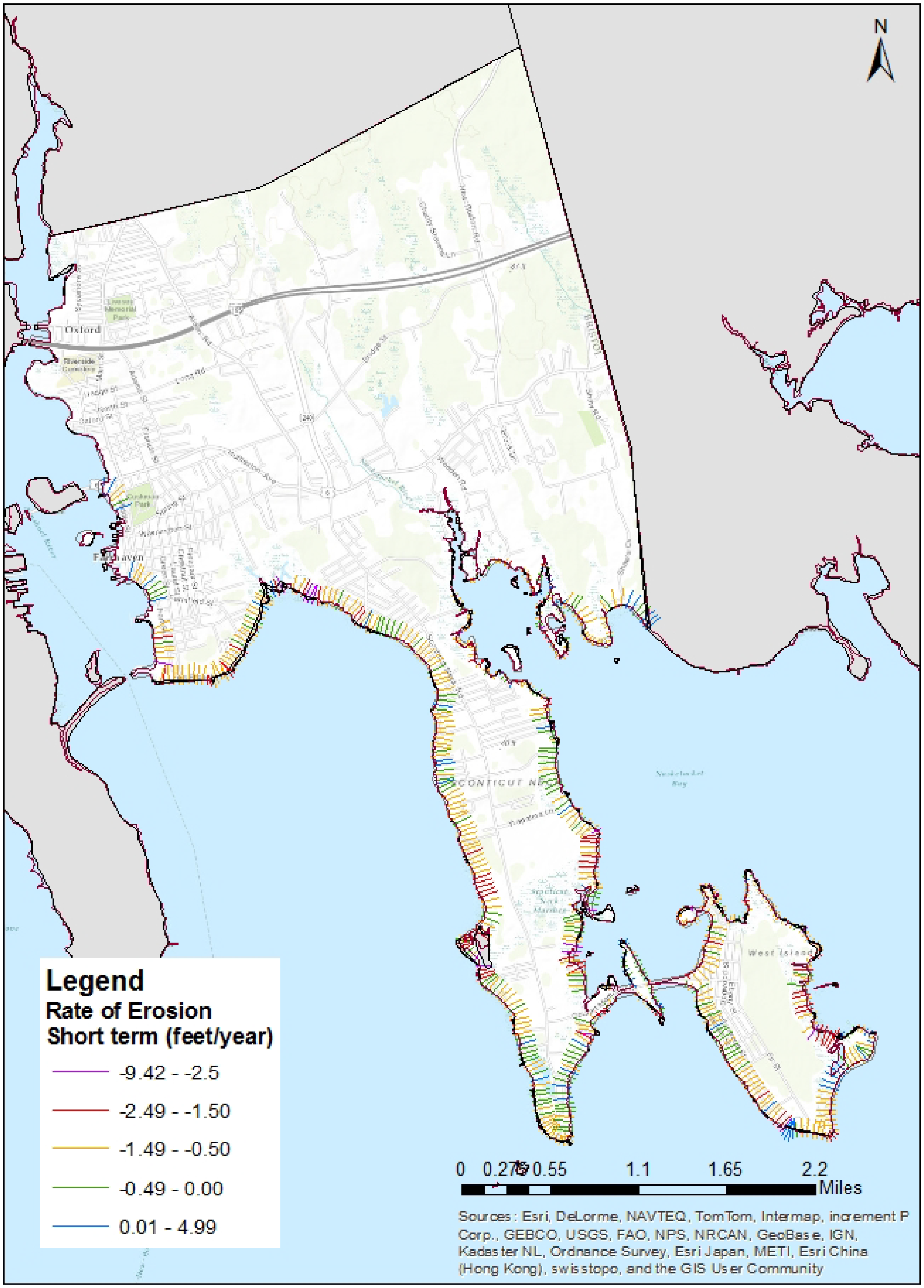
Figure A-1 illustrates the long-term shoreline change data from each shore-perpendicular transect in Fairhaven. It represents the long-term rate of change, from 1845 to 2009, where negative values indicate erosion and positive values indicate accretion. The rates of short-term shoreline change between (1975 and 2009) are shown in **Figure A-2**. From this data, it is evident that most of Fairhaven's coastline is experiencing some level of coastal erosion. Additionally, there are specific sections of Town, such as the barrier beach near Winsegansett Heights and other undeveloped shoreline segments of Sconticut Neck and West Island, where the erosion rates are significantly higher (more than 2.5 feet per year).

Figure A-1: Long-Term Shoreline Change (1845-2009)



Source: Massachusetts Office of Coastal Zone Management

Figure A-2: Short-Term Shoreline Change (1975-2009)



Source: Massachusetts Office of Coastal Zone Management

Sea Level Rise

Figure A-3 shows potential sea level rise inundation areas for Fairhaven based on NOAA's Digital Coast Sea Level Rise Viewer. The figure shows inland extent and relative depth of inundation from 0 to 6 feet above mean higher high water (MHHW). **Figure A-4** shows the potential expansion of existing flood hazard areas according to various sea level rise scenarios (1, 2, and 4 feet) based on a recent study completed by CZM and the Buzzards Bay National Estuary Program (BBNEP).[3]

A.3.1.3 Severity/Extent

There is no universal scientific scale or index used to classify the magnitude or severity of coastal erosion or sea level rise. Rather, the extent of each are quantitatively described according to their localized rate of change (historically observed and/or projected for the future), with rates often expressed as a unit of measure per year and/or over a specific timeframe. Coastal erosion is measured as the rate of change in the position or horizontal displacement of a shoreline, and quantified in units of feet (or meters) per year. Similarly, sea level rise is measured by the relative change in sea level observed or projected over a specific period, but is most typically expressed over longer time horizons (e.g., 25 to 100 years).

For mitigation planning purposes, the maximum probable extent of long-term coastal erosion in Fairhaven is approximately 2.5 feet per year, and the extent of sea level rise may be as high as nearly 5 feet by the year 2100 (under the high emissions scenario).

A.3.1.4 Previous Occurrences

Coastal erosion has been occurring along much of the Fairhaven coastline since at least the 1800s. Much of this erosion has been episodic and caused by coastal storms, flooding and wave impacts rather than continuous erosion (see previous occurrences under Coastal Storms for more information). According to the December 2015 Report of the Massachusetts Coastal Erosion Commission, Fairhaven has experienced a long-term (approximately 150-year) average shoreline change rate of -0.4 feet per year, and a short-term (approximately 30-year) average shoreline change rate of -0.8 feet per year. **Table A-3** shows the long-term and short-term erosion or accretion trends for seven shoreline types in Fairhaven.

Table A-3: Shoreline Change Rate by Shoreline Type

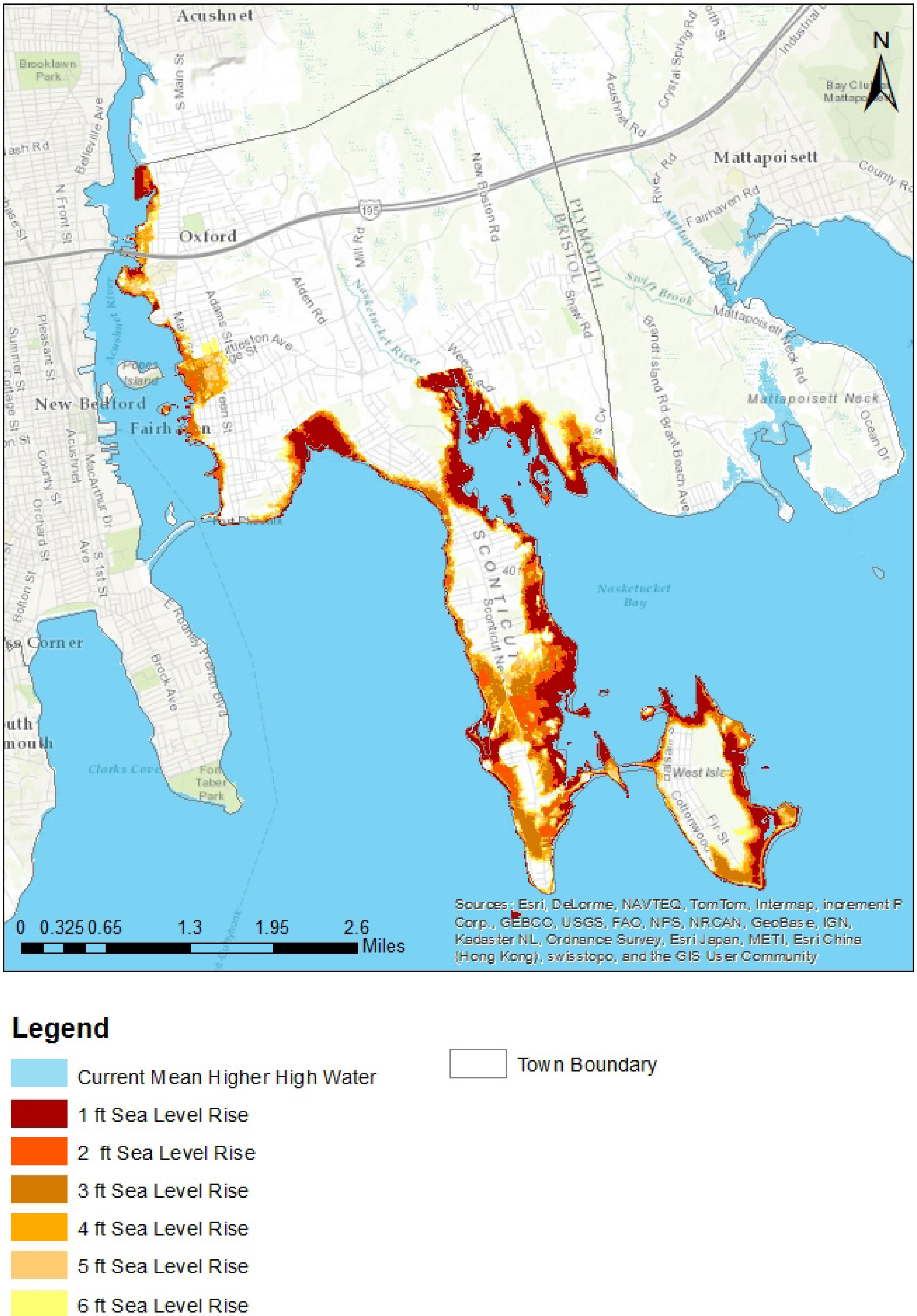
Shoreline Type	Long-Term Rate (feet/year)	Short-Term Rate (feet/year)
Beach	-0.33	-0.72
Beach w/ Dune	-0.57	-0.75
Beach w/ Bank	-0.32	-1.02
Beach w/ Structure	-0.18	-0.45
Bank	-0.33	-0.90
Salt Marsh	-0.39	-0.96
Structure	-0.11	-0.34

[3] For more information, see website for Buzzards Bay NEP / MCZM Study of Flood Zone Expansion with Sea Level Rise at: http://climate.buzzardsbay.org/flood-zone-expansion.html

Shoreline Type	Long-Term Rate (feet/year)	Short-Term Rate (feet/year)

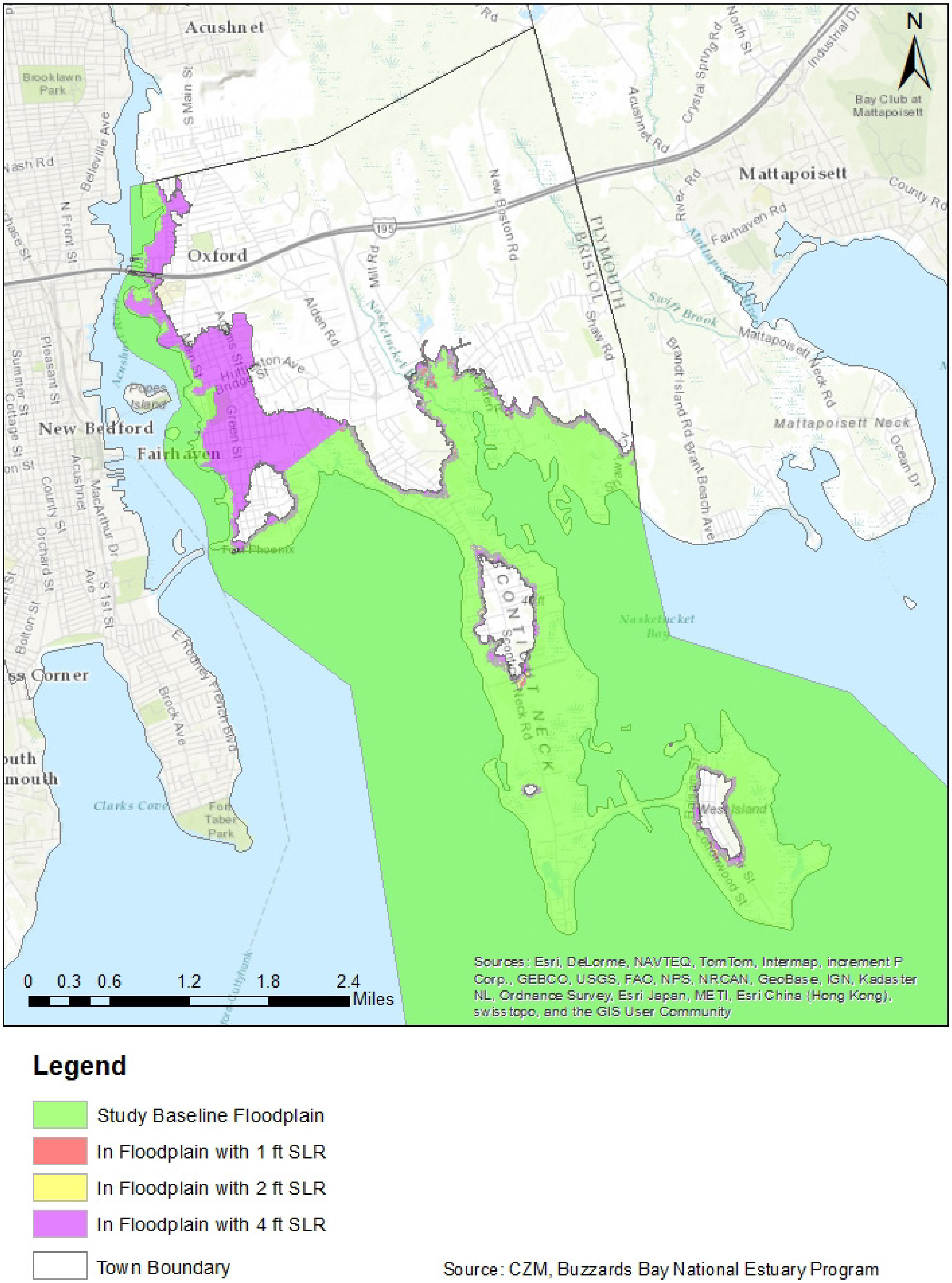
Source: Massachusetts Coastal Erosion Commission, 2015

Figure A-3: Potential Sea Level Rise Inundation



Source: NOAA

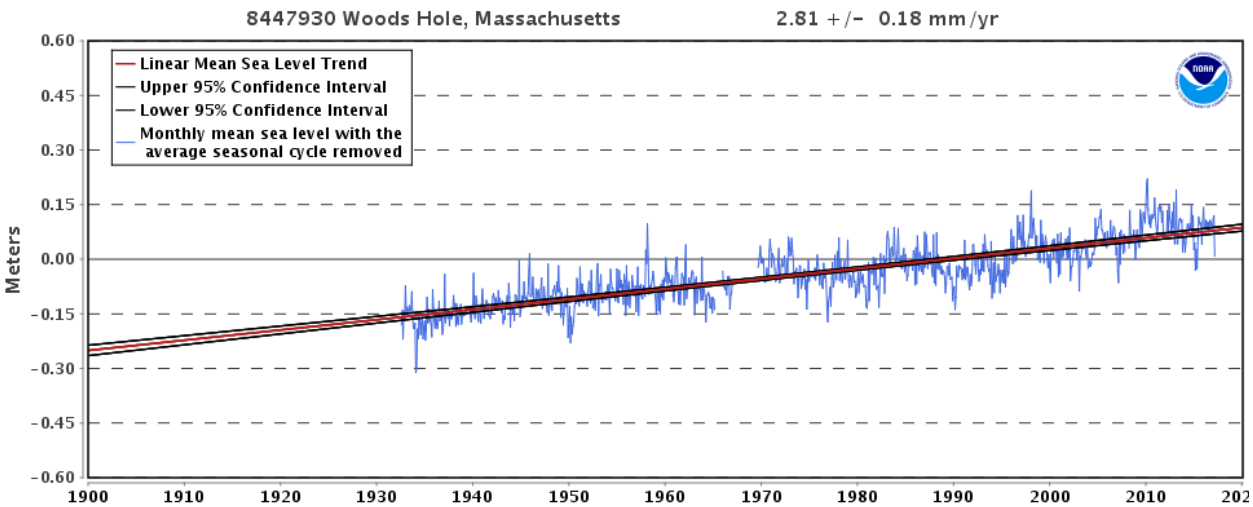
Figure A-4: Potential Expansion of Flood Hazard Areas Due to Sea Level Rise



Source: CZM, Buzzards Bay National Estuary Program

Data from the Woods Hole tide gauge show a relative rate of sea level rise of 2.81 millimeters per year based on monthly data from 1932 to 2015. This is equivalent to a change of 0.92 feet in 100 years. **Figure A-5** illustrates this long-term trend without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents.

Figure A-5: Mean Sea Level Trend (Woods Hole, MA)



A.3.1.5 Probability of Future Occurrences

The probability of future coastal erosion in Fairhaven is ***highly likely***[4] for most shoreline areas based primarily on historical data and the projected continuation of observed trends for shoreline change. This includes both the continuous, slow onset, long-term effects of natural coastal processes as well as rapid, episodic erosion caused by large coastal storms. It is anticipated that the effects of climate change, including sea level rise, will result in an increase in the extent of coastal erosion.

The probability of future sea level rise in Fairhaven is also ***highly likely*** based on current projections as included in the Massachusetts Climate Change Projections Report as provided by EEA. **Figure A-6** includes these projections for the Buzzards Bay tide gauge. Projections are given for medium and high emissions scenarios, at multiple levels of likelihood, in feet relative to mean sea level in 2000. For planning purposes, the Town of Fairhaven will use the median value for the high emissions scenario, including a rise of 0.7 feet by 2030, 1.2 feet by 2050, 1.9 feet by 2070, and 3.1 feet by 2100.

Similar to coastal erosion, sea level rise is a slow onset hazard, the severity and impacts of which may only be realized over many years. Of greater concern is the influence sea level rise will have on the severity of episodic hazard events such as storm surge, wave action and coastal flooding, as well as long-term coastal erosion. It can be expected that sea level rise will be an amplifier of the magnitude for these other coastal hazards.

[4] For definitions and the criteria used to classify hazard probability, please see the *Priority Risk Index* on page A-81.

Figure A-6: Sea Level Rise Projections at the Buzzards Bay Tide Gauge

BUZZARDS BAY		Median (50th percentile) 50% probability SLR exceeds	Likely Range (17th-83rd percentiles) 66% probability that SLR is between…	99.9th Percentile Value Exceptionally unlikely that SLR will exceed
Emissions Scenarios: Medium (RCP 4.5); High (RCP 8.5)		Feet (relative to Mean Sea Level in 2000)		
2030	Med	0.6	0.5-0.8	1.2
	High	0.7	0.4-0.9	1.4
2050	Med	1.1	0.8-1.4	2.5
	High	1.2	0.9-1.6	2.7
2070	Med	1.6	1.1-2.2	4.6
	High	1.9	1.3-2.5	5.1
2100	Med	2.3	1.5-3.2	8.3
	High	3.1	2.0-4.1	9.8

Source: Massachusetts Climate Change Projections Report, as provided by EEA in December 2017

A.3.2. COASTAL STORM

A.3.2.1 General Description

Coastal storms include hurricanes and tropical storms, in addition to nor'easters and similar low pressure storm systems with cyclonic flows.

Hurricanes and tropical storms are classified as cyclones and defined as any closed circulation of winds developing around a low-pressure center in which the winds rotate counter-clockwise (in the Northern Hemisphere) and with a diameter averaging 10 to 30 miles across. 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. When sustained winds reach or exceed 74 miles per hour the storm is deemed a hurricane. The primary damaging forces associated with these storms are high-level sustained winds, heavy precipitation, and tornadoes. Coastal areas are also vulnerable to the additional forces of storm surge, wind-driven waves, and tidal flooding which can be more destructive than wind (and are covered separately in this section under Flood). Most hurricanes and tropical storms form in the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico during the official Atlantic hurricane season, which extends from June through November.

Nor'easters are low pressure, severe storm systems that affect the Mid-Atlantic and New England states primarily during winter months. They can form over land or water and are notorious for producing heavy snow, rain, and tremendous waves that crash onto Atlantic beaches, often causing beach erosion and structural damage. Wind gusts associated with these storms can exceed hurricane force in intensity, and when combined with snow result in blizzard conditions that form deep drifts capable of paralyzing a region. Like hurricanes, nor'easters are capable of causing substantial damage to coastal areas due to their associated strong winds and heavy surf. A nor'easter gets its name from the continuously strong northeasterly winds blowing in from the ocean ahead of the storm.

A.3.2.2 Location

The entire planning area is susceptible to the occurrence of coastal storms including hurricanes, tropical storms and nor'easters. While the entire planning area is uniformly susceptible to wind effects, the immediate coastal areas are more susceptible to the destructive forces of storm surge and tidal flooding (see Figure A-12 under Flood).

A.3.2.3 Severity/Extent

The National Weather Service's Saffir-Simpson Hurricane Wind Scale, shown in **Table A-4**, is used to categorize the strength and magnitude of hurricane events according to sustained wind speed, and provides estimates of potential property damage. New England is also prone to tropical storms and tropical depressions which have wind speeds less than a Category 1 Hurricane (39-73 mph for tropical storms, and 38 mph or less for tropical depressions), but may still cause damage across large areas.

Table A-4: Saffir-Simpson Hurricane Wind Scale

Category	Sustained Winds	Types of Damage Due to Hurricane Winds
1	74-95 mph	**Very dangerous winds will produce some damage:** Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96-110 mph	**Extremely dangerous winds will cause extensive damage:** Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3 (major)	111-129 mph	**Devastating damage will occur:** Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4 (major)	130-156 mph	**Catastrophic damage will occur:** Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Category	Sustained Winds	Types of Damage Due to Hurricane Winds
5 (major)	157 mph or higher	**Catastrophic damage will occur:** A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Source: NOAA

There is no widely used scale to classify nor'easters. However, the classification scheme developed by Gregory A. Zielinski and presented in **Table A-5** is a useful index to categorize nor'easters (and other severe winter storms) by intensity. It consists of a five-level hierarchy similar to the Saffir-Simpson Hurricane Wind Scale, with a category 1 storm being the least severe in terms of its intensity and a category 5 storm being the most severe.

Table A-5: Classification Scheme for Nor'easters

Intensity Index Category	Maximum Snowfall Amounts	Maximum Snowfall Rate	Potential Wind Speeds	Maximum Drifting Potential	Closings/Delays on Communities, Schools, and Travel	Impact on Coastal and Maritime Interests	Nature of Disruption
1	< 10 in.	Very low < 1 in./hr	Weak	Minor < 20 in.	Maybe minor (hours)	Minor	Minimal-nuisance
2	10-20+ in.	Moderate 1+ in./hr	Strong	Moderate 3 ft.	Maybe moderate (hours to a day common)	Minor to moderate	Nuisance-inconvenience
3	20-30+ in.	High 2+ in./hr	Gale force	High 4-6+ ft.	Possibly extensive/ lengthy (several days possible)	Moderate to severe	Inconvenience-crippling
4	30-40+ in.	Very High 2-3 in./hr	Gale force hurricane	Very High 6-10+ ft.	Probably extensive/ lengthy (up to a week may be common)	Severe	Crippling-paralyzing
5	40-50+ in.	Overwhelming > 3+ in.hr	Gale force hurricane	Exceptional 10-15 ft.	Extensive/ lengthy (up to a week common)	Extreme	Paralyzing

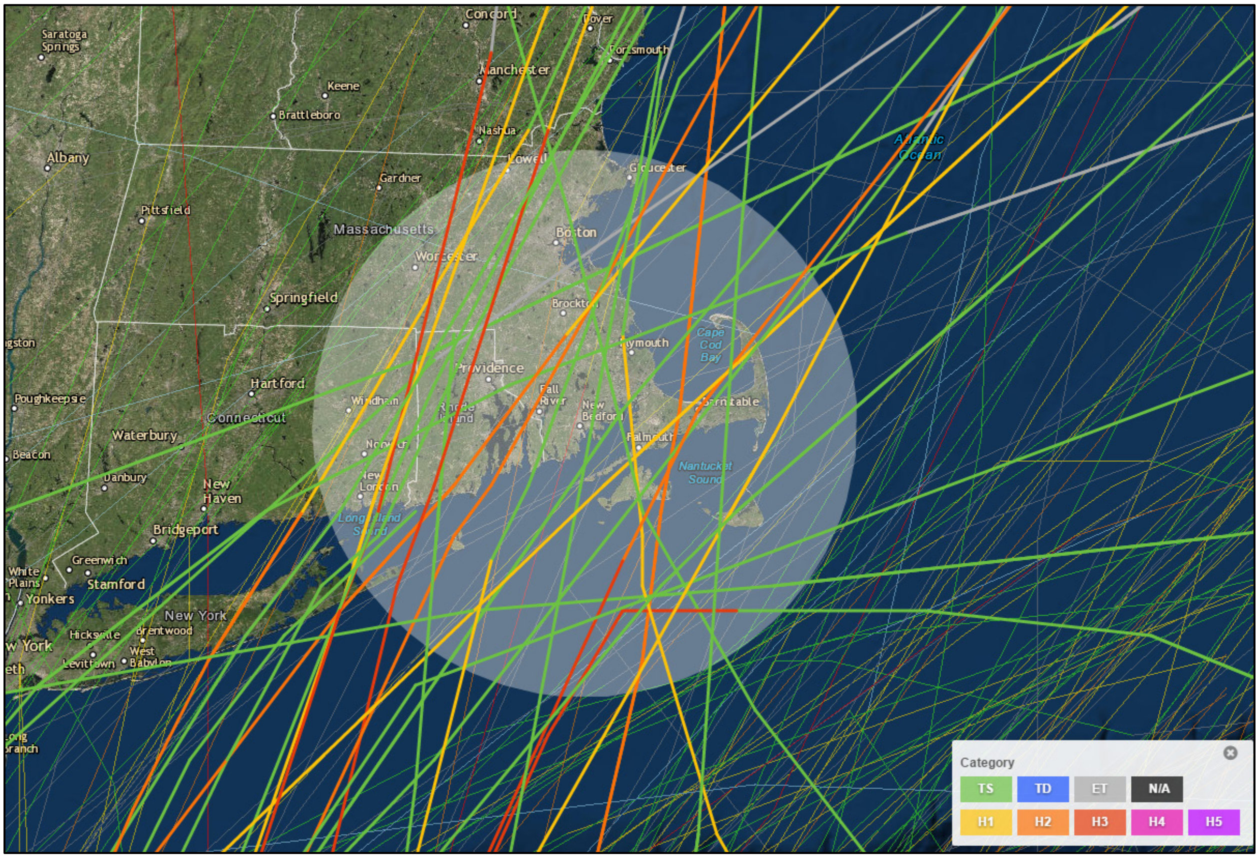
Source: Gregory A. Zielinski, Institute for Quaternary and Climate Studies, University of Maine

For mitigation planning purposes, the maximum probable extent of coastal storms in Fairhaven is a Category 3 hurricane on the Saffir-Simpson Hurricane Wind Scale; or an Intensity Index Category 4 on Classification Scheme for Nor'easters.

A.3.2.4 Previous Occurrences

According to NOAA historical records, 28 hurricane/tropical storm tracks have come within 75 miles of the planning area since 1858. This includes 15 tropical storms, six (6) Category 1 hurricanes, three (3) Category 2 hurricanes, and four (4) Category 3 hurricanes. **Figure A-7** shows the historical tracks of these storms, some of which are further described below. The figure does not include the tracks of an additional extra-tropical systems, tropical depressions or nor'easters that also came within 75 miles of the planning area.

Figure A-7: Historical Storm Tracks Since 1958



Source: NOAA

Event descriptions for some of the historic and major coastal storm events impacting the region are provided below. These summaries are based heavily on information available in the NOAA Storm Event Database, FEMA Flood Insurance Study for Bristol County, and the Massachusetts State Hazard Mitigation Plan. Local impacts to Fairhaven are included where available.

- October 29-30, 2012 – Hurricane Sandy, with a wind diameter stretching more than 1,000 miles, became the largest Atlantic hurricane on record and is estimated to be the second costliest in history, only surpassed by Hurricane Katrina in 2005. The storm made landfall as a "post-tropical cyclone" in Atlantic City, New Jersey with sustained winds of 90 miles per hour and a devastating storm surge for communities in the northeast area. Though damage along the South Coast was limited, its effects were directly felt, with damaging winds and storm surge that caused extensive flooding and erosion along the immediate shoreline (covered under Flood). In Fairhaven, an amateur radio operator recorded sustained winds to 35 mph and a wind gust to 62 mph, and a tree was reportedly downed onto a car on Adams Street. This event resulted in a major disaster declaration for Bristol County.
- August 28, 2011 – Hurricane Irene made landfall as a Category 1 hurricane in New Jersey, weakened to a tropical storm, and then traversed Connecticut and Massachusetts while producing significant amounts of rain, storm surge, inland and coastal flooding, and wind damage across southern New England. Despite relatively low wind speeds, sustained winds

over a 6 to 12-hour long duration resulted in widespread tree damage and resulted in power outages to roughly half a million customers throughout Massachusetts. Numerous roads were flooded throughout Bristol County, and maximum storm tides of 5 to 7 feet were recorded. During the passage of Irene, the winds resulted in $34.7M in property damages, storm surge resulted in $75,000 in property damages, and inland flooding resulted in $24.13M in property damages, all in Massachusetts. In Fairhaven, numerous trees and branches were downed and an amateur radio operator recorded sustained winds of 50 mph and a gust of 63 mph. A storm surge of 3.84 feet impacted coastal areas and Sconticut Neck Road was flooded. This event resulted in a major disaster declaration for Bristol County.

- September 6, 2008 – Tropical Storm Hanna resulted in wind damage in Bristol County. Several trees and wires were blown down in southern Bristol County, but the storm resulted in no loss of life or injuries and only a reported $3K in property damage to the area, all wind related. No coastal flooding was reported.
- October 2005 – A strong Nor'easter, combined with the remnants of Tropical Storm Wilma, brought heavy rainfall, damaging winds, and coastal flooding to the eastern portion of Massachusetts. Rainfall totals ranged between two and 2.5 inches. The high winds brought down limbs, trees, and wires, resulting in power outages to thousands of people. This event caused approximately $733,000 in property damage and resulted in a FEMA disaster declaration for Bristol County.
- December 11, 1992 – A strong nor'easter brought intense snowfall, freezing rain, heavy rainfall near the coast, coastal flooding, and damaging winds. Strong winds combined with wet, heavy snow and ice caused considerable tree damage and widespread power outages. Much of southern New England received up to 5 inches of liquid equivalent precipitation during a 2 to 3-day period, with locally close to 8 inches recorded in parts of southeast Massachusetts. Along coastal sections and in some interior valleys, much of the precipitation fell as rain or rain mixed with snow. This caused considerable ponding and localized flooding in poorly drained areas. The greatest damage from this storm was due to coastal flooding.
- October 1991 – An unnamed coastal storm joined up with the remains of Hurricane Grace and strengthened to become labeled as the "Perfect Storm" by the National Weather Service. Winds measured over 80 mph and waves were over 30 feet in some parts of the Massachusetts coastline, causing flooding and wind damage to several counties, including Bristol County.
- August 1991 – Hurricane Bob was the second named storm and the first hurricane of the 1991 hurricane season, reaching a Category 3 status. In Massachusetts, this storm struck the southern coast, causing $900 million in property damage from Westport east to New Bedford, Buzzards Bay, Cape Cod, and the Islands. Damage to crops was approximately $10 million, including 20 to 50% of the apple crop. Corn and vegetable crops were also seriously damaged or destroyed. The eye of the storm tracked north-northeast between Fall River and Providence through Bristol and Plymouth Counties, traveling at a speed of 40 mph. Over 500 boats broke away from their moorings, sank, or were driven ashore. Many boats were either heavily damaged or destroyed. The tidal surge reached 5.8 feet in New Bedford, inundating barrier beaches from Westport to Marion and flooding beaches around Buzzards Bay. Winds exceeded 80 mph, with gusts of up to 143 mph, and rainfall totals ranged between two and seven inches in the Commonwealth. In Fairhaven, the newly constructed $35,000 walkway on the causeway

to West Island was destroyed. This event resulted in a major disaster declaration for Bristol County.

- September 27, 1985 – Hurricane Gloria caused extensive damage along the east coast of the U.S. This event was responsible for eight fatalities and approximately $1.94 billion in damage. Wind gusts were sustained at 145 mph, causing Gloria to reach a Category 4 status. When it reached Massachusetts, it was considered a Category 1 storm, with wind speeds of up to 74 mph. The storm arrived in Massachusetts at low tide and resulted in storm surges less than 5 feet above normal (3.42 feet at Woods Hole), minimizing damage to the coastline. However, Gloria's winds did cause extensive wind damage in isolated areas along the shore and well inland, resulting in some long-term power outages. This event resulted in a major disaster declaration for Bristol County.
- February 1978 – The "Blizzard of 1978" remains as the benchmark storm for comparison by all subsequent nor'easters. This life-threatening nor'easter crippled most of the Commonwealth with blizzard conditions, extraordinarily heavy snow, high winds, and devastating coastal flooding. The storm claimed 73 lives in Massachusetts and over 10,000 people had to be sheltered. An unprecedented ban on non-emergency vehicle traffic lasted for a week in much of eastern Massachusetts. Snowfall generally ranged from 1 to 3 feet with a large swath of 30+ inch amounts in the southwest suburbs of Boston, and up to 26 inches was reported for Fairhaven. Major coastal flooding occurred over multiple high tide cycles and destroyed or severely damaged over 2,000 homes across the state. This event resulted in a major disaster declaration for Bristol County.
- August 19, 1955 – Hurricane Diane, a Category 3 hurricane event, was one of the costliest hurricanes in U.S. history, with estimated total damage exceeding $831 million. The storm brought strong winds (sustained winds of 120 mph) and approximately 16 inches of rain in many areas, which lead to extensive flooding in much of the New England region. Throughout the impacted areas, the hurricane caused between 184 and 200 deaths. This event resulted in a major disaster declaration for Bristol County.
- September 11, 1954 – Hurricane Edna, a Category 3 hurricane, made landfall near Martha's Vineyard and Nantucket before crossing the eastern tip of Cape Cod. Hurricane force winds of 75 to 95 mph buffeted all of eastern Massachusetts and coastal Rhode Island. Peak winds included 120 mph on Martha's Vineyard, 110 mph on Block Island, and 100 mph at Hyannis, Massachusetts. The strong winds knocked out electrical power across sections of Rhode Island, eastern Massachusetts, and nearly all of Cape Cod and the islands. Edna arrived during a rising tide and resulted in severe flooding across Martha's Vineyard, Nantucket, and Cape Cod, where storm surges of over 6 feet were common. Farther west, storm surge values were 4 feet or less, resulting in storm tides that remained below flood stage. Damage to the boating community was severe across Cape Cod, but was much less across the remainder of Massachusetts and Rhode Island. Rainfall amounts of 3 to 6 inches were common, with over seven inches across northeastern Massachusetts. The rainfall aggravated the already saturated conditions caused by Hurricane Carol ten days earlier. The total combined rainfall for Carol and Edna ranged from 5 to 7 inches along and west of the Connecticut River and over Cape Cod, to as much as 11 inches from southeast Connecticut, across most of Rhode Island, to northeast Massachusetts. Edna was responsible for 21 deaths across the region. This event resulted in a major disaster declaration for Bristol County.

- August 31, 1954 – Hurricane Carol, a Category 3 hurricane with wind gusts of Category 4 strength, made landfall just west of Fairhaven near Old Saybrook, Connecticut. It was the most destructive hurricane to strike Southern New England since the Great New England Hurricane of 1938. During this event, 65 individuals were killed; nearly 4,000 homes, 3.500 automobiles, and over 3,000 boats were destroyed; and scores of trees and miles of power lines were blown down leaving all of Rhode Island, much of eastern Connecticut, and eastern Massachusetts without electrical power. Hurricane Carol made landfall shortly after high-tide, causing widespread tidal flooding. Narragansett Bay and New Bedford Harbor received the largest surge value of over 14 feet in the upper reaches of both waterways. Winds of 110 mph were reported for the Fairhaven area but the heaviest amounts of rainfall, up to 6 inches, occurred in Connecticut and across extreme north central Massachusetts. This event resulted in a major disaster declaration for Bristol County.

Margaret's Restaurant building at the corner of Main and Ferry Streets in Fairhaven following Hurricane Carol in 1954. *Courtesy of M.L. Baron / West Island Weather Station.*

- September 21, 1938 – The most intense hurricane to strike Massachusetts occurred in 1938. Known widely as the "Great New England Hurricane of 1938" or "Long Island Express," it made landfall as a strong Category 3 hurricane on Long Island, New York and moved rapidly through New England. Initially, the hurricane was forecast to curve out into the Atlantic Ocean, and because official forecasts expected mere overcast conditions, residents were unaware of the impending storm. Approximately 600 people died in the storm in New England, most in Rhode Island, and up to 100 people elsewhere in the path of the storm. An additional 708 people were reported injured. The hurricane also devastated the forests of the Northeast, knocking down an estimated 2 billion trees in New York and New England. The hurricane produced wind gusts as high as 130 mph, up to 17 inches of rainfall, and a coastal storm surge of 18 to 25 feet from New London, Connecticut to Cape Cod in Massachusetts. Local areas along the South Coast were submerged under 8 feet of water and two-thirds of all the boats in New Bedford harbor sank. Damage is estimated at $6 billion (2004 USD), making it among the costliest hurricanes to strike the U.S. mainland. To date it remains the most powerful, costliest, and deadliest hurricane in New England history, and it is estimated that if an identical hurricane struck today it would cause $39.2 billion (2005 USD) in damage.

A.3.2.5 Probability of Future Occurrences

Hurricanes and tropical storms will continue to be a ***likely*** occurrence in the planning area. Based on historical event data, the annual probability of a hurricane or tropical storm coming within 75 miles of the planning area is 18 percent, though the chance of a major hurricane (Category 3-5) at landfall is much less. According to the *Massachusetts State Hazard Mitigation Plan*, the annual probability of a major hurricane approaching the southern portion of the Commonwealth is 1-2 percent.

Although there is insufficient scientific evidence to firmly determine the effects of climate change on future storms, large events are becoming more frequent and research indicates the warming climate may double the frequency of Category 4 and 5 hurricanes by the end of the century, and decrease the frequency of less severe hurricane events.[5]

A.3.3. DROUGHT

A.3.3.1 General Description

Drought is defined as a period of abnormally dry weather sufficiently prolonged for the lack of water to cause serious hydrologic imbalance in the affected area. Drought is a natural climatic condition caused by an extended period of limited rainfall beyond that which occurs naturally in a broad geographic area. High temperatures, high winds and low humidity can worsen drought conditions, and can make areas more susceptible to wildfire. Human demands and actions can also hasten drought-related impacts.

Droughts are frequently classified as one of following four types: meteorological, agricultural, hydrological or socio-economic. Meteorological droughts are typically defined by the level of "dryness" when compared to an average, or normal amount of precipitation over a given period. Agricultural droughts relate common characteristics of drought to their specific agricultural-related impacts. Hydrological drought is directly related to the effect of precipitation shortfalls on surface and groundwater supplies. Human factors, particularly changes in land use, can alter the hydrologic characteristics of a basin. Socio-economic drought is the result of water shortages that limit the ability to supply water-dependent products in the marketplace.

A.3.3.2 Location

The entire planning area is susceptible to the occurrence of droughts, though the areas of greatest concern to Fairhaven in terms of potential local impacts are the agricultural lands located mostly in the northeast portion of town.

Based on past events and current criteria outlined in the 2013 *Massachusetts Drought Management Plan*, it appears that western Massachusetts may be more vulnerable than eastern Massachusetts to severe drought conditions. However, many factors such as water supply sources, population, economic factors, and infrastructure, may affect the susceptibility, severity, and length of a drought event.

A.3.3.3 Severity/Extent

As dry conditions can have a range of different impacts, numerous indices are available to determine the severity and extent of drought conditions. The Commonwealth of Massachusetts uses seven indices to determine the severity of a drought or extended period of dry conditions, including the following: Standardized Precipitation Index, Crop Moisture Index, Keetch-Byram Drought Index, Precipitation Index, Groundwater Level Index, Stream Flow Index, and Reservoir Index. Detailed descriptions for each index is available in the Massachusetts Drought Management Plan (pp. 7-10).[6]

Drought levels in Massachusetts are determined monthly based on the number of indices which have reached a given threshold (drought level) as shown in **Table A-6**. Most of the indices would need to be triggered in a region in order for a drought designation for the region to move to a more severe level. Drought warnings, watches, and advisories can be reduced based normal levels of precipitation

[5] Massachusetts Executive Office of Energy and Environmental Affairs. *Massachusetts Climate Adaptation Report*. 2011.
[6] http://www.mass.gov/eea/docs/eea/wrc/droughtplan.pdf

returning or groundwater levels returning to the "normal" range. A drought emergency will end when the conditions that led to the specific emergency have abated.

Table A-6: Drought Indices

Drought Level	Standardized Precipitation Index	Crop Moisture Index*	Keetch-Byram Drought Index*	Precipitation	Groundwater	Streamflow	Reservoir***
Normal	3-month > -1.5 **or** 6-month > -1.0 **or** 12-month > -1.0	0.0 to -1.0 slightly dry	< 200	1 month below normal	2 consecutive months below normal**	1 month below normal**	Reservoir levels at or near normal for the time of year
Advisory	3-month = -1.5 to -2.0 **or** 6-month = -1.0 to -1.5 **or** 12-month = -1.0 to –1.5	-1.0 to -1.9 abnormally dry	200-400	2 month cumulative below 65% of normal	3 consecutive months below normal**	At least 2 out of 3 consecutive months below normal**	Small index Reservoirs below normal
Watch	3-month < -2.0 **or** 6-month = -1.5 to -3.0 **or** 12-month = -1.5 to -2.0	-2.0 to –2.9 excessively dry	400-600	1 of the following criteria met: 3 month cum. < 65% **or** 6 month cum. < 70% **or** 12 month cum. < 70%	4-5 consecutive months below normal**	At least 4 out of 5 consecutive months below normal**	Medium index Reservoirs below normal
Warning	6-month < -3.0 **or** 12-month = -2.0 to -2.5	< -2.9 severely dry	600-800	1 of the following criteria met: 3 month cum. < 65% and 6 month cum. <65%, **or** 6 month cum. <65% and 12 month cum. <65%, **or** 3 month cum. <65% and 12 month cum. <65%	6-7 consecutive months below normal**	At least 6 out of 7 consecutive months below normal**	Large index reservoirs below normal
Emergency	12-month < -2.5	<-2.9 severely dry	600-800	Same criteria as Warning and previous month was Warning or Emergency	>8 months below normal**	>7 months below normal**	Continuation of previous month's conditions

* The Crop Moisture Index is subject to frequent change. The drought level for this indicator is determined based on the repeated or extended occurrence at a given level.
****** Below normal for groundwater and streamflow are defined as being within the lowest 25th percentile of the period of record.
******* Water suppliers should be consulted to determine if below normal reservoir conditions are due to operational issues.

Source: Massachusetts Drought Management Plan, 2013

For mitigation planning purposes, the maximum probable extent of a drought in Fairhaven is a Drought Emergency as described in Table A-6.

A.3.3.4 Previous Occurrences

Average annual precipitation in Fairhaven is nearly 45 inches per year, with approximately 3 to 4 inch average amounts for each month of the year. According to the Massachusetts Executive Office of

Energy and Environmental Affairs (EEA) Precipitation Database, Fairhaven has experienced below average annual precipitation in 35 different years since 1931.[7] However, drought warning or emergency conditions would have been reached infrequently, with an estimated three severe events occurring between the years 1931 and 2001 (including 1943, 1957, and 1965). The 1965-1966 drought period is viewed as the most severe drought to have occurred in modern times in Massachusetts given the period of record for precipitation data because of its long duration. This was part of the most severe drought on record in the northeastern US which lasted a total of 8 years (1961-1969).

More reliable information on official drought level determinations started to become available in the year 2001, when the Massachusetts Drought Management Plan was first developed and when data for all drought indices became more available. EEA compiles information about past drought conditions at a regional level, with Fairhaven located in the Southeast region. **Table A-7** lists the more recent drought history for the Southeast region as compiled using all seven indices described above (under Severity/Extent). As can be seen in the table, a drought warning was declared for the period between August 2016 and January 2017.

Table A-7: Recent Drought History (MA Southeast Drought Region)

Year	Month	Drought Level
2001	December	Advisory
2002	February	Advisory
	March	Watch
	April	Watch
	May	Watch
	June	Advisory
	July	Advisory
	August	Watch
	September	Watch
	October	Advisory
2007	October	Advisory
2014	October	Advisory
2016	June	Advisory
	July	Watch
	August	Warning
	September	Warning
	October	Warning
	November	Warning

[7] Based on data for the precipitation observation station in New Bedford.

Year	Month	Drought Level
	December	Warning
2017	January	Warning
	February	Watch
	March	Advisory

Source: Massachusetts EEA

According to NOAA records, there have been no reported physical or economic losses (including crop losses) reported in Fairhaven because of historic drought conditions. The Fairhaven Water Department has imposed municipal water use restrictions in response to previous events (most recently in September 2016), though these have had minimal to no impact in terms of reportable losses. Water use restrictions generally limit or prohibit non-essential outdoor watering and may implement other conservation measures deemed appropriate to ensure an adequate supply of water to all water consumers.

Fairhaven's agricultural industry is most at risk in terms of economic impact and damage due to extremely dry conditions and drought events which can directly impact livestock and crop production, however no previously recorded instances of such losses are known.

A.3.3.5 Probability of Future Occurrences

Based on the data summarized above on previous occurrences, drought will continue to be considered a ***possible*** occurrence in the planning area (between 1-10 percent probability in the next year, or at least one occurrence in the next 10 years). This probability determination is also consistent with statewide data on drought occurrences. Review of EEA data demonstrates that on a monthly basis, the Commonwealth of Massachusetts has been in a Drought Watch to Emergency condition 11 percent of the time between 1850 and 2012. Further, on a monthly basis, there is a 1 percent chance of being in a Drought Emergency, and a 2 percent chance of being in a drought Warning.

It is anticipated that the effects of climate change will result in an increase in the frequency, duration and intensity of short-term droughts. According to the *Massachusetts Climate Change Adaptation Report*, by the end of the century and under the high emissions scenario, the occurrence of droughts lasting one to three months could go up by as much as 75 percent over existing conditions. Also, per the downscaled climate projections for the Buzzards Bay basin as made available by EEA, both fall and summer seasons are expected to continue to experience the highest number of consecutive dry days. The summer season is expected to experience an increase of 0-4 days in consecutive dry days by the end of the century.

A.3.4. EARTHQUAKE

A.3.4.1 General Description

An earthquake is the sudden motion or trembling of ground caused by an abrupt release of accumulated strain on tectonic plates that comprise the Earth's crust. While these thick plates move slowly and continuously over the interior of the earth, they collide, slide, catch, and hold – but eventually, when the mounting stress exceeds the elastic limit of the rock, faults along or near plate boundaries rupture or slip abruptly and an earthquake occurs. The ensuing seismic hazard effects on the Earth's surface include ground shaking, surface fault ruptures, and ground failures, which have the potential to cause widespread damage to buildings and infrastructure. Earthquakes may also provoke secondary hazards such as tsunamis, landslides, dam failures, or large fires ignited by ruptured gas lines.

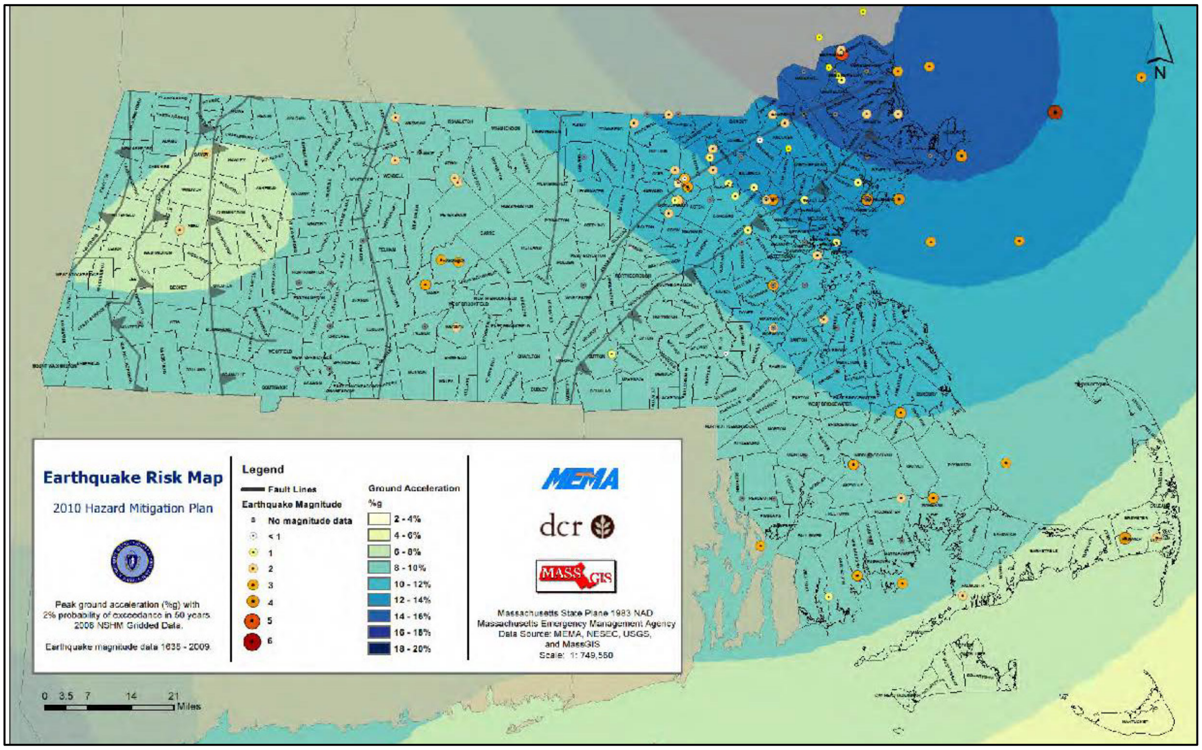
The underground point of initial rupture is known as an earthquake's focus or hypocenter, and the point at ground level directly above the hypocenter is known as its epicenter. In general, the severity of the resulting ground motion increases with the amount of energy released and decreases with distance from the epicenter. Larger earthquakes usually begin with slight tremors but rapidly take the form of one or more violent shocks, and are followed by vibrations of gradually diminishing force called aftershocks. While the great majority of earthquakes strike near continental margins or in areas where large plates collide or move past each other, some, including those in the Northeast United States, can occur within plate boundaries.

A.3.4.2 Location

The entire planning area is uniformly susceptible to the occurrence of earthquakes. Unlike other areas of the country where earthquakes occur along known fault lines, earthquakes in the Northeast do not correlate with the many known faults that exist in the region. They occur in the middle of plates, far from the plate boundaries.

Figure A-8 includes a statewide earthquake risk map for Massachusetts as included in the State Hazard Mitigation Plan, showing major fault lines and the location of epicenters for some historical earthquakes according to the United States Geological Survey (USGS). The figure also shows seismic risk zones according to peak ground acceleration, which is expressed as a percentage of the force of gravity (%g). Peak ground acceleration is the amount of earthquake generated ground shaking that, over a specified period, is predicted to have a specified chance of being exceeded. Figure A-8 shows the peak acceleration with 2 percent probability of exceedance in 50 years, a common standard for USGS earthquake hazard maps. Fairhaven falls within a zone with a peak ground acceleration value of 8-10%g, which is considered a low risk zone in terms of potential ground shaking and damage from such an event.

Figure A-8: Earthquake Risk Map for Massachusetts



A.3.4.3 Severity/Extent

The magnitude of an earthquake is a measure of the amount of energy released as seismic waves at the hypocenter. The Richter Scale classifies earthquake magnitude as determined from measurements recorded by seismographs, and according to a single number on an open-ended logarithmic scale. Each unit increase in magnitude on the Richter Scale corresponds to a ten-fold increase in wave amplitude, or a 32-fold increase in energy.

The intensity of an earthquake is a measure of the strength of ground shaking and its effects on the Earth's surface at a certain location. Intensity is most commonly measured using the Modified Mercalli Intensity Scale, which is based on observed seismic effects versus any mathematical basis. The Scale is composed of 12 increasing levels of intensity (designated by Roman numerals) that range from imperceptible shaking to catastrophic destruction.

Table A-8 summarizes the range of magnitudes and related intensities for earthquakes according to the Richter and Modified Mercalli Intensity (MMI) scales, along with abbreviated descriptions of effects on people, human structures, and the natural environment near the epicenter.

Table A-8: Classification of Earthquake Magnitude and Intensity

Magnitude (Richter Scale)	Typical Maximum Intensity (MMI Scale)	Abbreviated Description of Effects (Near Epicenter)
1.0 to 3.0	I	Not felt except by a very few under especially favorable conditions.

<table>
<tr><th colspan="2">Magnitude (Richter Scale)</th><th>Typical Maximum Intensity (MMI Scale)</th><th>Abbreviated Description of Effects (Near Epicenter)</th></tr>
<tr><td colspan="2" rowspan="2">3.0 to 3.9</td><td>II</td><td>Felt only by a few persons at rest, especially on upper floors of buildings.</td></tr>
<tr><td>III</td><td>Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.</td></tr>
<tr><td colspan="2" rowspan="2">4.0 to 4.9</td><td>IV</td><td>Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably.</td></tr>
<tr><td>V</td><td>Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.</td></tr>
<tr><td rowspan="2">5.0 to 5.9</td><td></td><td>VI</td><td>Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.</td></tr>
<tr><td rowspan="3">6.0 to 6.9</td><td>VII</td><td>Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.</td></tr>
<tr><td rowspan="5">7.0 and higher</td><td>VIII</td><td>Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, and walls. Heavy furniture overturned.</td></tr>
<tr><td>IX</td><td>Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.</td></tr>
<tr><td rowspan="3"></td><td>X</td><td>Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.</td></tr>
<tr><td>XI</td><td>Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.</td></tr>
<tr><td>XII</td><td>Damage total. Lines of sight and level are distorted. Objects thrown into the air.</td></tr>
</table>

Source: USGS

For mitigation planning purposes, the maximum probable extent of an earthquake in Fairhaven is a 6.5 on Richter Scale and Intensity VII on Modified Mercalli Intensity scale.

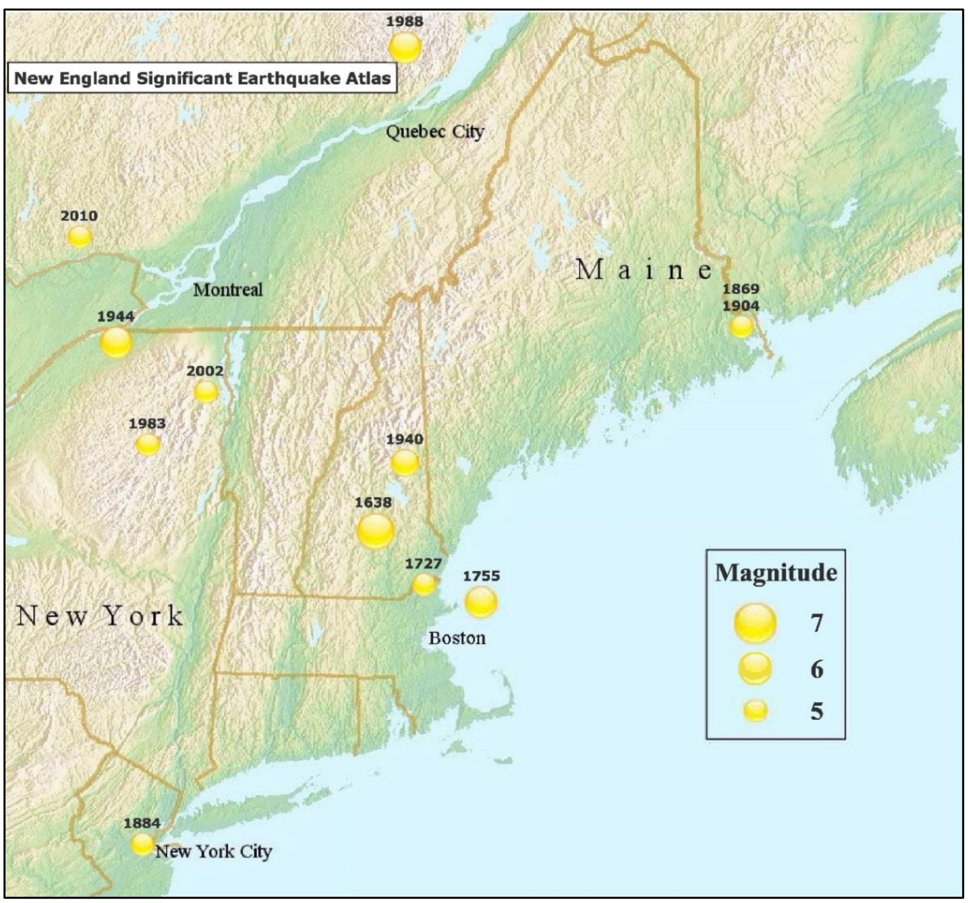
A.3.4.4 Previous Occurrences

Earthquakes occur on a regular basis in the Northeast US. According to the Weston Observatory Northeast Earthquake Catalog, more than 5,000 earthquakes have occurred in the region since 1638, including more than 1,500 earthquakes in New England and more than 350 with epicenters in

Massachusetts. Generally, most earthquakes that occur in the Northeast US are small in magnitude and cause little to no damage, though ground shaking is felt across large areas due to the geologic composition and rock structure of the region. In terms of potential impacts, this makes the specific location of the epicenter in the Northeast less relevant than in other regions of the US.

Between 1924 and 2016, there were 105 earthquakes in the Northeast measuring a magnitude 4.5 or greater on the Richter scale. Out of these 104 earthquakes, 10 were centered within New England and the other 94 occurred within New York State and the Province of Quebec. Historically, moderately damaging earthquakes strike somewhere in the region every few decades, and smaller earthquakes are felt approximately twice per year. The Boston area was damaged three times within 28 years in the middle 1700s, and New York City was damaged in 1737 and 1884. The largest known New England earthquakes occurred in 1638 (magnitude 6.5) in New Hampshire, and in 1755 (magnitude 5.8) offshore from Cape Ann northeast of Boston. The Cape Ann earthquake caused severe damage to the Boston waterfront on infilled lands near the wharves. About 100 chimneys toppled and more than 1,500 were damaged, and the walls of several brick buildings collapsed. The most recent New England earthquake to cause moderate damage occurred in 1940 (magnitude 5.6) in central New Hampshire. Reported damages included toppled chimneys, cracked walls, broken water pipes, fallen plaster, and broken furniture. **Figure A-9** shows the location for some of the most significant historical events per the Weston Observatory's New England Significant Earthquake Atlas.

Figure A-9: Significant New England Earthquakes



Source: Weston Observatory at Boston College

Moderate earthquakes in 1847 (August 8), 1852 (November 27), 1854 (December 10), 1876 (September 21), 1880 (May 12), 1903 (January 21 and April 24), 1907 (October 15), 1925 (January 7 and April 24), 1940 (January 28), and 1963 (October 16 and 30), were felt over limited areas of eastern Massachusetts. The epicenter of the January 7, 1925, earthquake was off Cape Ann; the reported felt area extended from Providence, Rhode Island, to Kennebunk, Maine. The October 16, 1963, earthquake caused minor damage in towns near Boston including fallen plaster, cracked windows and walls, broken dishes, and stones fell from a building foundation (intensity VI). The other earthquakes did not exceed intensity V. The residents of Nantucket Island were jolted by a moderate earthquake on October 24, 1965. Very slight damage, mostly to ornaments, was reported. Doors, windows, and dishes rattled, and house timbers creaked.

Based on a review of available data through the USGS and other reliable sources, no damages or casualties associated with these previous earthquake occurrences have been recorded locally in Fairhaven. However past ground shaking events in the region have been felt by town residents. Most recently this occurred on the evening of February 11, 2014, when the USGS subsequently confirmed that a 2.4-magnitude earthquake had been centered near the neighboring town of Dartmouth.

A.3.4.5 Probability of Future Occurrences

Earthquakes with a magnitude of 3.0 and greater will remain a ***possible*** occurrence for being felt in the planning area, though based on historical data and existing seismic hazard maps, Fairhaven is considered susceptible to only minor ground shaking and light damages (if any). Moderately damaging earthquakes are only expected to strike somewhere in the New England region every few decades. The effects of climate change will have no relation to the probability or magnitude of future earthquake events.

A.3.5. EXTREME TEMPERATURES

A.3.5.1 General Description

According to the National Weather Service, extreme temperatures (including extreme heat and extreme cold) are the number one weather-related killer in the United States.

Extreme heat may be generally defined as temperatures that hover 10 degrees or more above the average high temperature for the region, last for prolonged periods of time, and are often accompanied by high humidity. At certain levels the human body cannot maintain proper internal temperatures and may experience severe health disorders including heat cramps, heat exhaustion or heatstroke (a life-threatening condition).

Extreme cold may be generally defined as prolonged periods of time with freezing temperatures, often made worse by the impact of wind chill factors (the combined elements of air temperature and wind on exposed skin). At certain levels the human body may suffer from frostbite or hypothermia, making extreme cold a potential severe and life-threatening hazard to people left unprotected from the elements. Freezing temperatures may cause severe damage to crops and other vegetation, and pipes may freeze and burst in structures that are poorly insulated or without heat. Long cold spells may cause rivers and lakes to freeze and lead to ice jams that can act as a dam, resulting in severe flooding.

A.3.5.2 Location

The entire planning area is uniformly susceptible to the occurrence of extreme temperatures. In general, Fairhaven's coastal areas are less susceptible to extreme heat than lower-lying inland areas due to the moderating and cooling effect of sea breezes from Buzzards Bay.

A.3.5.3 Severity/Extent

The National Weather Service's Heat Index is a measure of the effects of the combined elements of air temperature and relative humidity on the human body, particularly for people in higher risk groups (elderly persons, young children, persons with respiratory difficulties, and those who are sick or overweight). **Table A-9** summarizes the extent of these effects.

Table A-9: Effects of Extreme Heat on the Human Body

Heat Index	Heat Disorder
80–89° F	Fatigue possible with prolonged exposure and/or physical activity.
90–104° F	Sunstroke, heat cramps and heat exhaustion possible with prolonged exposure and/or physical activity.
105–129° F	Sunstroke, heat cramps or heat exhaustion likely, and heatstroke possible with prolonged exposure and/or physical activity.
130° F and Higher	Heatstroke/sunstroke highly higher likely with continued exposure.

The National Weather Service's Wind Chill Index is used to measure the dangers of frostbite caused by the combined elements of freezing temperatures and wind. **Table A-10** summarizes the extent of these effects.

Table A-10: Effects of Extreme Cold on the Human Body

Wind (mph)	Temperature (ºF) 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	29	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

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

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

Effective 11/01/01

For mitigation planning purposes, the maximum probable extent of extreme temperatures in Fairhaven is 5 consecutive days with a heat index exceeding 100 degrees, or a wind chill of less than -20 degrees.

A.3.5.4 Previous Occurrences

Extreme temperatures are not a very frequent occurrence in the planning area. As summarized in **Table A-11**, NOAA historical records indicate only 3 reported events in Bristol County since 1996, causing no casualties or property damages (including crop losses). This includes 1 extreme cold event and 2 extreme heat events.

Table A-11: Previous Occurrences for Extreme Temperatures (1996-2016)

Date(s)	Event Type	Description	Casualties (Deaths/Injuries)	Property Damage
2/14/2016	Extreme Cold/ Wind Chill	Arctic high pressure brought strong northwest winds and extremely cold wind chills to southern New England. Many locations reported wind chills between 25 and 35 degrees below zero. Wind chills as low as 29 below zero were reported in New Bedford.	0/0	$0
7/22/2011	Excessive Heat	Heat index values rose above 105 degrees for a period of a few hours.	0/0	$0
17/6/2010	Excessive Heat	Temperatures neared 100 degrees with high humidity. Heat index values ranged from 100 to 106 for most of Southern New England.	0/0	$0
		Total	**0/0**	**$0**

Source: NOAA Storm Events Database

A.3.5.5 Probability of Future Occurrences

Extreme temperatures will continue to be a ***possible*** occurrence in the planning area. It is anticipated that the effects of climate change will result in an increase in the frequency, duration and intensity of extreme heat events, and a decrease in the frequency of extreme cold events. Heat waves are projected to become much more commonplace in a warmer future with potentially major implications for human health, particularly as it relates it more vulnerable populations such as children, seniors, lower income residents, and those already dealing with respiratory or other health problems.

Per the downscaled climate projections for the Buzzards Bay basin as made available by EEA, Fairhaven should expect to experience increased average temperatures throughout the 21st century. Specific data projections on future temperature conditions include the following:

- Maximum and minimum temperatures are expected to increase throughout the end of the century. These increased temperature trends are expected for annual and seasonal projections.
- Seasonally, maximum summer and fall temperatures are expected to see the highest projected increase throughout the 21st century.

- Summer mid-century increase of 1.9 °F to 6.1 °F (2-8% increase); end of century increase of 2.9 °F to 11.2 °F (4-14% increase).
- Fall mid-century increase of 3.0 °F to 6.2°F (5-10% increase); end of century increase by and 3.3 °F to 10.9 °F (5-17% increase).

- Seasonally, minimum winter and fall temperatures are expected to see increases throughout the 21st century.
  - Winter mid-century increase of 3.1 °F to 6.9 °F (14-30% increase); end of century increase by 4.0 °F to 10.5 °F (18-46% increase).
  - Fall mid-century of 3.3 °F to 6.1 °F (7-14% increase); end of century increase of 3.7 °F to 10.7 °F (8-24% increase).
- Due to projected increases in average and maximum temperatures throughout the end of the century, the Buzzards Bay basin is also expected to experience an increase in days with daily maximum temperatures over 90 °F, 95 °F, and 100 °F.
  - Annually, the Buzzards Bay basin is expected to see days with daily maximum temperatures over 90 °F increase by 4 to 21 more days by mid-century, and 8 to 55 more days by the end of the century.
  - Seasonally, summer is expected to see an increase of 4 to 19 more days with daily maximums over 90 °F by mid-century.
  - By end of century, the Buzzards Bay basin is expected to have 7 to 48 more days with daily maximums over 90 °F.
- Due to projected increases in average and minimum temperatures throughout the end of the century, the Buzzards Bay basin is expected to experience a decrease in days with daily minimum temperatures below 32 °F and 0 °F.

A.3.6. FIRE

A.3.6.1 General Description

Fire is a combustion or burning, in which substances combine chemically with oxygen from the air and typically give out bright light, heat, and smoke. For the purposes of this plan, the fire hazard includes two types of fire events: urban fires and wildfires.

Urban fires occur primarily in more densely developed areas of cities and towns with the potential to rapidly spread to adjoining structures. These fires damage and destroy homes, schools, commercial buildings and vehicles. A major urban fire or conflagration is a large, destructive, and often uncontrollable fire that spreads substantial destruction. Although they can be ignited by numerous sources, major urban fires are often the result of other hazards, such as storms, earthquakes, gas leaks, transportation accidents, hazardous material spills, criminal activity (arson), or acts of terrorism. Small structural fires, which occur more frequently, can result from mundane events such as cooking, smoking, or electrical equipment/appliance malfunctions. Nationally, the leading causes of urban fires are arson, open flames, and cooking. The leading causes of fire deaths are smoking, arson, and heating, with urban fires causing the most fire deaths and injuries. Between 70 and 80 percent of deaths result from residential fires. People under the age of 5 and over the age of 55 have a much higher death rate than the average population, accounting for more than one-third of all deaths nationally.

A ***wildfire*** is an unwanted, uncontrolled fire burning in an area of vegetative fuels such as grasslands, brush, or woodlands. Other names such as brush fire or forest fire may be used to describe the same phenomenon depending on the type of vegetation being burned. Heavier fuels with high continuity, steep slopes, high temperatures, low humidity, low rainfall, and high winds all work to increase the frequency and severity of wildfire for people and property located within wildfire hazard areas, and particularly for those in rural areas with limited capabilities for rapid fire suppression. When not quickly detected and contained, wildfires have the potential to cause extensive damage to property and threaten human life.

Wildfires are part of the natural management of many forest ecosystems, but most are caused by human ignition factors. Nationally, over 80 percent of wildfires are started by negligent human behavior during dry conditions such as improperly discarding cigarettes, burning debris, or not extinguishing campfires in wooded areas. The second most common cause of wildfires is lightning strikes that occur during dry thunderstorms. Similar statistics are found for Massachusetts, as the Bureau of Forestry and Fire Control estimates that 98% of fires in the Commonwealth are started by negligent human behavior, followed by lightning.

The wildfire season in Massachusetts usually begins in late March and typically culminates in early June, corresponding with the driest live fuel moisture periods of the year. However, wildfires can occur every month of the year, and other factors such as drought, snow pack, and local weather conditions can expand the length of the typical fire season.

A.3.6.2 Location

Urban Fire

The urban fire hazard in Fairhaven involves areas where residential, commercial and/or industrial structures are clustered close together, increasing the possibility of a rapid spread to another structure. Specific areas of concern include locations where closely-spaced wood frame structures and/or adjoining and multi-unit buildings are found such as Fairhaven's commercial corridors and more densely developed districts. The shipyard is another area of significant concern due to the proximity of structures in combination with the storage of flammable materials and accelerants that accompany their current industrial use.

Wildfire

The wildland-urban interface is defined as the area where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels. **Figure A-10** illustrates wildfire hazard areas based on the location of wildland-urban interface zones across the planning area as mapped by the SILVIS Laboratory at the University of Wisconsin.[8] These hazard areas include two types of wildland-urban interface areas: intermix and interface. Intermix areas are described as areas where housing and vegetation intermingle; interface areas are described as areas with housing in the vicinity of contiguous wildland vegetation. Some specific problem areas of concern include the following:

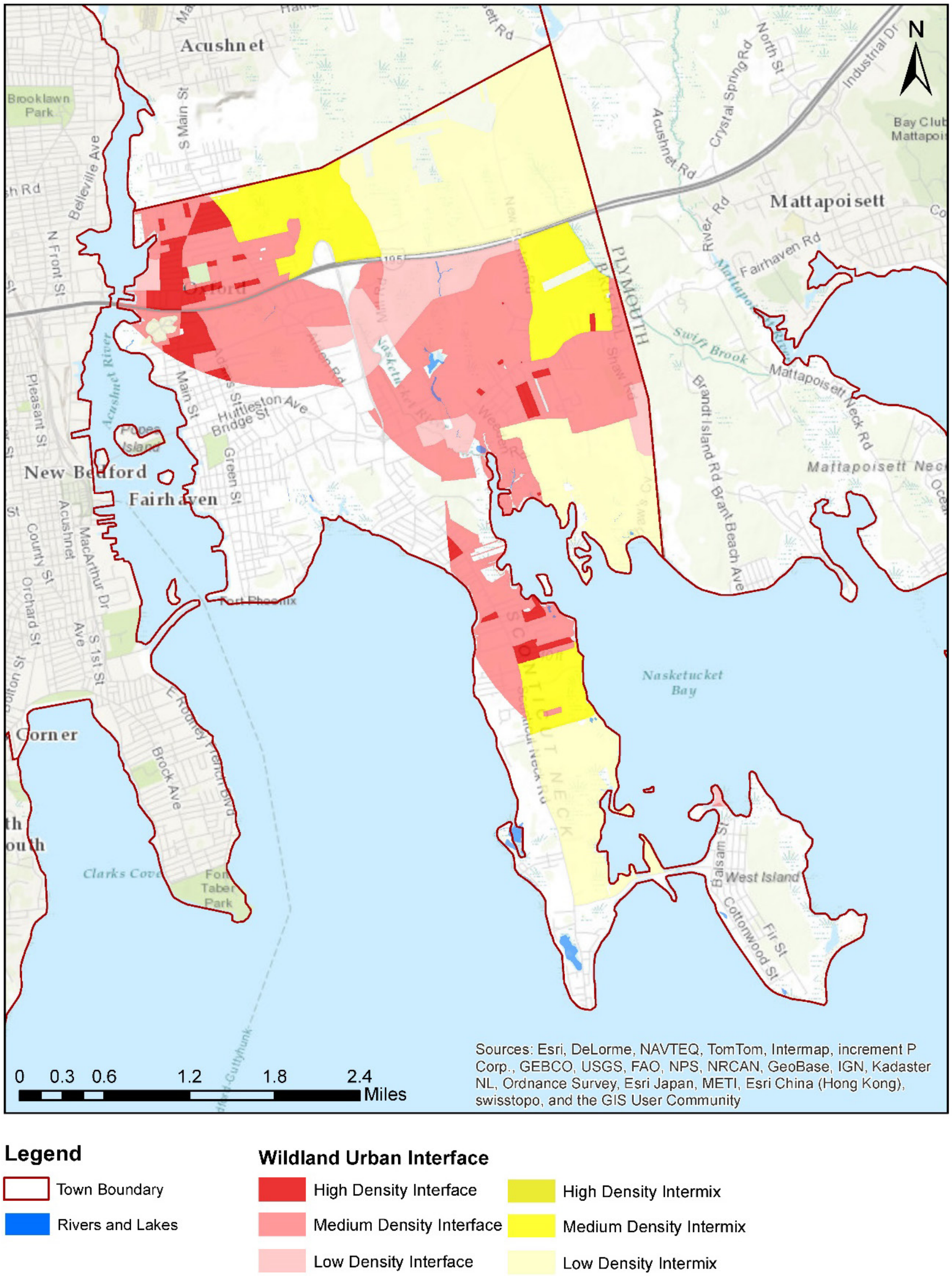
- Although it doesn't show up on the wildfire hazard map in Figure A-10, West Island should be considered a high-risk zone due to the large area of woodlands (more than 300 acres) located adjacent to some densely populated areas along the western side of the island. There are only several fire roads in the West Island State Reservation and no fire suppression equipment is

[8] Radeloff, V.C., R.B. Hammer, S.I Stewart, J.S. Fried, S.S. Holcomb, and J.F. McKeefry. 2005. The Wildland Urban Interface in the United States. Ecological Applications 15: 799-805.

permanently stored on the island, which will negatively affect local firefighting response times. Two more specific areas of concern on West Island include the cattails and invasive phragmites that tend to catch fire near Town Beach, and areas near the site of the old Town dump.

- Per the HMPC, there is a large area of potential wildfire risk from New Boston Road to Mill Road, north of interstate (densely forested area with no fire roads).
- Bay View Avenue, which reportedly lost several houses in early 1980's when cattails caught fire.
- Southern end of Farmfield Street is considered a potential risk area.

Figure A-10: Wildfire Hazard Areas



Source: SILVIS Lab, University of Wisconsin-Madison

A.3.6.3 Severity/Extent

The magnitude of fire events is often characterized by their size and level of impact. For urban fires this includes the total number and value of structures and other property burned, casualties, and in some cases the number of fire companies responding. For wildfires, this includes the speed of propagation, total number of acres and structures burned, and other resulting impacts to people and property. The magnitude and severity of fire events is greatly dependent on weather, fuel conditions, and existing fire detection, control and suppression capabilities.

For mitigation planning purposes, the maximum probable extent of a fire event in Fairhaven is 100 acres burned along wildland-urban interface.

A.3.6.4 Previous Occurrences

Fires are a very frequent occurrence in the planning area. **Table A-12** provides an overview of Fairhaven's experience with various types of fire events, including urban fire and wildfire (inclusive of "other fires"), from 2001 through 2013. The table summarizes individual fire reports as made available and published in the Massachusetts Fire Incident Reporting System. Information includes data on previous fire occurrences categorized by type (structure, motor vehicle, and other) and highlights the total number of fires; deaths, injuries, and monetary losses caused by fires. In total, there were 808 fires reported for Fairhaven during this available reporting period, causing 2 fatalities, 40 injuries, and approximately $5.8 million in losses.

Table A-12: Fire Data and Statistics for Fairhaven (2001-2013)

Year	Total Fires	Structure Fires	Vehicle Fires	Other Fires*	Civilian Casualties (Deaths/Injuries)	Fire Service Casualties (Deaths/Injuries)	Dollar Losses
2013	34	16	7	11	0/1	0/1	$1,287,601
2012	53	21	8	24	1/0	0/1	$1,043,500
2011	62	30	13	19	0/2	0/5	$785,302
2010	46	17	4	25	0/1	0/1	$359,250
2009	48	24	11	13	0/3	0/0	$203,842
2008	70	15	16	39	0/1	0/1	$238,625
2007	87	25	15	47	0/6	0/3	$675,676
2006	73	34	8	31	1/1	0/7	$238,625
2005	71	21	8	42	0/0	0/0	$410,000
2004	78	25	14	39	0/1	0/1	$55,000
2003	54	21	11	22	0/0	0/0	$189,000
2002	80	33	12	35	0/0	0/3	$318,700
2001	52	19	19	14	0/0	0/1	$27,680
Totals	**808**	**301**	**146**	**361**	**2/16**	**0/24**	**$5,832,801**

Year	Total Fires	Structure Fires	Vehicle Fires	Other Fires*	Civilian Casualties (Deaths/Injuries)	Fire Service Casualties (Deaths/Injuries)	Dollar Losses

**Other Fires include wildfire, brush, trash, and other outside fires.*
Source: Massachusetts Department of Fire Services

A.3.6.5 Probability of Future Occurrences

Urban fires and wildfires will continue to be a ***highly likely*** occurrence in the planning area, though the magnitude and impact of most events will be contained due to early detection and fire suppression. However, the potential for larger, destructive fires does exist for Fairhaven due to several factors including the availability of fuel, large concentrations of wood frame structures, the effects of offshore winds, and development within densely wooded areas throughout town.

It is anticipated that the effects of climate change, including more frequent and prolonged drought conditions, will increase the frequency and intensity of wildfire events; however, the United States Forest Service indicates that it is difficult to project what the exact impacts of climate change may be. Another related factor that is expected to increase the probability of future wildfire events is the introduction of disease, pests, and invasive plants that result in the dieback of mature tree species thus creating increased vegetative fuel loads in forested areas.

A.3.7. FLOOD

A.3.7.1 General Description

Flooding is the most frequent and costly natural hazard in the United States. Nearly 90 percent of presidential disaster declarations result from natural events where flooding was a major cause of human casualties and property damages. Flooding may be generally defined as the partial or complete inundation of normally dry land by the overflow and accumulation of excess water.

Flooding may be classified according to three distinct hazard types:

- ***Riverine floods*** include overbank flooding from a river or stream channel onto adjacent floodplains, and are generally caused by excessive precipitation from large-scale weather systems. A rapid accumulation of heavy localized downpours may also impact smaller streams and creeks to cause flash floods, characterized by a rapid rise in water level and/or high velocity flow with little warning. Other potential causes of riverine floods include ice jams or dam failures.
- ***Coastal floods*** occur along the shorelines of large water bodies and are caused by the wind-driven waves, storm surge and heavy rainfall produced by hurricanes, tropical storms, nor'easters and other large, low-pressure coastal storms with cyclonic flows. Coastal flood hazards are often exacerbated over the long term by coastal erosion and sea level rise.
- ***Urban floods*** occur where the physical development of a community has decreased the ability of natural groundcover to absorb and retain surface water runoff, and existing drainage systems are incapable of conveying or retaining storm water flow. They are most often caused by isolated, high-intensity rainfall events of relatively short duration (1 to 3 hours). Even when

drainage systems are designed to acceptable standards, urban flooding may occur when they are obstructed by debris, sediment or other materials that limit their functional capacity.

A.3.7.2 Location

Fairhaven lies within the Buzzards Bay watershed, which drains approximately 432 square miles of land, including lakes, rivers, streams, wetlands, and groundwater into Buzzards Bay. The bay itself is approximately 228 square miles in size and has a coastline which stretches over 280 miles. The principal sources of riverine flooding in Fairhaven are the Acushnet River and its tributaries, and Buzzards Bay is the source for all coastal flood hazards. Urban floods are most typically caused by heavy precipitation events that overwhelm local drainage systems in lower-lying areas across town.

Riverine Flood
Figure A-11 shows the location of all special flood hazard areas in the Town of Fairhaven as shown on current FEMA Digital Flood Insurance Rate Maps (DFIRMs). Descriptions for these special flood hazard areas are provided in the *Extent* portion of this section.

Coastal Flood
Coastal special flood hazard areas as currently mapped on FEMA DFIRMs are included in Figure A-11 as listed above for riverine flood. This includes "VE Zones" which are defined as areas subject to inundation by the 1 percent annual chance flood event with additional hazards due to storm-induced velocity wave action. **Figure A-12** shows the location of all hurricane storm surge inundation areas for Fairhaven. This figure illustrates areas that could be inundated by "worst case" scenarios associated with Category 1 through 4 hurricanes striking the coast of Massachusetts.

Urban Flood
Urban floods often strike rapidly, terminate quickly, and occur in areas generally not considered at risk to major flooding (including areas outside of mapped floodplains). Urban floods in Fairhaven have most often occurred because of very heavy precipitation that exceeds local drainage capacities, and in some cases, where trees, brush, and other vegetation growing along stream banks or other conveyances impede flood flows. In addition, trees, ice, and other debris may be washed away and carried downstream to collect on bridges, culverts, and other obstructions. As flood flow increases, significant amounts of this debris often break loose, sending water and debris surging downstream until another obstruction is encountered. It is difficult however to predict the degree to which, or the location where, debris may accumulate.

Figure A-11: Special Flood Hazard Areas

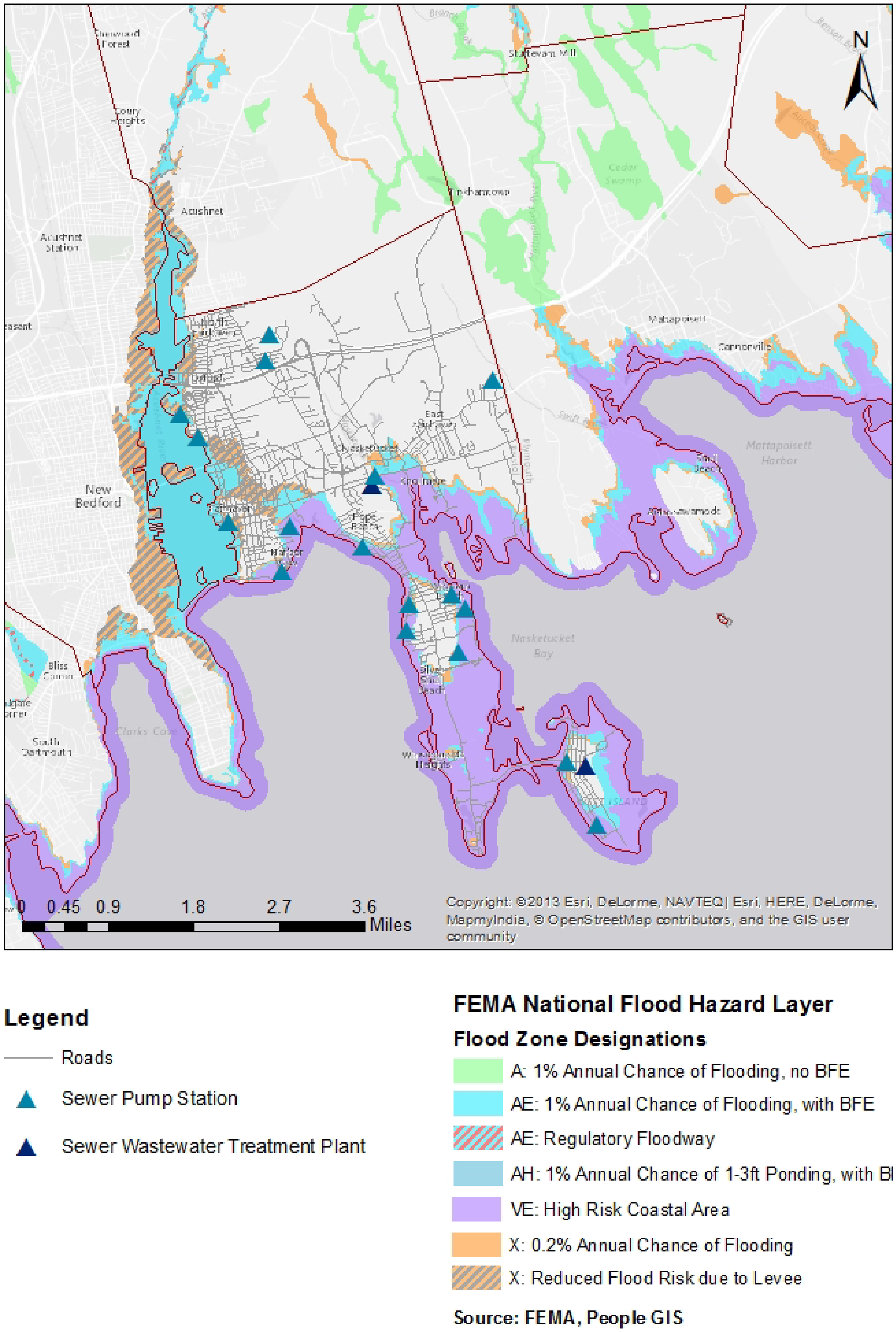
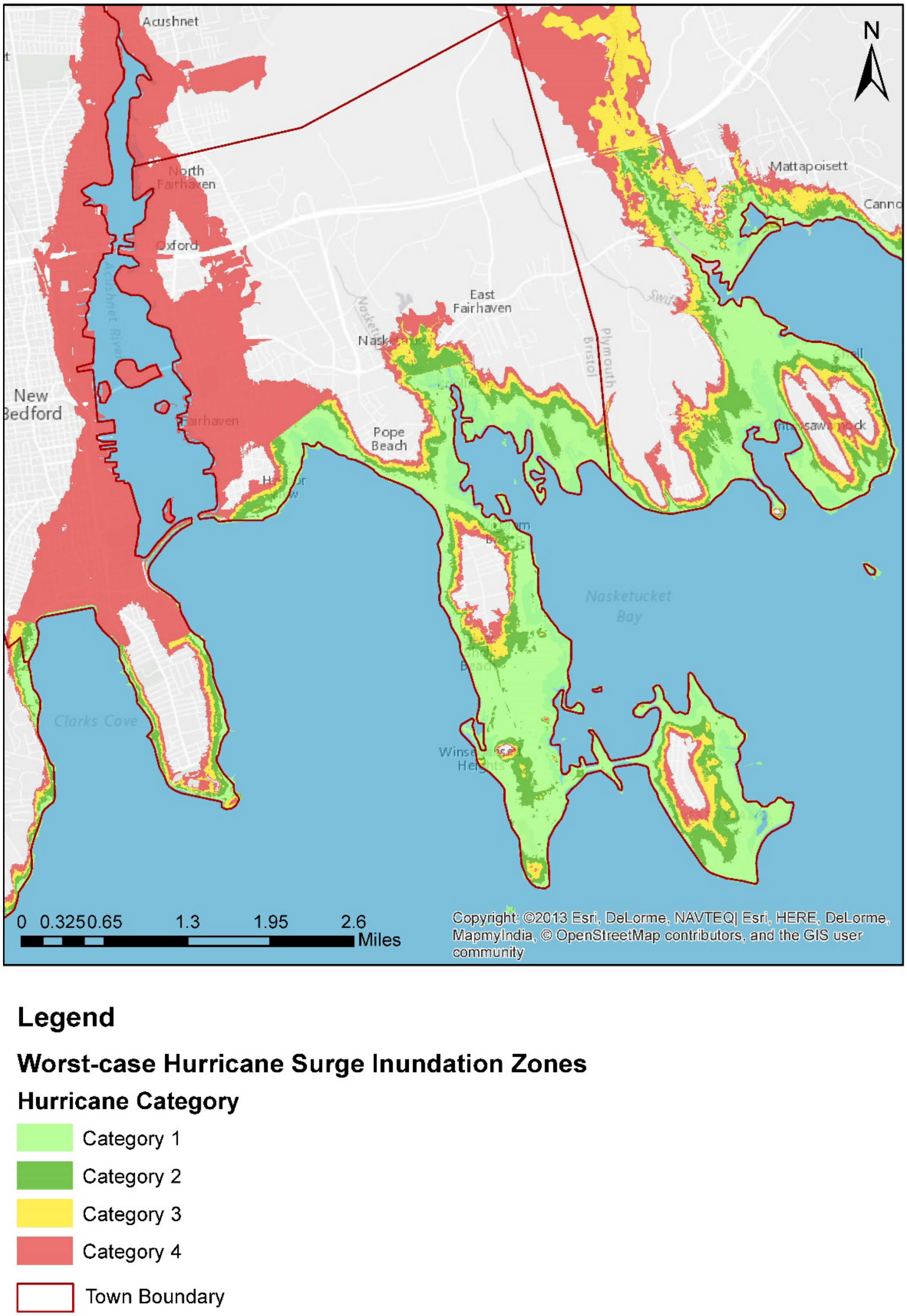


Figure A-12: Hurricane Storm Surge Inundation Areas



Source: U.S. Army Corps of Engineers, New England District

Description of Known Flood Hazards in Fairhaven

Past flood events in the region indicate that flooding can occur during any season of the year. According to the most recent FEMA Flood Insurance Study report (July 2015), most major riverine floods in Bristol County have occurred during February, March, and April and are usually the result of spring rains and/or snowmelt. Riverine floods occurring during the midsummer and late summer are often associated with hurricanes or tropical storms moving up the Atlantic coastline. Severe inland flooding generally occurs as a result of hurricanes or melting snows and spring rains, with more localized flooding caused by summer thunderstorms. Some specific riverine flood hazards or problem areas of concern include the following:

- Riverine flooding along the Town of Fairhaven waterfront also occurs when the Acushnet River is ponded behind the New Bedford-Fairhaven hurricane barrier during periods of concurrent high runoff and surge activity. For the most part, this flooding is limited to parking lots and shipyard properties.
- The Nash Riverway floods during every “100-year” storm event

The low-lying shoreline areas of Fairhaven have experienced periodic coastal flooding and wave attack that often accompany coastal storms and hurricanes. In recent years, most of these storms have caused damage only to boats, low coastal roads, beaches, and seawalls. Occasionally, a major nor’easter or hurricane accompanied by strong onshore winds and high tides resulted in surge and wave activity that caused extensive property damage and erosion. The most severe coastal flooding in the region has occurred due to high tides and storm surge caused hurricanes, tropical storms and nor’easters (covered under Coastal Storms). Some of the most significant coastal storms include the hurricanes of September 1938 and August 1954. The resultant storm surge flood levels in Fairhaven were estimated by the USACE at 12.8 and 12.1, respectively. These storms claimed lives and damaged residential, recreational, and small commercial developments, including harbors and marinas. Some specific coastal flood hazards or problem areas of concern include the following:

- Of particular concern is the West Island Causeway, which has been flooded and damaged multiple times during past storms. The causeway routinely floods during abnormally high (new/full moon) and king tides and coastal storms which restricts access to and from West Island, including to first responders (no emergency response vehicles such as fire trucks, EMS, etc. are housed on the island).
- Egypt Lane – seaward of the hurricane barrier
- Dyke/culvert located near G Bourne Knowles & Company, Inc. (near 267 Huttleston Avenue)

The primary areas of concern with regard to urban flooding include the following locations:

- Cushman Park Area, between Bridge and Spring Streets – primarily due to inadequate drainage structures, though recent improvements have decreased the vulnerability of this area.
- Huddleston Avenue, between Francis and Green Street *(reported by resident at Public Meeting #2)*

A.3.7.3 Severity/Extent

Riverine Flood

The severity of a riverine flood event is typically determined by a combination of several major factors, including: stream and river basin topography and physiography; precipitation and weather patterns;

recent soil moisture conditions; the degree of vegetative clearing; and impervious surface. The periodic flooding of lands adjacent to rivers, streams and shorelines (floodplains) is a natural and inevitable occurrence that can be expected to take place based upon established recurrence intervals. The recurrence interval of a flood is typically defined as the average time interval, in years, expected between a flood event of a particular magnitude and an equal or larger flood. Flood magnitude (spatial extent and depths) increases with increasing recurrence intervals.

Floodplain areas are delineated according to the frequency of the flood that is large enough to cover them. For example, the 10-year floodplain will be covered by the 10-year flood and the 100-year floodplain by the 100-year flood. A more appropriate way of expressing flood frequency is the percent chance of occurrence in any given year (annual probability). For example, the 100-year flood has a 1 percent chance of occurring in any given year, and the 500-year flood has a 0.2 percent chance of occurring in any given year. Statistically, the 1 percent annual chance flood has a 26 percent chance of occurring during a 30-year period, equal to the duration of many home mortgages. Contrary to what the term suggests, a "100-year flood" is not a flood that occurs only once every 100 years. A "100-year flood" can and often does occur in the same location multiple times in a century.

Special flood hazard areas identified on FEMA DFIRMs (as shown in Figure A-11) are defined as the areas that will be inundated by the flood event having a 1 percent chance of being equaled or exceeded in any given year. The 1-percent-annual-chance flood is also referred to as the base flood elevation (BFE), and is the national minimum standard for applying FEMA's NFIP floodplain management regulations and mandatory flood insurance purchase requirements. Areas shown to be inundated by the 0.2-percent-annual-chance flood are considered moderate flood hazard areas, and areas outside of these areas are considered minimal flood hazard areas. In Fairhaven, this also includes the area protected by the New Bedford-Fairhaven hurricane barrier (shown on the effective FIRM as "Reduced Flood Risk due to Levee"). The hurricane barrier has been accredited to provide protection from the 1-percent-annual-chance-flood, though it has been assumed that it would fail in a 0.2-percent-annual-chance flood event.

Coastal Flood

The intensity and duration (or forward speed) of a storm is the most influential factor affecting the severity and impact of storm surges. While hurricanes and tropical storms often move through areas relatively quickly, nor'easters can last for days and multiple tidal cycles, often causing major coastal flooding, erosion and damage from wind-driven wave action.

Special flood hazard areas identified as "VE Zones" on FEMA DFIRMs (as shown in Figure A-11) are defined as areas subject to inundation by the 1 percent annual chance flood event with additional hazards due to storm-induced velocity wave action. Mandatory flood insurance purchase requirements and floodplain management standards apply for these areas.

Figure A-12 shows the location of all storm surge inundation areas for Fairhaven. This figure illustrates areas that could be inundated by "worst case" scenarios associated with Category 1 through 4 hurricanes striking the coast of Massachusetts.

Urban Flood

The severity of urban flooding varies greatly and is highly dependent on rainfall intensity and duration, but is generally limited to minimal, localized damages and/or temporary disruptions to transportation infrastructure. However, the lack of warning associated with urban flood events often creates significant threats to public safety due to flooded roadways, and results in increased damage to property that could have been prevented with more advance notice (particularly for vehicles left unattended in areas susceptible to urban flooding).

For mitigation planning purposes, the maximum probable extent of a flooding event in Fairhaven is the 1 Percent Annual Chance Flood for all inland FEMA Special Flood Hazard Areas (riverine flood); the worst case storm surge inundation for a category 3 hurricane (coastal flood); and the 10-year Design Storm Event (urban flood).

A.3.7.4 Previous Occurrences

Floods are a frequent occurrence in the planning area. NOAA historical records include 104 flood events[9] in Bristol County since 1996, causing no fatalities, 2 injuries, and approximately $40 million in reported property damages. **Table A-13** lists the past events that are listed for Southern Bristol County and/or with impacts specific to Fairhaven. The damage figures associated with these events are believed to greatly underestimate the value of actual flood losses that have occurred but gone unreported and/or unrecorded in NOAA records.

Table A-13: Previous Occurrences for Flood[10] (2005-2016)

Date(s)	Event Type	Description	Casualties (Deaths/Injuries)	Property Damage
9/30/2015	Coastal Flood	A cold front moved across southern New England bringing heavy rain, strong winds, and periods of coastal flooding along the South Coast. There was minor splash-over on the West Island Causeway and several backyards of houses on Almond Street were flooded.	0/0	$0
7/28/2015	Flood	A strong upper level disturbance sparked showers and thunderstorms across much of southern New England. A few of these storms became severe, producing damaging winds. Others produced heavy rain that resulted in flooding.	0/0	$0
7/15/2015	Flood	Showers and thunderstorms developed across the area as a result of an upper level disturbance and a cold front. A couple of these slow-moving storms resulted in flooding.	0/0	$0
11/17/2014	Flood	Low pressure moving over southern New England brought heavy rain, strong to damaging winds, and a convective line of showers and thunderstorms to the region.	0/0	$0

[9] Includes events that were classified as flood, flash flood, coastal flood, or storm surge/tide.
[10] Includes data for events reported to have occurred in the National Weather Service's Forecast Zone for Southern Bristol County, including but not limited to Fairhaven.

Date(s)	Event Type	Description	Casualties (Deaths/Injuries)	Property Damage
7/15/2014	Flash Flood	A slow-moving frontal boundary, combined with plenty of heat and humidity, led to the development of showers and thunderstorms during the afternoon and evening. Some of the storms were severe and produced localized flash flooding.	0/0	$5,000
3/30/2014	Flood	Anywhere from two to five inches of rain fell across southern New England with the highest amounts falling along the South Coast. This resulted in flash flooding across much of the area.	0/0	$0
9/3/2013	Flood	Flash flooding also occurred in several locations across the region.	0/0	$0
6/7/2013	Flood	The remnants of Tropical Storm Andrea tracked across the region bringing heavy rain (3-5 inches), resulting in significant urban flooding as well as river and small stream flooding.	0/0	$50,000
5/11/2013	Flood	Deep layer moisture and lift associated with a low-level jet resulted in widespread showers across Southern New England. High precipitable water values led to heavy rain and flooding of low lying urban and other poor drainage areas.	0/0	$5,000
12/10/2012	Flood	Scattered showers and thunderstorms with rainfall rates of 1 to 2 inches per hour were observed. In Fairhaven, flooding affected Route 6 at Green Street as well as on Bridge and Spring Streets, where as much as 18 inches of water covered the road. Two cars were stranded on Adams Street after attempting to drive through the flooded roadway.	0/0	$15,000
10/29/2012	Coastal Flood	Superstorm Sandy, a hybrid storm with both tropical and extra-tropical characteristics, brought high winds and coastal flooding to southern New England. Storm surge was 4 to 6 feet along the South Coast. In Fairhaven, Causeway Road was flooded and impassable, and the Seaview Avenue boat ramp was flooded at the bottom of Ocean Avenue.	0/0	$500,000

Date(s)	Event Type	Description	Casualties (Deaths/Injuries)	Property Damage
8/15/2012	Flood	Showers and severe thunderstorms created rainfall rates that were high enough to result in flash flooding.	0/0	$15,000
9/8/2011	Flood	Heavy rainfall across the region over a period of four days resulted in flooding both on rivers and small streams and in urban areas. The bulk of the flooding occurred on September 8th as a band of very heavy rain moved through, dumping up to two inches of rain in an hour in some locations.	0/0	$50,000
8/28/2011	Storm Surge/ Tide	Tropical Storm Irene produced significant amounts of rain, storm surge, inland and coastal flooding, and wind damage across southern New England. A storm surge of 3.84 feet impacted coastal areas and Sconticut Neck Road was flooded.	0/0	$0
12/3/2009	Coastal Flood	Strong low pressure moving through New York State coupled with a vigorous low level jet resulted in periods of damaging wind, rain, and moderate coastal flooding.	0/0	$5,000
8/11/2008	Flash Flood	Severe thunderstorms produced a waterspout and very heavy rains resulting in flash flooding across southeastern Massachusetts. Numerous streets and basements were flooded across the area.	0/0	$500,000
4/16/2007	Coastal Flood	Minor to moderate coastal flooding occurred through several high tide cycles due to the combination of strong onshore winds, high seas, and astronomically high tides. Along the South Coast, the worst coastal flooding occurred with morning high tide on April 16th, where flood waters and debris closed several shore roads.	0/0	$5,000
10/28/2006	Coastal Flood	Low pressure intensified rapidly as it tracked from the mid-Atlantic states into New England. This storm system caused significant coastal flooding along the south coast of Massachusetts.	0/0	$10,000

Date(s)	Event Type	Description	Casualties (Deaths/Injuries)	Property Damage
6/7/2006	Flood	A late season coastal storm brought heavy rainfall to much of eastern Massachusetts, resulting in widespread flooding of roads and small streams. Rainfall totals in Bristol County reached as high as 7 inches.	0/0	$25,000
10/15/2005	Flood	A low-pressure system interacted with a plume of tropical moisture as the low slowly moved parallel to the Long Island and south Massachusetts coasts, resulting in excessive rain and flooding across the region. This event resulted in a major disaster declaration for Bristol County.	0/0	$50,000
		Total	**0/0**	**$1,235,000**

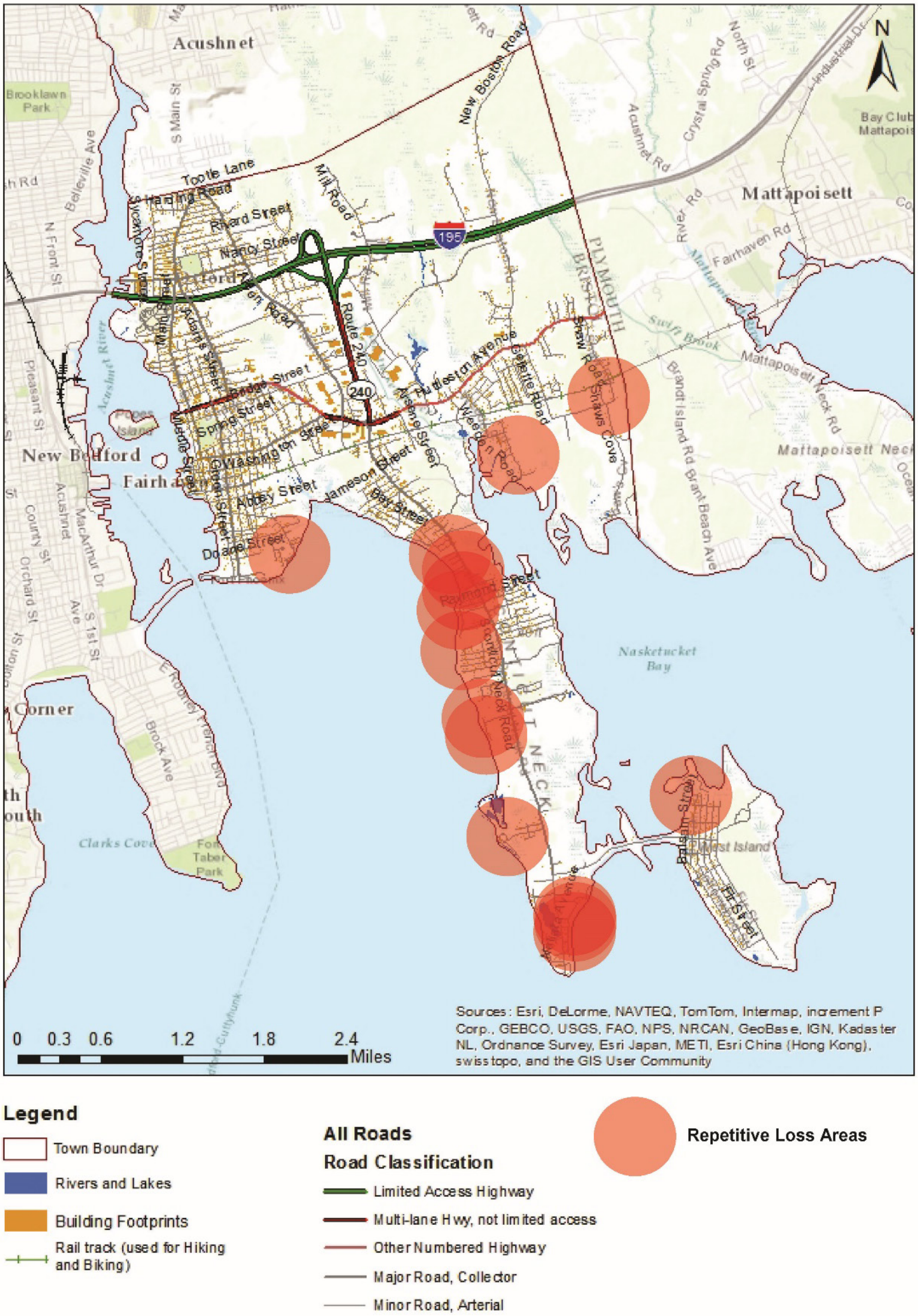
Source: NOAA Storm Events Database

One local flooding event that went unreported by NOAA occurred on July 4, 2014. According to HMPC members this event caused major street flooding in Fairhaven and led to approximately 120 calls in 24 hours for flooded basements, mostly in the areas surrounding Cushman Park.

According to the most recent FEMA Flood Insurance Study for the region, Bristol County also saw flooding from severe storms in October 1996, June 1998, March 2001, April 2004. The June 1998 storm was slow moving and produced rainfall of 6 to 12 inches over much of eastern Massachusetts. In late February through March 2010, three separate rainfall events resulted in about 17 to 23 inches over much of southern New England, causing major flooding across eastern Massachusetts and Rhode Island. These rain storms caused several small streams in Bristol County to rise above flood stage, and several communities had areas that were closed for several days due to small stream, urban, and poor drainage flooding. This series of events resulted in a major disaster declaration for Bristol County.

According to FEMA flood insurance records, there have been a total of 420 individual losses and nearly $3.5 million in insured damages for Fairhaven as recorded through the National Flood Insurance Program (NFIP) since 1976. The average claims payment per flood loss during this period was approximately $8,200. However, this information only reflects previous losses as reported through claims under the NFIP, and it is understood that many additional losses have occurred in Fairhaven that were either uninsured or unreported. NFIP records have also identified 17 “repetitive loss properties” in Fairhaven, which are defined by FEMA as an NFIP insured structure that has had at least two paid flood losses of more than $1,000 each in any 10-year period since 1978. The general location of these repetitive loss properties in Fairhaven are illustrated in **Figure A-13**. According to the data made available from FEMA these properties are all residential buildings, with 15 classified as single-family structures and two assumed to be condominiums. These repetitive loss properties have accounted for a total of 49 losses and nearly $650,000 in claims paid through the NFIP.

Figure A-13: Repetitive Loss Areas in Fairhaven



Source: FEMA

A.3.7.5 Probability of Future Occurrences

Floods of varying extent will continue to be a ***likely*** occurrence in the planning area. Riverine floods will likely be an occasional occurrence in planning area, while coastal and urban floods will likely occur more frequently. It is anticipated that the effects of climate change, including sea level rise, will result in an increase in the extent and frequency of storm surge and coastal flooding. Severe urban flooding due to more precipitation and very heavy downpours is also very likely to occur more frequently. According to the 2014 National Climate Assessment, the Northeast experienced a 71 percent increase in very heavy precipitation events from 1958 to 2012, and it is projected that this trend will continue and even worsen under all future emissions scenarios. Under the rapid emissions reduction scenario, these events would still occur nearly twice as often. For the scenario assuming continued increases in emissions, these events would occur up to five times as often.[11]

Although the number of heavy precipitation events is anticipated to increase in the future, per the downscaled climate projections for the Buzzards Bay basin as made available by EEA, Fairhaven should expect some variability in precipitation patterns throughout the 21st century. Specific data projections include the following:

- The expected number of days receiving precipitation over one inch are variable for the Buzzards Bay basin, fluctuating between loss and gain of days.
    - Seasonally, the winter season is generally expected to see the highest projected increase.
    - The winter season is expected to see an increase in days with precipitation over one inch of 0-1 days by mid-century, and by 0-2 days by the end of century.
    - The spring season is expected to see an increase in days with precipitation over one inch of 0-1 days by mid-century, and by 0-1 days by the end of century.
- Similar to projections for number of days receiving precipitation over a specified threshold, seasonal projections for total precipitation are also variable for the Buzzards Bay basin.
    - The winter season is expected to experience the greatest change with an increase of 0-15% by mid-century, and 1-31% by end of century.
    - Projections for the summer and fall seasons are more variable and could see either a drop or increase in total precipitation throughout the 21st century.
        - The summer season projections for the Buzzards Bay or basin could see a decrease of 0.9 to an increase of 1.5 inches by mid-century (decrease of 8% to increase of 14%), and a decrease of 2.3 to an increase of 1.8 inches by the end of the century (decrease of 21% to increase of 17%).
        - The fall season projections for the Buzzards Bay basin could see a decrease of 1.0 to an increase of 1.5 inches by mid-century (decrease of 8% to increase of 13%), and a decrease of 1.7 to an increase of 1.2 inches by the end of the century (decrease of 14% to increase of 10%).

[11] U.S. Global Change Research Program. *Climate Change Impacts in the United States: U.S. National Climate Assessment*. 2014.

A.3.8. SEVERE WEATHER

A.3.8.1 General Description

Severe weather hazards include high winds, severe thunderstorms, tornadoes and other extreme weather effects which often accompany such storm systems.

High winds can be generated from several types of weather events, including before and after frontal systems, hurricanes and tropical storms, severe thunderstorms and tornadoes, and nor'easters. 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 and are also a hazard for the boating, shipping, and aviation industry sectors. Wind gusts of only 40 to 45 miles per hour can cause scattered power outages from trees and wires being downed. This is especially true after periods of prolonged drought or excessive rainfall, since both are situations which can weaken the root systems and make them more susceptible to the winds' effects. Winds measuring less than 30 miles per hour are not considered to be hazardous under most circumstances.

Severe thunderstorms are created when air masses of varying temperatures meet, and can occur singularly, in lines, or in clusters, but generally affect a small area when they occur. When thunderstorm winds reach 58 miles per hour, the thunderstorm is considered severe and a warning is issued. Thunderstorms can occur during any season, but are more likely to occur during the spring and early summer months of March through June. They can occur at any time of day, but are more likely to form in the late afternoon and early evening. They can move through an area very quickly or linger for several hours. The primary damaging forces associated with these storms are straight-line winds, hail, and lightning as described below, but they can also cause flash flooding or spawn tornadoes.

- *Straight-line winds* (including downbursts and microbursts), which in extreme cases have the potential to cause wind gusts that exceed 100 miles per hour, are capable of toppling trees, downing down power lines, and causing moderate to major property damage.
- *Hail* has the potential to cause minor to moderate property damage, particularly the larger hail stones associated with severe thunderstorms. The size of hailstones is a direct result of the size and severity of the storm.
- *Lightning* remains one of the top three storm-related killers in the United States and is a significant life/safety threat to people, but also has the potential to damage property and ignite both urban and wildland fires.

Tornadoes are violent windstorms characterized by a twisting, funnel-shaped cloud extending to the ground. Tornadoes are most often generated by strong thunderstorm activity (but may also be spawned from hurricanes and other coastal storms) when cool, dry air intersects and overrides a layer of warm, moist air forcing the warm air to rise rapidly. The damage caused by a tornado is a result of the high wind velocity and wind-blown debris, also accompanied by lightning or large hail. Most tornadoes are a few dozen yards wide and touch down only briefly, but even small short-lived tornadoes can inflict tremendous damage. Highly destructive tornadoes may carve out a path over a mile wide and several miles long.

Tornadoes often develop so rapidly that little, if any, advance warning is possible making them a significant life/safety threat to people. They are more likely to occur during the spring and early summer months of March through June and can occur at any time of day, but are more likely to form in the late afternoon and early evening. Tornadoes associated with tropical cyclones are most frequent in September and October when the incidence of tropical storm systems is greatest.

A.3.8.2 Location

The entire planning area is uniformly susceptible to the occurrence of severe weather including high winds, severe thunderstorms, and tornadoes.

A.3.8.3 Severity/Extent

A thunderstorm is classified as "severe" when it contains one or more of the following damaging effects: winds gusting in excess of 50 knots (57.5 mph), hail measuring at least one inch in diameter, or a tornado.

The Enhanced Fujita Scale (EF-scale), shown in **Table A-14**, is used to categorize the strength and magnitude of tornado events based on estimated wind speeds and related damage. This represents an update to the original Fujita Scale (F-scale) and has been implemented since February 2007.

Table A-14: Enhanced Fujita Scale

Rating	Wind Speed (3 second gust)	Potential Damage
EF-0	65–85 mph	Light – Causes some damage to siding and shingles.
EF-1	86–110 mph	Moderate – Considerable roof damage. Winds can uproot trees and overturn singlewide mobile homes. Flagpoles bend.
EF-2	111–135 mph	Considerable – Most singlewide mobile homes destroyed. Permanent homes can shift off foundations.
EF-3	136–165 mph	Severe – Hardwood trees debarked. All but small portions of houses destroyed.
EF-4	166–200 mph	Devastating – Complete destruction of well - built residences, large sections of school buildings.
EF-5	Over 200 mph	Incredible – Significant structural deformation of mid- and high-rise buildings.

Source: NOAA

For mitigation planning purposes, the maximum probable extent of severe weather in Fairhaven is wind gusts exceeding 50 knots, hail measuring at least three-quarters of an inch in diameter, or a tornado occurrence.

A.3.8.4 Previous Occurrences

Severe weather is a frequent occurrence in the planning area. NOAA historical records include 467 severe weather events[12] in Bristol County since 1950, causing 1 fatality, 6 injuries, and approximately $4.4 million in reported property damages. Most damages were caused by severe thunderstorm winds,

[12] Includes events that were classified as thunderstorm wind, high wind, strong wind, lightning, hail, or heavy rain.

though $377,500 in damage was attributed to lightning and $5,000 to hail. It is believed that many additional historic events and/or losses have occurred but gone unreported or unrecorded.

Some notable recent occurrences with impacts in Fairhaven include:

- November 27, 2013 – An anomalously strong low level jet coupled with strong pressure falls associated with a low-pressure region approaching southern New England resulted in strong to damaging winds across southern New England. Damage was largely to trees. Amateur radio operators in Fairhaven recorded wind gusts of 61 mph.
- November 1, 2013 – An anomalously strong low pressure region moved from Ontario into southern Quebec. Southern New England was sandwiched in between this and high pressure off the coast to the southeast, creating a very tight pressure gradient over the region. This resulted in strong gusty winds which caused some damage, especially to areas where the trees were still fully leaved. An amateur radio operator in Fairhaven recorded a wind gust of 46 mph, and a twenty by forty-foot section of roof was peeled off the Seaport Inn (in Fairhaven).
- December 27, 2012 – Low pressure moved up the coast over Southern New England from the mid-Atlantic. An amateur radio operator in Fairhaven recorded a wind gust of 61 mph.
- November 7, 2012 – Low pressure moved up the east coast spreading snow, rain, and wind across southern New England. Wind gusts of 60 to 65 mph were reported by amateur radio operators. In Fairhaven, trees and wires were downed.
- January 25, 2010 – Unseasonably warm temperatures moved into southern New England ahead of a cold front which allowed for excellent atmospheric mixing. This resulted in strong to damaging winds across much of eastern Massachusetts and Rhode Island. In Fairhaven, trees were downed, a large branch was downed onto a car, and a utility pole was snapped in two.
- December 3, 2009 – Strong low pressure moving through New York State coupled with a vigorous low level jet resulted in periods of damaging wind across Southern New England. Trees were downed in Fairhaven.
- October 24, 2009 – A warm front brought rain and warm temperatures to much of Southern New England before a cold front swept through during the late evening/overnight hours bringing gusty winds. Reports of damage include large branches and trees downed in Fairhaven.
- October 7, 2009 – A cold front moved through Southern New England resulting in showers and gusty westerly winds. Based on damage reports in the area, occasional gusts to 58 mph are believed to have occurred throughout coastal Bristol County. Some of these reports include large branches and trees down in Fairhaven.

NOAA historical records include 8 tornado events in Bristol County since 1950, causing no fatalities, 5 injuries, and approximately $2.6 million in reported property damages. More information on each of these events is provided in **Table A-15**.

Table A-15: Previous Occurrences for Tornado in Bristol County (1950-2016)

Date(s)	Magnitude	Description	Casualties (Deaths/Injuries)	Property Damage
7/23/2008	EF0	Tornado began as a waterspout over Narragansett Bay and traveled east-northeast reaching land over the southern portion of Warren, Rhode Island. The tornado continued for 4.2 miles into Swansea, Massachusetts over a mostly continuous track. Most of the damage sustained was to trees which fell on power lines and houses.	0/0	$15,000
8/6/1997	F0	Photos and eyewitness reports confirmed that a very weak tornado touched down in the Drift Road section of Westport. A few tree tops were broken off.	0/0	$0
9/14/1972	F0	Approximate tornado track shows the tornado began in New Bedford and continued 4.1 miles offshore as a waterspout and potentially skirted the very southern end of Sconticut Neck in Fairhaven before dissipating.	0/0	$2,500
8/28/1970	F2	Tornado reportedly began in southern portion of New Bedford and traveled up to 1 mile with an estimated width of 33 yards.	0/0	$25,000
8/2/1970	F1	Tornado reportedly began near Mansfield and traveled up to 2 miles with an estimated width of 100 yards.	0/0	$25,000
8/9/1968	F1	Tornado reportedly began in Acushnet and traveled up to 1 mile with an estimated width of 100 yards.	0/0	$2,500
8/9/1968	F1	Tornado reportedly began in North Attleboro and traveled only a tenth of a mile with an estimated width of 33 yards.	0/0	$25,000
6/9/1953	F3	Tornado reportedly began near Mansfield with an estimated width of 667 yards.	0/4	$2,500,000
		Total	**0/5**	**$2,595,000**

Source: NOAA Storm Events Database

While none of the officially confirmed tornado events in Table A-15 occurred within Fairhaven, there was a major windstorm event that occurred in Fairhaven on July 1, 1998. No official data is available on the magnitude and reported losses for this event, which according to local records was classified as a microburst versus a tornado, however **Figure A-14** shows some of the damage that occurred at a local business (Fairhaven Lumber).

Figure A-14: Major Wind Damage, Fairhaven Lumber (July 1, 1998)

Photo courtesy of Wayne Fostin, Town of Fairhaven

A.3.8.5 Probability of Future Occurrences

High wind and severe thunderstorm events will continue to be a ***highly likely*** occurrence in Fairhaven. Tornadoes will continue to be a possible occurrence in the planning area, though it is unlikely that very strong tornadoes (EF-3, EF-4 or EF-5) will strike the area. According to NOAA, the effects of climate change on future severe weather events cannot be determined at the present time due to insufficient scientific evidence. However, multiple studies cite that the Northeast region of the US will continue experience more very heavy rainfall events which are often associated with severe thunderstorms and other extreme weather events (covered under Flood).

A.3.9. SEVERE WINTER STORM

A.3.9.1 General Description

Severe winter storms can range from a moderate snowfall over a period of a few hours to blizzard conditions (sustained winds or frequent gusts of 35 miles per hour or more) with blinding wind-driven snow that lasts for several days. Heavy accumulations of snow or ice can bring down trees and power lines, disabling electric power and communications for days or weeks, and can paralyze a region by shutting down all air and rail transportation and disrupting medical and emergency services. Severe winter storms are indirectly and deceptively a significant threat to human life and safety, primarily due to automobile accidents, overexertion and exposure. The cost of snow removal, repairing damages, and loss of business can have large economic impacts on local communities.

Severe winter storms may include snow, ice, sleet, freezing rain, or a mix of these wintry forms of precipitation. Heavy accumulations of snow create hazards to transportation, as well buildings with flat rooftops or other structures not engineered to withstand heavy snow loads. Sleet – raindrops that freeze into ice pellets before reaching the ground – usually bounce when hitting a surface and do not stick to objects; however, sleet can accumulate like snow and cause a hazard to motorists. Freezing rain is rain that falls onto a surface with a temperature below freezing, forming a glaze of ice. Even small accumulations of ice or freezing rain can cause a significant hazard, especially to trees and power lines. An ice storm occurs when heavy accumulations of freezing rain falls and freezes immediately upon impact. Communications and power can be disrupted for days, and even small accumulations of ice may cause extreme hazards to motorists and pedestrians.

A.3.9.2 Location

The entire planning area is susceptible to the occurrence of severe winter storms. Coastal areas are more susceptible to the forces of strong winds, heavy surf, and tidal flooding (covered under Flood).

A.3.9.3 Severity/Extent

NOAA's National Centers for Environmental Information (NCEI) recently developed the Regional Snowfall Index (RSI) for significant snowstorms that impact the eastern two thirds of the U.S. The RSI ranks snowstorm impacts on a scale from 1 to 5, as shown in **Table A-16**. RSI values are based on the spatial extent of the storm, the amount of snowfall, and the association of these elements with population and societal impacts. NCEI has analyzed and assigned RSI values to over 500 storms going as far back as 1900 and new storms are added operationally. As such, RSI puts the regional impacts of snowstorms into a century-scale historical perspective. The index is useful for those who wish to compare regional impacts between different snowstorms, and is recommended for classifying major winter storms in combination with the Classification Scheme for Nor'easters presented in section A.3.2.3, as appropriate.

Table A-16: Regional Snowfall Index (RSI)

Category	RSI Value	Description
1	1–3	Notable
2	3–6	Significant
3	6–10	Major
4	10–18	Crippling
5	18.0+	Extreme

Source: NOAA

For mitigation planning purposes, the maximum probable extent of a severe winter storm in Fairhaven is a Category 5 on the Regional Snowfall Index; or Intensity Index Category 4 on Classification Scheme for Nor'easters.

A.3.9.4 Previous Occurrences

Severe winter storms are a frequent occurrence in the planning area. NOAA historical records include 145 winter storm events[13] in Bristol County since 1996, causing no casualties[14] and approximately $4.1 million in reported property damages. It is believed that additional losses have occurred but gone unreported or unrecorded in NOAA records, and it is also worth noting that one of the most significant financial impacts from winter storms to local communities is attributed to snow removal costs (not included in reported property damages).

A Fairhaven home was damaged during Winter Storm Stella in March 2017. *Courtesy of Wayne Oliveira, Fairhaven Fire Department.*

Notable recent occurrences in the planning area include:

- March 14, 2017 – Winter Storm Stella wreaked havoc across the East Coast and Massachusetts in the form of heavy snow and strong winds. Although snow totals didn't exceed three inches in Fairhaven, wind gusts of 70+ mph were recorded in the area resulting in power outages and minor property damages.
- January 7, 2017 – Low pressure, the second in three days, developed along the coast of the Carolinas the night of January 6 and moved up the coast to bring snow and wind to Southern New England on January 7. Up to seventeen inches of snow fell on Southern Bristol County during the day and evening.
- February 8, 2016 – A very powerful low-pressure system tracked up the east coast, passing southeast of Southern New England. This storm brought heavy snow and gusty winds, resulting in blizzard conditions along the Massachusetts east coast. Five to seven inches of snow fell across Southern Bristol County, and a tree was downed on Deerfield Street in Fairhaven.
- February 14, 2015 – Low pressure off the Delmarva peninsula intensified rapidly as it moved northeastward. Its path just southeast of Nantucket brought heavy snow to all of southern New England and blizzard conditions and coastal flooding to coastal areas. Seventeen to twenty-three inches of snow fell across southern Bristol County.
- January 26, 2015 – An historic winter storm brought heavy snow to southern New England with blizzard conditions to much of Rhode Island and eastern Massachusetts. The "Blizzard of January 2015" produced very strong where gusts of 50 to 65 mph were common and significant coastal flooding occurred along the Massachusetts coast. A federal disaster declaration was issued for the eastern parts of Massachusetts for this storm, allowing federal assistance for emergency work and repairs to facilities damaged by the storm. Sixteen to twenty-six inches of snow fell across southern Bristol County, and winds gusting as high as 64 mph were reported in

[13] Includes events that were classified as winter storm, blizzard, heavy snow, or winter weather.
[14] Excluding indirect but storm-related casualties (e.g., automobile accidents, heart attacks while shoveling, etc.)

Fairhaven causing scattered wind damage. This event resulted in a major disaster declaration for Bristol County.

- February 15, 2014 - Low pressure moved off the DelMarVa peninsula and moved northeastward passing southeast of southern New England. This brought strong winds and heavy snow to the southern portions of the region. Seven to ten inches of snow fell across southern Bristol County. A few branches and wires were downed due to the heavy snow and wind gusts to around 40 mph.

- January 2, 2014 - A significant, rapidly developing coastal storm moved southeast of Southern New England bringing heavy snow, bitter cold temperatures, coastal flooding, and strong winds to Massachusetts. Up to eleven inches of snow fell across southern Bristol County.

- March 7, 2013 – This storm brought heavy snow and significant coastal flooding to the area. This was an unusual synoptic set-up, with low pressure lingering off the coast of southern New England for several days. Snowfall was difficult to forecast due to concerns about precipitation type and boundary layer temperature. In the end, precipitation type turned out to be all snow for much of the area, with most locations receiving 1 to 2 feet of snow. In addition, the Massachusetts east coast was hit by widespread moderate and pockets of major coastal flooding for two high tide cycles and beach erosion for at least 5 high tide cycles. Eight to eighteen inches of snow fell across southern Bristol County.

- February 8, 2013 – An historic winter storm deposited tremendous amounts of snow over all of southern New England. Along the southeast coast, average amounts ranged from 1 to 2 feet. The "Blizzard of 2013" also produced a prolonged period of very strong winds Friday night along the Massachusetts coast. Gusts exceeded hurricane force (74 mph) at a few locations. The strong winds, combined with a wet snow, led to extensive power outages from downed trees and wires in southeast coastal MA. Although there was some structural damage, it did not come close to what was experienced during the Blizzard of 1978. Minor tidal flooding occurred along the south coast of Massachusetts during times of high tide. Blizzard conditions were observed at New Bedford Regional Airport for a total of four and a half hours. This event resulted in a major disaster declaration for Bristol County.

The Blizzard of 2013 brought down power lines on and made travel difficult on West Island. *Courtesy of M.L. Baron / West Island Weather Station.*

- January 12, 2011 – A developing nor'easter coastal storm dumped up to two feet of snow across Massachusetts in a 24-hour period. Strong winds combined with the heavy snow along the coast producing numerous downed trees and wires, resulting in 100,000 homes without power statewide, though most were in southeastern Massachusetts. Seven to ten inches of snow fell across southern Bristol County which experienced approximately $75,000 in property damage. In Fairhaven, a local amateur radio operator recorded a wind gust of 47 mph and numerous trees and power poles were reportedly downed.

- From December 2010 through February 2011, southern New England, including Bristol County, saw a series of winter storms that led to record snowfall for the season. Heavy snow, combined with rain led to numerous flooding problems across the county, roof collapses, and downed trees and utility lines.

Event descriptions for some additional historic severe winter storm events impacting the region are provided below. These summaries are based heavily on information available in the Massachusetts State Hazard Mitigation Plan. Local impacts to Fairhaven are included where available.

- January 23, 2005 – A major winter storm brought heavy snow, high winds, and coastal flooding to southern New England. This was the first blizzard to affect the Commonwealth since the April 1997 storm. Near-blizzard conditions were reported in other areas and brought between one and three feet of snow and produced wind gusts of up to 65 mph. The highest snowfall totals were reported in eastern Massachusetts (between two and three feet). Minor to moderate coastal flooding was observed around high tide in eastern Massachusetts coast. This event resulted in a major disaster declaration for Bristol County.
- December 6-7, 2003 – A major winter storm brought one to three feet of snow and strong winds to southern New England. In Massachusetts, snowfall amounts averaged between one and two feet across the Commonwealth. Minor coastal flooding was reported due to high seas of up to 30 feet off the eastern coast. This event resulted in a federal emergency declaration for Bristol County.
- March 2003 – A major winter storm struck southern New England, bringing heavy snow and strong winds. This event was the most significant of the 2002-2003 winter, with snowfall totals of one to two feet. This event resulted in a major disaster declaration for Bristol County.
- March 5-6, 2001 – A major winter storm impacted Massachusetts with near blizzard conditions, high winds, and coastal flooding. It brought over two feet of snow across the interior and caused power outages to approximately 80,000 people. Businesses and schools were closed for several days. There were numerous reports of downed trees and wires during the height of the storm. After the storm, the weight of the snow caused several roof collapses throughout the Commonwealth. Northeast winds affected much of the east coast and southeast of Massachusetts. Speeds of 50 to 60 mph were observed. High tides during the storm were two to three feet above normal, which resulted in widespread coastal flooding. This event resulted in a federal emergency declaration for Bristol County.
- January 1996 – This storm was one of the most significant winter storms to hit southern New England in the past 20 years and was named "The Blizzard of '96" as it dumped record snowfalls from the mid-Atlantic states to southern New England. Technically, this storm only reached a true blizzard by National Weather Service criteria for a few hours in a small section of eastern Massachusetts around South Weymouth during the early morning hours on January 8th. Very heavy snowfall, which was measured in feet, was the main effect of this storm. It was the most region-wide heavy snowfall since the "Blizzard of '78." Totals ranged from 15 to 25 inches, with many totals of 20 to 25 inches in parts of Plymouth and Bristol Counties. This event resulted in a major disaster declaration for Bristol County.
- March 13-17, 1993 – A major winter storm brought high winds and heavy snow to Massachusetts. Boston's Logan Airport recorded a wind gust to 81 mph, and a gust to 83 mph occurred at the Blue Hill Observatory. Snowfall was generally 10 to 20 inches across the area and blizzard conditions existed for a 3 to 6-hour period during the afternoon of March 13. Unlike the December 1992 storm, the snow was a dry enough to minimize accumulation on

trees and wires which precluded widespread power outages. The coastal flood potential was not realized, since the strongest onshore winds did not correspond to high tide and the duration was not long enough to produce exceptionally large waves. This event resulted in a major disaster declaration for Bristol County.

- February 1978 – The town is buried under about 26 inches of snow that was accompanied by hurricane force winds in the "Blizzard of '78." More details on this storm event are provided under Coastal Storms (see under previous occurrences).

A.3.9.5 Probability of Future Occurrences

Severe winter storms will continue to be a ***highly likely*** occurrence in the planning area. It is anticipated that the effects of climate change will result in winters that are much shorter with fewer cold days and more precipitation, but less precipitation falling as snow and more as rain. This will result in reduced snowpack, earlier breakup of winter ice on lakes and rivers, and earlier spring snowmelt resulting in earlier peak river flows.

A.4. VULNERABILITY ASSESSMENT

This section provides information on the methods and results of a GIS-based vulnerability assessment for select hazards in Fairhaven. It includes the following sub-sections:

- **Approach and Methodology** – Provides a brief description of the data sources and methods applied, along with any notable assumptions, limitations, or resource constraints.
- **Hazard Exposure Tables** – Provides the results of the exposure analysis conducted for community assets and those natural hazards with geographically-defined risk areas.
- **Future Development/Vulnerability –** Provides a summary of potential future vulnerability based on the analysis of current development trends, population projections, future land use policies, and the analysis of vacant and potentially developable land parcels.
- **Summary of Potential Hazard Impacts –** provides a summary of key findings and conclusions from the vulnerability assessment.

A.4.1. APPROACH AND METHODOLOGY

Fairhaven's GIS-based vulnerability analysis included two assessments: (1) for all parcels and buildings; and (2) for Town-identified critical facilities. The approach and methodology for each are provided below.

Vulnerability Analysis for Parcels and Buildings

The vulnerability of existing parcels and buildings in Fairhaven to natural hazards was determined through a GIS-based exposure analysis that combined the Town's Assessor data records with available hazard data layers used to map and illustrate hazard risk. The Town's existing tax parcel and property value data (dated 2012) were used to estimate the number of parcels (developed and undeveloped) and buildings located in identified hazard areas along with their respective assessed values. The parcel data set provides information about the parcel size, land use type, and assessed value among other characteristics. The parcel data was also classified into various land use types based on the Massachusetts Department of Revenue's Property Type Classification Code for Fiscal Year 2018, as described below in **Table A-17** below.

Table A-17: Fairhaven's Land Use Classification Based on Massachusetts Land Use Codes

Land Use Category	Land Use Codes Used in Vulnerability Analysis	Description
Residential (Single Family)	101, 106	Residential single-family lots
Residential (Multi-Family)	013, 102, 103, 104, 105, 109, 111, 112, 121, 959	Multi-family units, apartments, condos etc.
Commercial	031, 037, 0137, 140, 323, 325, 326, 330, 331, 332, 335, 337, 340, 342	Retail stores and shops, offices, restaurants, automotive centers, commercial parking lots etc.
Industrial	034, 041, 313, 315, 316, 318, 334, 400, 401, 402, 403, 423	Oil and gas storage, gas stations, lumberyards, and other storage and warehouse facilities
Public Services	091, 350, 351, 354, 900, 910, 931, 934, 935, 951, 953, 954, 955, 957, 960, 961, 962, 970, 972, 990	Banks, hospitals & medical offices, childcare services, schools, fire stations, buses, marinas, funeral services, electrical substation and other utility towers, town offices, post offices, churches, courthouses, libraries, etc.
Temporary Lodging	300, 301, 304	Hotels, inns, resorts, nursing homes
Agriculture	016, 017, 076, 601, 713, 716, 717, 718	Agricultural land, orchards, forested land, cranberry bogs, etc.
Open Space	910, 950	Residential open space, non-productive agricultural land, beaches, conservation land etc.
Vacant	130, 131, 132, 390, 391, 392, 395, 930, 932, 936	Vacant developable, potentially developable, and undevelopable land
Recreation	384, 958	Golf courses, bowling, tennis, golf, ice skating, campground, boat ramps, bike paths, function halls, community centers, clubs etc.

To determine each parcel and building's vulnerability, a GIS overlay analysis was conducted in which hazard extent maps (as shown in section A.3, Hazard Profiles) were overlaid with the parcel data and existing building footprint data. This vulnerability analysis was conducted for the following hazards:

1. Riverine and Coastal Flooding
2. Hurricane Storm Surge
3. Wildfire
4. Sea Level Rise*
   ** Data developed by Buzzards Bay National Estuary Program (BBNEP) and the Massachusetts Office of Coastal Zone Management (CZM) was used for this analysis.*

Description of Data Sources:

1. Riverine and Coastal Flooding – Hazard location and extent was determined using the current effective FEMA Flood Insurance Rate Map (FIRM) data for Fairhaven, dated July 16, 2014. The FIRM is the official map on which FEMA has delineated both the special flood hazard areas and the risk premium zones applicable to the community under the National Flood Insurance Program (NFIP). This includes high risk areas that have a 1 percent chance of being flooded in any year (often referred to as the "100-year floodplain"), which under the NFIP, is linked to mandatory purchase requirements for federally-backed mortgage loans. It also identifies moderate to low risk areas, defined as the area with a 0.2 percent chance of flooding in any year (often referred to as the "500-year floodplain"). For purposes of this exposure analysis, the following special flood hazard areas as identified in the Town of Fairhaven's current FIRMs were included:

    - Flood Zone A (AE, AH) – 1% Annual Chance Flood Hazard
    - Flood Zone VE – 1% Annual Chance Flood Hazard with Velocity Wave Action (Coastal High Hazard Area)
    - Flood Zone X (shaded) – 0.2% Annual Chance Flood Hazard
    - Flood Zone X (unshaded) – Area with Reduced Risk Due to Levee

2. Hurricane Storm Surge – Hazard location and extent was determined using data from the Sea, Lake and Overland Surges from Hurricanes (SLOSH) model as generated by the U.S. Army Corps of Engineers, New England District. Developed to assist emergency management officials in hurricane preparedness and operations, this data layer represents worst-case Hurricane Surge Inundation areas for Category 1 through 4 hurricanes striking the coast of Massachusetts. Hurricane surge values for the four different scenarios included in our analysis were developed by the National Hurricane Center using the PV2 basin SLOSH Model data, and was obtained through the Massachusetts Office of Geographic Information (MassGIS) in February 2017.

3. Wildfire – Hazard location and extent was determined using data from the Silvis Lab at the University of Wisconsin, which in partnership with the USDA Forest Service, has developed a methodology to spatially identify wildland urban interface (WUI) areas across the US. The WUI is defined as the area where urban development meets vegetated, wildfire prone lands, and the mapping by the Silvis Lab identifies two different types of WUI areas: intermix and interface. Intermix WUI are areas where housing and vegetation intermingle; interface WUI are areas with housing in the vicinity of contiguous wildland vegetation. More information on the data sources and methods used for this mapping is available at http://silvis.forest.wisc.edu/maps/wui. For purposes of this exposure analysis the following six density classes were used:

    - High density / interface
    - High density / intermix
    - Medium density / interface
    - Medium density / intermix
    - Low density interface
    - Low density intermix

    The use of these different classes in the exposure analysis allowed for a more detailed differentiation of wildfire risk by considering the density factor, with the assumption being that increased density correlates with an increased risk of fire and fire spread. Using GIS, built parcel areas were classified according to their density to identify three risk classes (low, medium, and high-risk areas).

4. Sea Level Rise – Hazard location and extent for sea level rise was determined using the future base flood elevation (BFE) scenarios developed by the Buzzards Bay National Estuary Program (BBNEP) and Massachusetts Office of Coastal Zone Management (CZM). This data was created as part of a study completed in early 2013 to determine the potential of future flood zone expansion with sea level rise. More information on the study, including the data sources and methods used, is available at http://climate.buzzardsbay.org/flood-zone-expansion.html. For purposes of this exposure analysis, the following four sea level rise scenarios were applied:
    - BFE
    - BFE +1 feet sea level rise
    - BFE + 2 feet sea level rise
    - BFE + 4 feet sea level rise

Description of Methods:

1. Riverine and Coastal Flooding, Hurricane Storm Surge, and Wildfire – To calculate the exposure of parcels and buildings to these first three hazards, we simply identified the parcels with buildings that are located (completely or partially) within identified hazard zones using the ArcGIS overlay analysis (i.e., select by location using the intersect function). The number of parcels and buildings for each land use category was then totaled, along with the value of buildings and real property values associated with those parcels. These figures provide a strong indication of current hazard vulnerability, as well potential future vulnerability as it relates to vacant and potentially developable parcels.

2. Sea Level Rise – By overlaying the various sea level rise scenarios on top of the BFE, areas at risk to future flooding inundation with sea level rise were identified and mapped. The BFE and sea level rise data included parcel information for each of the impacted buildings and allowed for a differentiation into building and property values. For the purposes of this analysis we totaled values for building and property value for each of the potential sea level rise scenarios.

Vulnerability Analysis for Critical Facilities

The following types and numbers of critical facilities were identified for the Town of Fairhaven and included in the exposure analysis:

- Sewer Pump Station (17)
- Sewer Wastewater Treatment Plant (2)
- Town Hall (1)
- School (5)
- Nursing Home (3)
- Police Station (1)
- Fire Station (1)
- Library* (1)
- Housing Authority Property (4)
- Emergent Medical Associates (1)
- Animal Shelter (1)

- Recreation Center (1)
  * *The library located at the public school is not counted separately, but as part of the school.*

Once all critical facilities were confirmed by the HMPC, they were identified and mapped in ArcGIS based on the confirmed physical location/address. Similar to the vulnerability analysis for parcels and buildings, each was then overlaid with the identified and mappable hazard zones (Riverine and Coastal Flooding, Hurricane Storm Surge, Wildfire, and Sea Level Rise). For purposes of this analysis it was assumed that the physical location of a critical facility within a hazard area (completely or partially) meant that it is exposed and potentially vulnerable to that specific hazard; however, it is recognized that more site-specific evaluations are required to confirm this assumption.

A.4.2. HAZARD EXPOSURE TABLES

The results of the vulnerability assessment conducted for Fairhaven's existing community assets are summarized on the following pages, which include a series of exposure tables for those natural hazards with geographically-defined risk areas (riverine and coastal flooding, hurricane storm surge, wildfire, and sea level rise). These tables include the following:

- Table A-18: Exposure to Flooding in FEMA Zone A (1-percent-annual-chance without velocity wave action)
- Table A-19: Exposure to Flooding in FEMA Zone VE (1-percent-annual-chance with velocity wave action)
- Table A-20: Exposure to Flooding in FEMA Zone X (0.2 percent annual chance)
- Table A-21: Exposure to Flooding in FEMA Protected Zone X (Reduced Flood Risk Due to Levee)
- Table A-22: Exposure to Hurricane Storm Surge (Category 1)
- Table A-23: Exposure to Hurricane Storm Surge (Category 2)
- Table A-24: Exposure to Hurricane Storm Surge (Category 3)
- Table A-25: Exposure to Hurricane Storm Surge (Category 4)
- Table A-26: Exposure to Future/Expanded Flood Zone Due to Sea Level Rise
- Table A-27: Exposure to Wildfire (High Risk)
- Table A-28: Exposure to Wildfire (Moderate Risk)
- Table A-29: Exposure to Wildfire (Low Risk)
- Table A-30: Exposure of Critical Facilities to Flood Hazards
- Table A-31: Exposure of Critical Facilities to Wildfire Hazards

For all other natural hazards, it is generally assumed that the Town's community assets are uniformly exposed (for example, to severe winter storms). However, it is also understood that some segments of the population and specific physical assets may inherently be more vulnerable to the effects of these hazards based on their individual characteristics. While this plan does not include an in-depth study of these specific vulnerabilities, they were acknowledged and discussed by the HMPC upon completion of this hazard analysis and risk assessment and in the development of the mitigation strategy.

Flood

Table A-18: Exposure to Flooding in FEMA Zone A (1-percent-annual-chance without velocity wave action)

Land Use	Number of Parcels			Value of Buildings			Value of Total Property		
	Total	Total in Hazard Area	% in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area
Residential (Single Family)	9,244	600	6.5	$1,012,879,200	$60,397,800	6	$2,282,062,100	$150,060,500	6.6
Residential (Multi Family)	921	84	9.2	$123,750,404	$13,818,500	11.2	$231,605,904	$25,490,600	11
Commercial	250	33	13.2	$91,430,500	$6,004,500	6.6	$176,497,613	$10,747,813	6.1
Industrial	143	17	11.9	$38,312,200	$7,162,400	18.7	$79,310,600	$18,467,000	23.3
Public Services	205	20	9.8	$83,859,400	$5,076,800	6	$139,097,900	$10,543,000	7.6
Temporary Lodging	12	9	75	$17,105,400	$12,624,300	73.8	$33,620,400	$25,535,700	76
Agriculture	45	1	2.2	$2,223,800	$332,000	14.9	$5,564,610	$578,228	10.4
Open Space	150	2	1.3	$1,294,800	0	0	$30,524,600	$143,000	0.5
Vacant	2,622	26	1	$292,400	0	0	$177,082,800	$3,058,400	1.7
Recreation	39	3	7.7	$16,818,500	$1,682,700	10	$26,889,400	$4,490,000	16.7
Total	**13,631**	**795**	**5.8**	**$1,387,966,604**	**$107,099,000**	**7.7**	**$3,182,255,927**	**$249,114,241**	**7.8**

Table A-19: Exposure to Flooding in FEMA Zone VE (1-percent-annual-chance with velocity wave action)

Land Use	Number of Parcels			Value of Buildings			Value of Total Property		
	Total	Total in Hazard Area	% in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area
Residential (Single Family)	9,244	1,097	11.9	$1,012,879,200	$107,146,200	10.6	$2,282,062,100	$352,994,800	15.5
Residential (Multi Family)	921	18	2	$123,750,404	$2,442,500	2	$231,605,904	$7,633,200	3.3
Commercial	250	1	0.4	$91,430,500	$22,000	0.02	$176,497,613	$193,500	0.1
Industrial	143	2	1.4	$38,312,200	$160,900	0.4	$79,310,600	$908,100	1.1
Public Services	205	5	2.4	$83,859,400	$509,100	0.6	$139,097,900	$2,808,900	2
Temporary Lodging	12	0	0	$17,105,400	$0	0	$33,620,400	$0	0
Agriculture	45	2	4.4	$2,223,800	$558,200	25.1	$5,564,610	$1,166,151	21
Open Space	150	4	2.7	$1,294,800	$431,600	33.3	$30,524,600	$2,761,600	9
Vacant	2,622	45	1.7	$292,400	$25,900	8.9	$177,082,800	$6,265,600	3.5
Recreation	39	0	0	$16,818,500	$0	0	$26,889,400	$0	0
Total	**13,631**	**1,174**	**8.6**	**$1,387,966,604**	**$111,296,400**	**8.0**	**$3,182,255,927**	**$374,731,851**	**11.8**

Table A-20: Exposure to Flooding in FEMA Zone X (0.2-percent-annual-chance)

Land Use	Number of Parcels			Value of Buildings			Value of Total Property		
	Total	Total in Hazard Area	% in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area
Residential (Single Family)	9,244	302	3.2	$1,012,879,200	$32,822,600	3.2	$2,282,062,100	$73,766,200	3.2
Residential (Multi Family)	921	7	0.7	$123,750,404	$1,768,300	1.4	$231,605,904	$3,381,700	1.5
Commercial	250	6	2.4	$91,430,500	$1,654,700	1.8	$176,497,613	$2,615,913	1.5
Industrial	143	0	0	$38,312,200	$0	0	$79,310,600	$0	0
Public Services	205	2	1	$83,859,400	$2,955,900	3.5	$139,097,900	$3,242,800	2.3
Temporary Lodging	12	0	0	$17,105,400	$0	0	$33,620,400	$0	0
Agriculture	45	0	0	$2,223,800	$0	0	$5,564,610	$0	0
Open Space	150	0	0	$1,294,800	$0	0	$30,524,600	$0	0
Vacant	2,622	6	0.2	$292,400	$0	0	$177,082,800	$201,700	0.1
Recreation	39	0	0	$16,818,500	$0	0	$26,889,400	$0	0
Total	**13,631**	**323**	**2.4**	**$1,387,966,604**	**$39,201,500**	**2.8**	**$3,182,255,927**	**$83,208,313**	**2.6**

Table A-21: Exposure to Flooding in FEMA Protected Zone X (Reduced Flood Risk Due to Levee)

Land Use	Number of Parcels			Value of Buildings			Value of Total Property		
	Total	Total in Hazard Area	% in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area
Residential (Single Family)	9,244	737	8	$1,012,879,200	$83,840,300	8.3	$2,282,062,100	$174,584,600	7.7
Residential (Multi Family)	921	206	22.3	$123,750,404	$34,948,300	28.2	$231,605,904	$59,114,000	25.5
Commercial	250	23	9.2	$91,430,500	$4,381,000	4.8	$176,497,613	$6,660,300	3.7
Industrial	143	14	9.8	$38,312,200	$7,016,800	18.3	$79,310,600	$17,614,200	22.2
Public Services	205	20	9.8	$83,859,400	$16,284,100	19.4	$139,097,900	$21,693,600	15.6
Temporary Lodging	12	1	8.3	$17,105,400	$1,493,700	8.7	$33,620,400	$2,694,900	8
Agriculture	45	0	0	$2,223,800	$0	0	$5,564,610	$0	0
Open Space	150	0	0	$1,294,800	$0	0	$30,524,600	$0	0
Vacant	2,622	3	0.1	$292,400	$0	0	$177,082,800	$95,600	0.05
Recreation	39	0	0	$16,818,500	$0	0	$26,889,400	$0	0
Total	**13,631**	**1,004**	**7.4**	**$1,387,966,604**	**$147,964,200**	**10.7**	**$3,182,255,927**	**$282,457,200**	**8.9**

Hurricane Storm Surge

Table A-22: Exposure to Hurricane Storm Surge (Category 1)

Land Use	Number of Parcels			Value of Buildings			Value of Total Property		
	Total	Total in Hazard Area	% in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area
Residential (Single Family)	9,244	730	7.9	$1,012,879,200	$65,786,900	6.5	$2,282,062,100	$235,420,200	10.3
Residential (Multi Family)	921	15	1.6	$123,750,404	$1,928,000	1.6	$231,605,904	$6,490,100	2.8
Commercial	250	1	0.4	$91,430,500	$22,000	0.02	$176,497,613	$193,500	0.1
Industrial	143	1	0.7	$38,312,200	$138,900	0.4	$79,310,600	$714,600	0.9
Public Services	205	3	1.5	$83,859,400	$466,300	0.6	$139,097,900	$2,269,000	1.6
Temporary Lodging	12	0	0	$17,105,400	$0	0	$33,620,400	$0	0
Agriculture	45	1	2.2	$2,223,800	$226,200	10.2	$5,564,610	$587,923	10.6
Open Space	150	3	2	$1,294,800	$431,600	0	$30,524,600	$2,660,300	8.7
Vacant	2,622	28	1.1	$292,400	$25,900	8.9	$177,082,800	$4,811,000	2.7
Recreation	39	0	0	$16,818,500	$0	0	$26,889,400	$0	0
Total	**13,631**	**782**	**5.7**	**$1,387,966,604**	**$69,025,800**	**5.0**	**$3,182,255,927**	**$253,146,623**	**8.0**

Table A-23: Exposure to Hurricane Storm Surge (Category 2)

Land Use	Number of Parcels			Value of Buildings			Value of Total Property		
	Total	Total in Hazard Area	% in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area
Residential (Single Family)	9,244	1,488	16.1	$2,025,758,400	$150,339,700	14.8	$4,564,124,200	$471,208,300	20.6
Residential (Multi Family)	921	22	2.4	$247,500,808	$3,673,100	3.0	$463,211,808	$10,371,500	4.5
Commercial	250	6	2.4	$182,861,000	$2,133,900	2.3	$352,995,226	$3,660,613	2.1
Industrial	143	1	0.7	$76,624,400	$138,900	0.4	$158,621,200	$714,600	0.9
Public Services	205	7	3.5	$167,718,800	$3,078,600	3.7	$278,195,800	$7,705,600	5.5
Temporary Lodging	12	0	0.0	$34,210,800	$0	0.0	$67,240,800	$0	0.0
Agriculture	45	3	6.6	$4,447,600	$784,400	35.3	$11,129,220	$1,754,074	31.6
Open Space	150	6	4.0	$2,589,600	$863,200	0.0	$61,049,200	$5,351,900	17.5
Vacant	2,622	57	2.2	$584,800	$25,900	8.9	$354,165,600	$7,612,200	4.3
Recreation	39	0	0.0	$33,637,000	$0	0.0	$53,778,800	$0	0.0
Total	**13,631**	**1,590**	**11.7**	**$2,775,933,208**	**$161,037,700**	**5.8**	**$6,364,511,854**	**$508,378,787**	**8.0**

Table A-24: Exposure to Hurricane Storm Surge (Category 3)

Land Use	Number of Parcels			Value of Buildings			Value of Total Property		
	Total	Total in Hazard Area	% in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area
Residential (Single Family)	9,244	2,124	23.0	$3,038,637,600	$221,434,700	21.8	$6,846,186,300	$637,931,400	27.9
Residential (Multi Family)	921	35	3.8	$371,251,212	$6,463,300	5.3	$694,817,712	$15,939,800	6.9
Commercial	250	18	7.2	$274,291,500	$5,458,800	5.9	$529,492,839	$9,130,626	5.2
Industrial	143	1	0.7	$114,936,600	$138,900	0.4	$237,931,800	$714,600	0.9
Public Services	205	9	4.5	$251,578,200	$6,034,500	7.2	$417,293,700	$10,948,400	7.8
Temporary Lodging	12	0	0.0	$51,316,200	$0	0.0	$100,861,200	$0	0.0
Agriculture	45	5	11.0	$6,671,400	$1,342,600	60.4	$16,693,830	$2,920,225	52.6
Open Space	150	7	4.7	$3,884,400	$863,200	0.0	$91,573,800	$5,453,200	17.8
Vacant	2,622	69	2.7	$877,200	$25,900	8.9	$531,248,400	$7,909,200	4.5
Recreation	39	0	0.0	$50,455,500	$0	0.0	$80,668,200	$0	0.0
Total	**13,631**	**2,268**	**16.6**	**$4,163,899,812**	**$241,761,900**	**5.8**	**$9,546,767,781**	**$690,947,451**	**7.2**

Table A-25: Exposure to Hurricane Storm Surge (Category 4)

Land Use	Number of Parcels			Value of Buildings			Value of Total Property		
	Total	Total in Hazard Area	% in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area
Residential (Single Family)	9,244	4,789	51.8	$4,051,516,800	$519,650,200	51.2	$9,128,248,400	$1,261,137,200	55.2
Residential (Multi Family)	921	529	57.4	$495,001,616	$85,882,500	69.5	$926,423,616	$153,161,500	66.2
Commercial	250	97	38.8	$365,722,000	$19,614,500	21.4	$705,990,452	$33,267,439	18.9
Industrial	143	26	18.2	$153,248,800	$8,674,300	22.7	$317,242,400	$22,312,700	28.1
Public Services	205	65	31.8	$335,437,600	$44,486,900	53.1	$556,391,600	$61,567,400	44.2
Temporary Lodging	12	12	100.0	$68,421,600	$17,105,400	100.0	$134,481,600	$33,620,400	100.0
Agriculture	45	6	13.2	$8,895,200	$1,594,300	71.7	$22,258,440	$3,333,548	60.0
Open Space	150	9	6.0	$5,179,200	$863,200	0.0	$122,098,400	$5,601,900	18.3
Vacant	2,622	119	4.6	$1,169,600	$25,900	8.9	$708,331,200	$11,269,300	6.4
Recreation	39	4	10.3	$67,274,000	$907,000	5.4	$107,557,600	$2,656,400	9.9
Total	**13,631**	**5,656**	**41.5**	**$5,551,866,416**	**$698,804,200**	**12.6**	**$12,729,023,708**	**$1,587,927,787**	**12.5**

Sea Level Rise

Table A-26: Exposure to Future/Expanded Flood Zone Due to Sea Level Rise

BFE Scenario	Number of Parcels			Value of Buildings			Value of Total Property		
	Total	Total in Hazard Area	% in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area
BFE	6,488	1,198	18.5	$1,058,279,218	$146,278,900	13.8	$2,214,462,288	$449,492,361	20.3
BFE +1 foot SLR		52	0.8		$5,813,500	0.5		$13,810,600	0.6
BFE +2 feet SLR		47	0.7		$5,590,100	0.5		$12,765,300	0.6
BFE +4 feet SLR*		1,538	23.7		$252,482,500	23.8		$490,297,900	22.14
Total	**6,488**	**2,835**	**43.7**	**$1,058,279,218**	**$410,165,000**	**38.8**	**$2,214,462,288**	**$966,366,161**	**43.6**

* *The Buzzards Bay Floodplain Elevation Study assumes that at 4 feet SLR, the hurricane barrier would be overtopped.*

Wildfire

Table A-27: Exposure to Wildfire (High Risk)

Land Use	Number of Parcels			Value of Buildings			Value of Total Property		
	Total	Total in Hazard Area	% in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area
Residential (Single Family)	9,244	1,010	10.9	$1,012,879,200	$98,904,300	9.8	$2,282,062,100	$214,732,900	9.4
Residential (Multi Family)	921	168	18.2	$123,750,404	$22,747,700	18.4	$231,605,904	$39,556,500	17.1
Commercial	250	19	7.6	$91,430,500	$2,864,600	3.1	$176,497,613	$5,137,400	2.9
Industrial	143	1	0.7	$38,312,200	$570,700	1.5	$79,310,600	$791,700	1
Public Services	205	11	5.4	$83,859,400	$6,467,400	7.7	$139,097,900	$8,205,200	5.9
Temporary Lodging	12	0	0	$17,105,400	$0	0	$33,620,400	$0	0
Agriculture	45	0	0	$2,223,800	$0	0	$5,564,610	$0	0
Open Space	150	0	0	$1,294,800	$0	0	$30,524,600	$0	0
Vacant	2,622	13	0.5	$292,400	$0	0	$177,082,800	$441,400	0.3
Recreation	39	0	0	$16,818,500	$0	0	$26,889,400	$0	0
Total	**13,631**	**1,222**	**9.0**	**$1,387,966,604**	**$131,554,700**	**9.5**	**$3,182,255,927**	**$268,865,100**	**8.4**

Table A-28: Exposure to Wildfire (Moderate Risk)

Land Use	Number of Parcels			Value of Buildings			Value of Total Property		
	Total	Total in Hazard Area	% in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area
Residential (Single Family)	9,244	2,835	30.7	$1,012,879,200	$337,104,500	33.3	$2,282,062,100	$695,163,400	30.5
Residential (Multi Family)	921	116	12.6	$123,750,404	$20,777,900	16.8	$231,605,904	$36,795,800	15.9
Commercial	250	59	23.6	$91,430,500	$32,890,400	36	$176,497,613	$58,506,311	33.2
Industrial	143	14	9.8	$38,312,200	$1,848,000	4.8	$79,310,600	$5,175,000	6.5
Public Services	205	22	10.7	$83,859,400	$19,893,300	23.7	$139,097,900	$29,612,400	21.3
Temporary Lodging	12	1	8.3	$17,105,400	$5,745,200	33.6	$33,620,400	$6,847,600	20.4
Agriculture	45	8	17.8	$2,223,800	$751,800	33.8	$5,564,610	$1,601,721	28.8
Open Space	150	1	0.7	$1,294,800	$0	0	$30,524,600	$107,000	0.4
Vacant	2,622	79	3.01	$292,400	$234,800	80.3	$177,082,800	$5,349,600	3
Recreation	39	4	10.3	$16,818,500	$709,700	4.3	$26,889,400	$2,645,700	9.8
Total	**13,631**	**3,139**	**23.0**	**$1,387,966,604**	**$419,955,600**	**30.3**	**$3,182,255,927**	**$841,804,532**	**26.5**

Table A-29: Exposure to Wildfire (Low Risk)

Land Use	Number of Parcels			Value of Buildings			Value of Total Property		
	Total	Total in Hazard Area	% in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area	Total Value	Total Value in Hazard Area	% Value in Hazard Area
Residential (Single Family)	9,244	189	2	$1,012,879,200	$21,920,300	2.2	$2,282,062,100	$52,209,200	2.6
Residential (Multi Family)	921	6	0.7	$123,750,404	$1,372,400	1.2	$231,605,904	$3,108,700	1.3
Commercial	250	6	2.4	$91,430,500	$1,819,200	2	$176,497,613	$8,190,023	4.6
Industrial	143	7	4.9	$38,312,200	$5,052,500	13.2	$79,310,600	$9,774,100	12.3
Public Services	205	4	2	$83,859,400	$3,072,800	3.7	$139,097,900	$4,913,400	3.5
Temporary Lodging	12	0	0	$17,105,400	$0	0	$33,620,400	$0	0
Agriculture	45	12	26.7	$2,223,800	$1,008,300	45.3	$5,564,610	$3,052,065	54.8
Open Space	150	1	0.7	$1,294,800	$0	0	$30,524,600	$537,500	1.8
Vacant	2,622	8	0.3	$292,400	$0	0	$177,082,800	$852,900	0.5
Recreation	39	0	0	$16,818,500	$0	0	$26,889,400	$0	0
Total	**13,631**	**233**	**1.7**	**$1,387,966,604**	**$34,245,500**	**2.5**	**$3,182,255,927**	**$82,637,888**	**2.6**

Critical Facilities

Table A-30: Exposure of Critical Facilities to Flood Hazards

Critical Facility	FEMA Flood Zones				Hurricane Storm Surge				Future/Expanded Flood Zone Due to Sea Level Rise			
	Zone A	Zone VE	Zone X	Protected Zone X	Cat 1	Cat 2	Cat 3	Cat 4	BFE	BFE +1'	BFE +2'	BFE +4'
Sewer Pump Station	3	8	2	1	5	4	2	3	13			1
Wastewater Treatment Plant												
Town Hall								1				1
School				1				1				1
Nursing Home				1				2				2
Police Station												
Fire Station												
Library								1				1
Other critical facilities												

Table A-31: Exposure of Critical Facilities to Wildfire Hazards

Critical Facility	Risk Zone		
	Low	Moderate	High
Sewer Pump Station	1	4	
Wastewater Treatment Plant		1	
Town Hall			
School		2	
Nursing Home		1	
Police Station			
Fire Station			
Library			
Other critical facilities: Housing Authority Properties			3
Other critical facilities: Animal Shelter, Senior / Recreation Center		2	

A.4.3. FUTURE DEVELOPMENT/VULNERABILITY

The preceding analysis and tabular data provide specific details on the current exposure of various properties, buildings, and other community assets to those natural hazards with geographically-defined risk areas. However, in completing the hazard analysis and risk assessment, it is also important to consider and factor in potential *future* exposure and vulnerability of these assets and new development to hazards.

As described in Section 3 (Community Profile), Fairhaven's population has remained steady since the 1970s, and that this trend of a general static population count is expected to continue. Similarly, growth and development over the past few decades have been relatively slow and will be managed as such moving forward into the future. Any new or substantially-improved development will be constructed to higher regulatory standards than much of the existing development (e.g., in compliance with modern building codes and existing ordinances designed with natural hazards in mind), and thus is generally expected to be less vulnerable. Appendix B (Capability Assessment) provides detailed descriptions of the Town's existing capabilities and resources to reduce hazard risk to future development through these measures. The greater concern for Fairhaven as it relates to future development is the likelihood of some natural hazards becoming more frequent and/or severe due to changing climate conditions as summarized in the hazard profiles in Section A.3 (under *Probability of Future Occurrences*).

Nonetheless, one method to help quantify the potential of future development that could be exposed to natural hazards is to consider the number and location of vacant and potentially developable land parcels. In total, there are 2,622 parcels in Fairhaven that fall into this category. For analysis purposes, it is assumed that all 2,622 parcels could potentially be developed because according to the data provided, these lands do not include any permanently protected open space. **Table A-32** identifies the number of these vacant and potentially developable land parcels that are located within each geographically-defined risk area, and if developed, potentially exposed to riverine and coastal flooding, hurricane storm surge, and wildfire. As can be see there is a relatively very small percentage of remaining vacant parcels that are within identified hazard risk areas, suggesting that future exposure to these hazards will not be dramatically increased even if vacant parcels become developed. In addition, as stated above, it is generally felt by the HMPC that any new or substantially-improved development on these parcels would be constructed to standards that make it more resilient and less vulnerable to the effects of natural hazards.

Table A-32: Exposure of Vacant Parcels to Select Natural Hazards

Natural Hazard Risk Areas	Vacant Parcels	
	Number Exposed	Percentage Exposed
Flood		
FEMA Zone A (1-percent-annual-chance without velocity wave action)	26	1
FEMA Zone VE (1-percent-annual-chance with velocity wave action)	45	1.7
FEMA Protected Zone X (Reduced Flood Risk Due to Levee)	3	0.1

Hurricane Storm Surge		
Category 1	28	1.1
Category 2	29	1.1
Category 3	12	0.5
Category 4	50	1.9
Wildfire		
High Risk	13	0.5
Moderate Risk	79	3.01
Low Risk	8	0.3

A.4.4. SUMMARY OF POTENTIAL HAZARD IMPACTS

Tables A.33 through A-35 quantify the total number of developed parcels, buildings, and their total property values that are considered exposed to riverine and coastal flooding, hurricane storm surge, and wildfire. A narrative summary of the tables is provided below.

Table A-33: Summary of Exposure to Flood (FEMA Mapped Flood Zones)

Flood Zone	Number of Parcels with Buildings		Value of Buildings		Value of Total Property	
	Total in Hazard Area	% in Hazard Area	Total Value in Hazard Area	% Value in Hazard Area	Total Value in Hazard Area	% Value in Hazard Area
Zone A	795	5.8	$107,099,000	7.7	$249,114,241	7.8
Zone VE	1,174	8.6	$111,296,400	8.0	$374,731,851	11.8
Zone X	323	2.4	$39,201,500	2.8	$83,208,313	2.6
Protected Zone X	1,004	7.4	$147,964,200	10.7	$282,457,200	8.9
Total	**3,296**	**24.2**	**$405,561,100**	**29.2**	**$989,511,605**	**31.1**

Table A-34: Summary of Exposure to Hurricane Storm Surge

Storm Category	Number of Parcels with Buildings		Value of Buildings		Value of Total Property	
	Total in Hazard Area	% in Hazard Area	Total Value in Hazard Area	% Value in Hazard Area	Total Value in Hazard Area	% Value in Hazard Area
Category 1	782	5.7	$69,025,800	5	$253,146,623	8
Category 2	1,590	11.7	$161,037,700	5.8	$508,378,787	8
Category 3	2,268	16.6	$241,761,900	5.8	$690,947,451	7.2

Category 4	5,656	41.5	$698,804,200	12.6	$1,587,927,787	12.5

Table A-35: Summary of Exposure to Wildfire

Wildfire Risk Zone	Number of Parcels with Buildings		Value of Buildings		Value of Total Property	
	Total in Hazard Area	% in Hazard Area	Total Value in Hazard Area	% Value in Hazard Area	Total Value in Hazard Area	% Value in Hazard Area
High Risk	1,222	9	$131,554,700	9.5	$268,865,100	8.4
Moderate Risk	3,139	23	$419,955,600	30.3	$841,804,532	26.5
Low Risk	233	1.7	$34,245,500	2.5	$82,637,888	2.6
Total	**4,594**	**33.7**	**$585,755,800**	**42.2**	**$1,193,307,520**	**37.5**

As can be seen in the figures there are nearly 3,300 developed parcels (with buildings) and nearly $1 billion in property value located in FEMA mapped flood zones; however, 1,004 of these parcels are considered protected by the hurricane barrier, and another 323 are located in the 0.2-percent-annual-chance flood zone (500-year floodplain), so also considered at a moderate risk. In total, there are nearly 2,000 developed parcels located in identified high-risk flood zones, with the majority (1,174) located in coastal high hazard areas with velocity wave action (Zone VE).

As expected, many of the properties that are located in high-risk flood zones identified by FEMA are also in hurricane storm surge inundation zones as mapped by the US Army Corps of Engineers. Nearly 2,300 properties are considered at risk to storm surge flooding from a Category 3 hurricane. An additional 3,388 properties could be inundated by the worst-case scenario Category 4 storm, which assumes failure of the hurricane barrier (note: this is an assumption that was considered beyond the "maximum probable extent" for mitigation planning purposes, as indicated in the next section).

While more than 4,500 properties have been identified in areas that are potentially at risk to wildfire, only approximately 1,200 are in areas classified as high risk.

A.5. SUMMARY FINDINGS AND CONCLUSIONS

The Hazard Analysis and Risk Assessment completed for the Town of Fairhaven includes both quantitative and qualitative information to help determine the potential impact of each identified hazard on community assets. This information provides significant findings that allow the HMPC to prioritize hazard risks and proposed hazard mitigation strategies and actions.

To assist in this process, the HMPC applied a "Priority Risk Index" (PRI). The PRI is a tool designed to (1) summarize relevant hazard profile information as included in section A.2; and (2) measure the degree of relative risk each hazard poses to Fairhaven based on that information. The PRI was used to assist the HMPC in ranking and prioritizing hazards based on a variety of characteristics including location, probability, potential impact, warning time, and duration.

The PRI results in numerical values that allow identified hazards to be ranked against one another – the higher the PRI value, the greater the hazard risk. PRI values are obtained by assigning varying degrees of risk to each of the five characteristics, or categories. Each degree of risk has been assigned an index value (1 to 4) and an agreed upon weighting factor, as summarized in **Table A36**.

To calculate the PRI value for a given hazard, the assigned index value for each category is multiplied by the weighting factor. The sum of all five categories equals the final PRI value, as demonstrated in the below equation:

PRI VALUE =

(LOCATION x .20) + (PROBABILITY x .30) + (POTENTIAL IMPACT x .30) + (WARNING TIME x .10) + (DURATION x .10)

According to the weighting scheme applied for the Town of Fairhaven, the highest possible PRI value is 4.0. Prior to being finalized, PRI values for each hazard were reviewed and accepted by the HMPC.

Table A-36: Priority Risk Index (PRI)

PRI CATEGORY	DEGREE OF RISK			ASSIGNED WEIGHTING FACTOR
	LEVEL	CRITERIA	INDEX VALUE	
Location	Negligible	Less than 1% of planning area affected	1	20%
	Small	1-10% of planning area affected	2	
	Moderate	10-50% of planning area affected	3	
	Large	50-100% of planning area affected	4	
Probability	Unlikely	Less than 1% annual probability	1	30%
	Possible	1-10% annual probability	2	
	Likely	10-90% annual probability	3	
	Highly Likely	90-100% annual probability	4	
Potential Impact *	Minor	Very few injuries, if any. Only minor property damage and minimal disruption to quality of life. Partial or complete shutdown of critical facilities for less than one day.	1	30%
	Limited	Minor injuries only. 10-25% of property in affected area damaged or destroyed. Complete shutdown of critical facilities for more than one day.	2	
	Critical	Multiple fatalities/injuries possible. More than 25% of property in affected area damaged or destroyed. Complete shutdown of critical facilities for more than one week.	3	
	Catastrophic	High number of fatalities/injuries possible. More than 50% of property in affected area damaged or destroyed. Complete shutdown of critical facilities for more than one month.	4	
Warning Time	More than 24 hours		1	10%
	12 to 24 hours		2	
	6 to 12 hours		3	
	Less than 6 hours		4	
Duration	Less than 6 hours		1	10%
	6 to 24 hours		2	
	1 to 7 days		3	
	More than 1 week		4	

* Potential impact is based upon the estimated *maximum probable extent* (magnitude/severity) for each hazard based on historic events or future probability data, as shown in **Table A-37**.

Table A-37: Maximum Probable Extent

HAZARD	MAXIMUM PROBABLE EXTENT
Coastal Erosion and Sea Level Rise	Long-term erosion rate of 2+ feet per year or sea level rise of 5 feet by 2100
Coastal Storm	Category 3 hurricane on Saffir-Simpson Hurricane Wind Scale; or Intensity Index Category 4 on Classification Scheme for Nor'easters
Drought	Drought Emergency as determined by the Massachusetts Drought Management Plan
Earthquake	6.5 on Richter Scale and Intensity VII on Modified Mercalli Intensity scale
Extreme Temperatures	5 consecutive days with heat index exceeding 100°F or wind chill of less than -20°F
Fire	100 acres burned along wildland-urban interface
Flood (3 Types):	
Riverine Flood	1 Percent Annual Chance Flood for all inland FEMA Special Flood Hazard Areas
Coastal Flood	Worst Case Storm Surge Inundation for Category 3 Hurricane
Urban Flood	10-year Design Storm Event
Severe Weather	Wind gusts in excess of 50 knots, hail measuring at least three-quarters of an inch in diameter, or tornado occurrence
Severe Winter Storm	Category 5 on Regional Snowfall Index; or Intensity Index Category 4 on Classification Scheme for Nor'easters

Table A-38 summarizes the degree of risk assigned for all identified hazards in Fairhaven based on the application of the PRI tool, along with the calculated PRI values. Please note that more detailed information on the specific locations, probabilities, vulnerabilities and potential impacts for each hazard in Fairhaven are provided in each hazard-specific profile in section A.3, in addition to the vulnerability assessment tables provided in section A.4. This detailed information was the basis for determining the overall summary of hazards as provided in Table A-38.

Table A-38: Summary of PRI Results

HAZARD	CATEGORY/DEGREE OF RISK					PRI Value
	LOCATION	PROBABILITY	POTENTIAL IMPACT*	WARNING TIME	DURATION	
Coastal Erosion and Sea Level Rise	Moderate	Highly Likely	Limited	More than 24 hours	More than 1 week	**2.9**
Coastal Storm	Large	Likely	Catastrophic	More than 24 hours	1 to 7 days	**3.3**
Drought	Large	Possible	Minor	More than 24 hours	More than 1 week	**2.2**
Earthquake	Large	Possible	Minor	Less than 6 hours	Less than 6 hours	**2.2**
Extreme Temperatures	Large	Possible	Minor	More than 24 hours	1 to 7 days	**2.1**
Fire	Moderate	Highly Likely	Limited	Less than 6 hours	6 to 24 hours	**3.0**
Flood (3 Types):						
Riverine Flood	Small	Likely	Limited	More than 24 hours	1 to 7 days	**2.7**
Coastal Flood	Large	Likely	Catastrophic	More than 24 hours	1 to 7 days	**3.3**
Urban Flood	Small	Likely	Minor	Less than 6 hours	Less than 6 hours	**2.1**
Severe Weather	Moderate	Highly Likely	Critical	Less than 6 hours	Less than 6 hours	**3.2**
Severe Winter Storm	Large	Highly Likely	Critical	More than 24 hours	1 to 7 days	**3.3**

The calculated PRI values were used by the HMPC to classify each hazard according to three defined risk levels (Low, Moderate, or High) as shown in **Table A-39**. It should be noted that although some hazards are classified as posing "low" risk, their occurrence of varying or unprecedented magnitudes is still possible and they will continue to be evaluated by the Town of Fairhaven during future updates to this plan.

Table A-39: Conclusions on Hazard Risk

HIGH RISK	Coastal Storm Coastal Flood Severe Winter Storm Severe Weather
MODERATE RISK	Fire Coastal Erosion and Sea Level Rise Riverine Flood
LOW RISK	Drought Earthquake Extreme Temperatures Urban Flood