



2021 Hazard Mitigation Plan Update

40 Shattuck Road | Suite 110
Andover, Massachusetts 01810
800.426.4262

woodardcurran.com

229808.00
Town of Barnstable, MA
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1. THE PLANNING PROCESS

The Town of Barnstable (the Town or Barnstable), located in Barnstable County, Massachusetts, has developed this Hazard Mitigation Plan (HMP) update to identify and profile the town's risk and vulnerability to potential natural hazards and to build upon the resiliency efforts first outlined in its 2010 HMP. Specifically, this update assesses the potential impacts of hurricanes, winter storms, shoreline change/coastal erosion, earthquakes, drought/wildfire, and dam failure and identifies properties, resources, and critical facilities which may be impacted by these hazard events. The update identifies mitigation strategies and actions aimed at reducing the loss of or damage to life, property, infrastructure and natural, cultural, and economic resources. A corresponding implementation plan has been prepared to address the prioritization and administration of the identified strategies and actions. Lastly, the update includes a schedule for monitoring, evaluating, and further updating the plan in the future.

This plan was prepared in compliance with the Robert T. Stafford Disaster Relief and Emergency Assistance Act, the Disaster Mitigation Act of 2000, and 44 CFR §201.6. Furthermore, this plan was developed in collaboration with the Cape Cod Commission (CCC), the Cape's regional land use planning and regulatory agency.

1.1 PURPOSE OF THE PLAN

Hazard mitigation is defined as any sustained action to reduce and/or eliminate short or long-term risk to life and property from natural hazards. The purpose of this plan update is to lessen the impact of a disaster before it occurs and provide the following benefits to the Town of Barnstable:

1. Protect lives and reduce social, emotional, and economic disruption following a disaster event;
2. Prevent the loss of property, infrastructure, and natural and cultural resources from natural disasters;
3. Increase public awareness of risk and vulnerability to natural disasters;
4. Increase access to funding sources for hazard mitigation projects; and
5. Improve the ability to implement post-disaster recovery projects.

These disaster mitigation goals are an effort to reduce or avoid both short and long-term vulnerabilities to the identified hazards. The objectives of the proposed mitigation strategies will include a section that identifies specific mitigation actions and analysis to reduce the effects of each hazard with particular attention on new and existing buildings and structures.

1.2 THE PLANNING TEAM

The hazard mitigation planning team consisted of representatives from a comprehensive range of Town Departments and local agencies dealing with issues related to hazard mitigation and risk assessment. The team was comprised of the following members that either attended the HMP update workshop at Town Hall or participated via separate virtual meeting session with Woodard & Curran and the Planning Staff for the Town of Barnstable:

Workshop Attendees:

- Elizabeth Jenkins, AICP, Director of Planning & Development
- Kate Maldonado, Assistant Director Planning & Development
- James Kupfer, AICP, MPA, Senior Planner, Planning & Development
- Derek Lawson, Marine and Environmental Affairs Director
- Brian Taylor, Harbor Master, Marine and Environmental Affairs
- Peter Burke, Hyannis Fire Chief

- David Wedd, Hyannis Fire Department
- Megan Savage, Safety Officer
- Gordon Starr, Town Council
- Mary House and Matthew Jones, Woodard & Curran
- Joe Maruca, West Barnstable Fire Chief
- Amber Unruh, Senior Project Manager, DPW
- Nathan Collins, Assistant Town Engineer, DPW
- Darcy Karle, Conservation Administrator
- Jeff Carter, Deputy Director, Inspectional Services
- Nina Z Coleman, Natural Resources Director/Sandy Neck Park Manager

Virtual Meeting Attendees:

- Shannon Hulst, Deputy Director; Floodplain Specialist & CRS Coordinator, Cape Cod Cooperative Extension & Woods Hole Sea Grant
- Greg Berman, Coastal Processes Specialist, Cape Cod Cooperative Extension & Woods Hole Sea Grant
- Heather McElroy, Natural Resources Specialist, Cape Cod Commission
- Chloe Schaefer, Chief Planner, Cape Cod Commission
- Martha Hevenor, Planner, Cape Cod Commission

1.3 THE PLANNING PROCESS

The Town's Planning & Development Department oversaw the development of this HMP plan update. The Planning & Development project lead, James Kupfer, identified the HMP update team and convened the team at a half day workshop on November 8, 2021, to review the 2010 HMP and evaluate hazards, risks, and vulnerabilities and recommend and prioritize mitigation actions.

An HMP team was originally assembled in 2004, in conjunction with the Cape Cod Commission's initiative to develop a multi-jurisdictional multi-hazard mitigation plan in compliance with the Disaster Management Act of 2000. The Town of Barnstable Planning Department (GMD) completed a considerable amount of work on a local HMP plan during 2004, but the plan was never locally adopted or submitted to FEMA for certification. The GMD resumed the HMP planning process in 2010 by reviewing and updating the original draft of the plan and reconvening the MHM team. The following provides a summary of the planning process.

The HMP team first identified and reviewed the goals of the multi-hazard mitigation plan for the Town of Barnstable and reviewed the natural hazards that could potentially affect the Town. In the initial planning stages, the MHM team accomplished the following:

- A review of a history of past events, which are represented primarily by the Regional Hazard Risk Maps.
- An evaluation of the risk or frequency of each hazard occurring.
- An evaluation of the potential extent, or severity, of each identified hazard.
- A determination of the scope of potential damage that could be inflicted by each identified hazard.

The HMP team reviewed the Town's overall vulnerability to the hazards addressed in this plan and the Hazard Identification Matrix to ensure the scope and severity of potential disasters were accurately represented. The team reviewed the Risk and Vulnerability Assessment Map and Regional Hazard Risk Maps to ensure they represented all specific geographic locations that are vulnerable for the identified hazards. An existing list of critical facilities was

reviewed, updated, and analyzed for this plan. The Town's GIS department conducted an analysis of structures vulnerable to flooding. Finally, the Town's participation in the National Flood Insurance Program was reviewed.

Led by the Town's Planning & Development department with outside support from Woodard & Curran, an update to the 2010 HMP was attempted and several of the plan's components were completed in 2016, but the HMP was not finalized or submitted. At this time, a workshop was held with key stakeholders to obtain input on hazards, vulnerabilities and critical facilities and develop mitigation actions. Goals and objectives were revised to be more comprehensive and encompass the top hazards identified.

In 2018, the Town received a grant from the Massachusetts Executive Office of Energy and Environmental Affairs Municipal Vulnerability Preparedness (MVP) Program to identify vulnerabilities from natural hazards and climate change and develop actions to mitigate the hazards. The Town of Barnstable contracted with staff from the Cape Cod Commission and Woods Hole Sea Grant & Cape Cod Cooperative Extension to guide the process to become a MVP certified community and engage community stakeholders through a community resilience building workshop held on March 29, 2019. Subsequently, The Town published the findings from the community resilience building workshop and achieved its MVP designation.

In 2021, the Town's Planning & Development department contracted with Woodard & Curran to revisit the work completed in 2016 and to refresh and finalize an update to the 2010 HMP. The Town of Barnstable held a half day workshop with the planning team on November 8, 2021, to discuss the 2021 HMP update. At this meeting, the Town of Barnstable reviewed the components of previous hazard mitigation documents, discussed proposed revisions and project timelines, presented major hazard concerns, identified asset changes, reviewed recent emergency events and planned preventative actions, discussed repetitive losses, and determined mitigation projects to continue and introduce in the 2021 update. To close out the meeting, the Town of Barnstable discussed the next steps for public involvement, formal adoption, and submission to MEMA and FEMA.

On November 19, 2021 and December 10, 2021 members of the Cape Cod Cooperative Extension and the Cape Cod Commission respectively, had a virtual meeting to provide input into the plan. Conversations focused on crucial mitigation project interests and implementation.

1.4 REGIONAL COOPERATION

The Cape Cod Commission (CCC) led a regional effort to develop a multi-jurisdictional hazard mitigation plan for Barnstable County. The Barnstable County Natural Hazards Pre-Disaster Mitigation Plan (the Regional PDM plan) addresses natural hazards affecting all of Cape Cod. The Town of Barnstable has maintained continuing representation on the regional Multiple Hazard Community Planning Team. The regional team consists of representatives from all 15 Cape Cod communities and representatives from regional environmental, social, and emergency management groups. The CCC began the process to update the 2004 regional plan in June of 2009 and has provided ongoing technical support for the development of this plan, and other local plans.

1.5 PUBLIC PARTICIPATION

This plan update was formulated and reviewed by the Town's HMP Team, but also benefited from review by the general public. A Public review process is essential to the development of an inclusive and effective plan. A draft of the plan was made available for review on the Town website on [date] and a public comment period was open through [date].

Finally, the draft plan was presented to the Town of Barnstable Planning Board at its [date] meeting. The meeting was advertised and open to the public for public comment. The public provided valuable comments regarding [summarize comments received]. The contents of the plan were reviewed with the Board at a televised meeting.

2. GOALS AND OBJECTIVES

This section outlines the goals and objectives identified by the Town of Barnstable to guide its philosophy and approach to creating a more resilient community. The goals were expanded significantly from the 2010 HMP to more directly address the top priority hazards faced by this coastal community.

2.1 HAZARD IDENTIFICATION

According to FEMA guidance documentation, a goal serves as a general guideline that explains what a community would like to achieve and an objective defines a specific strategy or implementation step that will help reach a specific goal. The following goals and objectives in **Table 2-1** are reflective of goals articulated in Barnstable's previous hazard mitigation plans and include changes and updates based on stakeholder and staff input to guide the implementation of the 2021 Hazard Mitigation Plan.

Table 2-1: Barnstable 2021 Hazard Mitigation Plan Goals

Goal #	Details
Goal 1	Protect lives and reduce social, emotional, and economic disruption following a disaster event as soon as practicable.
Goal 2	Prevent the loss and reduction in value of property, infrastructure, and natural and cultural resources from natural disasters.
Goal 3	Increase public awareness of risk and vulnerability to natural disasters.
Goal 4	Increase access to funding sources for hazard mitigation projects.
Goal 5	Improve the ability to implement post-disaster recovery projects.

Barnstable reviewed the 2010 Mitigation Strategies and made some modifications including referring to them in this 2021 plan update as objectives to accompany and help achieve the identified goals. The strategy for the goals and objectives is to address the threat and impact of natural hazard events through preventative regulations, property and natural resource protection, structural improvements and increased public awareness. Mitigation Objectives were reviewed and revised for this 2021 Barnstable Hazard Mitigation Plan update, which are shown in **Table 2-2**.

Table 2-2: Barnstable 2021 Hazard Mitigation Plan Objectives

Objective #	Details
Objective 1	Preserve the natural and beneficial functions of the town's floodplain, wetlands, beaches and dunes through continued support of natural resource protection.
Objective 2	Limit development in high hazard and environmentally-sensitive areas to minimize loss of life and structures, reduce erosion and prevent other environmental damage resulting from natural hazards.
Objective 3	Support the protection and restoration of barrier beaches and coastal banks to the greatest extent possible to protect important wildlife habitat from storm surge, preserve recreational amenities and enhance these natural features that provide flood protection.
Objective 4	Reduce wildfire hazard within vulnerable open space lands and urban interface zones through integrated and proactive land management programs as well as education and outreach efforts.
Objective 5	Adopt and/or amend (re)development regulations applicable to land, structures and wastewater systems in hazard-prone areas to ensure structures are designed to withstand potential events and to prevent the disturbance of natural areas.

Objective #	Details
Objective 6	Incorporate hazard mitigation goals into the Town's land acquisition strategy, considering both direct acquisition and acquisition of development rights. Focus on acquiring parcels with high development pressure in hazard-prone areas and reducing the number of repetitive loss properties.
Objective 7	Continue to foster educational outreach programs that promote awareness of hazard risks and vulnerabilities and increase community responsibility for actions and their impacts.
Objective 8	Educate property owners on the affordable, individual mitigation and preparedness measures that can be taken before a hazard event.
Objective 9	Increase the resilience of critical facilities and infrastructure so that it is capable of withstanding or being protected from the impacts of natural hazards.
Objective 10	Coordinate local hazard mitigation planning, climate change and resiliency and associated activities with the Cape Cod Commission, Barnstable County Regional Emergency Planning Committee and neighboring towns.
Objective 11	Enhance and support the Town's capability to conduct hazard risk assessments, demonstrate funding needs and track mitigation activities. Improve institutional knowledge of cost-effective mitigation and preparedness measures.
Objective 12	Identify and implement infrastructure projects that will increase the level of protection of vulnerable areas from natural hazards and will provide long-term mitigation benefits.

3. NATURAL HAZARDS

The Town of Barnstable has the potential to be impacted by a wide range of natural hazards and each one presents certain risks to life and property. Understanding what specific hazards have and may impact the community is required by FEMA regulations and guidance detailed in the Disaster Mitigation Act of 2000. This section identifies the natural hazards that have impacted Barnstable in the past and those that could affect the community in the future.

3.1 HAZARD IDENTIFICATION

The term hazard in this plan is defined as an extreme natural event that poses a risk to people, infrastructure, property or resources. The natural hazards identified and included in this plan received their initial consideration from FEMA Guidance documentation. The hazards were then further researched by utilizing current and historical data points from various sources including but not limited to NOAA, US Census, FEMA Disaster Declarations and other regional/state planning documents, including the Massachusetts Hazard Mitigation Plan (2013). The Town of Barnstable reviewed the findings of each identified natural hazard and considered them against local knowledge to finalize the list of natural hazards that have impacted Barnstable in the past or could impact the community in the future.

3.1.1 Natural Hazards Impacting Barnstable

Table 3-1 identifies hazards that may affect the Town of Barnstable, a profile of the associated risks, and a record of previous occurrences.

Table 3-1: Natural Hazards Impacting Barnstable

Natural Hazard	Impacted Barnstable in the Past?	Sources Used to Make Determination	Verified by Barnstable Local Plan Review Team	Why is this Natural Hazard Relevant to Barnstable?
Coastal Erosion, Shoreline Change	Yes	<ul style="list-style-type: none"> Town of Barnstable Multi-Hazard Mitigation Plan (2010) Town of Barnstable MVP Summary of Findings Report (2019) Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) Barnstable County, Cape Cod Hazard Mitigation Plan (2010) StormSmart Coasts - Massachusetts Shoreline Change Project Local Knowledge from Town Staff 	Yes	There is a strong history and documentation of coastal erosion and shoreline change in Barnstable.

Natural Hazard	Impacted Barnstable in the Past?	Sources Used to Make Determination	Verified by Barnstable Local Plan Review Team	Why is this Natural Hazard Relevant to Barnstable?
Hurricane	Yes	<ul style="list-style-type: none"> • Town of Barnstable Multi-Hazard Mitigation Plan (2010) • Town of Barnstable MVP Summary of Findings Report (2019) • Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) • Barnstable County, Cape Cod Hazard Mitigation Plan (2010) • Local Knowledge from Town Staff 	Yes	There is a history of hurricane events impacting Barnstable.
Dam Failure	No	<ul style="list-style-type: none"> • Town of Barnstable Multi-Hazard Mitigation Plan (2010) • Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) • Local Knowledge from Town Staff 	Yes	Barnstable has several “significant” hazard dams located in the community.
Earthquake	No	<ul style="list-style-type: none"> • Town of Barnstable Multi-Hazard Mitigation Plan (2010) • Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) • Barnstable County, Cape Cod Hazard Mitigation Plan (2010) • USGS Information by Region: Massachusetts (2021) • Local Knowledge from Town Staff 	Yes	The state plan acknowledges Massachusetts is at risk for an earthquake event.
Wildfire	Yes	<ul style="list-style-type: none"> • Town of Barnstable Multi-Hazard Mitigation Plan (2010) • Town of Barnstable MVP Summary of Findings Report (2019) • Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) • Local Knowledge from Town Staff 	Yes	There is a history of wildfires in Barnstable.

Natural Hazard	Impacted Barnstable in the Past?	Sources Used to Make Determination	Verified by Barnstable Local Plan Review Team	Why is this Natural Hazard Relevant to Barnstable?
Flood	Yes	<ul style="list-style-type: none"> • Town of Barnstable Multi-Hazard Mitigation Plan (2010) • Town of Barnstable MVP Summary of Findings Report (2019) • Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) • Barnstable County, Cape Cod Hazard Mitigation Plan (2010) • Local Knowledge from Town Staff 	Yes	There is a history of flooding occurrences in Barnstable.
Nor'easter	Yes	<ul style="list-style-type: none"> • Town of Barnstable Multi-Hazard Mitigation Plan (2010) • Town of Barnstable MVP Summary of Findings Report (2019) • Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) • Barnstable County, Cape Cod Hazard Mitigation Plan (2010) • Local Knowledge from Town Staff 	Yes	There is a history of nor'easter events in Barnstable.
Windstorm	Yes	<ul style="list-style-type: none"> • Town of Barnstable Multi-Hazard Mitigation Plan (2010) • Town of Barnstable MVP Summary of Findings Report (2019) • Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) • Local Knowledge from Town Staff 	Yes	There is a history of windstorm events in Barnstable.
Tornado	Yes	<ul style="list-style-type: none"> • Town of Barnstable Multi-Hazard Mitigation Plan (2010) • Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) • Barnstable County, Cape Cod Hazard Mitigation Plan (2010) • Local Knowledge from Town Staff 	Yes	In August 1977, an F1 tornado touched down in Barnstable. There have also been tornado warnings in Barnstable County.

Natural Hazard	Impacted Barnstable in the Past?	Sources Used to Make Determination	Verified by Barnstable Local Plan Review Team	Why is this Natural Hazard Relevant to Barnstable?
Drought	Yes	<ul style="list-style-type: none"> • Town of Barnstable Multi-Hazard Mitigation Plan (2010) • Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) • Barnstable County, Cape Cod Hazard Mitigation Plan (2010) • Local Knowledge from Town Staff 	Yes	There is a history of drought in Barnstable County.
Severe Winter Weather	Yes	<ul style="list-style-type: none"> • Town of Barnstable Multi-Hazard Mitigation Plan (2010) • Town of Barnstable MVP Summary of Findings Report (2019) • Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) • Barnstable County, Cape Cod Hazard Mitigation Plan (2010) • Local Knowledge from Town Staff 	Yes	There is a history of severe winter weather in Barnstable.
Tsunami	No	<ul style="list-style-type: none"> • Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) 	Yes	The state plan acknowledges coastal areas in Massachusetts are at risk with this type of natural hazard event.
Sea Level Rise	Yes	<ul style="list-style-type: none"> • Town of Barnstable Multi-Hazard Mitigation Plan (2010) • Town of Barnstable MVP Summary of Findings Report (2019) • Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) • Barnstable County, Cape Cod Hazard Mitigation Plan (2010) • Cape Cod Commission Sea Level Rise Viewer • 2014 New England Climate Adaptation Project • Local Knowledge from Town Staff 	Yes	There is a history of Sea Level Rise in Barnstable.

Natural Hazard	Impacted Barnstable in the Past?	Sources Used to Make Determination	Verified by Barnstable Local Plan Review Team	Why is this Natural Hazard Relevant to Barnstable?
Climate Change	Yes	<ul style="list-style-type: none"> • Barnstable County, Cape Cod Hazard Mitigation Plan (2010) • Town of Barnstable MVP Summary of Findings Report (2019) • Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) • 2014 New England Climate Adaptation Project • Local Knowledge from Town Staff 	Yes	There is evidence of Climate Change in Barnstable.
Extreme Temperatures	Yes	<ul style="list-style-type: none"> • Town of Barnstable MVP Summary of Findings Report (2019) • Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan (2018) • 2014 New England Climate Adaptation Project • Local Knowledge from Town Staff 	Yes	There is a history of Extreme Temperatures in Barnstable.

3.1.2 Definition of Probability

The Barnstable Hazard Mitigation Plan considers the probability of natural hazard events profiled in the plan and the potential for them to occur in the future. General descriptors to discuss the probability of these natural hazard events for the purposes of this planning effort include:

- **Highly likely** – Hazard event occurs every 1-10 years.
- **Likely** – Hazard event occurs every 10-50 years.
- **Unlikely** – Hazard event occurs infrequently and greater than every 50 years.
- **Unknown** – Insufficient data exists to make a more specific determination.

In some instances, a natural hazard event is more likely to occur during a specific time of year such as a winter storm or hurricane and this additional information is included in the individual hazard profiles.

3.2 HAZARD PROFILES

3.2.1 Coastal Erosion/Shoreline Change

In general, coastal erosion refers to the wearing away of land that may result in the removal of beaches, dunes or other shoreline vegetation by substantial wave action, tidal currents or drainage. Coastal erosion may result in long-term sediment, rock and sand loss or the redistribution of these features. In severe cases, the shoreline can be temporarily displaced landward and cause damage to personal property. Shoreline structures are a method of mitigation but while they may protect some structures and assets, they can also cause more damage in other areas as a result.

In Barnstable, the coastline is constantly changing, but long-term trends indicate that 73% of Barnstable's shores are experiencing erosion and 25% are experiencing accretion. Shoreline change, specifically erosion, can result in a direct threat to waterfront property and indirectly impacts the developed environment by increasing vulnerability to storm damage and flooding. Erosion and accretion are important natural processes that mitigation actions must respect to protect the long-term health of Barnstable's beaches and dunes.

Shoreline change can result from both natural and human activity. Gradual sea-level rise and coastal storms are the primary natural causes of erosion. The extent of the erosion or accretion in a particular location is affected by several variables, including the site's exposure to storms and waves and sediment size and transport rates. Human-induced shoreline change results from the interruption of sediment sources by armoring coastal bluffs and the interruption of longshore sediment transport by the construction of jetties and groins.

3.2.1.1 Hazard Location

Coastal erosion and accretion rates along Barnstable's coast are represented in Figure 1 in Appendix A. Areas most adversely impacted by erosion are found on Sandy Neck Beach and the north shore west of Barnstable Harbor where rates of erosion exceed two feet per year. On the south shore of Barnstable, areas with the most extreme erosion impacts are found in small areas west of Hyannis Point and along the west side of Long Beach in Centerville Harbor. **Figure 1** and **Figure 2** illustrate the historic shoreline change in Barnstable using data from the Massachusetts Ocean Resource Information System (MORIS).

Figure 1: Historic Shoreline Change for Barnstable, MA (North Coast)

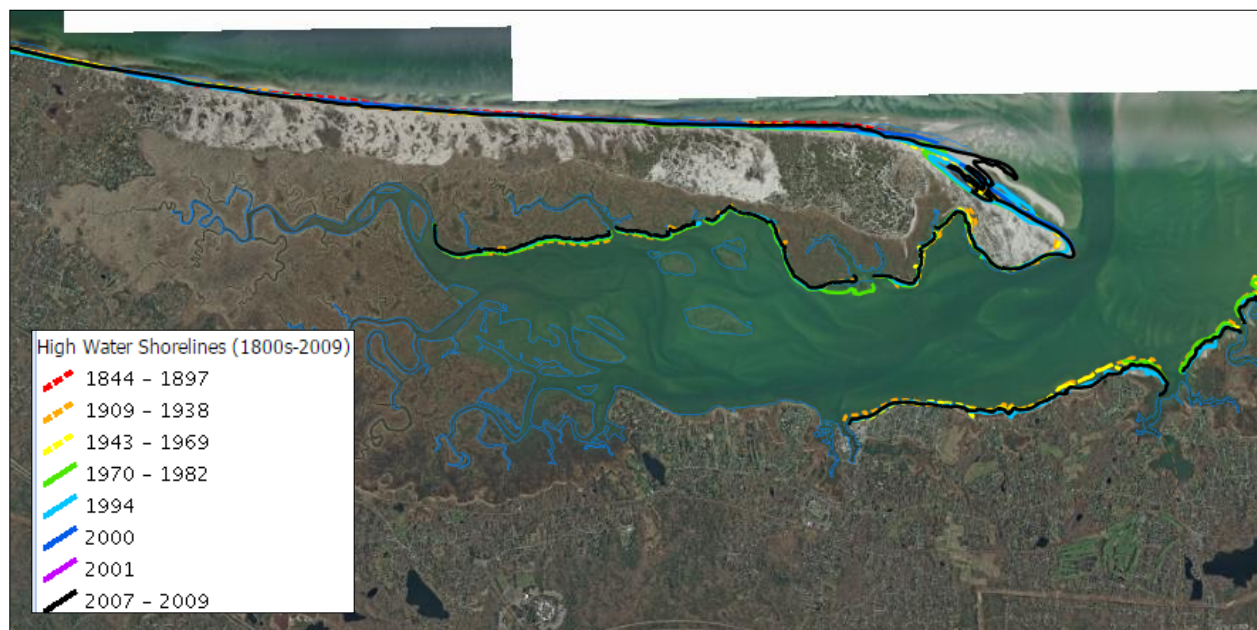


Figure 2: Historic Shoreline Change, Barnstable, MA (South Coast)



3.2.1.2 Previous Occurrences, Severity & Extent of the Hazard

In Massachusetts, the shoreline is eroding and has been over a long period of time at a rate of approximately .56 feet per year¹. A study of shoreline change in Massachusetts by the USGS survey, Woods Hole Oceanographic Institution Sea Grant Program, and Cape Cod Cooperative Extension reveals that approximately 68 percent, or 513 miles, of Massachusetts' ocean-facing shore exhibits a long-term erosion trend, 30 percent, or 226 miles, shows long-term accretion, and two percent, or 15 miles, shows no net change.

In December 2015, the *Report of the Massachusetts Coastal Erosion Commission Volume 1: Findings and Recommendations* was released which is the work, findings, and recommendations of the Massachusetts Coastal Erosion Commission. The tasks of the Commission included making a reasonable assessment of coastal erosion and corresponding financial damage, making a reasonable estimate of damages to occur in the next 10 years under current conditions, evaluating current rules, regulations and laws governing shoreline management, and examining possible changes and cost-effective measures to improve the potential to reduce or eliminate impacts of coastal erosion. Shoreline change analysis was conducted for each community covered by the Shoreline Change Project and the results for Barnstable are included in **Table 3-2**.

Table 3-2: Barnstable Average Shoreline Change Rates and Uncertainty

	Short Term Rate		Long Term Rate	
	Mean (ft/yr)	Standard Dev (ft/yr)	Mean (ft/yr)	Standard Dev (ft/yr)
Entire Town	0.4	5.2	-0.4	2.2
Cape Cod Bay	1.1	7.2	-0.2	2.3
Nantucket Sound	-0.3	2.1	-0.7	2.0

¹ Woods Hole Oceanographic Institute, "Shoreline Change and the Importance of Coastal Erosion," <http://www.whoi.edu/seagrant/page.do?pid=51817&tid=282&cid=88713>, 2021

Barnstable has experienced coastal erosion throughout the community due to its coastal location. Since 2013, the Town has taken emergency parking lot stabilization efforts by bringing in over 28,000 cubic yards of sediment in the Sandy Neck beach area.

3.2.1.3 Impact & Vulnerability

The Town of Barnstable is vulnerable to coastal erosion in the future. Erosion is a natural process, however when it occurs near coastal property, infrastructure or natural resource areas, damage can occur. Coastal erosion in general does not necessarily have an immediate impact on life, property or operations. The impacts of this hazard are a result of repeated occurrences over time of coastal storms that can result in property loss or severe consequences that often require hard infrastructure solutions to protect the built environment. However, coastal erosion and shoreline change can cause significant economic loss due to destruction of buildings, roads, infrastructure, natural resources and habitat areas either through one storm event or through repetitive storm events over time. In 2018, the Town collaborated with the University of Massachusetts to identify landscape-based adaptations for sea level rise documented in “At the Water’s Edge” report.

3.2.1.4 Probability of Future Occurrence

According to FEMA, there has never been a Presidential Disaster Declaration made for coastal erosion in the State of Massachusetts. The NCDC Storm Database does not keep record of erosion events, and the data in this section is anecdotal and research based.

According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the probability of future occurrences is defined by the number of events over a specified period of time. For the purpose of this plan, the probability of a future coastal erosion in Barnstable is **highly likely**. High rates of coastal erosion occur most frequently along long sections of shoreline which are consistently subjected to high wave energy and coastal storms. The factors that determine whether or not a community or area may exhibit greater probability for long term coastal erosion include:

- Exposure to high-energy storms;
- Exposure to high-energy storm waves;
- Sediment size and composition of eroding coastal landforms adjacent to shorelines;
- Relative sea level rise, and
- Human interference with sediment supply (seawalls, jetties).

3.2.2 Hurricane

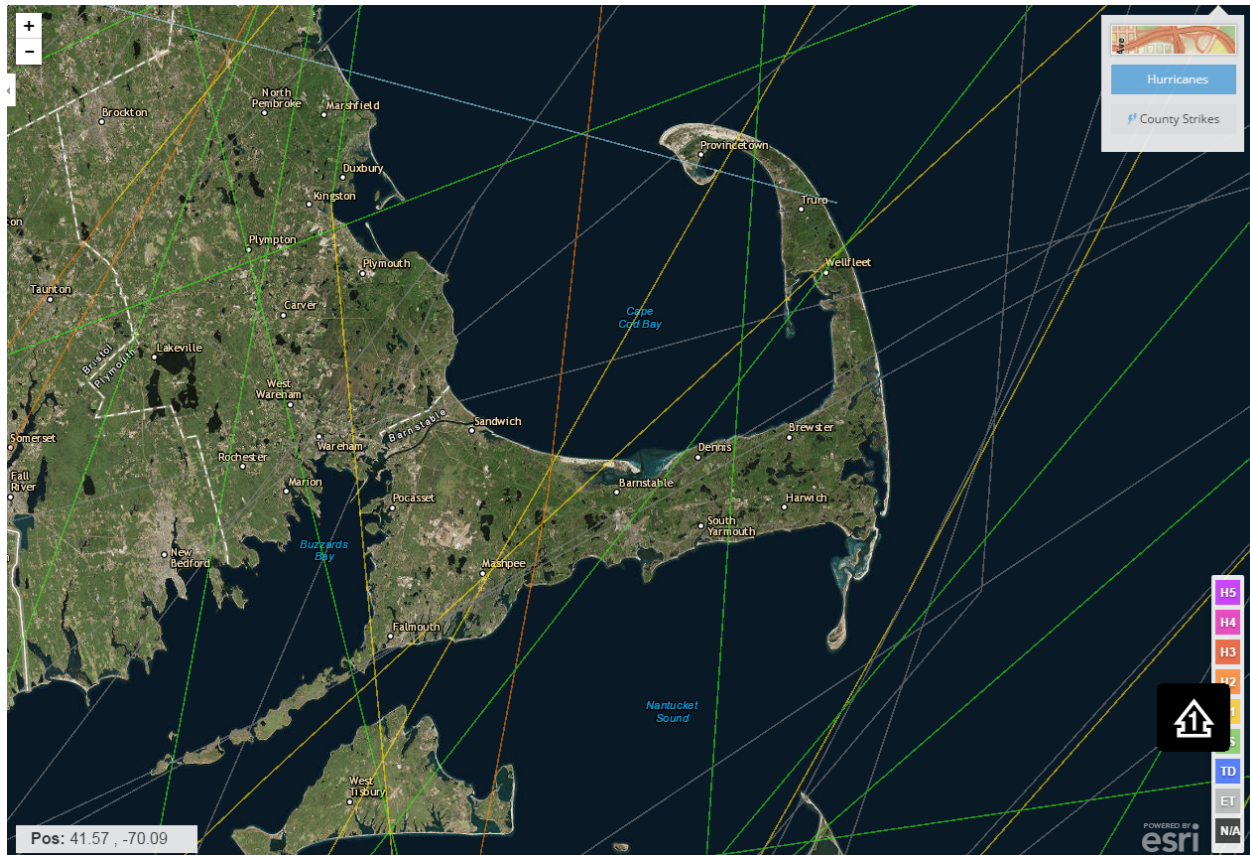
Hurricanes are characterized by a sustained wind speed of 74 miles per hour or more, wind that blows in a large spiral motion around a rotating “eye” (calm center of the storm), and an expansive reach that can extend for hundreds of miles. Powerful in nature, hurricanes can be short in duration or last for several days impacting numerous states, counties and towns along the coastline. The aftermath of a hurricane frequently causes additional damage due to lasting high winds, storm surge, and flooding. Storms that have associated wind speeds between 39 mph and 73 mph are classified as tropical storms. The Atlantic hurricane season runs from June 1st through November 30th. Based on the number and intensity of storms, mid-August through mid-October is defined as the peak period.

3.2.2.1 Hazard Location

Barnstable is susceptible to experiencing hurricane events. According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the entire state is susceptible to hurricanes and tropical storms, but the coastal areas are more susceptible due to the combination of high winds and surge. **Figure 3** shows the historical hurricane tracks that have impacted Barnstable. A map showing Hurricane Inundation Zones is located in **Appendix A**.

Since hurricane tracking began, there have been 10 direct hurricane hits to the Massachusetts coastline. The only other New England state to have as many direct hits was Connecticut. A “direct hit” means that the core of strong winds and/or storm surge was experienced. The Town of Barnstable, as a coastal community, is subject to flooding, storm surge, episodic erosion, tornadoes, and wind damage from hurricanes.

Figure 3: Historical Hurricane Tracks



Source: NOAA Office for Coastal Management

3.2.2.2 Previous Occurrences, Severity & Extent of the Hazard

Since 1954, there have been six Major Disaster Declarations in the State of Massachusetts due to a hurricane or tropical storm and four of those have resulted in Barnstable County receiving a designated area status from FEMA (see **Table 3-3**). Historically, the Town of Barnstable has been directly impacted by at least 3 hurricanes and 1 Tropical Storm (Irene), the most recent storm to impact Barnstable was Hurricane Sandy in 2012.

Table 3-3: Massachusetts Hurricane Major Disaster Declarations (1954 – Present)

	Disaster No.	Incident Period	Date Disaster Declared	Barnstable County a Designated Area?	Notes
Tropical Storm Henri	3566	8/20/2021 -- continuing	8/22/2021	No	Mainly impacted Mashpee Wampanoag Tribe on Cape Cod
Hurricane Sandy	4097	10/27/2012 – 11/08/2012	12/19/2012	Yes	Second costliest hurricane in U.S. history.
Tropical Storm Irene	4028	8/27/2011 – 8/29/2011	9/23/2011	Yes	Impacted most of east coast and is ranked as 6 th costliest hurricane in United States history.
Hurricane Bob	914	8/19/1991	8/26/1991	Yes	60% southern MA and RI residents lost power and the storm surge in Buzzards Bay was 10-15 feet.
Hurricane Gloria	751	9/27/1985	10/28/1985	Yes	Dramatic coastal impact including beach erosion and many flooding issues.
Hurricane Diane	43	8/20/1955	8/20/1955	Unknown	Was a Tropical Storm when it reached New England, had heavy rain of 10" – 20".
Hurricane	22	9/2/1954	9/2/1954	Unknown	There was heavy storm surge to Narragansett Bay and New Bedford Harbor.
<i>Source: FEMA Major Disaster Declarations 1954 – 2021</i>					

Some of the more notable hurricane events include:

- **Hurricane Sandy (2012)** – In the fall of 2012, Hurricane Sandy had a major impact on the New York and New Jersey coastline. The storm broke an all-time record for storm surge height in New York harbor, caused over 100 fatalities, and has reached a cost of over \$79 billion for federal aid to cover damages, recovery and mitigation measures. In Massachusetts, Sandy knocked out power to over 200,000 customers, disrupted travel and closed schools. Downed trees, power lines and flooding were also present during and after the storm. Heavy coastal flooding impacted 3,662 properties in Barnstable County while high winds caused destruction and downed utilities.
- **Hurricane Bob (1991)** – This was a costly hurricane at approximately \$1.5 billion and left extensive damage throughout New England. The loss of life and most of the damage occurred as a result of high winds and rough seas. There were six confirmed tornadoes during its passage. Power outages and a lack of running water were universal across Cape Cod, even at shelters. The Bourne and Sagamore Bridge were closed by officials, isolating the Cape from the mainland. Southern-facing shorelines experienced the most significant erosion, up to 50 feet in some places. Telephone lines were unreliable, if operable, and shelters across the Cape were overfilled with vacationers and boat residents, as well as those who lost their homes in the storm.
- **Hurricane Gloria (1985)** – A storm that hit Long Island, NY and New Jersey that caused minor storm surge, erosion damage and substantial wind damage. Gloria made landfall in the Outer Banks of North Carolina and was a fast-moving hurricane that struck at low tide, reducing storm surges and passing quickly before inflicting maximum wind damage to coastal communities. Its main track passed over eastern Massachusetts, sparing Cape Cod from any significant damage.

For reference and tracking purposes, hurricanes are categorized by class in accordance with the Saffir-Simpson Hurricane Wind Scale (SSHWS) summarized in **Table 3-4**. The SSHWS uses a 1-minute sustained wind speed at a

height of 33 feet over open water as the sole parameter to categorize storm damage potential.² A storm with organized circulation and sustained winds below a Category 1 Hurricane threshold (winds range from 39 to 73 mph) is categorized as a tropical storm.

Table 3-4: Saffir-Simpson Hurricane Wind Scale (SSHWS)

Category	Wind Speed	Storm Surge (feet above normal sea level)	Expected Damage
1	74-95 mph	4-5 feet	Minimal: Damage is done primarily to shrubbery and trees, unanchored mobile homes are damaged, some signs are damaged, damage to structures is minimal or none.
2	96-110 mph	6-8 feet	Moderate: Some trees are toppled, some roof coverings are damaged, and mobile homes may have major damage.
3	111-130 mph	9-12 feet	Extensive: Large trees are toppled, some structural roof damage occurs, mobile homes are destroyed, structural damage to small homes and utility buildings is possible.
4	131-155 mph	13-18 feet	Extreme: Extensive damage is done to roofs, windows and doors; roof systems on small buildings completely fail; some curtain walls fail.
5	> 155 mph	> 18 feet	Catastrophic: Roof damage is considerable and widespread, window and door damage is severe, there are extensive glass failures, and entire buildings could fall.

It is important to note that lower category storms, including tropical storms, can inflict greater damage than higher category storms depending on where and when the storm strikes. Tropical storms have been known to produce significant damage and loss of life, mainly due to flooding.

3.2.2.3 Impact & Vulnerability

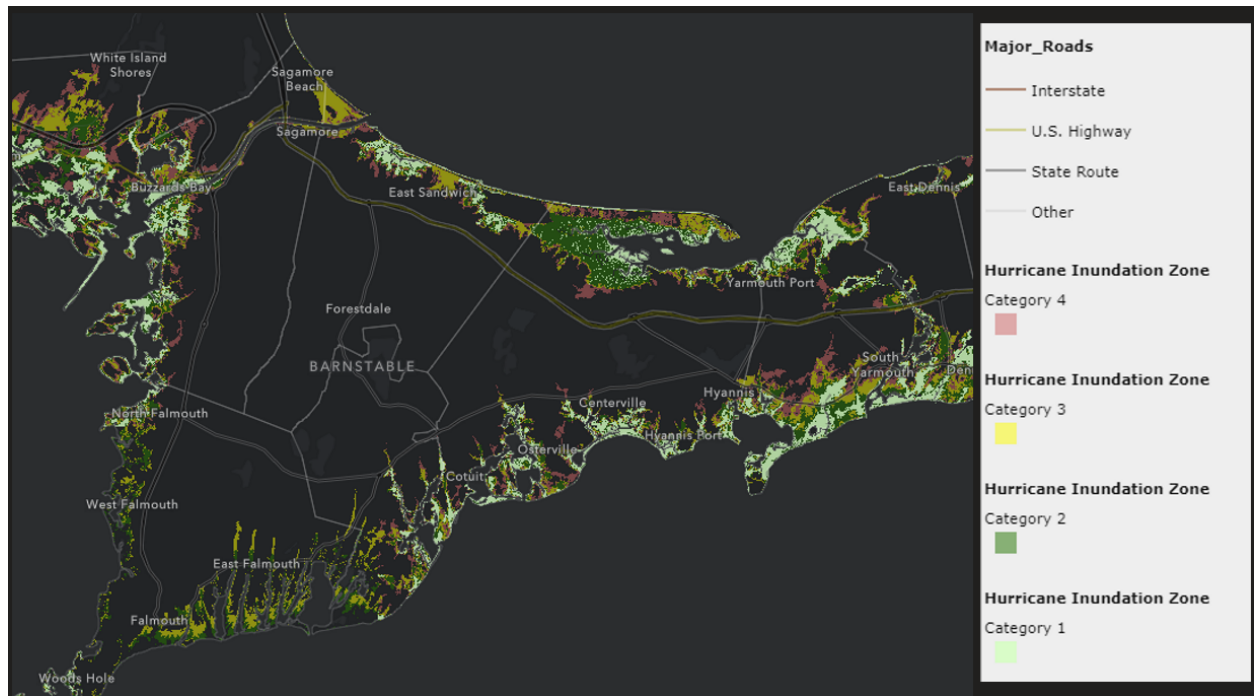
Barnstable is vulnerable to hurricanes due to its proximity to the coast. According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, impacts to the state in addition to a direct hit can include effects from tropical remnants such as heavy rain, localized flooding and storm surge. The greatest impacts from hurricanes to property and infrastructure include wind and water damage: flooding, utility failure, building damage, shoreline erosion, natural resource damage; interruptions with emergency, fire, and police services, and economic loss due to business property damage and loss of inventory. A hurricane can have devastating effects on a large area if directly in the path of a hurricane causing long term affects to the local economy and environment.

One unique impact to Barnstable is that ferry service to Nantucket and Martha's Vineyard operate from the Hyannis Terminal in the inner harbor. During a large-scale hurricane event which would require evacuating these communities, Barnstable would be impacted by a large influx of residents and visitors who may have to leave abruptly and require emergency shelter or other services. Barnstable serves as a lifeline to these two island communities. There is a general concern about the damage that would occur in the inner harbor during a substantial hurricane. The potential impacts to the hospital could also be problematic. If a hurricane does impact Barnstable, areas could be cut off from services,

² FEMA Coastal Construction Manual, 2011

which could impact emergency shelters or the ability to evacuate neighborhoods, most specifically, Osterville Grand Island and could reach the hospital itself. The U.S. Army Corps of Engineers (USACE) has recently updated the hurricane inundation maps for coastal Massachusetts. Each community received a map created using a Sea, Land, and Overland Surges from Hurricanes (SLOSH) model developed by the National Weather Service. The model estimates the potential for storm surge for categories 1-4 hurricanes. **Figure 4** shows the varying degrees of inundation Barnstable may be able to expect from each type of hurricane. Access to Osterville Grand Island, which was previously mentioned as an area of concern, would potentially become limited or impossible during even a Category 1 event.

Figure 4: Hurricane Inundation Zones



Source: [Massachusetts Hurricane Inundation Zones \(arcgis.com\)](https://arcgis.com)

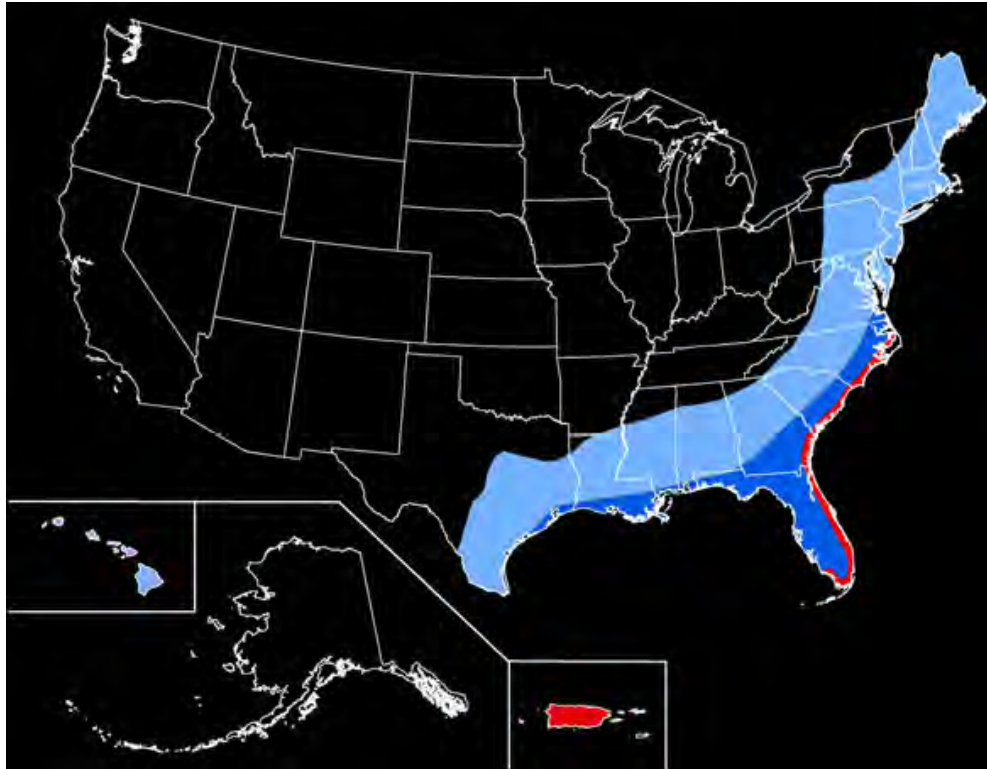
3.2.2.4 Probability of Future Occurrence

According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the probability of future occurrences is defined by the number of events over a specified period of time. For the purpose of this plan, the probability of Barnstable experiencing a hurricane is **highly likely**. Based on NOAA's Adapting to Climate Change Guide³, the power and frequency of Atlantic Ocean hurricanes has increased in recent decades and the intensity of Atlantic hurricanes is likely to increase over the extended long term.

Figure 5 shows the Number of Hurricanes for 100-year Return Period along the eastern seaboard. The light blue area over Massachusetts represents that the state can expect 20 to 40 hurricanes over a 100- year return period.

³ Source: NOAA's Adapting to Climate Change: A Planning Guide for State Coastal Managers (2010)

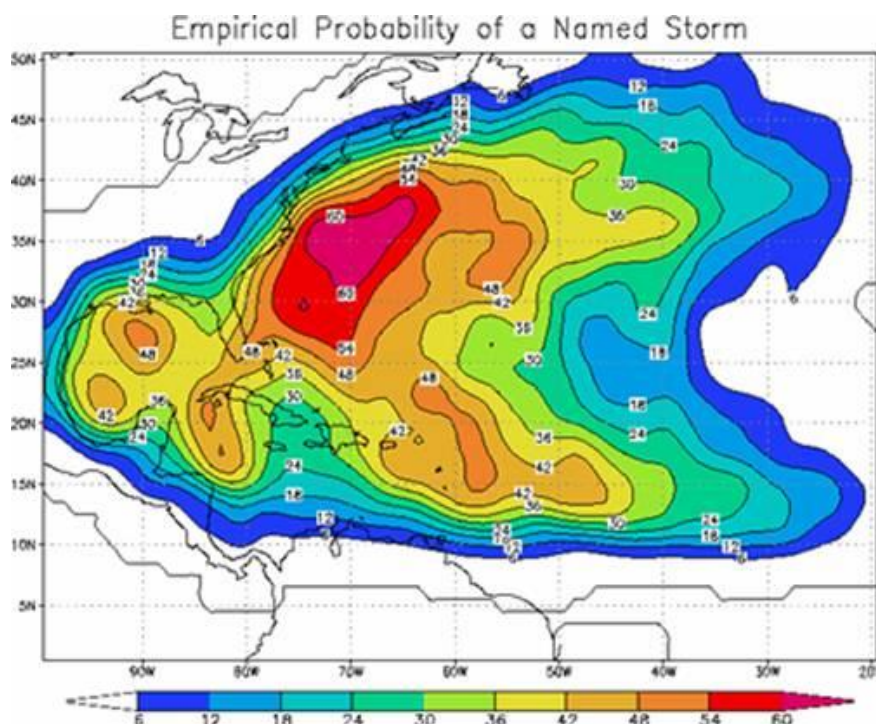
Figure 5: Number of Hurricanes for a 100-year Return Period



Source: 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan

NOAA published a map (**Figure 6**) showing the possibility that a tropical storm or hurricane will affect a given area during the hurricane season. Based on this research, Massachusetts has a 6 to 30 percent chance of a tropical storm or hurricane impacting the state in any given year. There is a greater probability along the coast.

Figure 6: Probability of Hurricane or Tropical Storm Events across Massachusetts



Source: <http://www.aoml.noaa.gov/hrd/tcfaq/G11.html>

3.2.3 Dam Failure

Dam failures are a catastrophic type of failure characterized by the sudden, rapid, and uncontrolled release of water. They can result from natural events, human-induced events, or a combination of the two. Failures due to natural events such as prolonged periods of rainfall and flooding can result in overtopping, which is the most common cause of dam failure.

3.2.3.1 Hazard Location

Barnstable currently has 10 dams in the community and three have been assigned a hazard potential classification of “significant.” The State determined that the Town is responsible for the ownership, maintenance, and operation of the Wequaquet Lake and Mill Pond Dams. The Lumbert Pond Dam is under private ownership. The Santuit Pond Dam in Mashpee has also been identified as a potential hazard for the town of Barnstable should the dam fail.

- Wequaquet Lake Dam** - Wequaquet Lake is the largest lake in the Town of Barnstable and the third largest on Cape Cod. The 654-acre lake is located south of Route 6 and Route 132 in Centerville. The lake has 7.5 acres of shoreline that is heavily developed with cottages and year-round homes. The lake discharges through a man-made channel into Long Pond and ultimately to the Centerville River. The Wequaquet Lake dam consists of a concrete box culvert extending 37 feet under Phinney’s Lane with a concrete retaining wall on either side of the road. Although the dam carries a hazard ranking of “significant”, as of 2009, the condition of the dam is in satisfactory condition with no major deficiencies.
- Mill Pond Dam** - Mill Pond is located northwest of the intersection of Route 28 and Route 149 in Marstons Mills. The warm-water pond is fed by the Marstons Mills River and discharges into wetlands adjacent to Prince Cove and ultimately to the Three Bays. The Mill Pond dam is 52 feet in length and located at the southeast end of the pond, just east west of Route 149. The dam structure consists of an uncontrolled spillway, a tier pool, and a fish ladder pool outlet. Flows then pass through a trash rack and a 4’ pipe culvert

extending 280 feet under Route 149. Although the dam carries a hazard ranking of “significant”, the dam is in fair condition, as determined by a December 2009 inspection.

- **Santuit Pond Dam** - Santuit Pond is located just west of Barnstable in the Town of Mashpee; however, the Santuit Pond dam is a potential hazard for the Town of Barnstable should this dam fail. Santuit Pond is a 172-acre warm-water pond approximately a mile north of Route 28 and east of Route 130. The MCDR has assigned the Santuit Pond dam a hazard ranking of significant. In 2013, a new fish ladder and dam separating the Santuit River from Santuit Pond was completed.

A map showing the location of dams in Barnstable is located in **Appendix A**.

3.2.3.2 Previous Occurrences, Severity & Extent of the Hazard

According to FEMA, there has not been a Presidential Disaster Declaration made for dam failures in the State of Massachusetts since 1953 nor have there been any instances in Barnstable.

The Massachusetts Office of Dam Safety is responsible for maintaining records of dams statewide. The Office ensures compliance with practices pertaining to dam inspection, maintenance, repair and operation. As displayed in **Table 3-5**, the State utilizes the USACE classification system for the hazard potential of dam failures. The classification system outlines the expected impacts should a dam failure occur.

Table 3-5: USACE Hazard Potential Classification

Hazard Type	Description
High Hazard	Refers to dams located where failure will likely cause loss of life and serious damage to home(s), industrial or commercial facilities, important public utilities, main highway(s) or railroad(s).
Significant Hazards	Refers to dams located where failure may cause loss of life and damage home(s), industrial or commercial facilities, secondary highway(s) or railroad(s) or cause interruption of use of service of relatively important facilities.
Low Hazard	Refers to dams located where failure may cause minimal property damage to others. Loss of life is not expected.

According to Massachusetts State law, dam owners are required to prepare, maintain, and update Emergency Action Plans for all High Hazard Potential dams and certain Significant Hazard Potential dams. The Emergency Action Plans include the following information:

- Identification of equipment and materials required and available to execute the plan;
- Notification procedures for informing local emergency agencies;
- An inundation map that identifies potential flood areas; and
- A process for warning nearby residents if failure of the dam is imminent including a list of addresses and phone numbers for property owners who may be affected in the event of a dam failure.

3.2.3.3 Impact & Vulnerability

The Town of Barnstable is vulnerable to dam failures. According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, as infrastructure ages and maintenance and inspection costs increase, there is an increased likelihood of higher risk for full or partial dam failures. The location of several significant hazard dams in Barnstable contributes its dam failure vulnerability. Should a dam failure occur, it would likely cause serious damage and potentially loss of life to the surrounding area.

3.2.3.4 Probability of Future Occurrence

Based on the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the probability of future occurrences is defined by the number of events over a specified period of time. For the purpose of this plan, the probability of future dam failures in Barnstable is **unknown**. Likelihood would increase if the following events did occur:

- Natural hazards such as an earthquake/flood;
- Deliberate acts of sabotage;
- Structural failure of dam materials;
- Dam structures are overtopped or about to be overtopped due to floodwaters;
- Earth embankments breached by erosion or slope failure; and
- Spillways are blocked or seepage exists downstream.

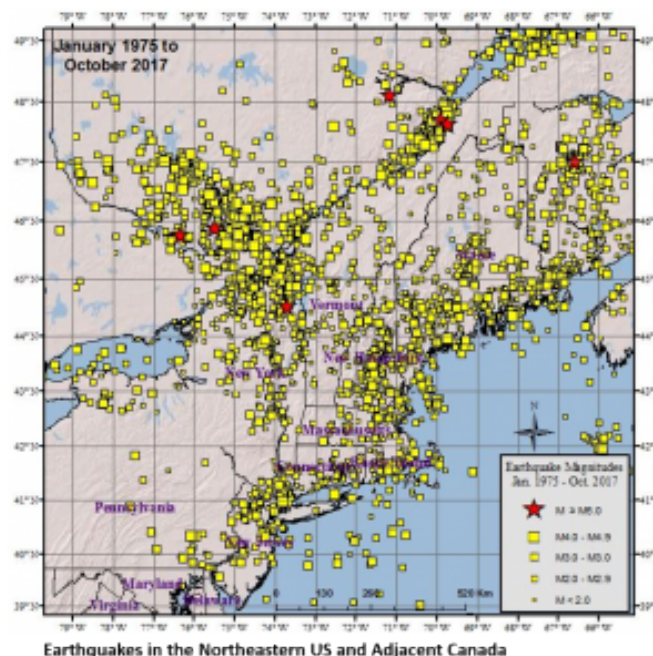
3.2.4 Earthquake

Earthquakes are the result of a release of energy (which can be observed by shifting and fracturing of rock materials beneath the surface) in the Earth's crust that creates seismic activity. Seismic activity is defined by the frequency, type and size of earthquakes that occur. Earthquakes are measured by the Richter magnitude scale or the Maximum Modified Mercalli Intensity Scale (MMI Scale) that assign a value number to each earthquake event as a form of measuring the energy released. Unfortunately, earthquakes can be large in magnitude, impact thousands of square miles and cause billions of dollars in damage to property.

3.2.4.1 Hazard Location

Earthquakes are possible in Massachusetts, including Barnstable. The Northeast States Emergency Consortium map in **Figure 7** indicates where the epicenters of specific events have occurred in the past. While an epicenter can be located far from Barnstable and still produce a Barnstable-affecting earthquake, the earthquake hazard possibility is low for the Northeast region in general. The rate of earthquakes in the Northeast is about 1% of the earthquake rate in California. A strongly damaging earthquake is expected once every 200-300 years in the Northeast.

Figure 7: Earthquakes in the Northeastern US and Adjacent Canada



Source: [Earthquakes Hazards: Northeast States Emergency Consortium \(nesec.org\)](https://www.nesec.org/earthquakes-hazards/) 2021

The 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan notes that the New England epicenters do not follow major mapped faults of the region, nor are they confined to specific geologic structures or terrain. In addition, past earthquakes in New England have not aligned along fault lines that are known or mapped by geologists. Due to the wide-ranging occurrences of earthquakes in New England, it is suspected that a strong event could occur anywhere in the region.

3.2.4.2 Previous Occurrences, Severity & Extent

As of 2021, there has never been an earthquake recorded in the Town of Barnstable. According to FEMA, there has never been a Presidential Disaster Declaration made for an earthquake in the State of Massachusetts. Between 1668 - 2021, Massachusetts experienced 379 earthquakes of varying magnitudes.⁴ According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the last major earthquake to affect Massachusetts was more than 200 years ago in 1755 with an estimated magnitude of about 6.0 to 6.25. The epicenter was probably located off the coast of Cape Ann, north of Boston. The area of greatest damage in Massachusetts stretched along the northern coast of the state from Cape Ann to Boston. **Figure 8** shows earthquakes in New England, the United States, and Canada from 1990-2010. Other earthquake events relevant to the Barnstable area are listed in **Table 3-6**.

⁴ The Northeast States Emergency Consortium, "Earthquakes," [<http://nesec.org/earthquakes-hazards/>], 2021

Figure 8: Earthquakes in New England, United States and Canada (1990 – 2010)

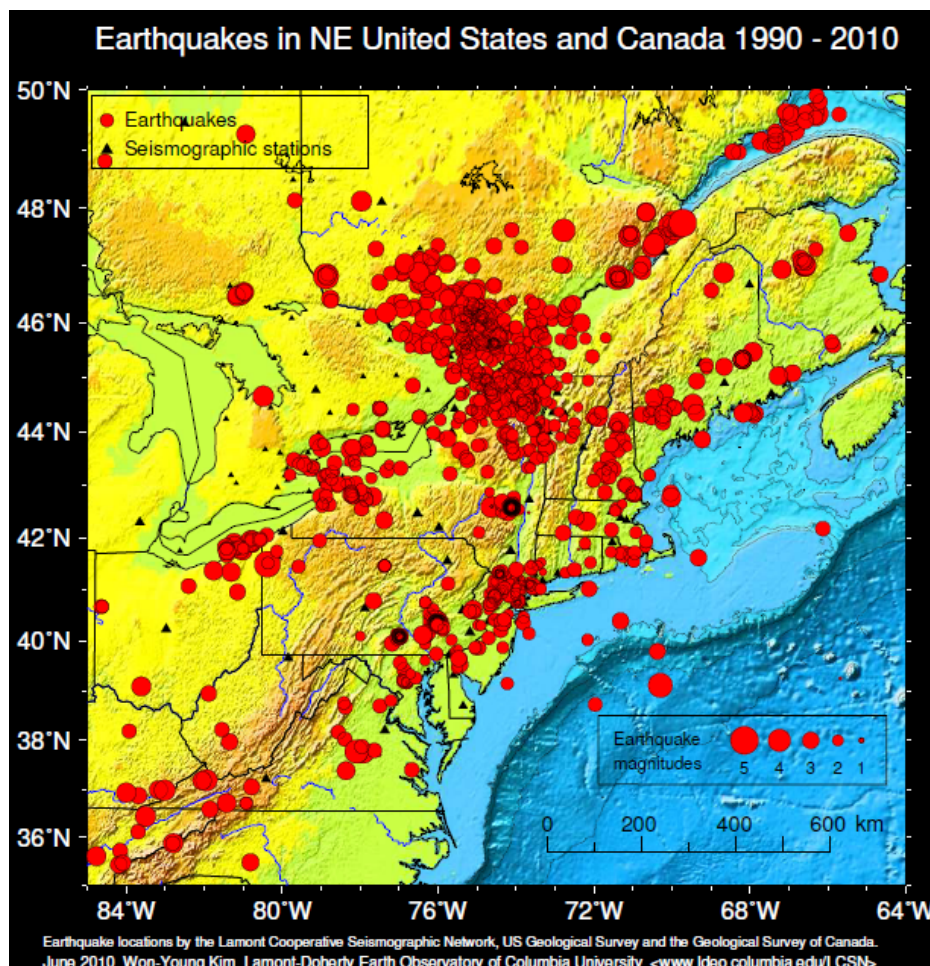
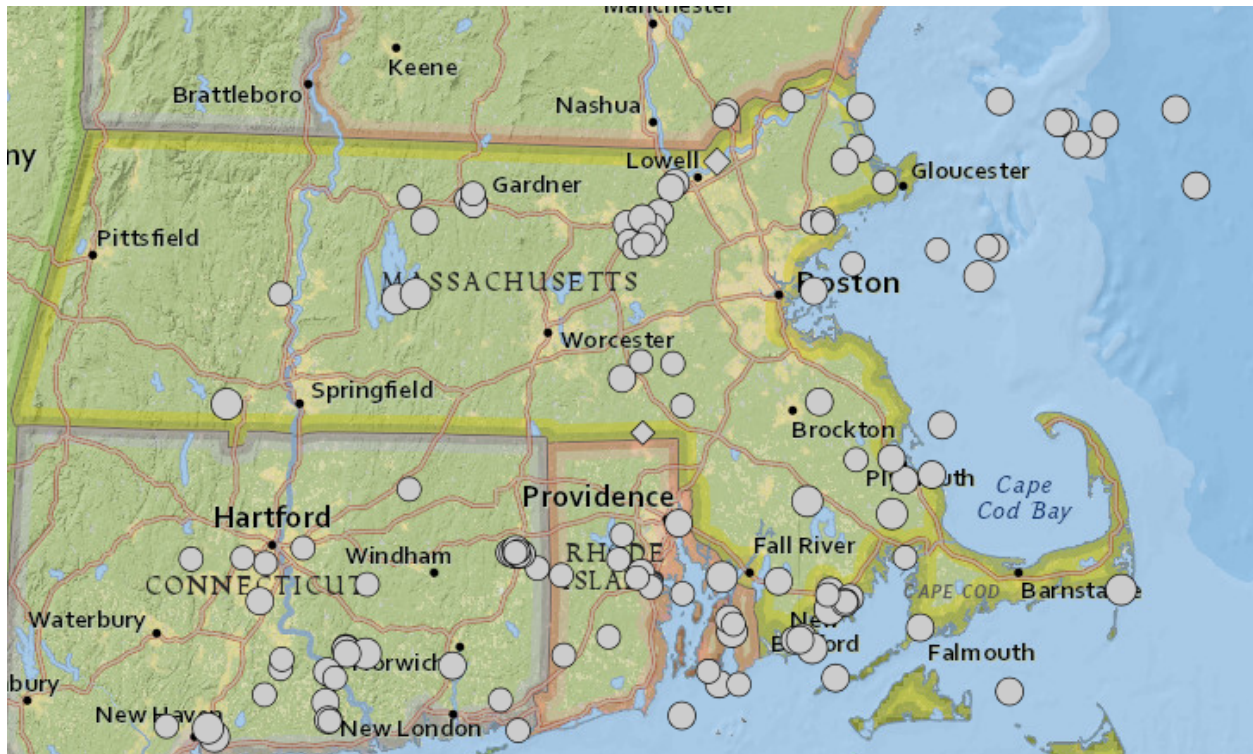


Table 3-6: Earthquake Events Greater Than Magnitude 2.0 in Massachusetts

Date	Magnitude	Location
November 8, 2020	3.6	Bliss Corner
December 3, 2019	2.1	Plymouth
December 23, 2018	2.2	Gardner
December 21, 2018	2.1	Templeton
April 2012	4.4	Offshore
May 15, 2011	2.1	Buzzard's Bay
July 22, 2003	3.6	Offshore
October 25, 1965	5	Nantucket
April 24, 1925	5	Wareham
January 7, 1925	5.0	Cape Ann
August 8, 1847	4.2	Brewster

Date	Magnitude	Location
January 2, 1785	5.4	Offshore
November 18, 1755	6.0	Cape Ann

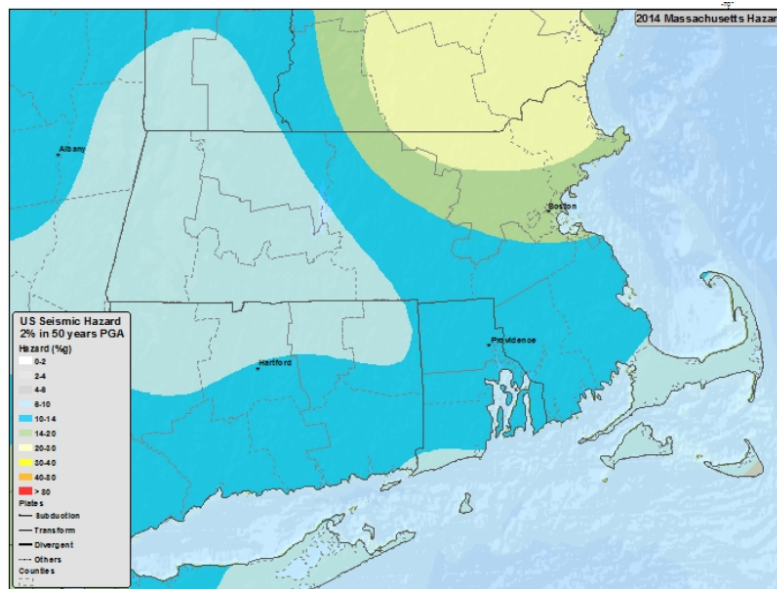
Figure 9: Massachusetts Seismicity (1973 – 2021)



Source: [Information by Region - Massachusetts | U.S. Geological Survey \(usgs.gov\)](https://www.usgs.gov/locations/northeast/information-by-region-massachusetts)

Figure 9 is an earthquake hazard map, commonly referred to as a PGA map, for Massachusetts that shows ground motion values with a 2% probability in 50 years. For moderate earthquakes, PGA is the best determinate of damage. According to **Figure 10**, Barnstable has a 2% probability of having ground movement with a severity of 14 to 20%, equivalent to a VI on the MMI Scale.

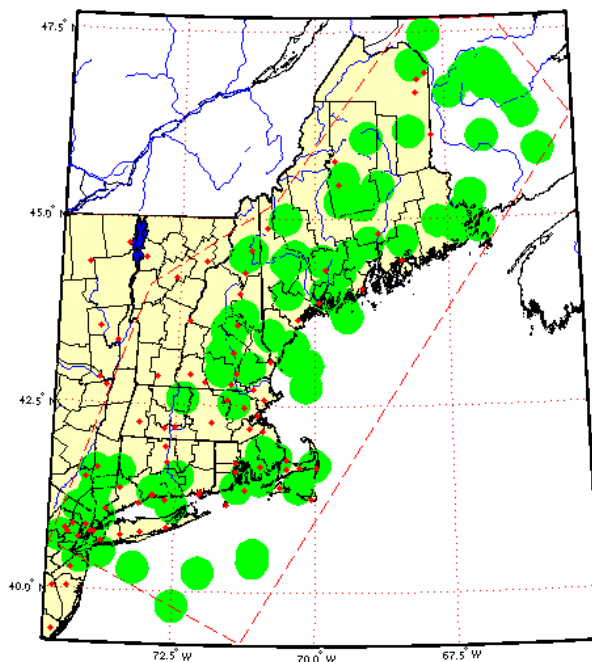
Figure 10: Massachusetts Seismic Hazards



Source: USGS [2014 Seismic Hazard Map- Massachusetts](https://www.usgs.gov/seismic/2014-seismic-hazard-map-massachusetts) | U.S. Geological Survey ([usgs.gov](https://www.usgs.gov))

The Weston Observatory at Boston College conducted an analysis on spatial probabilities in New England. According to the analysis there is a 66% chance that the next earthquake of magnitude 2.7 or greater in the region will occur in one of the green areas in **Figure 11**. Barnstable is in a higher probability area.

Figure 11: Spatial Probabilities for New England



Source: 2013 Massachusetts State Hazard Mitigation Plan

Earthquake impacts are measured by how much energy releases from the epicenter of the event and how far any given location is from the epicenter. Severity can be expressed for an earthquake by comparing the acceleration of the event to normal acceleration due to gravity. Peak ground acceleration (PGA) is how the strength of the ground movements can be measured and is expressed as a percent of the established rate of acceleration due to gravity. A common method used to describe the severity of an earthquake is the MMI Scale (see **Table 3-7**). The MMI Scale has preceded the Richter Scale (used until 1970) to measure the size of earthquakes in terms of how much energy is released. The scale identifies 12 increasing levels of intensity which are designated by a Roman numeral.

Table 3-7: Modified Mercalli Intensity Scale – Earthquake Intensity

MMI Scale Number	Typical Earthquake Impacts
I	Not felt except by a very few under especially favorable conditions.
II	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	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.
VIII	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, walls. Heavy furniture overturned.
IX	Damage considerable in specially designed structures. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Earthquakes are also often referred to on a magnitude base-10 logarithmic scale, which is noted in **Table 3-8**.

Table 3-8: Earthquake Magnitude Scale

Magnitude	Earthquake Effects	Estimated Number Each Year
2.5 or less	Usually not felt but can be recorded by seismograph.	900,000
2.5 to 5.4	Often felt, but only causes minor damage.	30,000
5.5 to 6.0	Slight damage to buildings and other structures.	500
6.1 to 6.9	May cause a lot of damage in very populated areas.	100
7.0 to 7.9	Major earthquake. Serious damage.	20

Magnitude	Earthquake Effects	Estimated Number Each Year
8.0 or greater	Great earthquake. Can totally destroy communities near the epicenter.	One every 5 to 10 years

3.2.4.3 Impact & Vulnerability

Barnstable is vulnerable to earthquakes according to data provided by Weston Observatory and USGS earthquake hazard maps. In general, earthquake vulnerability is based on cross referencing the built environment with the population for an area. Developed areas in high hazard zones are the most vulnerable due to their densely developed nature, age of structures and infrastructure and number of people. Structures that are newer construction are more resistant to earthquakes than older construction due to updated building codes and enforcement. Common impacts of an earthquake may include building and infrastructure damage or failure, rupture of underground utilities, fire, landslides and other disruptions. Secondary impacts of earthquakes can be just as serious and may include dam failure or explosions.

3.2.4.4 Probability of Future Occurrence

According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the probability of future occurrences is defined by the number of events over a specified period of time. For the purpose of this plan, the probability of future earthquakes in Barnstable is **likely** even though they cannot be predicted and may occur anytime. The State Plan also reports there have been 366 earthquakes of varying degrees recorded from 1627 to 2012 in Massachusetts. Due to inferior recording and reporting instruments, prior to the 20th century, it is difficult to estimate the probability of future occurrences based on historical data.

As also noted in the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, a 1994 USGS report found that the probability of a magnitude 5.0 or greater earthquake centered in New England in a 10-year period is about 10%-15%. The probability is expected to rise to 41% - 56% for a 50-year period. The last earthquake with a magnitude above 5.0 took place in New Hampshire's Ossipee Mountains in 1940.

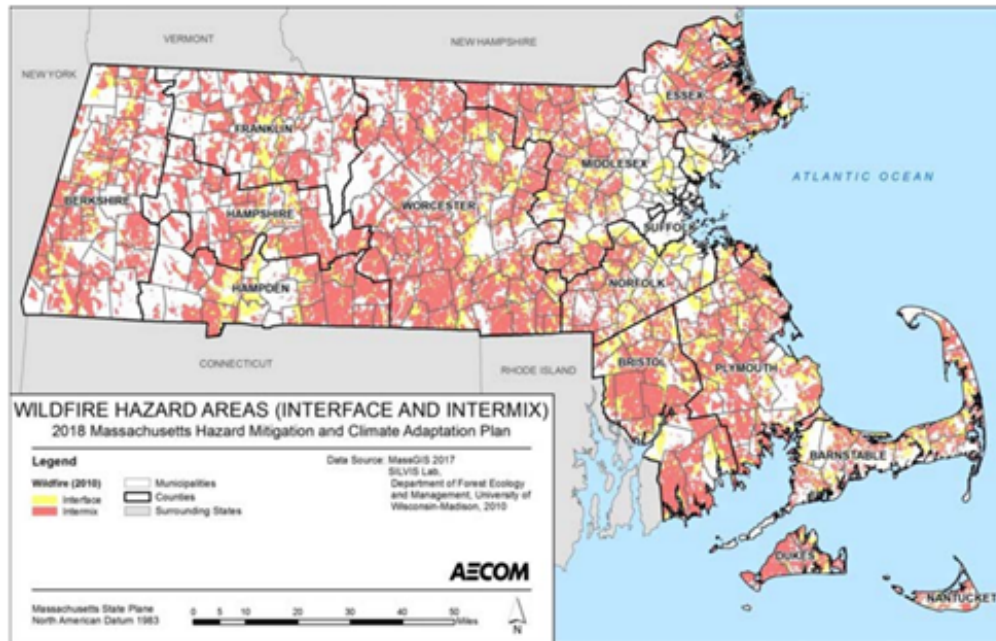
3.2.5 Wildfire

Wildfires are typically non-structural fires that occur in vegetated areas such as grass, shrubs and forested areas. In Massachusetts, the cause of a wildfire can either be the result of human impacts or natural events such as a lightning strike. Drought and/or windstorm conditions can fuel wildfires or cause them to spread rapidly. Wildfires not only destroy the vegetated areas where they occur, but they can also impact the built environment including structures, if in close proximity.

3.2.5.1 Hazard Location

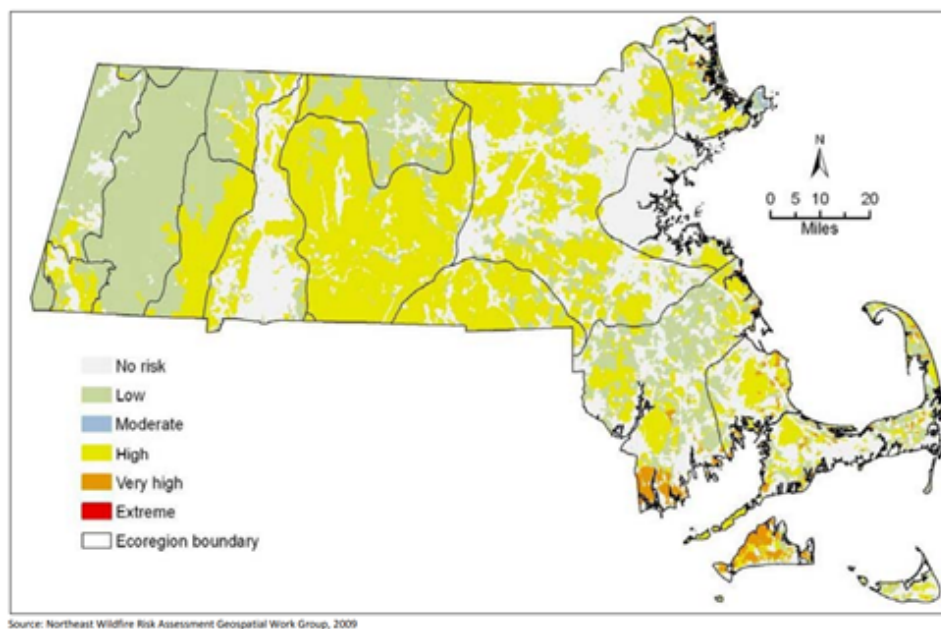
According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the southern part of Massachusetts is particularly susceptible to wildfire due to the availability of fuel, impact of offshore winds and increasing development. The Plan notes that a US Forest Service study identified Barnstable and Plymouth Counties as the most fire-prone due to their vegetation, sandy soil, and the presence of a drying wind. Pitch pine and oak forests are especially susceptible to wildfires. Areas on Cape Cod have some high susceptibility and in Barnstable, this is particularly true along the north coast of the community. **Figure 12** displays the wildfire throughout the state by Census block.

Figure 12: Wildfire Hazard Areas



The 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan outlines regions from no risk to extreme risk of wildfire. Barnstable's vegetated areas are at high risk of wildfire, while the salt marsh regions are at no risk of burning as show in **Figure 13**.

Figure 13: Wildfire Risk Areas for the Commonwealth of Massachusetts

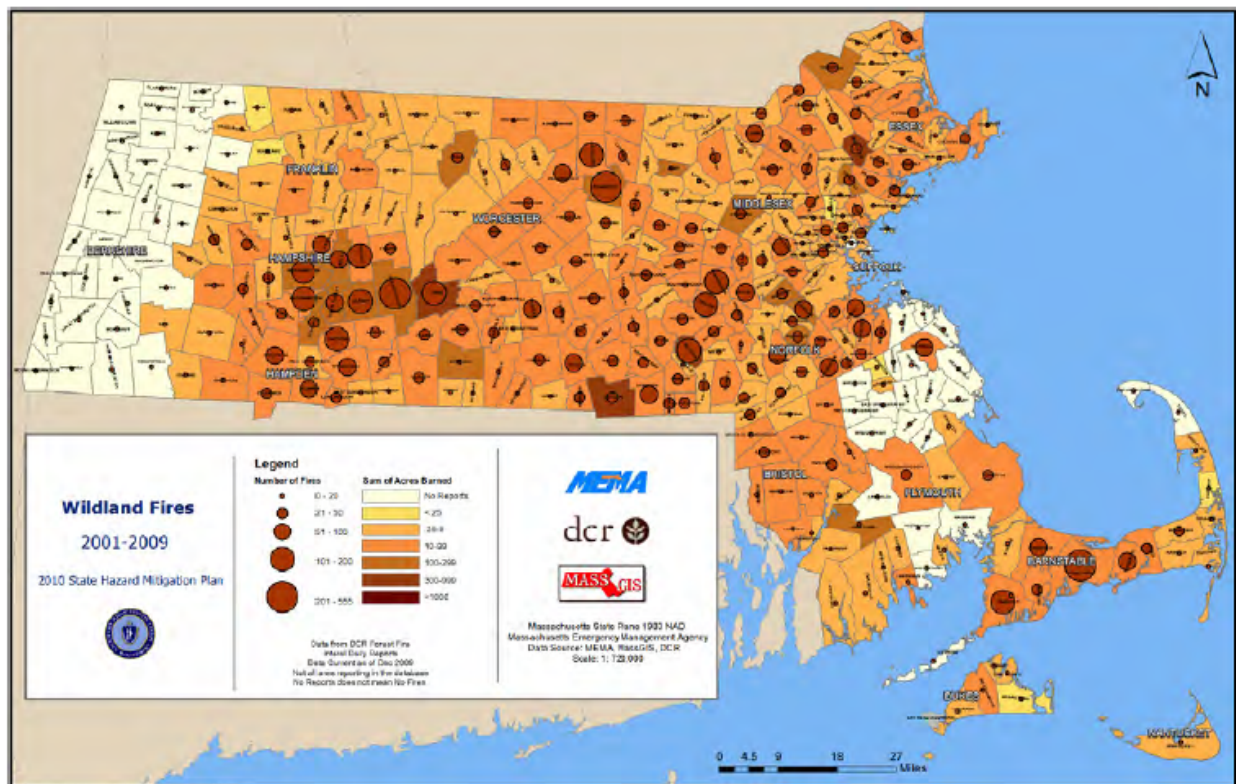


3.2.5.2 Previous Occurrences, Severity & Extent

According to FEMA, there have been no Presidential Disaster Declarations made for wildfire in Massachusetts since 1953. The NCDC tracks storm events and there have been no reported instances of wildfire in Barnstable County.

The 2013 Massachusetts State Hazard Mitigation Plan mapped the number of wildfire events statewide from 2001 to 2009 in **Figure 13b**. The figure illustrates, based on best available data, there were between 0-20 fires burning less than 100 acres during the eight-year span and some of the more substantial ones were in or near Barnstable.

Figure 13b: Locations of Historical Wildfires and Acres Burned in Massachusetts (2001-2009)



Source: 2013 Massachusetts State Hazard Mitigation Plan

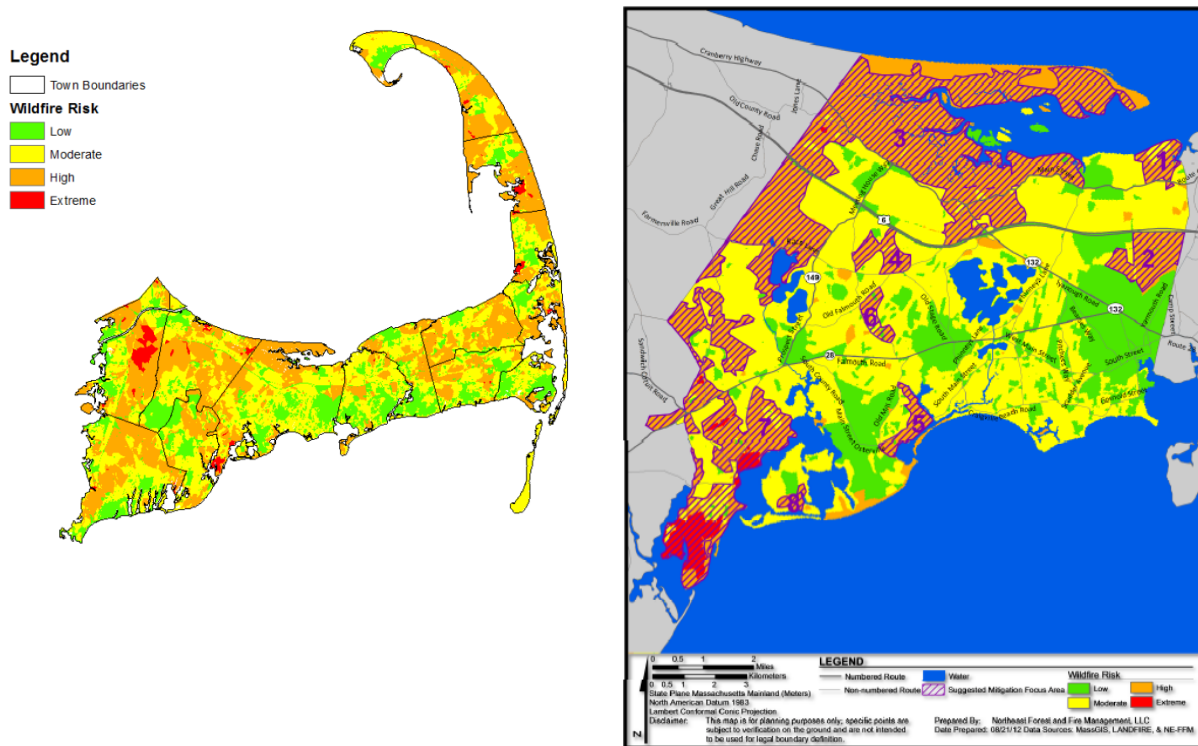
3.2.5.3 Impact & Vulnerability

Over the course of Barnstable's development, urban areas, both residential and commercial, have encroached into natural wildlife areas. People, structures, and facilities in urban/wildland interface areas are at the greatest risk from wildfires. The vast majority of wildfires are started by humans; some fires are attributable to accidents and negligence, but historically almost half have been attributed to arson. Although most wildfires begin unnaturally, it is important to keep in mind that wildfires can play an important role in the natural cycle of plant succession and can have positive impacts on wildlife areas. These benefits should be considered when developing mitigation actions and response strategies.

Barnstable is vulnerable to wildfires because of the type and amount of potential fuel in the community for this type of natural hazard event. The Cape is one of the highest risk areas for wildfire in the state; a U.S. Forest Service study found that Barnstable and Plymouth counties, with their sandy soils, drying winds and fuel types are as wildfire prone as the often fire ravaged regions of southern California. According to the Massachusetts Executive Office of Public Safety and Security, there are three classes of wildfires: surface fire, ground fire and crown fire. Crown fires would likely have the greatest probability of causing the greatest losses because of the speed at which the fire spreads.

The 2012 Barnstable County Wildfire Preparedness Plan included the preparation of wildfire risk areas (shown in **Figure 14**) which illustrates the areas of greatest wildfire risk on Cape Cod and in Barnstable. According to the assessment, portions of Barnstable are classified as “high” risk wildfire areas or areas for mitigation activities.

Figure 14: Wildfire Risk Areas



3.2.5.4 Probability of Future Occurrence

According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the probability of future occurrences is defined by the number of events over a specified period of time. For the purpose of this plan, the probability of future wildfires in Barnstable is **likely**. Wildfires are likely to most often occur in Barnstable County (including Barnstable) from late March to early June.

3.2.6 Flood

A flood is when there is a high flow or inundation of water that submerges land which is normally dry and causes or threatens damage. The most frequently flooded type of area is land adjacent to a water body and in a defined floodplain. Flooding can either be coastal, riverine or shallow flooding (associated with ponding or urban drainage). Flooding situations can develop slowly or very quickly in a situation known as a flash flood. Floods can be dangerous because the flow of water can be rapid and either impact a neighborhood, community or the larger watershed area. Varying types of floods can occur including⁵:

- **Coastal Flood:** Flooding of coastal areas due to the vertical rise above normal water level caused by strong, persistent onshore wind, high astronomical tide, and/or low atmospheric pressure, resulting in damage, erosion, flooding, fatalities, or injuries. Coastal areas are defined as those portions of coastal land zones

⁵ National Weather Service Instruction 10-1605 (August 17, 2007), Operations and Services Performance, NWSPD 10-16 Storm Data Preparation document (<http://www.nws.noaa.gov/directives>)

(coastal county/parish) adjacent to the waters and bays of the oceans. Farther inland, flood events are defined as Flash Flood or Flood. Terrain (elevation) features determine how far inland the coastal flooding extends.

- **Flash Flood:** Rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within six hours of the causative event (e.g., intense rainfall, dam failure, ice jam-related), on a widespread or localized basis. Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising flood waters. Flash floods do not exist for two or three consecutive days.
- **Riverine Flooding:** The flooding of rivers and streams over their pre-defined banks. In coastal regions, the riverine floodplain is generally a flat area along a larger river or in low-lying coastal areas. The volume that is manageable depends on the watershed, and climate and land use characteristics. Spring snowmelt, frozen ground conditions, and strong storms may all lead to riverine flooding.
- **Urban Flooding:** In densely developed areas, heavy rains/precipitation can produce flooding when groundwater levels are high and there is insufficient drainage infrastructure in place.

Other terminology frequently used to describe flood conditions includes:

- **Base Flood (100 Year Flood)** – Flood that has a 1% chance of being equaled or exceeded in any given year. A 100 Year flood can occur more than once in a short period of time. The term measures the size of the flood, not frequency of occurrence.
- **500 Year Flood** – Flood that has a .2% chance of being equaled or exceeded in any given year. The 500-Year flood is an infrequent event and can occur between once in eight years to once in fifty years. The term does not mean a flood occurs once in 500 years.

3.2.6.1 Hazard Location

Flooding is a regular occurrence in Massachusetts and is also one of the highest impact hazards. This type of natural hazard event typically occurs during other weather events like a hurricane, nor'easter, winter storm or heavy rain. The 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan indicates that flooding affects the majority of communities in the state.

FEMA defines flood hazard areas on the Flood Insurance Rate Maps (FIRMs) as Special Flood Hazard Areas (SFHA). A SFHA is an area that will be inundated or impacted by the flood event that has a 1% chance of happening during the year. At times, the 1% annual chance of flood is called the base flood. The flood areas are defined as follows:

- Special Flood Hazard Areas
 - Zone A, Zone AO, Zone AH, Zones A1-A30, Zone AE, Zone A99, Zone AR, Zone AR/AE, Zone AR/AO, Zone AR/A1-A30, Zone AR/A, Zone V, Zone VE, Zone V1-V30
- Moderate Flood Hazard Areas
 - Zone X (areas between the base flood and the .2% annual chance (or 500-year flood))
- Areas of Minimal Flood Hazard
 - Zone X (areas of minimal flood hazard, outside the SFHA and higher than the elevation of the .2% annual chance of flood)

Areas at risk for flooding are shown in Appendix A.

According to the Barnstable County Flood Insurance Study (2016), flooding in the Town of Barnstable is generally limited to coastal areas where waters can inundate during high tide conditions. The NFIP tracks information regarding the number of flood insurance policies in force, the dollar value in force, total losses and total payments as shown in **Table 3-9**.

Table 3-9: National Flood Insurance Program (NFIP) – Barnstable

# Policies in Force	Premium Coverage	Total Claims 1978-2016	Total Payments 1978-2016
1,189	\$341,069,900	301	\$3,058,512

3.2.6.2 Previous Occurrences, Severity & Extent

In the past 50 years, there have been 20 major flood events in Massachusetts. The coastal counties experienced the greatest number of federal declarations. According to FEMA, there have been 17 Presidential Disaster declarations for a flooding incident in Massachusetts and six of those have impacted Barnstable County (see Table 3-10).

Table 3-10: Massachusetts Flooding Major Disaster Declarations (1995 – Present)

	Disaster No.	Incident Period	Date Disaster Declared	Barnstable County a Designated Area?
Severe Winter Storm and Flooding	DR-4379	3/13/2018 – 3/14/2018	6/19/2018	No
Severe Winter Storm and Flooding	DR-4372	3/2/2018 – 3/3/2018	6/25/2018	Yes
Severe Winter Storm, Snowstorm, Flooding	DR-4214	1/26/2015 – 4/13/2015	4/13/2015	Yes
Severe Winter Storm, Snowstorm, Flooding	DR-4110	2/8/2013 – 2/9/2013	4/19/2013	Yes
Hurricane Sandy	DR-4097	10/27/2012- 11/8/2012	12/19/12	Yes
Tropical Storm Irene	DR-4028	8/27/2011-8/29/2011	9/3/2011	Yes
Severe Storm and Flooding	DR-1895	3/12/2010 – 4/26/2010	3/29/2010	No
Severe Winter Storm and Flooding	DR-1813	12/11/2008 – 12/18/2008	1/5/2009	No
Severe Storms, Inland and Coastal Flooding	DR-1701	4/15/2007 – 4/25/2007	5/16/2007	Yes
Severe Storms and Flooding	DR-1642	5/12/2006 – 5/23/2006	5/25/2006	No
Severe Storms and Flooding	DR-1614	10/7/2005 – 10/16/2005	11/10/2005	No
Flooding	DR-1512	4/1/2004 – 4/30/2004	4/24/2004	No
Severe Storms and Flooding	DR-1364	3/5/2001 – 4/16/2001	4/10/2001	No
Heavy Rain and Flooding	DR-1224	6/13/1998-7/6/1998	6/23/1998	No

	Disaster No.	Incident Period	Date Disaster Declared	Barnstable County a Designated Area?
Severe Storms and Flooding	DR-1142	10/20/1996-10/25/1996	10/25/1996	No
Severe Storms and Flooding	DR-790	3/30/1987-4/13/1987	4/18/1987	No
Coastal Storms, Flood, Ice, Snow	DR-546	2/6/1978-2/8/1978	2/10/1978	Yes
Severe Storms, Flooding	DR-325	3/6/1972	3/6/1972	No
Hurricane, Floods	DR-43	8/20/1955	8/20/1955	Unknown

The NCDC tracks storm events and the information below was available for Barnstable County regarding some of the flooding occurrences.

- **March 8, 2018** – The third Nor’easter in two weeks hit Massachusetts, with the eastern end of the state most effected. Widespread power outages accompanied high winds (greater than 60mph) and nearly two feet of snowfall.
- **March 2, 2018** – Nor-easter brought floodwaters making Route 6A impassable and flooding the Barnstable Marine parking area. Waterflow was under and around buildings and damaged windows and sidings. Beaches and dunes suffered erosion and overwashing after water breached barrier beaches. Wrack infiltrated wetlands.
- **January 4, 2018** – The storm of record, bringing high waters up to 100-year floodplain and damaging winds. Structures had waterflow around and under them and damage affected stairs, decks, windows, sidings, walls, and roofs. Other effects included eroded beaches, damaged sand fencing, overwashed dunes, and wrack in wetlands. The Milway neighborhood experienced major damage and most structures were flooded.
- **November 11, 2014** – Heavy rain and strong wind impacted Cape Cod and two cars became stuck in flood waters on Megan Road in Hyannis.
- **January 3, 2014** – Moderate coastal flooding impacted various parts of Cape Cod.
- **June 3, 2012** – Sandy Neck Road in Barnstable was flooded and impassable due to minor coastal flooding.
- **February 6-7, 1978** – Blizzard of the century permanently altered the shape of Cape Cod and nearly one hundred lives were lost across the Massachusetts coastal region. Waves as high as thirty feet and a seventeen-foot tide caused extensive flooding damage. Heavy snow and rain fell across the cape and many residents experienced power outages, stranded vehicles, and property damage.

3.2.6.3 Impact & Vulnerability

The Town of Barnstable is highly susceptible to coastal flooding, but inland flooding is also a risk. Flooding results from heavy rains and storm surges and can be exacerbated by tidal restrictions and coastal erosion. The most dangerous type of flooding occurs from storm surges, which can accompany hurricane and nor’easter events. Storm surge is a dome of water that comes ashore during or after a hurricane event. Flooding from storm surges poses the greatest risk to life during hurricanes and necessitates evacuation of vulnerable areas. Storm surges can wash out roads, damage infrastructure, overwhelm storm sewers, and contaminate drinking water. Local staff noted that Hyannis Harbor and the surrounding area floods on a consistent basis.

Flooding occurrences can have devastating impacts on life, property and operations in a community – particularly if the proper flood insurance is not in place. Throughout Massachusetts, there are no areas that are exempt from flooding

impacts, what varies is the type of flooding. Flooding can also alter the natural landscape and habitat areas and in Barnstable, this has been seen in the Sandy Neck area of the community on the northern coastline.

Barnstable's pump stations have flooded in the past. The community has set up a system where if a storm event may be predicted which could result in flooding, they have the ability to vacuum shut pump stations with the proper advanced warning. Other emergency systems in place include the use of installed and portable generators. During a large storm event, staff may intentionally and strategically shut down some pump stations.

There are also health impacts which can be associated with flooding, such as potential exposure to mold, pathogens in flood waters and long-term mental health issues. Rebuilding homes and buildings impacted by flooding can be extremely costly and time consuming. There is also a risk that rebuilding costs may be repetitive as often the same locations can be impacted more than once.

3.2.6.4 Probability of Future Occurrence

According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the probability of future occurrences is defined by the number of events over a specified period of time. For the purpose of this plan, the probability of Barnstable experiencing a flood event is **highly likely**. The historical record indicates that the State experienced 20 flood-related disaster declarations from 1955 to 2012. Therefore, based on statistics, a flood event of disaster declaration proportions may occur somewhere in Massachusetts once every three years.

3.2.7 Nor'easter/Coastal Storm

A nor'easter is a non-tropical storm that produces gale-force winds and precipitation in the form of heavy rain or snow. Nor'easters (also referred to as coastal storms) are common occurrences in the eastern United States. Events may cause substantial damage to coastal (and at times, inland) areas due to strong winds (can be hurricane force), storm surge and substantial rainfall or snow amounts. A storm is specifically a Nor'easter when the wind blows in from the northeast and pushes the storm up the east coast of the United States. Due to the slow movement of these weather events, storm surge can be in excess of 2 feet above normal high tide and impact the coastline over multiple high tide cycles making coastal erosion and flooding a common secondary effect of these storm events. These types of storms can occur anytime of the year but are more common in the winter months.

3.2.7.1 Hazard Location

In Massachusetts, typically one or two nor'easter events impact the coastline between October and April each year which may cause flooding, property damage and coastal erosion. The coastal areas of Barnstable are susceptible to property and natural resource damage from storm surge and wind while the entire community is often impacted by heavy rain, flooding and snow associated with nor'easter events.

3.2.7.2 Previous Occurrences, Severity & Extent

Nor'easters are the most frequently occurring natural hazard in the state. According to FEMA, there have been four Presidential Disaster Declarations made for "Coastal Storms" in the State of Massachusetts. In Barnstable, there have been varying degrees of impacts from the storms listed (**Table 3-11**).

Table 3-11: Massachusetts Coastal Storm Major Disaster Declarations (1953 – Present)

	Disaster No.	Incident Period	Date Disaster Declared	Barnstable County a Designated Area?
Severe Winter Storm and Flooding	DR-4372	3/2/2018 – 3/3/2018	6/25/2018	Yes
Severe Winter Storm, Snowstorm and Flooding	DR-4214	1/29/2015 – 4/13/2015	4/13/2015	Yes
Severe Storms and Inland and Coastal Flooding	1701	4/15/2007 – 4/25/2007	5/16/2007	Yes
Winter Coastal Storm	975	12/11/1992 - 12/13/1992	12/21/1992	Yes
Severe Coastal Storm	920	10/30/1991 – 11/4/1991	11/4/1991	Yes
Coastal Storms, Flood, Ice, Snow	546	2/6/1978 – 2/8/1978	2/10/1978	Yes
<i>Source: FEMA Disaster Declarations 1953- Present</i>				

Nor'easter events may occur as a single type storm event or develop from a hurricane or tropical storm that has weakened. The following is a list of some nor'easter events that have impacted Barnstable County in the past.

- January 2015 – Winter storm Juno impacted New England and a state of emergency was declared for Massachusetts. In Barnstable County, there were power outages, shelters were opened and there was heavy snow, storm surge, coastal flooding and erosion throughout Cape Cod. This event resulted in a federal disaster declaration (FEMA DR-4214). In Barnstable, shelters were open and over 200 people were served.
- October 29, 2012 – Hurricane Sandy brought high winds and coastal flooding to the area with storm surge reports of 2.5 – 4.5 feet.
- April 15-16, 2007 – Nor'easter caused widespread impacts to portions of Massachusetts. Some areas were impacted by coastal flooding while others experienced debris, snow, river and stream flooding.
- October-November 1991 – A large nor'easter occurred, and it was unusual because it moved south and strengthened when it joined with Hurricane Grace producing what is known as the "perfect storm". Winds measured over 80 mph with waves over 30 feet high in some parts of the coastline.
- February 1978 – A blizzard/nor'easter produced 8-12 inches of snow, ice and flooding and damaged buildings and infrastructure across Barnstable County.

3.2.7.3 Impact & Vulnerability

Barnstable is vulnerable to nor'easter occurrence events in the future as they will continue to impact the community and all of Cape Cod. Impacts will be seen from the heavy rain, wind, snow, storm surge, flooding and erosion from this type of weather events. Depending on the length and strength of the storm, death or serious injury, property damage and operations of local government and businesses can all occur. A common secondary impact of a coastal storm is short- and long-term electrical power outages. Nor'easters are a serious concern because of the damage potential and frequent rate of occurrence.

3.2.7.4 Probability of Future Occurrence

According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the probability of future occurrences is defined by the number of events over a specified period of time. For the purpose of this plan, the probability of Barnstable experiencing a nor'easter is **highly likely**. The historical record for the State indicates that there have been three nor'easter-related federally declared disasters between 1954 and 2012. The State Plan notes that this figure likely underestimates how often nor'easters occur and impact Massachusetts.

3.2.8 Windstorm

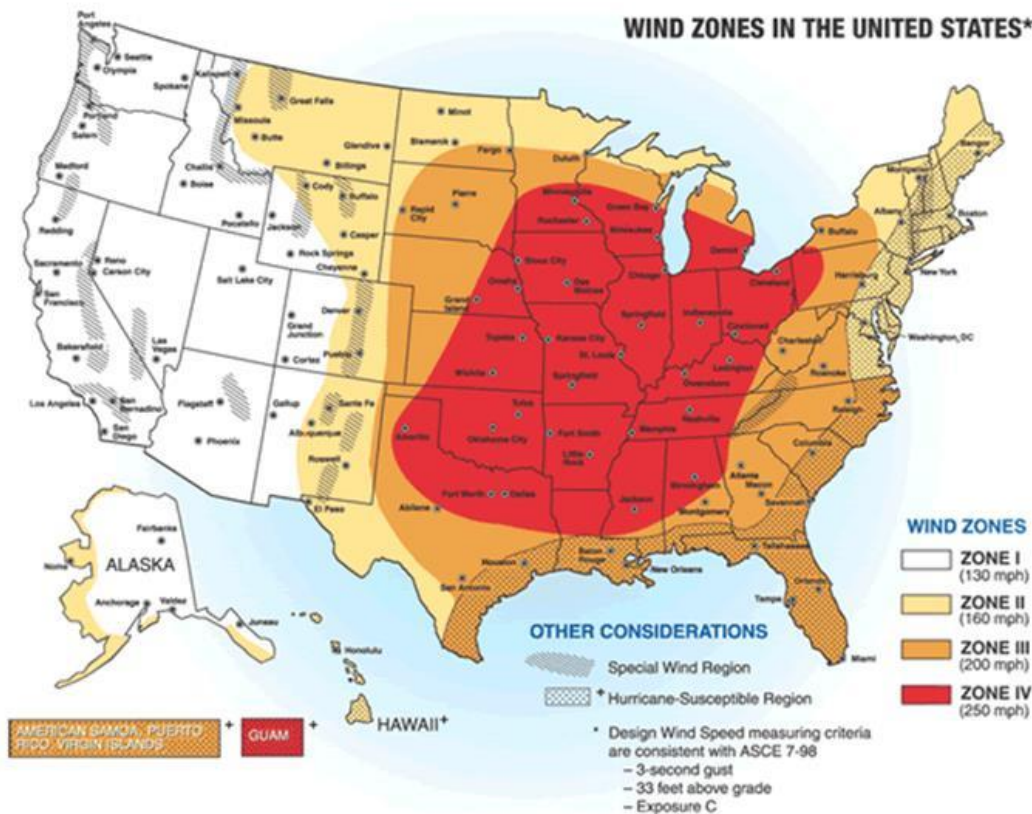
In general, wind is the horizontal motion of the air past a given point. Wind is in constant motion and windstorms can occur suddenly and without warning. Differences in air pressure is how a wind event begins and pressure that is higher at one place versus another sets up a force that pushes from the high toward the low pressure. Wind is used to describe the prevailing direction from which the air is blowing with the speed given usually in miles per hour or knots.

Extreme wind events are more often associated with a larger meteorological event such as a winter storm, hurricane, tornado, nor'easter or severe thunderstorm. In the absence of accompanying characteristics of these other events, the event would be considered a windstorm.

3.2.8.1 Hazard Location

According to FEMA's Winds Zone map (see **Figure 15**), the entire state of Massachusetts is susceptible to wind speeds. The map indicates various areas of the United States and their susceptibility to wind speeds in addition to highlighting Special Wind and Hurricane-Susceptible regions. Barnstable is located in a Zone II, as is the rest of the state, which means the community is susceptible to winds of up to 160 mph and is also located in a hurricane susceptible region.

Figure 15: Wind Zones in the United States



3.2.8.2 Previous Occurrences, Severity & Extent

Windstorm occurrences may be classified by the NWS as a Wind Advisory (winds sustained at 31-39 mph for at least an hour or gusts of 46-57 mph) or a High Wind Warning (sustained winds 40+ mph or gusts of 58+mph). Wind that is measured at less than 30 mph does not typically create a hazardous condition.

Windstorm events can occur regularly in Barnstable. The entire State of Massachusetts is susceptible to both extreme wind events such as hurricanes and tornadoes but also windstorms that do not have any other associated characteristics other than the movement of air (i.e., no precipitation). Impacts of a high wind event may include fallen trees or power lines, roof damage and dangerous marine conditions. According to the Massachusetts Hazard Mitigation Plan, the state is susceptible to high winds from extreme weather events and before and after frontal systems.

The information in **Table 3-12** was available for high wind (wind gusts greater than 55 knots) occurrences in Barnstable County from February 2006 to February 2016.

Table 3-12: High Wind Event Data for Barnstable County February 2006 – December 2020

Location	Date	Wind Speed (knots)	Event Type	Death	Injury	Property Damage
Barnstable Municipal Airport	11/1/2019	55	High Wind	0	0	0
Barnstable Municipal Airport	10/17/2019	56	High Wind	0	0	Unavailable
Barnstable Municipal Airport	3/2/2018	56	High Wind	0	0	Unavailable
Barnstable Municipal Airport	2/9/2017	55	High Wind	0	0	0
Barnstable County	1/27/2015	65	High Wind	0	0	\$50,000
Barnstable County	1/31/2013	56	High Wind	0	0	0
Barnstable County	10/29/2012	69	High Wind	0	0	\$500,000
Barnstable County	12/26/2010	70	High Wind	0	0	0
Barnstable County	1/25/2010	58	High Wind	0	0	\$5,000
Barnstable County	3/8/2008	66	High Wind	0	0	\$10,000
Barnstable County	11/3/2007	77	High Wind	0	0	\$50,000
Barnstable County	4/15/2007	58	High Wind	0	0	\$30,000
Barnstable County	10/28/2006	57	High Wind	0	0	\$8,000
Barnstable County	2/12/2006	69	High Wind	0	0	\$10,000

3.2.8.3 Impact & Vulnerability

Barnstable is vulnerable to windstorms and will continue to be impacted in the future. Impacts may include power outages that can impact residents and businesses, downed power lines, severe marine forecast that could damage coastal infrastructure and downed trees and branches.

3.2.8.4 Probability of Future Occurrence

According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the probability of future occurrences is defined by the number of events over a specified period of time. For the purpose of this plan, the probability of future windstorms in Barnstable is **highly likely**. The community is also susceptible to other natural hazards that typically have wind associated characteristics.

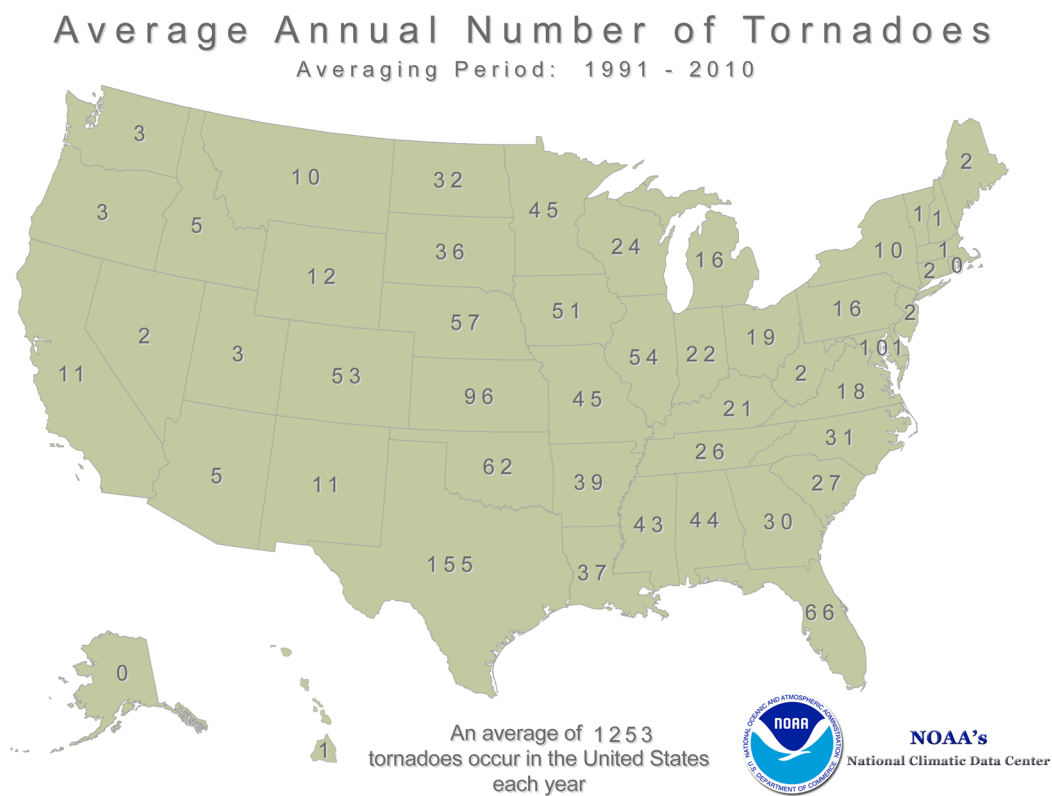
3.2.9 Tornado

Tornadoes typically appear as a violently rotating visible funnel cloud that is a rotating air column in contact with the ground. A loud, freight train-like, roaring noise will accompany a tornado. Wind speeds can range from 40 mph to 300 mph and are measured on what is known as the Fujita scale. Tornadoes generate in strong atmospheric winds where cool, dry air meets warm, humid air. Damage from a tornado can vary widely and be minimal to completely catastrophic. On a local level, a tornado is the most destructive of all atmospheric conditions. In Massachusetts, tornadoes are not a common occurrence, with an average of 1.7 events per year, mostly in central counties.

3.2.9.1 Hazard Location

Barnstable County is vulnerable to tornadoes. Based on the wind zone map provided earlier in the Windstorm section, Massachusetts is in wind zone II that can include winds up to 160 mph which may be associated with tornadoes. Tornadoes can occur in any region of Massachusetts. According to **Figure 16**, Massachusetts experienced one tornado event annually between 1991 and 2010.

Figure 16: Annual Average Number of Tornadoes (1991 – 2010)

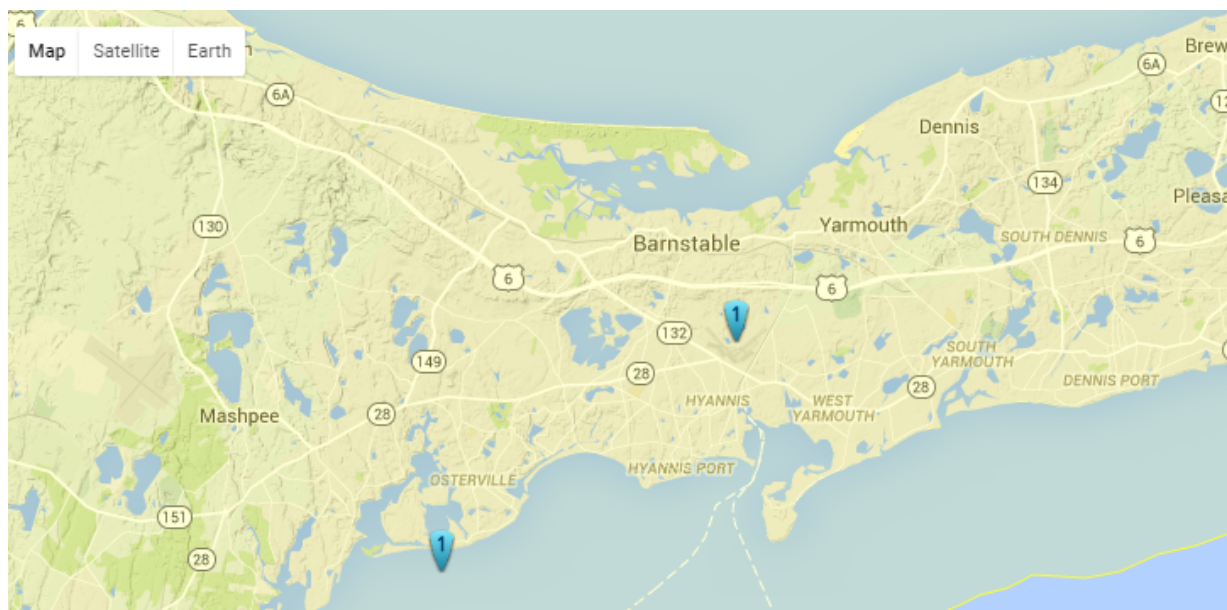


Source: <http://www1.ncdc.noaa.gov/pub/data/cmb/images/tornado/clim/ann-avg-torn1991-2010.gif>

3.2.9.2 Previous Occurrences, Severity & Extent

Since 1950, two F1 tornadoes have been recorded in Barnstable County (August 9, 1968 and August 22, 1977). There were no fatalities associated with the events. One occurrence was directly in Barnstable while the other was in nearby Osterville (see **Figure 17**).

Figure 17: Barnstable County Tornadoes (1950 – 2021)



Source: Barnstable County Tornadoes, 1950 – 2021, [Massachusetts Tornadoes \(tornadoproject.com\)](https://tornadoproject.com/massachusetts-tornadoes/)

Since 1954, there have been two Major Disaster Declarations in the State of Massachusetts for Tornadoes (see **Table 3-13**). The State Hazard Mitigation plan indicates that a tornado may occur anywhere in Massachusetts with the right atmospheric conditions and typically, there are 1-3 tornadoes in New England per year.

Table 3-13: Massachusetts Tornado Major Disaster Declarations (1954 – Present)

	Disaster No.	Incident Period	Date Disaster Declared	Barnstable County a Designated Area?
Severe Storms and Tornadoes	DR-1994	6/1/2011	6/15/2011	No
Tornado	DR-7	6/11/1953	6/11/1953	Unknown

Source: FEMA Disaster Declarations 1954 – Present

Tornadoes are rated using the commonly known Enhanced Fujita Scale (EF-scale) which provides a rating of the wind speed from the tornado event to a category from EF0 to EF5. The degree of damage helps to define the rating of an individual storm. The EF-scale below (**Figure 18**) has been updated and in use since 2007.

Figure 18: Enhanced Fujita Scale

EF Scale Rating	3-Second Gust Speed (mph)	Type of Damage
EF0	65–85	Light damage
EF1	86–110	Moderate damage
EF2	111–135	Considerable damage
EF3	136–165	Severe damage
EF4	166–200	Devastating damage
EF5	>200	Incredible damage

NOAA Storm Prediction Center issues tornado watches and warnings. A watch means tornadoes are possible and a warning means a tornado has been sighted or indicated by weather radar. The current average lead time for tornado warnings is only 13 minutes resulting in greater emphasis being placed on a watch for tornado preparedness compared to other hazards.

3.2.9.3 Impact & Vulnerability

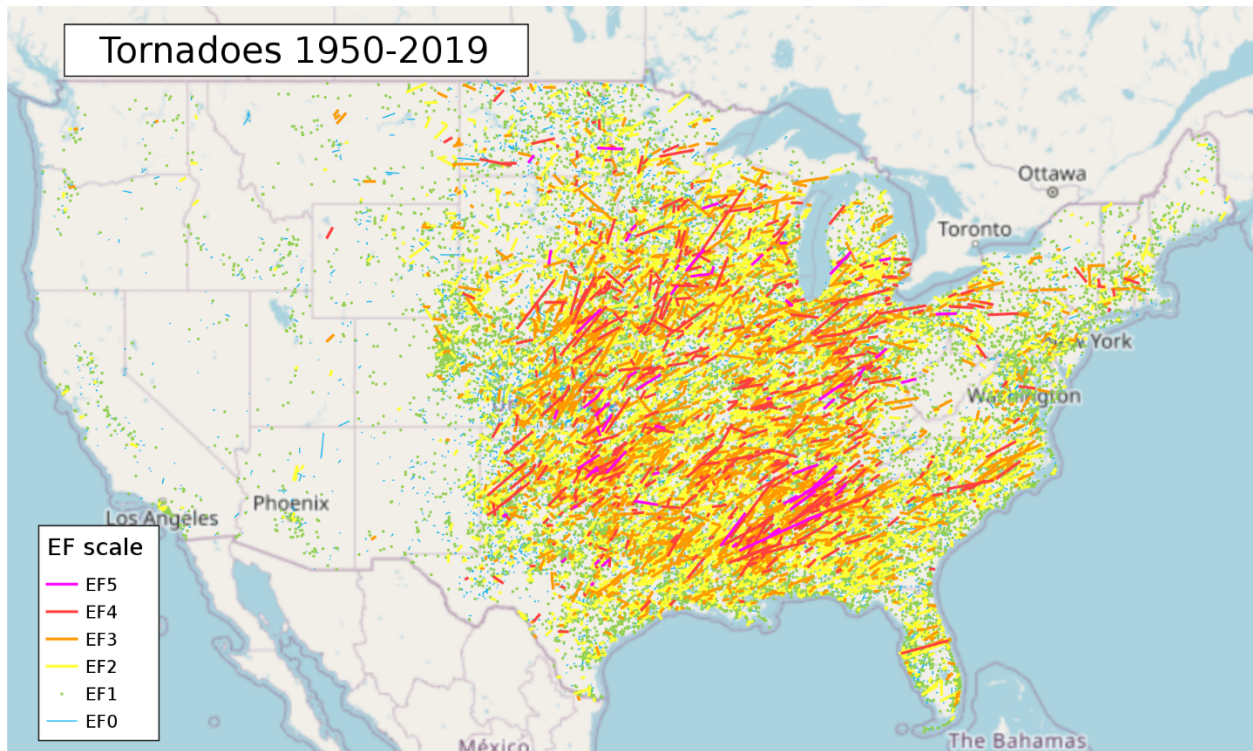
Barnstable is vulnerable to tornadoes and in Barnstable County, since 1951, there have been two recorded F1 tornadoes. The impact of a tornado can be sudden and significant with regard to property, human life and infrastructure. Heavy winds and hail are often associated with a tornado and injuries and fatalities can result from flying debris, building damage or being outside without cover. Post tornado, there are still dangerous situations due to damaged buildings, power outages and downed power lines and either delayed or inability to receive emergency services.

Property and operation impacts include damage to residential and commercial buildings, trees and vegetation, and exposed infrastructure that can be destroyed by a tornado. Damaged bridges and infrastructure may be weakened for use resulting in delays for individuals to move within the community to receive basic services. Although tornadoes are confined to certain areas, the impacts on communities affected can be devastating with major damage and destruction.

3.2.9.4 Probability of Future Occurrence

According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the probability of future occurrences is defined by the number of events over a specified period of time. For the purpose of this plan, the probability of future tornadoes in Barnstable is **unlikely**. NOAA's National Severe Storm Laboratory (NSSL) has estimated the likelihood for a tornado on a given day in the United States. The probability for a tornado in Massachusetts is 0.2 to 0.4 days per year based on tornado data from 1995 to 2020. **Figure 19** shows tornado tracks across the United States from 1950-2019.

Figure 19: Tornadoes in the United States



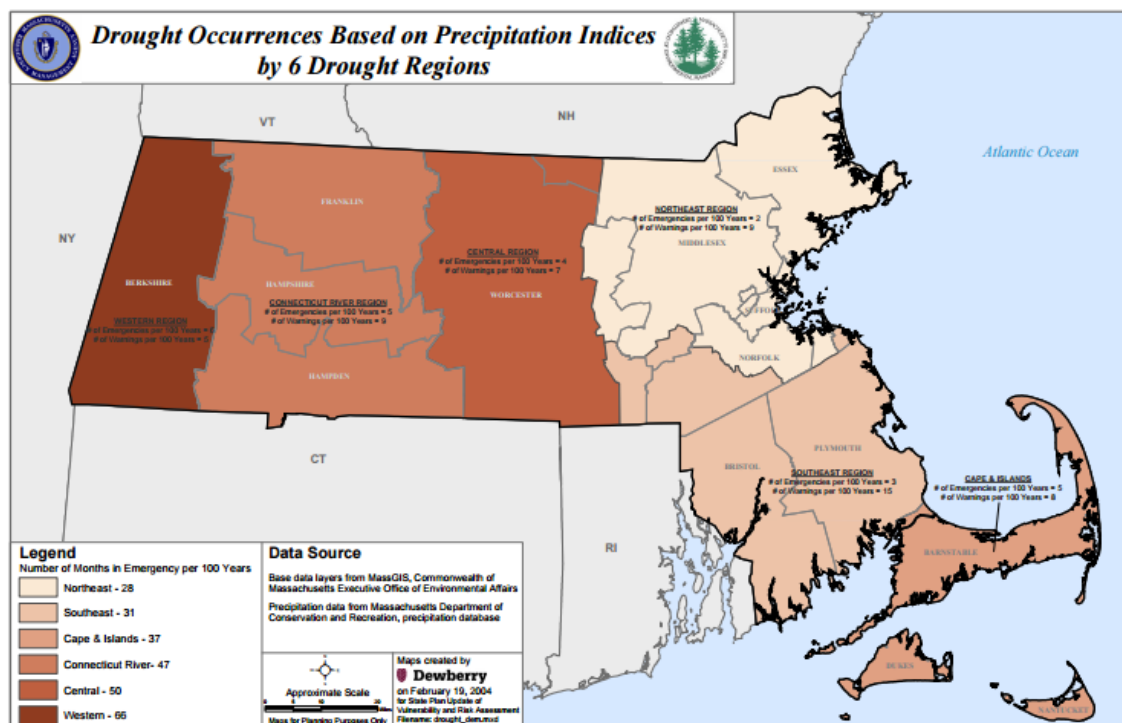
3.2.10 Drought

Drought occurs when there is an insufficient amount of moisture that has adverse impacts on people, animals or vegetation over a geographic area. Drought can occur over a prolonged period of time where the lack of precipitation directly impacts the hydrologic balance of the environment. Examples of impact include water supply shortages, dry soils which may result in crop failure and changed fish and wildlife behavior including death. Other weather characteristics like consistently high temperatures and low humidity can exacerbate the problem. Results of prolonged drought periods can also have a disastrous economic impact on communities and regions that rely upon water for agriculture and tourism.

3.2.10.1 Hazard Location

Massachusetts generally receives between 40 and 50 inches of precipitation on an annual basis, but it is not immune from experiencing drought conditions which often occur when there has been a dry winter. Barnstable and all of Cape Cod could be affected by drought. **Figure 20** indicates the number of drought occurrences based on precipitation indices for each of the six drought regions in Massachusetts.

Figure 20: Drought Emergencies Per 100 Years in Massachusetts



Source: 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan

3.2.10.2 Previous Occurrences, Severity & Extent

According to FEMA, there has never been a Presidential Disaster Declaration made for drought in the State of Massachusetts. The NCDC Storm Events Database listed the following two drought occurrence in Barnstable County:

- April to May 2012 – The U.S. Drought Monitor declared a severe drought across the eastern half of Massachusetts, Rhode Island and a portion of Connecticut from April 12 – May 15, 2012. Precipitation had been half of the normal amount between January 2012 and April 2012, which caused rivers and streams to run at low levels during the spring run-off season. One major impact of this meteorological drought was an increase in fire danger.
- August to November 2016 – The U.S. Drought Monitor expanded the ongoing drought in New England to include Barnstable County of August 30th, 2016, after a month of receiving below-average rainfall. The designation for Barnstable was upgraded to a Severe Drought (D2) at the beginning of October through October 11 when it was downgraded to Moderate Drought (D1). The Moderate Drought continued through the end of November 2016 as rainfall and streamflow continued at below-normal levels.

The most severe drought, on record, in Massachusetts occurred from 1961 - 1969. The eastern portion of the state experienced two drought scenarios in the past ten years, or an average of 0.18 drought events per year. As noted in the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the drought in 2016 was the most extensive drought event in Massachusetts since the 1960s.

According to the Massachusetts Drought Management Plan, a number of drought indices are available to assess the various impacts of dry conditions. The state uses a multi-index system that takes advantage of several of these indices to determine the severity of a given drought or extended period of dry conditions.

3.2.10.3 Drought Indices⁶

- **Palmer Drought Index (PDI)** – an index that reflects soil moisture and weather conditions, available from the National Weather Service or National Climate Data Center.
- **Crop Moisture Index (CMI)** – an index that reflects short-term soil moisture conditions as used for agriculture, available from the National Climate Data Center.
- **Fire Danger** – the fire danger level reflects how favorable conditions are for brush fires. Data factored into the index include weather conditions and available fuel. This is a short-term index, which can change daily. The duration of the index will be used to determine relative drought levels.
- **Precipitation** – a comparison of measured precipitation amounts to 30-year averages. Cumulative amounts for 3, 6 and 12-month periods are factored into the drought determination. This data is available from the DCR, Office of Water Resources.
- **Groundwater Levels** – a drought level determination is based on the number of consecutive months groundwater levels are below normal (lowest 25% of period of record). Groundwater conditions maps showing areas of above normal, normal and below normal are provided monthly by the USGS.
- **Streamflows** – a drought level determination is based on the number of consecutive months streamflow levels are below normal (lowest 25% of period of record). Streamflow condition maps showing areas of above normal, normal and below normal are provided monthly by the U.S. Geological Survey.
- **Reservoirs** – a drought level determination will be based on the level of small, medium and large index reservoirs across the state. The reservoir level relative to normal conditions will be considered. DCR and Office of Water Resources, as part of its monthly conditions report, will maintain a list of index water supply reservoirs and their percent full.

Table 3-14 defines the drought indices for Massachusetts according to the 2013 Drought Management Plan.

⁶ Massachusetts Drought Management Plan, 2013, website: <http://www.mass.gov/eea/docs/eea/wrc/droughtplan.pdf>

Table 3-14: Drought Index Indices (Massachusetts Drought Management Plan, 2013)

Drought Level	PDI	CMI*	Fire*	Precipitation	Groundwater	Streamflow	Reservoir
Normal	-1.0 to -1.99	0.0 to -1.0 slightly dry	Low	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	-2.0 to -2.99	-1.0 to -1.9 abnormally dry	Moderate	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	-3.0 to 3.99	-2.0 to -2.9 excessively dry	High	1 of the following criteria met: 3 month cumulative < 65% or 6 month cumulative < 70% or 12 month cumulative < 70%	4-5 consecutive months below normal**	At least 4 out of 5 consecutive months below normal**	Medium index Reservoirs below normal
Warning	-4.0 and below	< -2.9 severely dry	V. High	1 of the following criteria met: 3 month cumulative < 65% and 6 month cumulative < 65% Or 6 month cumulative < 65% and 12 month cumulative < 65% Or 3 month cumulative < 65% and 12 month cumulative < 65%	6-7 consecutive months below normal**	At least 6 out of 7 consecutive months below normal**	Large index reservoirs below normal
Emergency	-4.0 and below	< -2.9 severely dry	Extreme	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

3.2.10.4 Impact & Vulnerability

Massachusetts and all of Cape Cod experience regular rainfall events on an annual basis. According to the Massachusetts Department of Conservation and Recreation, the Cape receives on average, 44 inches of precipitation. Barnstable is vulnerable to drought which can cause public safety, health and social impacts. Drought can impact agriculture, wildlife, recreation, energy usage, municipal business, fish and wildlife and their associated habitats.

The majority of the Town of Barnstable, with the exception of west Barnstable, receives its water from the Hyannis Water System which consists of four water treatment facilities, two storage tanks, 12 well pumping stations and 107 miles of distribution system. Supplying its drinking water from ground sources, the Hyannis Water System draws about 2.77 million gallons per day (MGD) from wells with an annual production of 902 million gallons. The Hyannis Water System is currently registered through the Department of Environmental Protection (DEP) to withdraw water from twelve groundwater wells. The duration and frequency of drought is what would determine how it would impact the water supply.

Decreasing flow of streams and rivers due to a lack of precipitation can secondarily impact drinking water supplies, wildlife and recreational activities. It can also affect other users such as power generation and water and wastewater utilities. In Barnstable, drought conditions could impact landscaping, and potable water for homeowner and business use.

3.2.10.5 Probability of Future Occurrence

According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the probability of future occurrences is defined by the number of events over a specified period of time. For the purpose of this plan, the probability of future drought events in Barnstable is **likely**. The 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, designated drought as a low frequency hazard even though there is a potential for widespread impact.

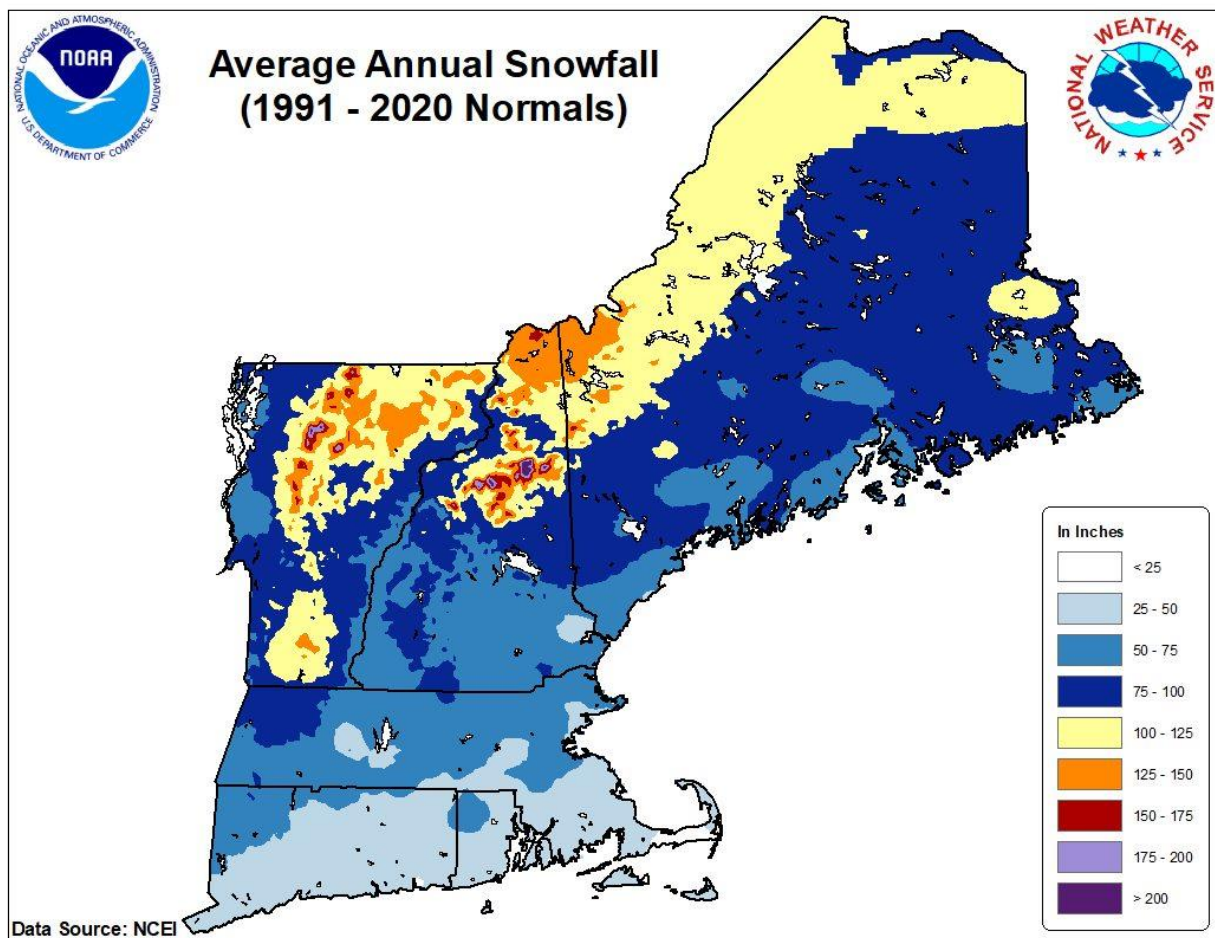
3.2.11 Severe Winter Weather

Winter storms typically consist of varying forms of precipitation including snow, sleet, freezing rain or a mix of these wintry conditions. Blizzards are the most dangerous and severe type of winter storm and are characterized by strong, sustained winds of at least 35 mph that last for a prolonged period of time – typically 3 hours or more. An ice storm is another form of winter storm that is defined as an event which results in the accumulation of at least .25-inch of ice on exposed surfaces and they occur when moisture falls and freezes immediately upon impact on trees, power lines, roads, structures and other surfaces. These types of storms can down trees, cause lengthy, widespread power outages, damage property and even cause fatalities.

3.2.11.1 Hazard Location

Winter storms are common on an annual basis throughout Massachusetts. **Figure 21** represents the normal (30-year average) annual snow totals in New England. The entire State of Massachusetts is at risk of snow, higher snow accumulations appear to be more common at higher elevations in Western and Central Massachusetts. Despite the ocean moisture and coastal proximity, Barnstable is susceptible to a combination of both snow and coastal flooding during a winter storm event.

Figure 21: New England Average Annual Snowfall (1991 – 2020)



3.2.11.2 Previous Occurrences, Severity & Extent

According to FEMA, there have been eight Presidential Disaster Declarations in the State of Massachusetts due to some form of winter storms and five have resulted in Barnstable County receiving a designated area status from FEMA (see **Table 3-15**).

Table 3-15: Massachusetts Winter Storm Disaster Declarations (1954 – Present)

	Disaster No.	Incident Period	Date Disaster Declared	Barnstable County a Designated Area?
Severe Winter Storm and Snowstorm	DR-4379	3/13/2018 – 3/14/2018	7/19/2018	No
Severe Winter Storm and Flooding	DR-4372	3/2/2018 – 3/3/2018	7/25/2018	Yes
Severe Winter Storm, Snowstorm, Flooding	4214	Multiple Events	4/13/2015	Yes
Severe Winter Storm, Snowstorm, Flooding	4110	2/8/2013 – 2/9/2013	4/19/2013	Yes

	Disaster No.	Incident Period	Date Disaster Declared	Barnstable County a Designated Area?
Severe Storm and Snowstorm	4051	10/29/2011 – 10/30/2011	1/6/2012	No
Severe Winter Storm and Snowstorm	1959	1/11/2011 – 1/12/2011	3/7/2011	No
Severe Winter Storm and Flooding	1813	12/11/2008 – 12/18/2008	1/5/2009	No
Severe Storms and Inland and Coastal Flooding	1701	4/15/2007 – 4/25/2007	5/16/2007	Yes
Blizzard	1090	1/7/1996 – 1/13/1996	1/24/1996	Yes
Winter Coastal Storm	975	12/11/1992 – 12/13/1992	12/21/1992	No
Coastal Storm, Flood, Ice, Snow	546	2/6/1978 – 2/8/1978	2/10/1978	Yes
<i>Source: FEMA Disaster Declarations 1954 - Present</i>				

The NCDC tracks storm events and the information below was available for Barnstable County regarding winter storm and blizzard occurrences (see **Table 3-16**).

Table 3-16: Winter Storm/ Blizzard Data for Bristol County (2003– Present)

Location (County)	Date	Type	Death	Injury	Property Damage
Barnstable	2/12/2006	Winter Storm	0	0	\$10,000
Barnstable	12/19/2009	Winter Storm	0	0	\$25,000
Barnstable	2/10/2010	Winter Storm	0	0	\$15,000
Barnstable	2/8/2013	Blizzard	0	0	0
Barnstable	1/3/2014	Blizzard	0	0	0
Barnstable	3/26/2014	Blizzard	0	0	\$65,000
Barnstable	1/26/2015	Blizzard	0	0	0
Barnstable	2/14/2015	Blizzard	0	0	0
Barnstable	1/23/2016	Blizzard	0	0	\$70,000
Totals:			0	0	\$185,000
<i>Source: NCDC Storm Events Database http://www.ncdc.noaa.gov/stormevents/</i>					

Specific details from the more significant events noted in the table above that have impacted Barnstable County include:

- **January 2016** - Six to sixteen inches of snow fell across Cape Cod and winds gusted as high as 63 mph.
- **February 2015** – Blizzard conditions were met briefly and near blizzard conditions continued for 24 hours on Cape Cod. Gusts of wind were measured at 64 mph.
- **January 2015** – Blizzard conditions occurred on Cape Cod including at the Barnstable municipal airport. Between fourteen and thirty inches of snow fell across Cape Cod.
- **March 2014** – This storm consisted of strong winds (gusts of over 80 mph) and heavy snow.

NOAA's NCDC has implemented the Regional Snowfall Index (RSI) to categorize significant snowstorms that impact the eastern two thirds of the United States. RSI includes a regional index for the northeast that includes Massachusetts and replaced with the Northeast Snowfall Impact Scale (NESIS) to account for snowfall accumulations, population data, and area affected (see **Table 3-17**). The index is similar to the Fujita scale for tornadoes or the Saffir-Simpson scale for hurricanes.

Table 3-17: NCDC 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

3.2.11.3 Impact & Vulnerability

Barnstable is vulnerable to winter storm events. Winter storm events on Cape Cod are typically associated with heavy snow, high winds, storm surge and flooding which makes the coastline especially vulnerable to flooding. The Barnstable County Hazard Mitigation Plan notes that winter storms that impact Cape Cod tend to have the most effect on the north shore. As a developed coastline, particularly in Barnstable, infrastructure is at risk and may be impacted directly by the winter storm event or by associated power outages and the inability to use safe transportation routes. Route 6 is the main roadway in and out of Cape Cod and it also serves as the evacuation route but during winter storm events, may become impassable.

Impacts to property and operations are usually temporary and include snow removal. However, heavy snow can lead to significant snow removal costs, infrastructure damages (such as weight of snow on roofs), and loss of business that can financially impact communities. Other potential impacts include knocked down trees, power lines, and utility poles. Freezing temperatures can result in downed trees, power lines, utility poles, ice jams that can cause flooding, and building pipe bursts due to poor insulation or lack of heat. Risks related to snow and ice are most often associated with automobile accidents followed by individuals caught outside in the storm. Winter storms can also result in fatalities that are most often not directly related to the storm itself. Fatalities due to traffic accidents on icy roads, heart attacks from excessive shoveling, and hypothermia from prolonged exposure to the cold are typical. Fatalities due to cold exposure are most often associated with infants and the elderly that are most susceptible.

During winter storm Juno in January 2015, Barnstable sheltered over 200 residents. In reflecting on this event, local staff indicated a challenge in the community is the number of older or elderly residents that don't require hospitalization but have medical conditions or medications that need to be taken. A potential collaboration with Cape Cod hospital to monitor these residents as "social admits" in the future may be necessary. The DPW Director noted during the discussion of whether or not the community should reconsider opening shelters for each village in the community that it is hard for DPW to keep roads open during a winter storm if there are many shelters open. It is easier to focus on one facility and the need to keep that access point open during an emergency. Another area of concern is long term power loss because much of West Barnstable is served by wells, and if residents lose the ability to have clean water, water quality could quickly become a problem.

In the summer of 2015, the Barnstable DPW conducted a Snow and Ice workshop to discuss snow and ice operations in the community. Some of the outcomes included adoption of a GPS based form of snow management and snow removal crew management and rest policies. Communicating through the Town website has been effective but there

should also be a way for citizens to call and hear a recorded version of the website message for those that do not have computer access. Better utilization of Channel 18 and radio announcements could also enhance communication efforts.

3.2.11.4 Probability of Future Occurrence

According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the probability of future occurrences is defined by the number of events over a specified period of time. For the purpose of this plan, the probability of Barnstable experiencing a winter storm is **highly likely**. Research indicates that the entire state is at risk for frequent winter storms. Moderate storms frequently impact Cape Cod and in addition to snow and ice accumulation and wind hazards, winter storms can produce storm surges and coastal erosion, particularly affecting Barnstable's north coast.

3.2.12 Tsunami

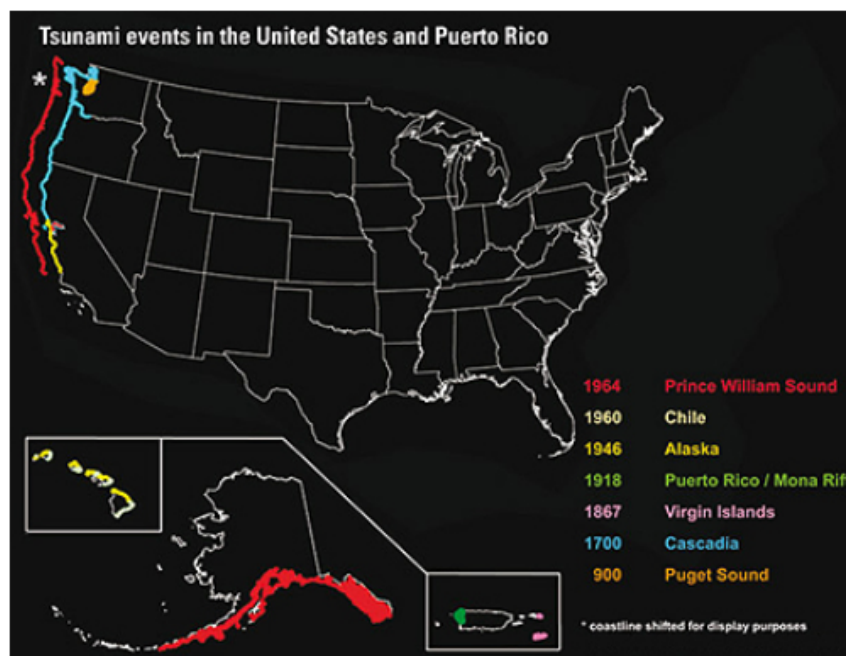
A tsunami occurrence is typically characterized by a series of waves that are generated by an undersea disturbance such as an earthquake, landslide, meteorite impact, glacier calving, or volcanic eruption. According to NOAA, the speed of a tsunami can range from 500 miles per hour to 20-30 miles per hour in shallower coastline conditions. A tsunami is different from a regular ocean wave because it is associated with a current that travels from the water surface down to the ocean floor. As tsunami waves approach shore, they slow down and cause a "wave pile-up" which causes wave heights to increase along with a continuously flowing "wall of water" which can cause devastating damage in coastal areas.

Tsunamis are rare, but not unprecedented in the Atlantic Ocean. For a tsunami to cause major damage, there must be an earthquake of a magnitude of at least 7 with an epicenter in the ocean. This is rare on the East Coast.

3.2.12.1 Hazard Location

The largest source region for tsunamis is the Pacific Ocean with approximately 70 percent of all world occurrences. Within the continental United States, the most vulnerable states are those located near the Pacific Ocean. **Figure 22** shows seven earthquake events that have caused tsunamis in the United States. The coastal areas of Massachusetts are exposed to the threat of tsunamis. Tsunamis on the East Coast of the United States are rare and the primary source of tsunamis is from landslides that occur along the continental slope in the Atlantic Ocean.

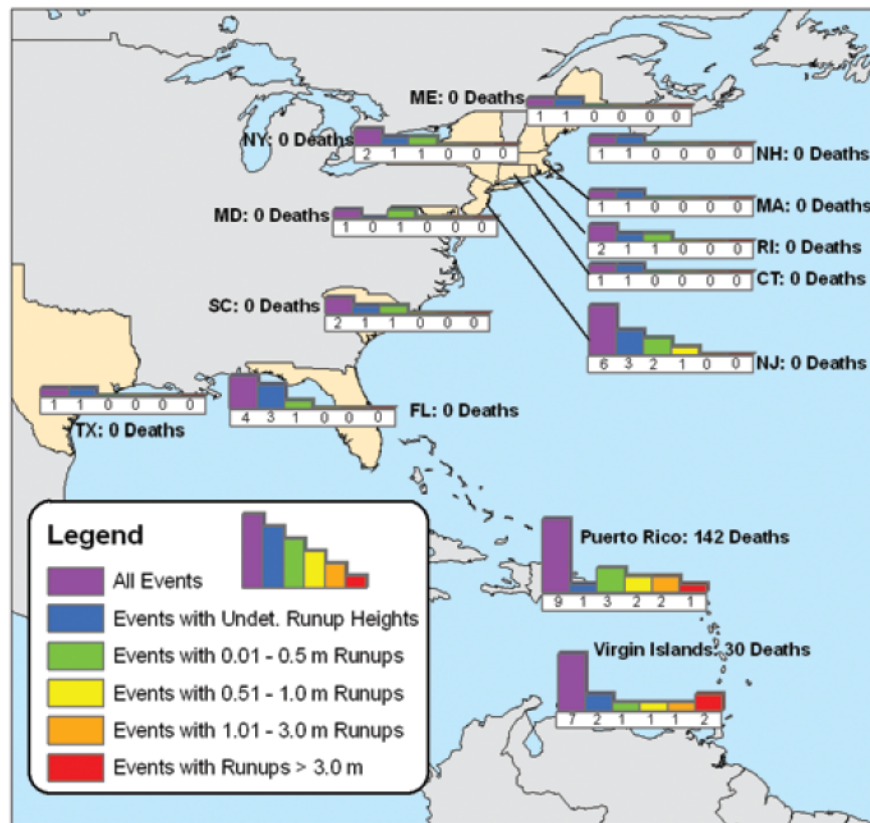
Figure 22: Earthquake Generated Tsunamis in the United States from 900 to 1964



3.2.12.2 Previous Occurrences, Severity & Extent

According to FEMA, there has not been a Presidential Disaster Declaration made for tsunamis in the State of Massachusetts since 1953. A significant tsunami has never struck the Massachusetts coast. The NCDC Storm Events Database does not report a tsunami occurring in any part of Massachusetts. **Figure 23** displays how many tsunami events have occurred in the Atlantic Ocean causing run-up heights of 0.01 m to greater than 3.0 m for U.S. states and territories. The figure shows how there have been no occurrences of tsunamis along the Eastern continental U.S.

Figure 23: Total Number of Tsunami Events



According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the probability of future occurrences is defined by the number of events over a specified period of time. For the purpose of this plan, the probability of future tsunamis in Barnstable is **unlikely**. The likelihood of damaging tsunami along the Massachusetts coastline is low compared to other hazards; however, the impacts could be very high. Most destructive tsunamis are classified as local or regional and caused by earthquakes.

A tsunami is classified according to its intensity; often characterized by one of the following types:

- **Microtsunami** – tsunami with a small amplitude that must be observed with instruments but is not observed visually.
- **Local Tsunami** – tsunami with destructive effects confined to the coast, usually caused from a nearby source less than 200 km (124 miles) away. Tsunami is usually generated by a small earthquake or landslide.
- **Regional Tsunami** – tsunami capable of destruction in a geographic region, generally within 1,000 km (621 miles) of its source.
- **Pacific-wide tsunami** – tsunami capable of widespread destruction in an immediate region or across the Pacific Ocean.

3.2.12.3 Impact & Vulnerability

Impacts of a tsunami vary depending on the size of the occurrence and can vary from minor damage to coastal infrastructure to complete destruction of everything in its path including buildings and severe land erosion. Tsunamis

can also impact human life and cause long term social and economic impacts depending on how much damage they cause. While not common, tsunamis are possible in the Atlantic Ocean and the Massachusetts Hazard Mitigation Plan notes that all of the coastal areas of the state are exposed to the threat of a tsunami event which could occur from a local offshore earthquake or from a major earthquake across the Atlantic Ocean.

3.2.12.4 Probability of Future Occurrence

According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the probability of future occurrences is defined by the number of events over a specified period of time. The probability of future tsunamis in Barnstable is unlikely. The likelihood of damaging tsunami along the Massachusetts coastline is low compared to other hazards; however, the impacts could be very high. According to Boston College research, the most probable cause of a tsunami on the East Coast could be from eruptions or underwater landslides of volcanic islands on the other side of the Atlantic Ocean, such as the Canary Islands. Historical frequency of tsunamis on the East Coast is approximately one event every 39 years, based on data from 1668-2017.

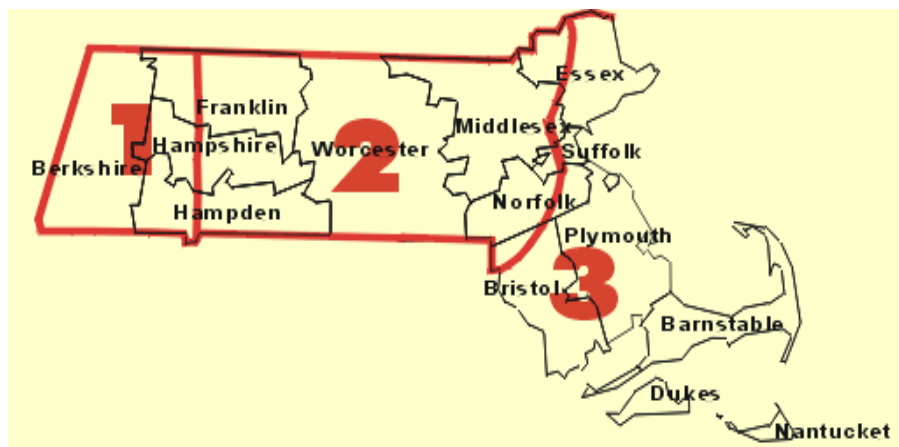
3.2.13 Extreme Temperatures

Extreme temperatures include both cold and hot events, which can have significant effects on human health, commercial businesses and primary or secondary impacts on infrastructure. An extreme cold event is recognized when temperatures drop below normal and increased wind speeds can cause harmful wind-chill factors. Wind Chill Advisories are issued if wind chill is forecasted to dip below -15°F for at least three hours. An extreme heat event for Massachusetts is defined as three or more days above 90°F.

3.2.13.1 Hazard Location

The National Oceanic and Atmospheric Administration (NOAA) has identified 359 climate divisions nationwide, which typically coincide with county lines. Massachusetts has been divided into three regions; Barnstable is located in Region 3 as shown in Figure 24.

Figure 24: NOAA's Massachusetts Climate Regions



Source: 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan

Extreme temperatures can occur anywhere in Massachusetts. Colder temperatures are most common in higher elevations. Even though coastal areas may also have lower daily temperatures, they do not typically sustain them for as great an amount of time. Inland urban areas are more prone to extreme heat events due to the increased population, dark colored infrastructure and limited vegetation.

3.2.13.2 Previous Occurrences, Severity & Extent

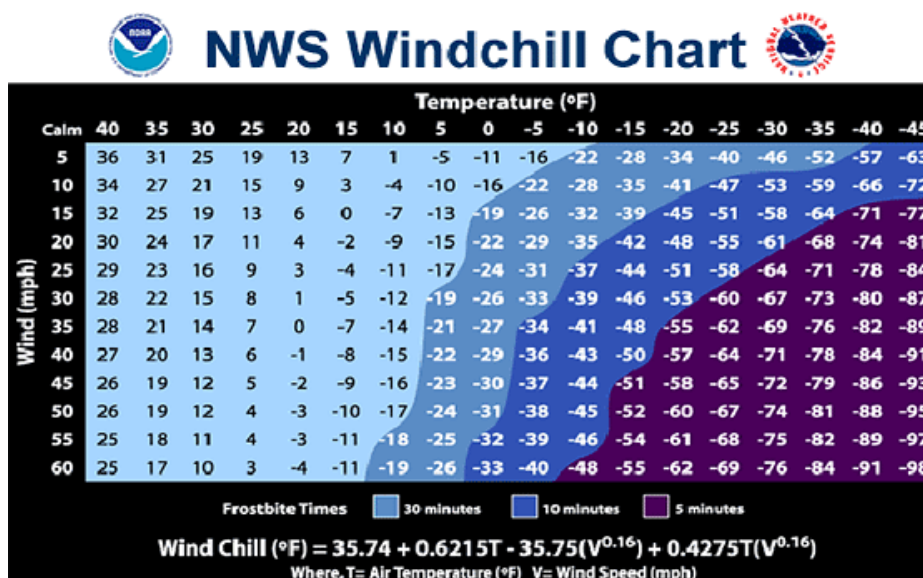
According to FEMA, there has never been a Presidential Disaster Declaration made for an extreme temperature event in the State of Massachusetts. The NCDC Storm Events Database listed the following as extreme temperature events in Barnstable County:

- **February 4, 2016** – Extremely cold wind chills impacted New England and wind chills as low as 32 below zero were reported in Falmouth and Hyannis.

Additional extreme temperature events were highlighted in the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan. Since 1994, there have been 33 cold weather events and 43 warm-weather events. Over the last two decades, an average of 1.5 extreme cold weather events (below 0 degrees Fahrenheit with wind chill) and an average of 2 extreme hot weather events (over 90 degrees Fahrenheit) have occurred in the state annually.

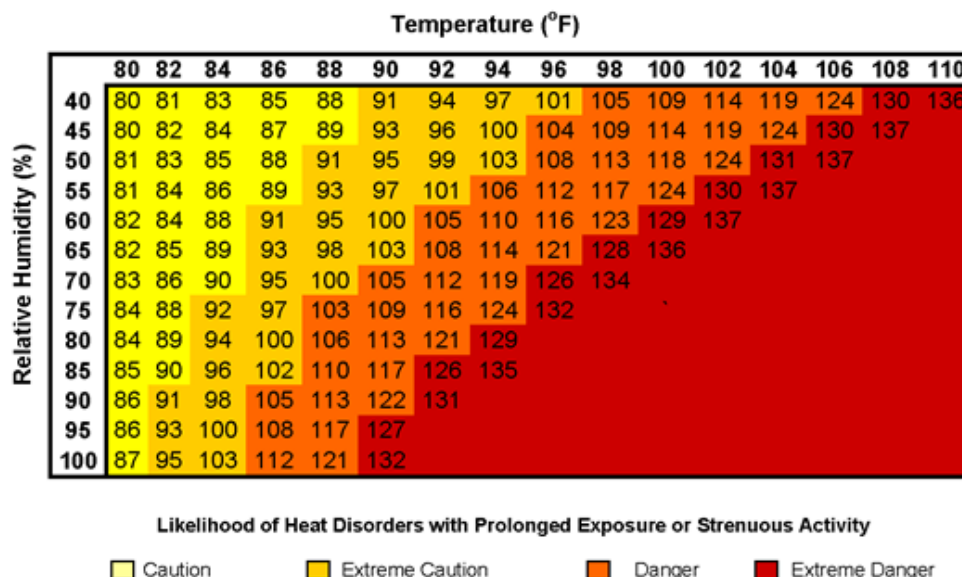
The severity of extreme cold temperatures is generally measured using NOAA's National Weather Service (NWS) Wind Chill Temperature Index provided in **Figure 25**. The index uses advances in science, technology, and computer modeling to provide an accurate, understandable and useful formula for calculating the dangers from winter winds and freezing temperatures. Extreme cold temperatures are characterized by the air temperature dropping to approximately 0 degrees Fahrenheit or below.

Figure 25: NOAA's National Weather Service Wind Chill Chart



The severity of extreme heat temperatures is generally measured using NOAA's NWS Heat Index. The Heat Index provided as **Figure 26** assigns indices of caution, extreme caution, danger, and extreme danger based on relative humidity and temperatures. The Heat Index is derived for shady, light wind conditions. Exposure to full sunshine can increase the index values by up to 15 degrees.

Figure 26: NOAA's National Weather Service Heat Index



3.2.13.3 Impact & Vulnerability

Barnstable is vulnerable to extreme temperature events. According to the National Weather Service, in 2013, cold weather events resulted in 24 fatalities with an average of 27 cases from 2004 to 2013. In the same year, there were 92 heat-related fatalities with 123 average cases from 2004 to 2013.

The most prominent impact of extreme temperatures is on human health. The Centers for Disease Control and Prevention (CDC) identified populations most at risk from extreme cold or heat to include the following: the elderly, infants and children under four years of age, individuals who are physically ill, low-income persons who cannot afford proper heating or cooling, and the general public who may overexert themselves during times of extreme heat or experience hypothermia during extreme cold events.¹ In Barnstable, according to the 2010 US Census, 21% of the population is age 65 and older while 4.6% is five years old or younger.

Extreme high temperatures have also resulted in power failures due to high demand for air conditioning. During extended power outages, the lack of refrigeration results in food spoilage, transportation problems, closure of schools and businesses, and places the sick at greater risk. Extended power failures associated with blackouts can result in significant property damage.

3.2.13.4 Probability of Future Occurrence

According to the 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, the probability of future occurrences is defined by the number of events over a specified period of time. For the purpose of this plan, the probability of future extreme temperature events in Barnstable is likely. The CDC indicates that climate change will result in longer, more severe, and more frequent extreme temperature events. Studies have shown that by the end of the century, the number of days with temperatures reaching 100 degrees Fahrenheit or more is projected to increase

¹ 2018 Massachusetts Integrated State Hazard Mitigation and Climate Adaptation Plan, website: <https://www.mass.gov/files/documents/2018/09/17/SHMCAP-September2018-Chapter4.pdf>

dramatically in the United States. Climate change is predicted to increase the frequency and intensity of heat waves, with significant increases in heat-related deaths.

3.2.14 Sea Level Rise

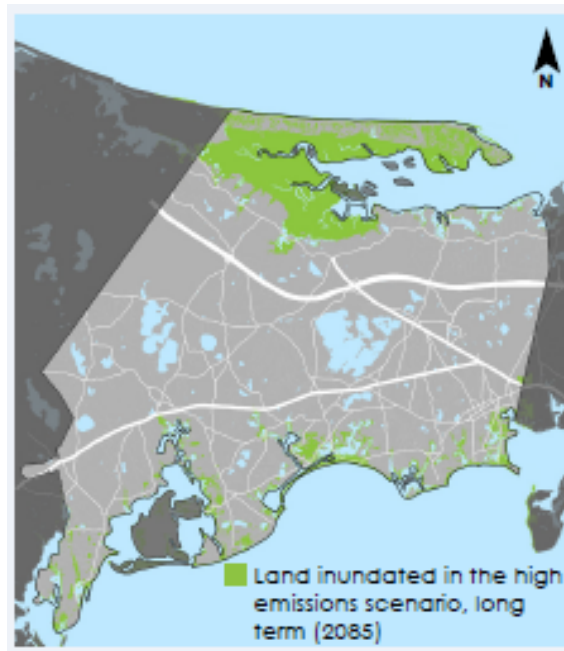
Sea level rise is the increase in mean sea level over time. During the last century, tide gauges and satellites recorded measurements that indicate an acceleration of sea level rise relative to the past rate globally, including Cape Cod. Relative sea level rise refers to the combination of eustatic, isostatic, and other effects at a specific location. Eustatic contributions to sea level rise are global-scale changes and include thermal expansion of seawater as it warms and the addition of water volume from melting land-based glacial ice sheets. Isostatic effects are more localized changes in land surface elevations (e.g., subsidence or sinking)

3.2.14.1 Hazard Location

, . Resilient MA: Climate Change Clearinghouse for the Commonwealth provides sea level rise projections under a range of scenarios. The intermediate-high scenario projects 1.7' by 2050 and 5.1' by 2100. The high emission scenario projects 2.4' of sea level rise by 2050 and 7.7' by 2100 for Barnstable (see **Figure 27**). While the “bathtub” or still-water models of sea level rise provide estimations for salt-water inundation over a broad area, continually changing factors such as groundwater depth and geomorphology ought to be looked at when considering sea level impacts in a specific area.

A community wide sea level rise map is included in **Appendix A**.

Figure 27: Sea Level Rise Inundation – Long Term Scenario



3.2.14.2 Previous Occurrences, Severity & Extent

Contributing to the severity of coastal storms is climate change and sea level rise which increase the volume of water in the ocean from melting ice sheets and glaciers. According to a report by the Massachusetts Office of Coastal Zone Management (CZM) the relative sea level has risen approximately 9 inches during the 20th century. A sea level rise of two feet will eliminate an estimated 10,000 square miles of land, including up to 43% of the country's current wetlands.

The Intergovernmental Panel on Climate Change (IPCC) has predicted that sea level rise and the risks that it poses to the shoreline communities will continue to accelerate. Cape Cod and the Mid-Atlantic will likely be disproportionately affected, as threats of sea level rise are accompanied by observed subsidence of coastal land.

3.2.14.3 Impact & Vulnerability

In Barnstable, sea level rise will have a direct and indirect impact. One reason is that there will be an increased risk of flooding inland is due to sea level rise reducing the ability of rivers and streams to absorb water during precipitation events and potentially raising groundwater levels. A high groundwater level limits the capacity of water bodies and natural resource areas to absorb water during a storm event which can cause more severe inland flooding. Additional development in Barnstable could also contribute to the problem by increasing stormwater runoff and eliminating open spaces that may serve as natural water storage areas for excess precipitation. Salt-water intrusion of estuarine habitats poses a threat to native species and their ecosystems, as well as fresh-water resources for drinking water.

The increasing sea level will increasingly impact homes, businesses, roads, utilities, infrastructure, wastewater treatment plants, and natural habits. These impacts are already evident in Millway and adjacent neighborhoods where beach access stairs are submerged during king tides. In time, the temporarily inaccessible roads and power outages experienced during storms will become the constant norm in increasingly widespread areas of Barnstable County. Storm surges will inundate increasingly larger areas and will occur more frequently. Elderly, disabled, and impoverished residents along the coast will be the most sensitive to the impacts of sea level rise due to a disproportionate lack of adaptive capacity and resources. However, all coastal residents will be impacted to some degree.

The adverse effects of rising waters are evidenced by the submersion of low-lying lands, erosion of beaches, conversion of wetlands to open water, and exacerbated coastal flooding. Rising seas can inundate coastal areas, increase storm-surge flooding, erode shorelines, and increase the salinity of estuaries and aquifers. A report by the EPA entitled “*Coastal Sensitivity to Sea Level Rise*” highlights the increased flooding risks associated with sea-level rise:

“Rising sea level increases the vulnerability of coastal areas to flooding because higher sea level increases the frequency of floods by providing a higher base for flooding to build upon. Erosion of the shoreline could also make flooding more likely because erosion removes dunes and other natural protections against storm waves. Higher sea level also raises groundwater levels, which can increase basement flooding and increase standing water. Both the higher groundwater tables and higher surface water levels can slow the rate at which areas drain, and thereby increase the flooding from rainstorms.”

A major challenge for Barnstable in the future will be evaluating the ecological and social impacts of sea level rise and developing planning and adaption strategies that will address both environmental and human interests.

3.2.14.4 Probability of Future Occurrence

The 2020 MIT Joint Program on the Science and Policy of Global Climate Change indicates that sea level rise is expected to significantly increase flood risks along both the north and south shores of town. Higher sea levels will also mean higher storm surges during severe weather events. In high and low emission scenarios, the projections show ongoing sea level rise throughout the century. For long term planning purposes, sea level in Barnstable has the potential to rise by 7.7 feet in the high emission scenario. The probability of future sea level rise in Barnstable is **highly likely**.

3.2.15 Climate Change

Climate is defined as average temperature and precipitation and includes the type, frequency, and intensity of weather events. At the local, regional and state level, climate change will alter the number and severity of extreme weather events, particularly those associated with high winds and precipitation. Understanding the impacts to infrastructure,

environment and human life is critical to developing a full picture of what climate change impacts will be. In general, the earth's average temperature has risen by 1.5 degrees Fahrenheit in the past 100 years, and it is expected to continue that trend.

In 2014, Barnstable worked with the MIT Collaborative Consensus Building Institute on a summary Climate Change Risk Assessment for the community. The report acknowledges Barnstable faces a number of climate related risks, some of which include increased occurrences of flooding, more intense coastal storms and more extreme and frequent precipitation events. These climate changes will have a direct impact on the local population, buildings, infrastructure and natural resources. The report indicates the following climate projections for Barnstable, they include:

- **Hotter Annual Temperatures** – The average annual maximum temperatures could increase between 2.9- and 6.4- degrees Fahrenheit
- **More Extreme Heat Events, Less Extreme Cold Events** – Barnstable historically experienced on average 2 extreme heat events per year (when temperatures rise above 90 degrees Fahrenheit), long term projections indicate Barnstable may see as many as 27 extreme heat events per day under high emission scenarios. Barnstable may experience between 20-40 fewer annual extreme cold events which is far below the historic average of 103 events per year.
- **More Annual Precipitation** – Barnstable may see as much as 2.8 additional inches of annual precipitation per year.
- **More Extreme Precipitation** – In the past, Barnstable has experienced an average of 1.8 events per decade where 4 inches of precipitation were present in 48 hours. Under the high emissions scenario, Barnstable could see as many as 4.1 events per decade.
- **Wetter Winters, Drier Summers** – Under the high emissions scenario, Barnstable may see up to 2.2 inches of precipitation during the winter.

According to the MIT report, major risks for Barnstable include:

- **Flooding** – Coastal and inland flood hazard risk will increase which is a concern because flooding is already one of the predominant natural hazards in the community and region.
- **Drought** – With a reduction in precipitation and higher temperatures possible due to climate change, drought could cause water supply shortages or water quality issues in Barnstable as well as increase the risk of wildfires.
- **Tourism & Economic Conditions** – Barnstable relies on a strong tourism economy. Longer summers and warmer winters may offer the opportunity to extend the season for residents and visitors. The potential downside to climate change impacts are impacts climate change may have on the local beaches and natural resource areas which would limit the public's ability to enjoy these areas. Barnstable has residential homes and commercial properties in floodplain areas (including coastal) vulnerable to flooding and sea level rise. As a part of the residential tax base, any damage to these properties could impact the tax base.
- **Ecosystem Change** – Barnstable is home to an abundance of natural resource areas including coastal habitats, freshwater wetlands and a designated Area of Critical Environmental Concern (ACEC). These areas will be impacted by climate change when sea level rise inundates coastal habitats and freshwater wetlands, threatening the plant and animal species that live there and impacting water quality.

4. VULNERABILITY ASSESSMENT

Vulnerability refers to the susceptibility of the Town's residents, infrastructure and natural, cultural, and historic resources to hazard events. Vulnerability indicates what is likely to be damaged by a hazard and how severe the damage might be. The vulnerability assessment conducted for the Town of Barnstable includes a profile of the Town's existing development patterns and natural environment. Critical facilities such as hospitals, public safety facilities, and schools are identified, mapped, and surveyed for potential vulnerability. GIS analysis was used to assess vulnerability of existing structures to flooding and estimates potential dollar losses. Finally, a review of the Town's participation in the National Flood Insurance Program is included.

4.1 COMMUNITY PROFILE

The Town of Barnstable is located in Barnstable County in Cape Cod, Massachusetts. The total land area of the Town is approximately 40,000 acres. Barnstable is one of the most urbanized towns on the Cape and is a regional center of administrative and commercial activity. Hyannis Village functions as a regional commercial center and Barnstable Village is the Barnstable County seat. Originally founded in 1639, the Town contains numerous historic resources; there are more than 40 known Native American archaeological sites, 14 national historic districts, two local historic districts, and an additional 74 individually designated sites. The town's coastal location, wetland habitats, and forested open spaces collectively create a high susceptibility to natural hazards. Specific information assembled by the Town's GIS Department is provided below:

Population	228,996 (2020 census)
Acres of Developed Land	11,812
Acres of Conservation Land	9,922
Miles of Coastline	104 (saltwater), 76 (freshwater)
Centerline Miles of Roads	542 (303 public, 239 private)
Acres of Open Water	7,197 (including inland bays), 2,971 (excluding inland bays)
Number of Great Ponds	13
Acres of Forested Woodland	17,653
Acres of Salt Marsh	3,946
Acres of Fresh Marsh	864
Acres of Cranberry Bogs	864
Acres of Shrub Swamp	434
Acres of Barrier Beach/Dunes	1,776
Acres in Hurricane Surge Zones	9,834
Acres in Flood Zones	15,240
Hazardous Waste Sites	10
Critical Facilities	109
Repetitive Loss Properties	[insert current data]

4.2 CRITICAL FACILITIES INVENTORY

A critical facilities inventory was compiled for the Town of Barnstable. Critical facilities identified within the Town of Barnstable include:

- Emergency Facilities/Shelters
- Public Safety Services
- Hospitals
- Town Government Facilities
- Wastewater Infrastructure
- Transportation Facilities
- Hazardous Material Facilities
- Schools
- Nursing Homes/Elderly Housing
- Group Day Care Facilities
- Senior/Youth/Recreation Facilities
- Designated Emergency Animal Shelters
- Marinas/Boat Yards

The critical facilities inventory is represented on the Critical Facilities Map in **Appendix A**. Ten of the critical facilities identified in the Town of Barnstable are also identified as regional critical facilities by the Cape Cod Commission. The regional facilities are the American Red Cross, the Barnstable County Complex, Cape Cod Hospital, Barnstable Municipal Airport, Cape Cod Community College, the Barnstable County Fire and Rescue Training Academy, the Humane Society, and the MSPCA Animal Shelter.

4.3 HURRICANE SURGE INUNDATION AREAS

Hurricane Surge Inundation Areas, also known as Sea, Lake, and Overland Surges from Hurricanes (SLOSH) zones, are based on a computer model designed by the National Weather Service to forecast storm surges and potential flooding from hurricanes that may make landfall in New England. Surge limits shown on the community maps represent potential flooding that may occur from critical combinations of hurricane track direction, forward speed, landfall location, and high astronomical tide.

The Town of Barnstable has approximately 15 square miles (9,834 acres) of property in Hurricane Inundation zones. In addition, critical facilities located in Hurricane Inundation zones are represented on the Risk Assessment and Vulnerability Map and as follows:

# of Critical Facilities in Hurricane Zone	# of Critical Facilities in Flood Zones	Total # of Critical Facilities	Regional Critical Facilities in Hurricane Zone	Total # of Regional Critical Facilities
27	23	109	2	1

Data: Town of Barnstable GIS

- 23 Cape Cod Hospital, Hyannis (Regional)
- 31 Barnstable Housing Authority, Hyannis
- 47 Pope John Paul II High School, Hyannis
- 71 Hyannis Head Start, Hyannis
- 83 Humane Society of the US, Barnstable
- 86 Anchor and Marine Ltd, Hyannis
- 87 Barnstable Harbor Marina, Barnstable
- 88 Barnstable Marine Service, Barnstable*
- 89 Bismore Park Marina, Hyannis
- 90 Crosby Yacht Yard, Osterville*
- 91 Gateway Marina, Hyannis
- 92 Hyannis Marine, Hyannis*
- 95 Millway Marina, Barnstable
- 96 Nauticus Marina, Osterville
- 97 Oyster Harbors Marine, Osterville
- 98 Sandy Neck Gatehouse, West Barnstable
- 99 West Bay (Oyster Harbors) Bridge, Osterville
- 100 Harbormaster's Building and Visitors Center, Hyannis
- 101 South Street Pump Station
- 102 Mill Way Pump Station
- 103 Steamship Authority, Hyannis
- 104 Lewis Bay Boat Ramp, Hyannis
- 105 Blish Point Boat Ramp, Barnstable
- 106 Bay Shore Road/Old Harbor Road Boat Ramp

4.4 WILDFIRE HAZARDS AREAS

A significant percentage of the Town's total acreage is identified as a wildfire hazard area. Wildfire hazard areas are defined as unfragmented forest habitat greater than 40 acres in size or salt marsh areas greater than three acres in size.

There are 13 Critical Facilities located in wildfire hazard areas or in wildfire/urban interface zones in the Town of Barnstable.

- 12 Osterville Elementary
- 26 Barnstable Water Department at 1841 Phinney's Lane
- 29 Cotuit Water Department
- 33 Hyannis Water Department
- 38 Town Offices – Marine and Environmental Affairs at 1189 Phinney's Lane
- 45 Cape Cod Academy
- 52 Cape Cod Community College
- 62 Bright Promises Preschool
- 64 Cape Cod Conservatory Preschool
- 78 West Parish Family School
- 82 Bayview Kennels
- 83 Humane Society of the U.S.
- 85 Special K Kennels

4.5 FLOOD ZONES – VULNERABILITY ANALYSIS [TO BE UPDATED]

To assess the vulnerability of the Town's built environment to flood hazards, an analysis of the structures and land uses in FEMA flood zones was conducted by the Town's GIS Department¹. The following table summarizes that analysis; the table represents the number of parcels located in FEMA A and V flood zones, building square footage, and assessed building values. The vulnerability analysis was conducted using the [update] FEMA Flood Insurance Rate Maps. Although these maps were not officially adopted by the Town at the time of the analysis, they provided the opportunity for the most accurate analysis.

Loss Estimates/Area Vulnerability Assessment Town of Barnstable Development in Flood Zones by Land Use				
Land Use	# of Parcels (including condo units)	# of Parcels (not including condo units)	Building Area (Sq.Ft.)	Assessed Building Value
Residential	1,114	924	5,018,550	\$425,944,300
Commercial	178	42	533,146	\$38,354,100
Industrial	0	0	0	\$0
Recreational	0	0	0	\$0
Agricultural	0	0	0	\$0
Tax Exempt	19	19	88,625	\$7,905,400
Mixed Use	13	13	116,619	\$14353,900
TOTAL	1,354	998	5,756,940	\$486,557,700

Loss Estimates/Area Vulnerability Assessment Town of Barnstable Development in Flood Zones by Village				
Land Use	# of Parcels (including condo units)	# of Parcels (not including condo units)	Building Area (Sq.Ft.)	Assessed Building Value
Barnstable	123	119	366,397	\$22,412,500
Centerville	309	272	1,101,363	\$84,563,200
Cotuit	73	73	501,117	\$38,342,100
Hyannis	596	281	1,508,021	\$148,064,500
Marstons Mills	15	15	124,134	\$11,526,500
Osterville	225	225	2,128,547	\$179,963,100
West Barnstable	13	13	27,391	\$1,685,800
TOTAL	1,354	998	5,756,940	\$486,557,700

¹ The methodology used by the Town of Barnstable GIS Department to calculate these figures can be found in Appendix C.

As expected, residential properties are the most vulnerable to flood damage in terms of numbers, square footage, and assessed value; 1,114 housing units totaling over \$425.9 million in value are located in flood hazard areas. Potential commercial losses from flooding total over \$38 million, not including commercial enterprises that might be included in the mixed-use category. Many of these uses are likely marine-related businesses that rely on having good access to the water. A closer evaluation of the locations and functions of these commercial properties would be valuable and facilitate efforts to minimize economic losses after major flood events.

The Village of Hyannis has the greatest number of structures vulnerable to flood damage; many of these structures are located around the Inner Harbor, Lewis Bay, Hyannis Harbor, and Stewart's Creek. The Village of Osterville faces the greatest potential dollar losses from flooding. The average assessed value of a structure in the flood zone in Osterville is almost \$800,000. This data reflects the vulnerability of high dollar homes located on Vineyard Sound and the Three Bays. The Village of Centerville also has a high number of structures vulnerable to flooding; these properties are located primarily around the Centerville Harbor and Centerville River.

In addition to concerns regarding vulnerability of structures, the MHM Planning Team identified several roads that are prone to flooding. Flooding of these roadways could potentially interfere with travel of emergency vehicles and evacuation of residents. The following areas are of concern:

- Route 6 in Barnstable (evacuation route)
- Mill Way in Barnstable
- Commerce Road in Barnstable
- West Bay (Oyster Harbors) Bridge (also vulnerable to wind hazards)

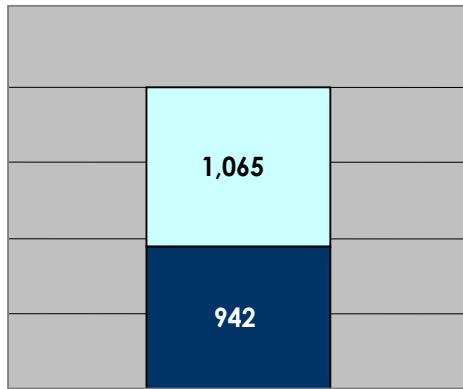
4.6 NATIONAL FLOOD INSURANCE PROGRAM AND REPETITIVE LOSS PROPERTIES [TO BE UPDATED]

The Town of Barnstable participates in the National Flood Insurance Program (NFIP). As of March 31, 2010, the town had 1,065 NFIP policies in force, totaling \$288,793,300 of coverage. Between 2002 and 2010, the number of policies held in Barnstable increased by 123, increasing the total coverage amount in force by \$106,065,100. From the inception of NFIP in 1972 to March 31, 2010, 277 loss claims were filed in the Town; 115 of those claims were paid totaling \$2,901,868.

Repetitive loss properties have been paid two or more claims by the NFIP worth at least \$1,000 each over a ten-year rolling period. The Town of Barnstable has 17 repetitive loss properties, the second most on the Cape behind the Town of Falmouth. Three of the properties are located Cape Cod Bay near Barnstable Harbor. Twelve of the properties are on Nantucket Sound, including a concentration of eight properties on Centerville Harbor. The final two properties are in the Village of Hyannis, near the intersection of Route 28 and Bearse's Way. Ten of the repetitive loss properties are located in "A" zones and one in a "V" zone. One property has 5 paid loss claims (a non-residential property), one has 4, and two have three paid loss claims. The areas where repetitive loss properties are located are shown on the Risk and Vulnerability Assessment Map.

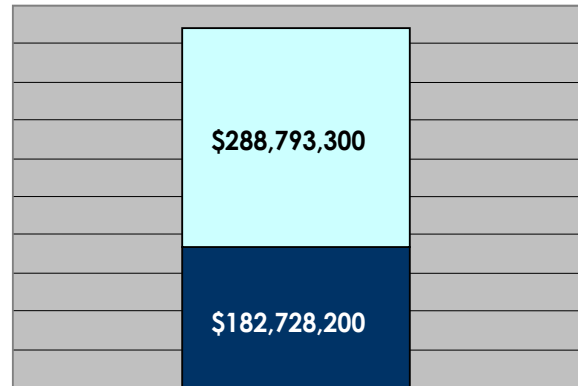
Barnstable's floodplains are managed through zoning, wetlands, and health regulations. The Town is committed to the ongoing enforcement of these regulations and will continue to review and enhance requirements to best protect the environment and vulnerable properties. Additionally, the Town is engaged in public outreach programs to promote private floodplain management best practices and participation in the NFIP. The floodplain bylaw is in the review and update process and will be in full compliance with the NFIP.

NFIP Policies in Force



2010
2002

NFIP Coverage Amount in Force



2010
2002

5. MITIGATION ACTIONS

This section describes the mitigation actions identified to contribute to the Town of Barnstable's resiliency and the capabilities available within the Town to implement the mitigation actions. The capabilities reside in Town leaders that are committed to resiliency and strong partnerships that support regional hazard mitigation planning efforts. The mitigation actions identified area intended to be comprehensive and far reaching to address the identified Town goals and objectives.

5.1 CAPABILITIES ASSESSMENT

Barnstable's commitment to hazard mitigation has been reinvigorated since the development of the 2010 plan based on new resources available within the Town departments and a strong commitment to support the community's resilience. Barnstable recognizes its coastal location presents added challenges for resilience. Barnstable has strong capabilities to continue to work toward resiliency as described below.

5.1.1 Planning & Development

The Town of Barnstable has a strong Planning & Development department and committed Director that has spearheaded this planning effort. Recent staff additions have included a Senior Planner that has experience in hazard mitigation planning, having led this effort at a previous municipality. Planning & Development also led the charge for the 2019 Municipal Vulnerability Planning effort and became designated as a MVP community. The department is also in the process of updating its 2010 Local Comprehensive Plan, with climate change as being one of the major drivers for the update. These efforts demonstrate the department's commitment to resiliency and its willingness to dedicate resources toward this effort.

5.1.2 Marine and Environmental Affairs

The Marine and Environmental Affairs Department strives to protect and preserve the Town's waterways and natural resources. Natural Resource officers patrol town conservation areas and beaches to enforce local by-laws and state and federal wildlife, fisheries, and environmental regulations. The program provides support for over sand operations at Sandy Neck, including environmental functions associated with endangered species and resource management. The Harbormaster is also very focused on community education associated with storm events. These resources are important in Barnstable's overall climate resiliency efforts.

5.1.3 Public Works

The Barnstable Department of Public Works mission is to preserve and improve the Town's infrastructure and related assets in a manner which meets and enhances the current and future social and economic needs of the community, to contribute to a healthy, safe, and quality environment for the town's citizens and visitors, and to provide a cost effective and environmentally sound means of disposing of solid waste and wastewater. Public Works is very involved in wastewater and clean water management and recycling. They are focused on driving resiliency in the Town's infrastructure.

5.1.4 Police and Fire departments

The Barnstable Police and Fire are very active partners in the path toward resilience. The department utilize CodeRED as its emergency notification service by which town officials can notify Barnstable residents and businesses by telephone, cellular phone, text message, or electronic mail about time-sensitive emergency situations or important community alerts. Both departments actively support emergency management associated with natural hazard events. They have a deep understanding of vulnerable areas and supporting vulnerable populations within the community.

5.1.5 Regional Cooperation

The Town of Barnstable is committed to fostering relationships and establishing partnerships to active resiliency.

5.1.6 Barnstable County

5.1.7 The Cape Cod Commission

Within Barnstable County, the Cape Cod Commission's (CCC) mission is to protect the unique values and quality of life on Cape Cod by coordinating a balanced relationship between environmental protection and economic progress. The CCC is housed in Barnstable and Barnstable is an active community participant. The CCC completes various studies and projects associated with resilience that benefits the various Cape Cod communities.

The CCC includes the Cape Cod Climate Initiative which was created to mitigate the challenges of climate change. Through the Cape Cod Climate Initiative, the Commission worked with stakeholders and partners to develop the 2021 Cape Cod Climate Action Plan. There are many other collaborations ongoing between CCC and the Town focused on resiliency and climate change adaptation.

5.1.8 Cape Cod Cooperative Extension

The Cape Cod Cooperative Extension (CCCE) focuses on hands-on work with towns across the county in regards to community health, nature conservation, and strengthening food systems. As the education department for Barnstable County, the CCCE plans and conducts programs based on local needs and interests, linking academia with practical applications to serve Barnstable County communities via staff, volunteers, and CCCE trustees.

5.2 MITIGATION ACTIONS

Barnstable identified the mitigation actions and projects noted in this section based on the goals and objectives prepared during the planning process, mitigation actions proposed during the 2010 planning effort, past occurrences of natural hazard events and the ability and commitment to work closely with staff, residents, neighboring communities and other key stakeholders to ensure public safety.

Below is a progress determination on mitigation actions from the 2010 Hazard Mitigation Plan and an explanation on whether or not the action was completed, if it's in progress, deferred or deleted. The actions were reviewed with Local Plan Review Team members to comprehensively evaluate plan implementation progress and to provide a starting point for identifying new mitigation actions. **Complete/Ongoing, In Progress** and some **Deferred** actions identified in **Table 5-1** were carried forward into the Future Mitigation Action List. The following status determinations were assigned to each action from the 2010 plan:

- **Complete:** the project was implemented and completed in 2010-2021.
- **Complete/Ongoing:** the project was implemented and completed in 2010-2021, but it will continue to be implemented on an annual basis.
- **In Progress:** The project was started in the 2010 – 2021 timeframe and it is still in progress.
- **Deferred:** The project is important, but it was deferred because there was no funding available, or it is not feasible to complete the project.
- **Deleted:** The project is no longer relevant to the community.

Table 5-1 is a summary of the status of the mitigation actions identified in the 2010 plan and subsequent mitigation actions.

Table 5-1: Progress Determination of Mitigation Actions from 2010 Hazard Mitigation Plan

Mitigation Action	Hazard to Mitigate	Responsible Department	Status	Explanation
Mitigation Action #1 - Develop necessary implementing regulations to adopt a “No Adverse Impact” policy and/or addressing EPA’s MS4 bylaws to mitigate the risks of flooding impacts on properties or public safety.	Flooding, Shoreline Change/ Coastal Erosion	GMD, DPW	In progress	The Town of Barnstable is currently in the process of addressing EPA’s MS4 stormwater bylaws.
Mitigation Action #2 - Develop additional Coastal Resources Management Plans for vulnerable coastal areas within the Town of Barnstable. Management plans should include: <ul style="list-style-type: none"> • An inventory of existing coastal resources, existing public and private access, and all available water quality data; • An overview of existing federal, state and local regulations; • An assessment of potential impacts from coastal storms; • Projections for future conditions including a buildout analysis for FEMA A and V zones, barrier beaches and coastal banks; and • Recommendations for protecting critical habitats and important resources while providing for recreational and commercial uses. • Construction of mitigation actions identified. 	Flooding, Shoreline Change/ Coastal Erosion	GMD, MEA, DNR, DPW	In Progress	A 2023 Coastal Resource plan has been submitted which requests a detailed analysis of the long-term viability of the Sandy Neck beach parking and supporting facilities. This plan was submitted as part of a grant from Coastal Zone Management (CZM) in the Fall of 2016. The analysis demonstrated that to provide protection to the existing infrastructure and maintain the viability of the parking, a relocation of the parking area was the most viable alternative. The Town is currently undertaking an evaluation of alternatives to supplement the information from this report. The selected alternative will be designed and permitted, which will increase the possibilities for grant funding and will prepare the Town to act quickly should a future storm even result in damage to the parking lot.

Mitigation Action	Hazard to Mitigate	Responsible Department	Status	Explanation
Mitigation Action #3 - Develop a Resource Management Plan for the Sandy Neck ACEC that meets Department of Environmental Protection and Massachusetts Coastal Zone Management requirements to aid in the management of this important resource.	Shoreline Change/ Coastal Erosion	GMD, Mass Estuaries Program, DNR, DPW	In progress	<p>A 2023 Coastal Resource plan has been submitted which requests a detailed analysis of the long-term viability of the sandy Neck beach parking and supporting facilities. This plan was submitted as part of a grant from Coastal Zone Management (CZM) in the Fall of 2016. The analysis demonstrated that to provide protection to the existing infrastructure and maintain the viability of the parking, a relocation of the parking area was the most viable alternative. The Town is currently undertaking an evaluation of alternatives to supplement the information from this report. The selected alternative will be designed and permitted, which will increase the possibilities for grant funding and will prepare the Town to act quickly should a future storm even result in damage to the parking lot.</p>
Mitigation Action #4 - Explore the adoption of regulations and incentives to restrict new development and redevelopment in A and V zones, on barrier beaches, or on coastal dunes where there is known to be danger of significant flood damage. <ul style="list-style-type: none"> • Inventory and map vacant land in velocity zones. • Existing structures may be reconstructed or renovated in conformance with all regulatory requirements provided there is no increase in area or intensity of use. • Where applicable, non-water dependent development shall be concentrated on that part of the lot outside the A and V Zones. 	Flooding, Shoreline Change	GMD, Town Council, Conservation Board of Health	Deferred	<p>The adopted District of Critical Planning Concern regulations, Wetland Protection Act, and other regulations continue to provide some limitations and protections in sensitive areas prone to flooding.</p> <p>The Conservation Commission adopted Guidelines for Activities in Land Subject to Coastal Storm Flowage (LSCSF) Velocity (V) Zones and Coastal A Zones Only 1/8/2019.</p> <p>Higher minimum standards for zoning and wetlands are currently being updated by the County.</p>

Mitigation Action	Hazard to Mitigate	Responsible Department	Status	Explanation
Mitigation Action #5 - Adopt a sewer neutral regulation through a General Ordinance. <ul style="list-style-type: none"> Where new sewers are proposed, residential development and redevelopment shall be permitted to have only the number of bedrooms allowed under Title V and local regulations for that property whether or not town sewer is available. In barrier beach areas and FEMA A and V Zones where there is existing development, the Town may install wastewater infrastructure to better protect or improve coastal waters or sensitive habitat areas subject to the sewer neutral regulation. 	Flooding, Shoreline Change/ Erosion Control	GMD, Planning Board, Town Council, Board of Health, DPW	Not Completed	The Citizen Advisory Committee raised the issue of considering a sewer neutral regulation in 2014. The regulation did not obtain sufficient community support to move forward.
Mitigation Action #6 - To prevent earth placement or removal that interferes with the natural flood protective function of barrier beaches and other coastal formations, develop a regulation that limits earth removal and placement and develop an appropriate building height definition.	Flooding, Shoreline Change/ Coastal Erosion	GMD, Planning Board, Town Council	Ongoing	Earth removal regulations are being addressed in the proposed MS4 bylaws.
Mitigation Action #7 - Explore adoption of a regulation that prevents armoring structures and mounded septic systems from interfering with the natural flood protective function of barrier beaches and other coastal formations.	Flooding, Shoreline Change/ Coastal Erosion	GMD, Planning Board, Town Council, Conservation, Board of Health	Deferred	No new regulations have been adopted. There have been some limited examples of conditions and limitations placed on individual projects by the Conservation Commission.

Mitigation Action	Hazard to Mitigate	Responsible Department	Status	Explanation
Mitigation Action #8 - Explore updating the floodplain bylaw to incorporate the additional provisions in the Cape Cod Commission's Model Floodplain Bylaw to better protect land subject to coastal storm flowage.	Flooding, Shoreline Change/ Coastal Erosion	GMD, Planning Board, Town Council	Ongoing	No new regulations have been adopted.
Mitigation Action #9 - Reduce impacts in FEMA A and V zones by amending the Zoning Ordinance to require floor area ratio requirements that allow development and redevelopment that does not create large impervious surface.	Flooding, Shoreline Change/ Coastal Erosion	GMD, Planning Board, Town Council	Ongoing	No new regulations have been adopted. The adopted District of Critical Planning Concern regulations and Wetlands Regulations continue to provide some regulatory controls over impervious surfaces in certain areas.
Mitigation Action #10 - Review and, if necessary, revise regulations to ensure development or redevelopment on a coastal bank or dune or within 100 feet landward of these resources shall be designed to have no adverse effect on the height, stability or use of the bank or dune as a natural sediment source.	Flooding, Shoreline Change/ Coastal Erosion	Conservation, Board of Health	Deferred	No new regulations have been adopted.
Mitigation Action #11 - Buildings and infrastructure in areas of projected sea level rise should be designed for protection from flooding as well as to minimize risk to human health and safety. <ul style="list-style-type: none"> Determine the extent of protection needed from the real threat of sea level rise. 	Flooding, Shoreline Change/ Coastal Erosion	GMD, Regulatory Services	In progress	The Town, in partnership with the Cape Cod Cooperative Extension, completed a conceptual sea level rise viewer to raise awareness of the changing extent of floodplains. Additional study of the impacts of sea level rise is planned as part of the Town's partnership with the Cape Cod Commission's "Resilient Cape Cod" project. Also – DPW CIP for Coastal Resiliency Master Plan.
Mitigation Action #12 - Design new stormwater management systems and replacement septic systems within FEMA A and V zones to accommodate sea level rise.	Flooding, Shoreline Change/ Coastal Erosion	DPW, Board of Health, Regulatory Services	Deferred	No new regulations have been adopted. Recent upgrades made to septic systems serving Town-owned water dependent facilities have included systems design to accommodate flooding, such as submersible pump stations.

Mitigation Action	Hazard to Mitigate	Responsible Department	Status	Explanation
Mitigation Action #13 - Continue to identify, certify and map vernal pools and other isolated lands subject to flooding. Determine their flood control and flood mitigation value and assess the need for additional regulation to protect this vital function.	Flooding	GMD, Conservation Division	Deferred	Identification and certification of vernal pools on private properties requires the cooperation of individual owners. The Town continues to recommend updating GIS data on these important resources.
Mitigation Action #14 - To increase preparedness for flood hazard events, explore certifying a member of the Town staff or hiring a Floodplain Manager with the Association of Floodplain Managers. Certified managers are kept up-to-date on flood mitigation requirements and strategies and work to reduce flood losses and protect and enhance the natural resources and functions of floodplains.	Flooding	Conservation Division	Deferred	The Town has benefited from the expertise of the Barnstable County CRS/Floodplain Coordinator, who is a certified CFM. The Town will explore hiring a Certified Floodplain manager in the future.
Mitigation Action #15 - Identify, pursue, and fund actions, regulations, or outreach efforts necessary to qualify for the National Flood Insurance Program's Community Rating System (CRS). CRS is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. Flood insurance premium rates are discounted to reflect the reduced flood risk resulting from the community actions meeting the three goals of the CRS: 1) reduce flood losses; 2) facilitate accurate insurance rating; and 3) promote the awareness of flood insurance.	Flooding	Conservation, GMD, Board of Health, Town Council, DPW, Regulatory Services	In Progress	With the benefit of a Coastal Community Resilience Grant from the Massachusetts Office of Coastal Zone Management, the Town will work with the Barnstable County CRS Coordinator to continue the CRS application process that was begun in 2015.

Mitigation Action	Hazard to Mitigate	Responsible Department	Status	Explanation
Mitigation Action #16 - Continue wildfire assessment and preparedness planning for conservation parcels with the highest risk, specifically the areas largest in size and in closest proximity to residential development. <ul style="list-style-type: none"> Consider developing a plan for the 95-acre Crocker Neck Conservation Area in Cotuit; this area consists of pine/oak forest and salt marshes and is in close proximity to residential development to the west. 	Drought/ Wildfire	Conservation Division, DPW, Fire Departments	Ongoing/ In Progress	Controlled burns took place at Crocker Neck Conservation Area 2017 and 2018 and West Barnstable Conservation Area 2019 and 2020. In addition, the West Barnstable Conservation Area annual trail maintenance and spot clearing was completed. Annual maintenance of the Old Jail Line was also completed.
Mitigation Action #17 - Coordinate with the Town of Mashpee on the upkeep, monitoring and maintenance of the Santuit Pond Dam. Explore the need for a Memorandum of Understanding to ensure the ongoing structural integrity of the dam.	Dam Failure	DPW, Town Manager, Natural Resources	Ongoing	Barnstable will develop a maintenance plan with the Town of Mashpee to maintain the Santuit Pond Dam.
Mitigation Action #18 - Incorporate multi-hazard mitigation actions into the Town's land acquisition program by: <ul style="list-style-type: none"> Selecting parcels to protect natural resources in flood prone areas of the Town; Preserving ecological systems in coastal, riverine and all areas subject to flooding; Acquiring properties and relocating flood prone structures; and Removing repetitive loss structures and preserving the land as open space. 	Flooding, Shoreline Change/ Coastal Erosion, Drought/ Wildfire	GMD, DNR	Ongoing	The Barnstable Community Preservation Committee's 2021 Plan outlines criteria that will receive preference in allocating CPA Open Space funds; those criteria include properties that provide flood control/storage, along with a number of criteria that address wetland preservation.

Mitigation Action	Hazard to Mitigate	Responsible Department	Status	Explanation
Mitigation Action #19 - To reduce or prevent future property damage and the loss of life or injury as a result of flooding, apply for HMGP and other federal and state funding, as available, for the acquisition and demolition of damaged property.	Flooding, Shoreline Change/ Coastal Erosion	GMD, DNR	Deferred	No acquisition projects were identified or implemented since the last plan update. Local funding was not available for the acquisition of property. Although no property was acquired, the Town continues to be proactive in making coastal infrastructure more resilient to flooding and related hazards.
Mitigation Action #20 - Identify, evaluate, and fund measures to reduce the vulnerability of critical facilities, including fire stations, hospitals and airports, to natural hazards.	Flooding, Drought/ Wildfire	Fire Departments DPW, Conservation Division, Natural Resources	Ongoing	The Town has developed an updated list of critical facilities including local emergency shelters, public safety facilities, hospitals, transportation facilities, wastewater infrastructure, hazardous materials facilities, schools, housing facilities, and animal shelters.
Mitigation Action #21 - Increase public awareness of hazard risk and vulnerability through a public education program. <ul style="list-style-type: none"> • Provide natural hazard seminars for contractors as well as the general public; • Provide natural hazard pre-mitigation materials to all residents of the Town via the website, cable shows, etc.; • Maintain, review and publicize the current action plan on an annual basis; • Coordinate with the County to maintain, review and publicize evacuation routes on an annual basis. 	All	GMD, Conservation CSD, Town Manager, Town Council	Ongoing/ In Progress	The update of the FEMA FIRMs in July 2014 provided ample opportunity for outreach and education regarding the risks of coastal flooding. Educational materials are regularly distributed at Town buildings and posted on the new CRS webpage. The Town continues to coordinate with Barnstable County to help distribute educational materials to residents across Cape Cod. The Town engaged a wide range of stakeholders to discuss climate-change risks as part of their partnership in the New England Climate Adaptation Project and as part of the MVP certification process. The Town continues to pursue opportunities for public education regarding coastal flooding and shoreline change as part of its pending participation in the CRS program and its partnership with the CCC.

Mitigation Action	Hazard to Mitigate	Responsible Department	Status	Explanation
Mitigation Action #22 - Increase public awareness of the hazards posed by wind-born debris. Provide public information about: <ul style="list-style-type: none"> • Protection of people and personal property. • Window glazing and other prevention techniques. • Benefits of tree trimming and removal around homes at risk. 	Wind	Regulatory Services, CSD, Fire Departments	Ongoing	Educational materials are regularly distributed at Town buildings and posted on the CRS webpage. The Town continues to coordinate with Barnstable County to help distribute educational materials to residents across Cape Cod.
Mitigation Action #23 - Prioritize public education about flood action and flood proofing. Make materials available describing simple and inexpensive means of flood proofing, which may be obtained from agencies such as FEMA.	Flooding	Conservation CSD	Ongoing/ In Progress	The update of the FEMA FIRMs in July 2014 and the 2019 MVP certification process provided ample opportunity for outreach and education regarding the risks of coastal flooding. Educational materials are regularly distributed at Town buildings and posted on the new CRS webpage, which includes information about flood proofing.
Mitigation Action #24 - Provide landowners abutting wildfire hazard areas with information regarding fire hazards and recommendations to protect life and property from wildfire. <ul style="list-style-type: none"> • The Town should advocate applicable “firewise standards” for dwellings, other structures, propane storage, and vegetation around dwellings in the wildland/residential interface. • Provide information to appropriate landowners on fire hazards and the recommendations to protect life and property from wildfire through a series of information workshops at local fire stations. 	Drought/ Wildfire	Conservation Division, Fire Departments	Ongoing	The Fire Department has developed multiple programs/resources regarding citizen fire preparedness and prevention such as the Ready, Set, Go program and the Firewire program.

Mitigation Action	Hazard to Mitigate	Responsible Department	Status	Explanation
Mitigation Action #25 - Continue to implement the recommendations of the Wildland Fire Preparedness Plan for the West Barnstable Conservation Area, the Old Jail Lane Conservation Area, and the Hyannis Ponds WMA. <ul style="list-style-type: none"> Explore possible sources of sustained funding for the ongoing maintenance of improvements made as a result of plan recommendations. 	Drought/ Wildfire	Conservation Fire Depts, DCR	Complete/ Ongoing	Ongoing maintenance of these conservation areas continues. West Barnstable Conservation Area – annual trail maintenance and spot clearing and Old Jail Lane – annual maintenance
Mitigation Action #26 - Restore tidally restricted salt marshes by upsizing or improving culverts, pipes, or other structures to provide increased protection from flooding and storm surges.	Flooding	DPW, Conservation Division, in coordination with US Army Corps of Engineers	In Progress	See Stewart's Creek project highlight. The Town continues to explore opportunities to remove tidal restrictions and restore salt marshes.
Mitigation Action #27 - Ensure continuing ability of the Barnstable Municipal Airport to aid in disaster response and recovery. Explore the need for training and awareness programs to improve the Airport's ability to respond and the potential vulnerability of the airport to disasters.	Flooding, Snow & Ice, Wildfire	Barnstable Municipal Airport	In progress	The Barnstable Municipal Airport has provided an Emergency/Hazard management update.
Mitigation Action #28 - Implement the recommendations of the Wequaquet Lake Dam Inspection and Evaluation Report. Recommendations of the report include: <ul style="list-style-type: none"> Conduct a detailed hydrological and hydraulic analysis for the impoundment drainage area and spillway outlet capacity; Complete a stability analysis of the spillway structure; and Develop an Operations and Maintenance Plan. 	Dam Failure	DPW, Natural Resources	In Progress/Ongoing	A Lake Wequaquet Study has been completed, and development of an Operations and Maintenance Plan is in progress.

Mitigation Action	Hazard to Mitigate	Responsible Department	Status	Explanation
Mitigation Action #29 - Implement the recommendations of the Mill Pond Dam Inspection and Evaluation Report. Recommendations of the report include: <ul style="list-style-type: none"> • Repair deteriorated concrete and stone/masonry at fish ladder entrance; • Repair left side of man-made channel, downstream of fish ladder entrance; • Repair spalled concrete and Notched Weirs No. 1 and 2; • Remove vegetation and debris from Notched Weirs No. 1 and 2 and trash rack. 	Dam Failure	DPW, Natural Resources	In Progress	In FY 2014, \$42,000 was appropriated for the design of improvements to the Mill Pond and Long Pond Fish Ways. The Mill Pond Dam required substantial rehabilitation. A 2023 Capital Improvement Plan will be submitted which will request funding the design and permitting to bring the dam and fish ladder into conformance with modern design standards. Final designs, specifications, and construction cost estimates will be prepared, and permit applications will be acquired in preparation for project implementation.
Mitigation Action #30 - Evaluate the condition of breakwaters and make repairs as necessary to ensure their long-term effectiveness for mitigating storm damage <ul style="list-style-type: none"> • Repair the inner (Town) portion of the Hyannisport breakwater • Repair the two breakwaters that protect the entrance into West Bay 	Flooding, Shoreline Change/ Coastal Erosion	DPW, Natural Resources, Conservation in coordination w/ USACE	In Progress	In March of 2014 a detailed existing conditions survey, analysis, and preliminary design report was completed for the West Bay breakwater. Additionally, a federal portion of Hyannisport Breakwater is scheduled for \$2.8 Million in repairs from the USACE in the near future. A 2023 Capital Improvement Plan will be submitted which will request funding for repairs of a navigational beacon located on the West Bay Breakwater. The plan will include design and permitting of breakwater repairs and construction of those repairs.

5.3 MITIGATION ACTIONS FOR 2021 HAZARD MITIGATION PLAN UPDATE

The Mitigation Actions listed below will be routinely reviewed to make sure they are consistent with current town priorities. The team carried forward Mitigation Actions from 2010 that were identified as “In Progress” and developed new Mitigation Actions based on other work conducted in the community over the past five years, input from key stakeholders and the hazard identification and risk assessment portion of this planning effort. Each project is tied to the specific hazard addressed and objective achieved. An estimated project cost, duration, implementation timeframe and potential funding source for each mitigation project is identified. The project duration is intended to be the amount of time needed for the Town to complete the project from start to finish. The implementation timeframe is the year from the Hazard Mitigation Plan approval date in which the Barnstable will try to move forward with the project. A **short** (within 1-2 years from Hazard Mitigation Plan update approval date), **medium** (within 3-4 years from Hazard Mitigation Plan update approval date) or **long** (5 years from the Hazard Mitigation Plan update approval date) reference was used to indicate what year of the five-year Hazard Mitigation Plan implementation Barnstable will try to focus on the project. The specific funding sources are discussed in **Table 5-2**.

Table 5-2: Mitigation Actions 2021 Hazard Mitigation Plan

#	Hazard Addressed	Project Description	Objectives Addressed	Estimated Cost	Project Duration/ Implementation Timeframe	Potential Funding Source
1	Flooding, Shoreline Change/ Coastal Erosion	Develop additional Coastal Resources Management Plans for vulnerable coastal areas within the Town Barnstable. Plans should incorporate other relevant work that has been completed such as the Sediment Budget conducted by the Center for Coastal Studies and the Resiliency Study completed for Sandy Neck.	1, 2, 3, 7, 10, 11	\$70,000	Medium	3, 13, 14, 22
2	Flooding, Shoreline Change	Explore the adoption of regulations and incentives to restrict new development and redevelopment in FEMA A and V zones, on barrier beaches, or on coastal dunes where there is known to be danger of significant flood damage. <ul style="list-style-type: none"> • Inventory and map vacant land in velocity zones. • Existing structures may be reconstructed or renovated in conformance with all regulatory requirements provided there is no increase in area or intensity of use. Where applicable, non-water dependent development shall be concentrated on that part of the lot outside the A and V Zones.	2, 5, 6	\$10,000	Medium	22
3	Flooding, Shoreline Change/ Erosion Control	<ul style="list-style-type: none"> • Explore adopting a General Ordinance specifically targeted at coastal areas that applies to residential and public development to better protect or improve coastal waters or sensitive habitat areas regarding wastewater infrastructure resiliency during storm events. 	2, 5, 9, 12	\$5,000	Medium	22, 22
4	Flooding, Shoreline Change/ Coastal Erosion	Reduce impacts in FEMA A and V zones by amending the Zoning Ordinance to require floor area ratio requirements that allow development and redevelopment that does not create large impervious surface and maintains coastal flood resiliency.	2, 5, 9, 12	\$5,000	Medium	22

#	Hazard Addressed	Project Description	Objectives Addressed	Estimated Cost	Project Duration/ Implementation Timeframe	Potential Funding Source
5	Flooding, Shoreline Change/ Coastal Erosion	Explore updating the floodplain bylaw to incorporate the additional provisions in the Cape Cod Commission's Model Floodplain Bylaw to better protect land subject to coastal storm flowage.	1, 2, 10-, 11	\$10,000	Short	22
6	Flooding, Shoreline Change/ Coastal Erosion	Review and, if necessary, revise regulations to ensure development or redevelopment on coastal banks or dunes or within 100 feet landward of these resources shall be designed to minimize risk of flooding.	1, 2, 5, 9, 12	\$5,000	Medium	22
7	Flooding	To increase preparedness for flood hazard events, explore training a member of the Town staff or hiring a Floodplain Manager with the Association of Floodplain Managers. Certified managers are kept up-to-date on flood mitigation requirements and strategies and work to reduce flood losses and protect and enhance the natural resources and functions of floodplains.	1, 2, 7, 8, 10, 12	\$75,000	Short	1, 22
8	Flooding	Identify, pursue, and fund actions, regulations or outreach efforts necessary to qualify for the National Flood Insurance Program's Community Rating System (CRS). Integrate CRS into the location Open Space and Recreation Plan during future planning efforts and/or updates to maximize CRS credit points for open space preservation. This may include creating an Elevation Certificate inventory for the NFIP.	1, 2, 7, 8, 10, 12	\$10,000	Short	1, 11, 22
9	Drought/ Wildfire	Continue wildfire assessment and preparedness planning for conservation parcels with the highest risk, specifically the areas largest in size and in closest proximity to residential development. <ul style="list-style-type: none"> Control burn on the west side of West Barnstable Conservation Area 	1, 2, 4, 12	\$40,000	Medium	22

#	Hazard Addressed	Project Description	Objectives Addressed	Estimated Cost	Project Duration/ Implementation Timeframe	Potential Funding Source
10	Dam Failure	<ul style="list-style-type: none"> Coordinate with the Town of Mashpee on the upkeep, monitoring and maintenance of the Santuit Pond Dam. Explore the need for a Memorandum of Understanding to ensure the ongoing structural integrity of the dam. 	1, 2, 10, 11, 12	\$5,000	Short	22
11	Flooding, Drought/ Wildfire	Identify, evaluate, and fund measures to reduce the vulnerability of critical facilities, including fire stations, hospitals and airports, to natural hazards. This may include incorporating mitigation for the development or expansion of these facilities.	1, 6, 7, 10, 11, 12	\$50,000	Medium	9, 10, 13, 14, 22
12	All	Increase public awareness of hazard risk and vulnerability through published education materials. These materials may be communicated through the Town's website which will help develop a common communications framework on community hazards and emergency resources (such as shelters and evacuation routes).	7, 8, 10, 11	\$20,000	Medium	13, 14, 22
13	Drought/ Wildfire	Continue to implement the recommendations of the Wildland Fire Preparedness Plan for the West Barnstable Conservation Area, the Old Jail Lane Conservation Area, Crocker Neck and the Hyannis Ponds WMA. Explore possible sources of sustained funding for the ongoing maintenance of improvements made as a result of plan recommendations.	4, 7, 8, 10, 11	\$25,000	Medium	3, 22
14	Flooding	<ul style="list-style-type: none"> Restore stormwater infrastructure by identifying failed/degraded stormwater systems. This may include upsizing or improving culverts, pipes, or other structures to provide increased protection from flooding and storm surges. Additionally, design new stormwater management systems and replacement septic systems within FEMA A and V zones to accommodate sea level rise. 	1, 2, 3, 6, 10, 11, 12	\$150,000	Medium	9, 10, 14, 16, 18, 20, 22

#	Hazard Addressed	Project Description	Objectives Addressed	Estimated Cost	Project Duration/ Implementation Timeframe	Potential Funding Source
15	Flooding, Snow & Ice, Wildfire	Ensure continuing ability of the Barnstable Municipal Airport to aid in disaster response and recovery. Explore the need for training and awareness programs to improve the Airport's ability to respond and the potential vulnerability of the airport to disasters.	7, 8, 11, 12	\$70,000	Medium	9, 10, 22
16	Dam Failure	Implement the recommendations of the Wequaquet Lake Dam Inspection and Evaluation Report. Recommendations of the report include: <ul style="list-style-type: none"> • Conduct a detailed hydrological and hydraulic analysis for the impoundment drainage area and spillway outlet capacity; • Complete a stability analysis of the spillway structure; and • Develop an Operations and Maintenance Plan. 	1, 2, 10, 11, 12	\$100,000	Medium	9, 10, 17, 22
17	Dam Failure	Implement the recommendations of the Mill Pond Dam Inspection and Evaluation Report. Recommendations of the report include: <ul style="list-style-type: none"> • Repair deteriorated concrete and stone/masonry at fish ladder entrance; • Repair left side of man-made channel, downstream of fish ladder entrance; • Repair spalled concrete and Notched Weirs No. 1 and 2; • Remove vegetation and debris from Notched Weirs No. 1 and 2 and trash rack. 	1, 2, 10, 11, 12	\$800,000	Medium	21
19	Flooding	Develop an inventory of mitigated floodplain properties and develop an inventory of properties for potential flood mitigation projects.	1, 2, 6, 7, 8, 10, 12	\$10,000	Short	22

#	Hazard Addressed	Project Description	Objectives Addressed	Estimated Cost	Project Duration/ Implementation Timeframe	Potential Funding Source
20	Drought	To help Barnstable assess risks, conduct a study on well depths of the water supply, and the present relative location of the freshwater/saltwater interface in the aquifers and soil characteristics. This project may also include researching additional water supply sources.	1, 2, 6, 7, 8, 9, 10, 11, 12	\$100,000	Medium	8, 13, 19, 22
21	All	Help organize and participate in a regional planning effort focused on Route 6 and emergency planning. This would include planning for bottlenecks that occurs/can occur when massive amounts of people are exiting or need to exit Cape Cod in an emergency. Additionally, this project would include developing a response plan for any hazardous spills that may occur during flooding. The goal would be to develop key action items or recommendations to address these issues.	7, 8, 10	\$30,000	Short	22
22	All	Investigate the potential of reinvigorating and supporting village shelter capacity and purchasing generators for all critical facilities.	7, 8, 9, 10, 12	\$150,000	Short	22
23	All	Develop a debris management plan. Currently Barnstable does not have any designated land to handle large amounts of debris.	7, 8, 9, 10, 12	\$40,000	Short	9, 22
24	All	Conduct tree trimming to move branches away from power lines and bury power lines where feasible to eliminate the potential for power outages. Focus on West Barnstable.	7, 8, 9, 10, 12	\$200,000	Short	22
25	All	Conduct a vulnerability and risk assessment of all critical facilities and infrastructure including pump stations. Considerations for hardening might include elevation, electrical improvements, generators, etc.	7, 8, 9, 10, 12	\$70,000	Short	9, 10, 13, 14, 22

#	Hazard Addressed	Project Description	Objectives Addressed	Estimated Cost	Project Duration/ Implementation Timeframe	Potential Funding Source
26	All	Educate and coordinate with the management of private facilities like hotels and grocery stores that may provide shelter. Identify other private sector partners that may be helpful in an emergency.	7, 8, 10	\$5,000	Short	22
27	All	Purchase and maintain a portable water tank/water buffalo for use during emergencies.	7, 8	\$40,000	Medium	22
28	All	Develop a fueling plan for generators and other emergency equipment.	7, 8, 9, 10, 12	\$10,000	Short	22
29	All	Monitor beach conditions and evaluate all vulnerable shoreline areas for possible future nourishment and beach stabilization projects.	1, 2, 3, 7, 8, 12	\$200,000	Long	13, 14, 22
30	All	Fill gaps and add redundancy in the current communications system which relies on functioning landlines, internet access, and cellular services. Consider upgrading to fiber optics. By introducing an additional form of communication that would be used when these systems fail, internal and external emergency communication would be supplemented in emergencies.	7, 8	\$500,000	Short	1, 22
31	Flooding	Implement the findings of the Cape Cod Commission's low-lying roads assessment which may require road maintenance or re-design. The project will identify potential road work to improve the resiliency and reduce the risk of flooded roads during storm events in addition to identifying critical evacuation roads for the public.	5, 9, 12	\$200,000	Medium	1, 6, 9,10
32	All	Collect social vulnerability data of high-risk areas. This data should include social stressors, health issues/immobility, those requiring in-home medical treatment, displaced peoples, and other relevant social data.	7, 8	\$10,000	Short	22

#	Hazard Addressed	Project Description	Objectives Addressed	Estimated Cost	Project Duration/ Implementation Timeframe	Potential Funding Source
33	Flooding, Shoreline Change/ Coastal Erosion	The Town is in the process of replacing the Bismore Bulkhead to reduce risk of flooding. This project involves consulting model predictions of Nor-Easter storms and high tides that may impact the design of the sea wall.	9	\$100,000	Short	9, 10, 11, 13, 14
34	Flooding, Shoreline change	Incorporate storm tide pathways maps into the community planning and emergency preparedness for storm events.	11	\$50,000	Medium	1, 9, 10,13, 14
35	All	As recommended by the Cape Cod Commission in their Cape Cod Climate Action Plan, develop regional and local initiatives to address greenhouse gas emissions, carbon sequestration, and coastal resilience relevant to Cape Cod communities.	12	\$100,000	Medium	9,13,14, 22
36	All	As recommended by the Cape Cod Commission in their Cape Cod Climate Action Plan, Barnstable communities should pursue obtaining the Green Communities designation through the Green Communities Act.	12	\$20,000	Medium	22
37	Flooding, Erosion Control	Identify, design, and implement stormwater infrastructure that increases infiltration capacity and reduces runoff to nearby ponds, rivers, wetlands, and estuaries. Particularly, in flood prone areas and areas with environmental hazards, such as harmful algal blooms.	12	\$2,000,000	Medium	3, 9,10, 18, 21, 22
38	All	Identify, evaluate, and fund measures to reduce the vulnerability of hospitals to natural hazards. This may include incorporating mitigation for the development or expansion of healthcare facilities. Cape Cod Hospital is not only critical for Barnstable but for a lot of surrounding communities as well.	1, 6, 7, 10, 11, 12		Medium	9, 10, 13, 14, 22

5.4 MITIGATION PROJECT PRIORITIZATION

The projects and mitigation activities noted in the previous section that have been proposed meet the FEMA STAPLEE criteria. To meet the STAPLEE criteria, projects and activities must be socially acceptable to the community, technically feasible, protective of or beneficial to the environment and are backed by legal authority and consistent with current laws, consider economic benefits and costs and include environmental considerations. The goals and objectives proposed in this Plan are intended to fulfill at a minimum the following STAPLEE criteria identified in **Table 5-3**.

Table 5-3: STAPLEE Criteria

STAPLEE CRITERIA	
<u>S</u>ocial	Improve the quality of life and reduce neighborhood impacts. <ul style="list-style-type: none"> • Include public support and involvement. • Consider effects on selected segments of the population. • Compatible with present and future community. • Consider cultural impacts on the community.
<u>T</u>echnical	Develop technically feasible mitigation efforts. <ul style="list-style-type: none"> • Effective in reduction of long-term losses, impacts and risks. • Effective in minimizing secondary losses. • Effective in solving the problem and not only the symptoms.
<u>A</u>ministrative	Provide resources and staffing to implement proposed actions. <ul style="list-style-type: none"> • Jurisdiction and capability necessary to implement an action. • Ability to accomplish activities in a timely manner. • Ability to maintain and manage the mitigation measure.
<u>P</u>olitical	Acceptable to and supported by community politicians. <ul style="list-style-type: none"> • Have full support of the Town Manager and other key stakeholders. • Involve political leaders in the planning process. • Support and involvement of stakeholders. • Public support and involvement.
<u>L</u>egal	Legal authority to undertake an action. <ul style="list-style-type: none"> • Meet all applicable regulatory requirements. • Define the roles of Local, State and Federal governments. • Provide a legal basis for mitigation actions. • Assure laws, regulations, ordinances, and resolutions are in place. • Identify liabilities for an action or lack of an action. • Consider needs for legal counsel.
<u>E</u>conomic	Develop affordable and cost-effective mitigation efforts. <ul style="list-style-type: none"> • Obtain budget and funding for an action. • Economic costs and benefits of a mitigation action. • Burden to the tax base or local economy.
<u>E</u>nvironmental	Improve environmental quality. <ul style="list-style-type: none"> • Identify and evaluate environmental impacts. • Compliance with all environmental laws and regulations. • Benefit the environment from a mitigation action.

Implementation of projects and mitigation activities were prioritized by a qualitative ranking of high, medium or low. STAPLEE criteria was applied to the extent possible to all of the projects and mitigation activities that have been identified in the Hazard Mitigation Plan and priorities were evaluated based on need, cost-effectiveness, number of hazards addressed, number of objectives met and funding eligibility.

Barnstable utilized a qualitative assessment (high, medium, low) for prioritizing projects and mitigation activities for this plan.

- **High Priority** – Denotes a project or mitigation activity that meets multiple plan objectives, addresses multiple hazards, has benefits that outweigh potential costs, has funding secured or is able to be funded through the municipal budget and may be eligible for grant funding. Projects of high priority have the potential to be completed within the next 5 years.
- **Medium Priority** – Denotes a project or mitigation activity that meets some goals and objectives, addresses some hazards, has benefits that outweigh potential costs, funding is not in place but could be through municipal allocation or grant funding.
- **Low Priority** – Denotes a project that meets at least one goal/objective, addresses at least one hazard, costs may outweigh the benefits, funding has not been secured and grant eligibility is unclear and the timeframe for completion is probably long term.

Plan implementation will focus on the projects and mitigation activities that have the highest level priority associated with them. Over time and as the plan is implemented, priorities may change due to new funding sources, information or future hazard events. During the annual review of this Plan there will be a specific review of the list of projects and mitigation activities to make sure that the prioritization ranking for each one is still the most appropriate.

Table 5-4 indicates the project number, responsible party and whether or not the project meets each individual STAPLEE criteria at a high, medium or low level. After taking this information into consideration, each project was given a qualitative high, medium or low ranking.

Table 5-4: Barnstable Project Prioritization

#	Project Description	Responsible Party	Cost Effectiveness of Activity	Socially Acceptable	Technically Feasible	Protect/Benefit Environment	Legal	Economic Benefit	Project Priority
1	Develop additional Coastal Resources Management Plans for vulnerable coastal areas within the Town Barnstable. Plans should incorporate other relevant work that has been completed such as the Sediment Budget conducted by the Center for Coastal Studies and the Resiliency Study completed for Sandy Neck.	Planning Conservation Commission, Harbor Master	High	High	High	High	Medium	High	High
2	Explore the adoption of regulations and incentives to restrict new development and redevelopment in A and V zones, on barrier beaches, or on coastal dunes where there is known to be danger of significant flood damage. <ul style="list-style-type: none"> • Inventory and map vacant land in velocity zones. • Existing structures may be reconstructed or renovated in conformance with all regulatory requirements provided there is no increase in area or intensity of use. • Where applicable, non-water dependent development shall be concentrated on that part of the lot outside the A and V Zones. 	Planning	High	Medium	Medium	Medium	Medium	Medium	Medium
3	Explore adopting a General Ordinance specifically targeted at coastal areas that applies to residential and public development to better protect or improve coastal waters or sensitive habitat areas regarding wastewater infrastructure resiliency during storm events.	Planning, Public Works	Low	Medium	Medium	Medium	Medium	Low	Low
4	Reduce impacts in FEMA A and V zones by amending the Zoning Ordinance to require floor area ratio requirements that allow development and redevelopment that does not create large impervious surface and maintains coastal flood resiliency.	Planning, Building Division	High	Medium	Medium	Medium	Medium	Medium	Medium

#	Project Description	Responsible Party	Cost Effectiveness of Activity	Socially Acceptable	Technically Feasible	Protect/Benefit Environment	Legal	Economic Benefit	Project Priority
5	Explore updating the floodplain bylaw to incorporate the additional provisions in the Cape Cod Commission's Model Floodplain Bylaw to better protect land subject to coastal storm flowage.	Planning	High	Medium	High	High	Medium	High	High
6	Review and, if necessary, revise regulations to ensure development or redevelopment on coastal banks or dunes or within 100 feet landward of these resources shall be designed to minimize risk of flooding.	Planning, Conservation	High	Medium	High	High	Medium	High	High
7	To increase preparedness for flood hazard events, explore hiring a member of the Town staff as a Floodplain Manager with the Association of Floodplain Managers. Certified managers are kept up to date on flood mitigation requirements and strategies and work to reduce flood losses and protect and enhance the natural resources and functions of floodplains.	Planning	High	High	High	High	High	High	High
8	Identify, pursue, and fund actions, regulations or outreach efforts necessary to qualify for the National Flood Insurance Program's Community Rating System (CRS). Integrate CRS into the location Open Space and Recreation Plan during future planning efforts and/or updates to maximize CRS credit points for open space preservation. This may include creating an Elevation Certificate inventory for the NFIP.	Planning	High	Medium	High	High	Medium	High	High

#	Project Description	Responsible Party	Cost Effectiveness of Activity	Socially Acceptable	Technically Feasible	Protect/Benefit Environment	Legal	Economic Benefit	Project Priority
9	<p>Continue wildfire assessment and preparedness planning for conservation parcels with the highest risk, specifically the areas largest in size and in closest proximity to residential development.</p> <ul style="list-style-type: none"> Consider developing a plan for the 95-acre Crocker Neck Conservation Area in Cotuit; this area consists of pine/oak forest and salt marshes and is in close proximity to residential development to the west. Develop maintenance plan for mechanical clearing of fire roads to reduce fuels and create fire breaks for wildfire response. 	Planning, Fire Department	High	High	High	High	High	High	High
10	Coordinate with the Town Mashpee on the upkeep, monitoring and maintenance of the Santuit Pond Dam. Explore the need for a Memorandum of Understanding to ensure the ongoing structural integrity of the dam.	DPW Division	Medium	Medium	Medium	High	Medium	Medium	Medium
11	Identify, evaluate, and fund measures to reduce the vulnerability of critical facilities, including fire stations, hospitals and airports, to natural hazards. This may include incorporating mitigation for the development or expansion of these facilities.	Planning, DPW Division	High	High	High	Medium	High	High	High
12	Increase public awareness of hazard risk and vulnerability through published education materials. These materials may be communicated through the Town's website which will help develop a common communications framework on community hazards and emergency resources (such as shelters and evacuation routes).	Planning, DPW, Fire, MEA	High	High	High	Medium	Medium	High	High

#	Project Description	Responsible Party	Cost Effectiveness of Activity	Socially Acceptable	Technically Feasible	Protect/Benefit Environment	Legal	Economic Benefit	Project Priority
13	Continue to implement the recommendations of the Wildland Fire Preparedness Plan for the West Barnstable Conservation Area, the Old Jail Lane Conservation Area, and the Hyannis Ponds WMA. <ul style="list-style-type: none"> Explore possible sources of sustained funding for the ongoing maintenance of improvements made as a result of plan recommendations. 	Planning, Fire Department	High	High	High	Medium	Medium	High	High
14	Restore stormwater infrastructure by identifying failed/degraded stormwater systems. This may include upsizing or improving culverts, pipes, or other structures to provide increased protection from flooding and storm surges. Additionally, design new stormwater management systems and replacement septic systems within FEMA A and V zones to accommodate sea level rise.	Planning, Conservation Commission, DPW	High	Medium	High	High	Medium	High	High
15	Ensure continuing ability of the Barnstable Municipal Airport to aid in disaster response and recovery. Explore the need for training and awareness programs to improve the Airport's ability to respond and the potential vulnerability of the airport to disasters.	Airport	High	High	Medium	Medium	Medium	High	High
16	Implement the recommendations of the Wequaquet Lake Dam Inspection and Evaluation Report. Recommendations of the report include: <ul style="list-style-type: none"> Conduct a detailed hydrological and hydraulic analysis for the impoundment drainage area and spillway outlet capacity; Complete a stability analysis of the spillway structure; and Develop an Operations and Maintenance Plan. 	DPW Division	Medium	Medium	Medium	High	Medium	High	Medium

#	Project Description	Responsible Party	Cost Effectiveness of Activity	Socially Acceptable	Technically Feasible	Protect/Benefit Environment	Legal	Economic Benefit	Project Priority
17	Implement the recommendations of the Mill Pond Dam Inspection and Evaluation Report. Recommendations of the report include: <ul style="list-style-type: none"> • Repair deteriorated concrete and stone/masonry at fish ladder entrance; • Repair left side of man-made channel, downstream of fish ladder entrance; • Repair spalled concrete and Notched Weirs No. 1 and 2; • Remove vegetation and debris from Notched Weirs No. 1 and 2 and trash rack. 	DPW Division	Medium	Medium	Medium	High	Medium	High	Medium
18	Create and maintain a CRS Impact Adjustment Map(s)	Planning	High	High	High	Medium	Medium	High	High
19	Develop an inventory of mitigated floodplain properties and develop an inventory of properties for potential flood mitigation projects.	Planning, Building Division	High	Medium	High	Medium	Medium	Medium	Medium
20	To help Barnstable assess risks, conduct a study on well depths of the water supply, and the present relative location of the freshwater/saltwater interface in the aquifers and soil characteristics. This project may also include researching additional water supply sources.	DPW Division	Medium	High	High	High	Medium	High	High

#	Project Description	Responsible Party	Cost Effectiveness of Activity	Socially Acceptable	Technically Feasible	Protect/Benefit Environment	Legal	Economic Benefit	Project Priority
21	Help organize and participate in a regional planning effort focused on Route 6 and emergency planning. This would include planning for bottlenecks that occurs/can occur when massive amounts of people are exiting or need to exit Cape Cod in an emergency. Additionally, this project would include developing a response plan for any hazardous spills that may occur during flooding. The goal would be to develop key action items or recommendations to address these issues.	Planning, Emergency Services	High	High	High	Medium	Medium	Medium	High
22	Investigate the potential of reinvigorating and supporting village shelter capacity and purchasing generators for all critical facilities.	Planning, Emergency Services, DPW Division	Medium	High	High	Medium	Medium	Medium	Medium
23	Develop a debris management plan. Currently Barnstable does not have any designated land to handle large amounts of debris.	DPW Division	Medium	Medium	High	High	Medium	High	High
24	Conduct tree trimming to move branches away from power lines and bury power lines where feasible to eliminate the potential for power outages. Focus on West Barnstable.	DPW Division	High	High	High	High	Medium	High	High
25	Conduct a vulnerability and risk assessment of all critical facilities and infrastructure including pump stations. Considerations for hardening might include elevation, electrical improvements, generators, etc.	Planning, DPW Division	High	High	High	Medium	Medium	High	High
26	Educate and coordinate with the management of private facilities like hotels and grocery stores that may provide shelter. Identify other private sector partners that may be helpful in an emergency.	Planning, Emergency Services	High	High	High	Low	Medium	Low	Medium

#	Project Description	Responsible Party	Cost Effectiveness of Activity	Socially Acceptable	Technically Feasible	Protect/Benefit Environment	Legal	Economic Benefit	Project Priority
27	Purchase and maintain a portable water tank/water buffalo for use during emergencies.	Planning, Emergency Services, DPW Division	High	High	High	Low	Medium	High	Medium
28	Develop a fueling plan for generators and other emergency equipment.	Planning, Emergency Services, DPW Division	High	High	High	Low	Medium	High	High
29	Monitor beach conditions and evaluate all vulnerable shoreline areas for possible future nourishment and beach stabilization projects.	Planning, DPW Division, Conservation Commission	Medium	High	High	High	Medium	Medium	Medium
30	Fill gaps and add redundancy in the current communications system which relies on functioning landlines, internet access, and cellular services. Consider upgrading to fiber optics. By introducing an additional form of communication that would be used when these systems fail, internal and external emergency communication would be supplemented in emergencies.	Planning, Emergency Services	Medium	High	High	Low	Medium	Medium	High
31	Implement the findings of the low-lying roads assessment which may require road maintenance or re-design. The project will identify potential road work to improve the resiliency and reduce the risk of flooded roads during storm events in addition to identifying critical evacuation roads for the public.	DPW Division	High	High	High	Low	Medium	High	High

#	Project Description	Responsible Party	Cost Effectiveness of Activity	Socially Acceptable	Technically Feasible	Protect/Benefit Environment	Legal	Economic Benefit	Project Priority
32	Collect social vulnerability data of high-risk areas. This should include social stressors, health issues/immobility, those requiring in-home medical treatment, displaced peoples, and other social data.	Planning	Medium	High		Low	Medium	Low	Medium
33	The Town is in the process of replacing the Bismore Bulkhead to reduce risk of flooding. This project involves consulting model predictions of Nor-Easter storms and tides that may impact the design of the sea wall.	DPW Division	High	Medium		Low	Medium	High	High
34	Develop a plan to map storm tide pathways and incorporate these maps into the community planning and emergency preparedness for storm events.	DPW Division	Medium	Medium	High	Medium	High	High	Medium
35	As recommended by the Cape Cod Commission in their Cape Cod Climate Action Plan, develop regional and local initiatives to address greenhouse gas emissions, carbon sequestration, and coastal resilience relevant to Cape Cod communities.	Planning	Medium	High	High	High	High	Medium	Medium
36	As recommended by the Cape Cod Commission in their Cape Cod Climate Action Plan, Barnstable communities should pursue obtaining the Green Communities designation through the Green Communities Act.	Planning	Medium	High	High	High	High	Medium	Medium
37	Identify, design, and implement stormwater infrastructure that increases infiltration capacity and reduces runoff to nearby ponds, rivers, wetlands, and estuaries. Particularly, in flood prone areas and areas with environmental hazards, such as harmful algal blooms.	DPW	Medium	High	Medium	High	Medium	High	High

5.5 POTENTIAL FUNDING SOURCES

Various funding sources may be available for Barnstable to pursue as they consider implementing various action items from this planning effort. **Table 5-5** details various federal, state and local agencies and programs that may be available.

Table 5-5: Potential Funding Sources

#	Agency	Program	Description	For More Information
FEDERAL				
1	DOD-USACE	Beneficial Uses of Dredged Materials	Direct assistance for projects that protect, restore, and create aquatic and ecologically related habitats, including wetlands, in connection with dredging an authorized Federal navigation project.	http://water.epa.gov/type/oceb/oceandumping/dredgedmaterial/beneficial_use.cfm
2	USDA-NRCS	Emergency Watershed Protection (EWP)	Provides technical and financial assistance Program for relief from imminent hazards in small watersheds, and to reduce vulnerability of life and property in small watershed areas damaged by severe natural hazard events.	http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/ewpp/
3	DOD-USACE	Section 205 of 1948 Flood Control Act	Resources for small flood damage reduction projects.	http://www.nwww.usace.army.mil/Portals/28/docs/assistanceprograms/sec205.pdf
4	Department of the Interior or National Park Service	Federal Land Transfer / Federal Land to Parks Program	Identifies federal real property available for open space transfer to states and local governments for development of parks and recreation.	http://www.nps.gov/nrcr/programs/fltp/index.htm
5	USDOT FHWA	Bridge Replacement and Rehabilitation	Funding for eligible bridges on any public road.	http://www.fhwa.dot.gov/bridge/hbrp.cfm
6	USDOT FHWA	Recreational Trails	Funding for trails used by motorized and non-motorized recreational vehicles.	https://www.fhwa.dot.gov/environment/recreational_trails/
7	US Economic Development Administration (EDA)	Disaster Relief Opportunity – Economic Adjustment Assistance	The EDA program provides recipients with flexible tools to develop and implement regionally based long term economic development strategies in response to major Federally declared disasters. The EDA program provides a wide range of technical, disaster recovery, economic recovery planning, and public works assistance. It responds adaptively to pressing economic recovery issues and is well-suited to help address challenges faced by regions affected by natural disasters.	https://eda.gov/disaster-recovery/

#	Agency	Program	Description	For More Information
STATE				
8	FEMA, MEMA	Hazard Mitigation Grant Program	The HMGP program is available after a presidentially declared disaster. It allows for the completion of post-disaster mitigation projects that will reduce or mitigate future disaster losses due to natural hazards. Mitigation projects must be cost-effective and designed to increase resilience and public safety; reduce injuries and loss of life; and reduce damage and destruction to property, critical services, facilities, and damage (e.g., stormwater drainage, culvert improvements, flood control, diversion, and storage: slope stabilization; etc.). The BRIC program also supports capability and capacity building projects (e.g., new and updated hazard mitigation plans, planning related activities, and project scoping/advanced assistance).	https://www.mass.gov/service-details/hazard-mitigation-grant-program-hmgp
9	FEMA, MEMA	Building Resilient Infrastructure and Communities	The nationally-competitive BRIC grant program provides funds to States, territories, Indian Tribal governments and communities for hazard mitigation planning and the implementation of mitigation projects prior to a disaster. Mitigation projects must be cost-effective and designed to increase resilience and public safety; reduce injuries and loss of life; and reduce damage and destruction to property, critical services, facilities, and damage (e.g., stormwater drainage, culvert improvements, flood control, diversion, and storage: slope stabilization; etc.). The BRIC program also supports capability and capacity building projects (e.g., new and updated hazard mitigation plans, planning related activities, and project scoping/advanced assistance).	https://www.mass.gov/service-details/building-resilient-infrastructure-and-communities-bric-flood-mitigation-assistance-fma-grant-programs
10	FEMA, MEMA	Flood Mitigation Assistance	The goal of the FMA program is to implement cost-effective measures that reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insured under the National Flood Insurance Program.	https://www.mass.gov/service-details/building-resilient-infrastructure-and-communities-bric-flood-mitigation-assistance-fma-grant-programs
11	Executive Office Housing and Economic Development	MassWorks	The MassWorks Infrastructure Program provides a one-stop shop for municipalities and other eligible public entities seeking public infrastructure funding to support economic development and job creation.	http://www.mass.gov/hed/economic/eohed/pro/infrastructure/massworks/

#	Agency	Program	Description	For More Information
12	EEA	Municipal Vulnerability Preparedness Action Grant Program	The MVP Action Grant provides funding to designated MVP Communities, such as Barnstable, to advance priority climate adaptation actions to address climate change impacts resulting from extreme weather, sea level rise, inland and coastal flooding, severe heat, and other climate impacts.	https://www.mass.gov/service-details/mvp-action-grant
13	Coastal Zone Management	Coastal Resilience Grant Program	The Coastal Resilience Program is open to the 78 municipalities located within the Massachusetts coastal zone, including Barnstable. Projects must focus on coastal resiliency.	https://www.mass.gov/service-details/coastal-resilience-grant-program
14	Coastal Zone Management	Coastal Pollutant Remediation Program	The CPR program provides funding to the 220 Massachusetts municipalities located within the coastal watershed boundaries to assess and treat stormwater pollution from paved surfaces and to design and construct commercial boat waste pump out facilities.	https://www.mass.gov/service-details/coastal-pollutant-remediation-cpr-grant-program-eligible-communities
15	MassDOT	Chapter 90 Program	This program reimburses municipalities for costs incurred for eligible transportation projects on locally owned roads, including improvements to drainage and culverts.	https://www.mass.gov/chapter-90-program
16	EEA	Dam and Seawall Repair or Removal Program	This program funds the design, permitting, and construction of projects for the repair and removal of dams, levees, seawalls, and other forms of flood control.	https://www.mass.gov/dam-and-seawall-repair-or-removal-program
17	MassDEP	Clean Water State Revolving Funds	This program funds planning and construction of projects that are aimed at meeting water quality standards, emphasizing watershed management priorities, stormwater management, and green infrastructure. The program has recently offered an asset management grant program that can be used for stormwater assets.	https://www.mass.gov/service-details/srf-clean-water-program
18	MassDEP	Drinking Water State Revolving Funds	This program funds planning and construction of projects that are needed to achieve or maintain compliance with the Safe Drinking Water Act requirements and protect public health. aimed at meeting water quality	https://www.mass.gov/service-details/srf-drinking-water-program
19	DER	Culvert Replacement Municipal Assistance Grant	This program funds projects to replace undersized, perched, and/or degraded culverts located in areas of high ecological value.	https://www.mass.gov/how-to/culvert-replacement-municipal-assistance-grant-program

#	Agency	Program	Description	For More Information
20	Massachusetts Bays National Estuary Partnership	MassBays Healthy Estuaries Grants	The program focuses on protecting, restoring, and enhancing the estuarine ecosystems of Massachusetts and Cape Cod Bays (e.g., seagrass beds, salt marshes, beaches, and rocky shores) and to inform management efforts to reduce stressors (e.g., climate change, wastewater, stormwater, habitat fragmentation) impacting these habitats.	https://www.mass.gov/orgs/massachusetts-bays-national-estuary-partnership
21	FEMA	Safeguarding Tomorrow through Ongoing Risk Mitigation Act (STORM Act)	The program would allow FEMA to help states to establish revolving loan funds to be used by local governments to complete mitigation projects to reduce risks from natural hazards, specifically including shoreline erosion and rising water levels.	All Info - S.3418 - 116th Congress (2019-2020): STORM Act Congress.gov Library of Congress
22	DCR	Volunteer Fire Assistance Program (VFA)	The West Barnstable FD is eligible for wildland fire grants for up to 50% reimbursement for projects up to \$6,000.	Volunteer Fire Assistance Grants / Grant Opportunities / Business Services / Home - Florida Department of Agriculture & Consumer Services (fdacs.gov)
LOCAL				
23	Town of Barnstable	Town Budget	Through mechanisms such as the Capital Improvement Plan Budget, Community Preservation Act or other means, fund the implementation of mitigation projects.	Town Manager, Town Council, Planning Department, DPW Department

6. PLAN REVIEW AND ADOPTION

The implementation of this HMP update will be overseen by the Town of Barnstable Planning & Development Department. The Planning & Development Director will be supported by departmental resources and the HMP team to engage the Town and community on how various action items might be implemented and to ensure that they are prioritized in the highest order of importance.

6.1 PLAN MAINTENANCE

Periodic monitoring and reporting on this plan is necessary to ensure appropriate and timely plan implementation. The HMP team will be responsible for conducting an annual review of the plan. The annual review should include an evaluation of the identified mitigation actions to monitor their appropriateness, progress, and prioritization.

The HMP team should also evaluate the Plan after disaster events to examine the effectiveness of mitigation strategies and the impact of disasters on critical facilities and other infrastructure. An additional evaluation will be initiated if any funding opportunities are introduced. If necessary, recommendations for revisions or amendments should be made in response to the evaluation.

Any revisions or amendments made to the Plan should be done with the approval of the Town Council. Proposed amendments should be distributed to all relevant Town Departments and other interested parties for review. The public should be made aware of pending changes through traditional channels and an open review and comment period should be established. Proposed and adopted amendments should be sent to the Cape Cod Commission and to MEMA.

The Plan will be updated at least every five years in accordance with FEMA requirements under 44 CFR § 201.6(d)(3). This is essential in order to continue eligibility for FEMA hazard mitigation project grant funding. The HMP team will reconvene to reevaluate the Town's risks and vulnerabilities. The team will evaluate new development patterns, increased exposure to risk, advances in mitigation capabilities or techniques, or changes in Federal, State, or County legislation. An analysis of the plan mitigation strategy and action items will be conducted to ensure all measures are appropriate.

This plan will be made available to the public on the Town of Barnstable's website.

6.2 LOCAL ADOPTION

Once the 2021 HMP update is determined to be Approved Pending Adoption (APA) by FEMA, the proposed mitigation approach will be put into action and the plan will be adopted. Adoption must occur within one calendar of FEMA's approval. Plan implementation progress will be contingent on the availability of staff and funding towards mitigation. On [date xxx], the Barnstable Town Council voted to pass a resolution adopting the 2021 Barnstable Hazard Mitigation Plan as presented (**Appendix B**).

APPENDIX A: TOWN OF BARNSTABLE COMPREHENSIVE FIGURES

1: Regional Hazard Risk (Shoreline Erosion)

2: Hurricane Inundation Areas

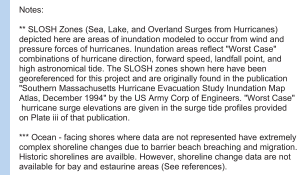
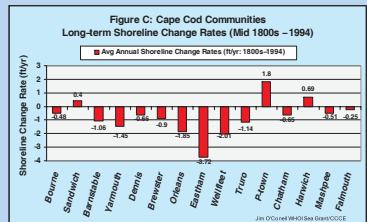
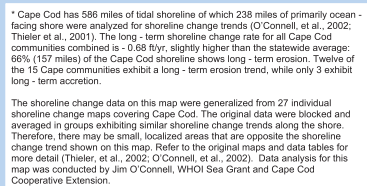
3: Dams

4: Flood Zones

5: Sea Level Rise

6: Critical Facilities

- Landslide Susceptibility
- Long -Term Shoreline Change Susceptibility
- Historic Tornado Activity
- Historic Earthquake Activity



Earthquakes: 144 recorded events in MA, 1668 -1990

NOTE AND CAUTION: The shoreline change data on this map were generated from 27 individual shoreline change maps covering Cape Cod. The shoreline change data span approximately 150 years (mid 1800s to 1994), with an uncertainty range of ± 0.4 foot per year. The original data were blocked and averaged in groups exhibiting similar shoreline change trends along the shore. Therefore, there may be localized areas that are opposite the shoreline change trend shown. Furthermore, caution should be taken when interpreting any shoreline change data as recent trends in shoreline movement may have changed as a result of natural causes, or importantly, human activities, such as seawall/replacement, jetty or groin construction. It is important to analyze the short-term shoreline change data that were used to calculate the long-term rates of change to identify recent changes in shoreline movement that may be more applicable for planning purposes. For case examples, see O'Connell, et al. 2002 & 2003, and Thielert, et al. 2002 listed in the references below. Data tables and maps can be viewed at www.state.ma.us/czm/czm.htm.

Data Sources:

Northeast States Emergency Consortium (NESEC) www.nesec.org, MassGIS Executive Office of Environmental Affairs, "Coastal Erosion on Cape Cod: Some Questions and Answers" (<http://woodhole.er.usgs.gov/staffpages/boldale/capecod/>), Federal Emergency Management Agency (FEMA), and the Cape Cod Commission's Geographic Information System Department.

References

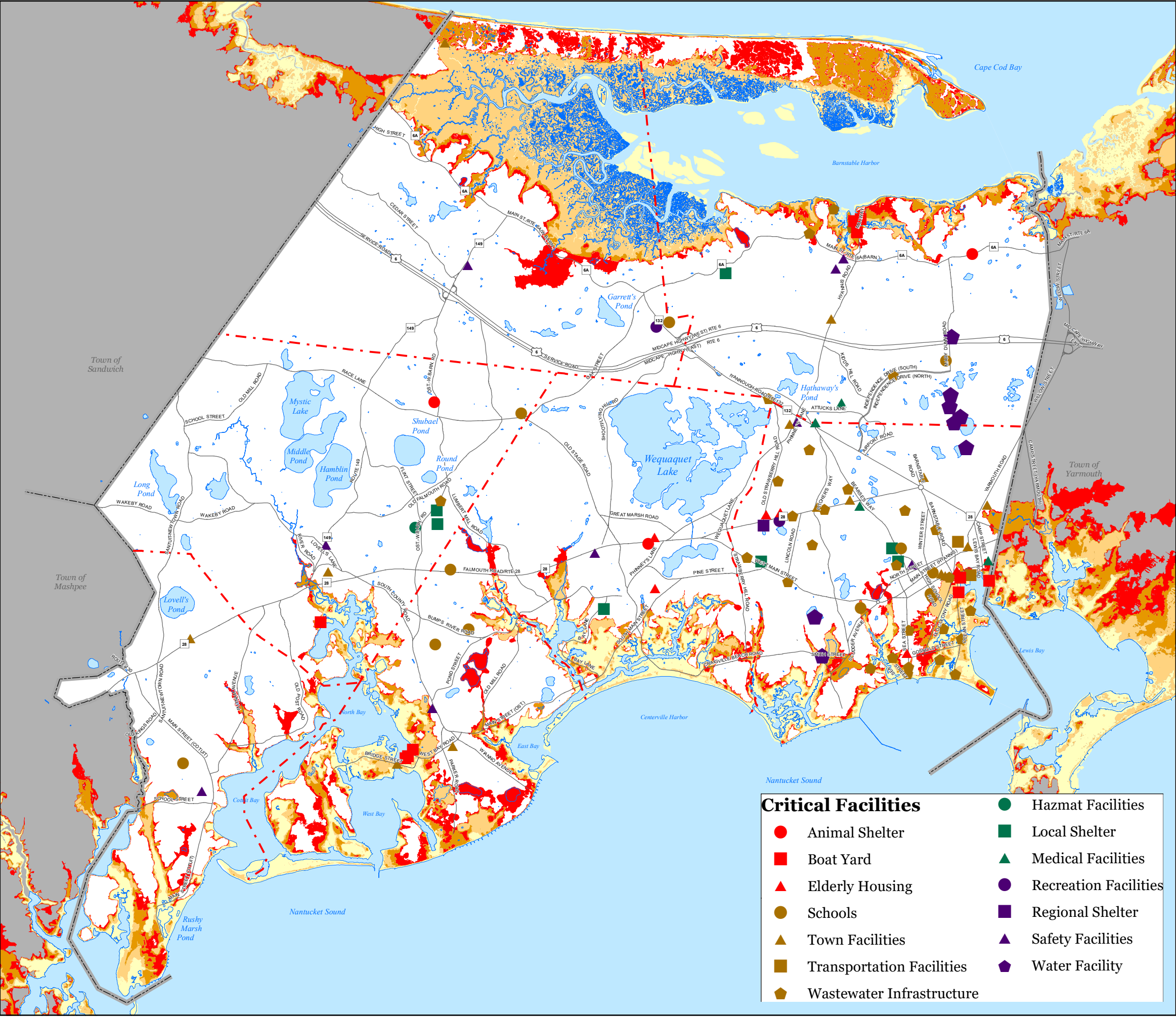
IPCC, 1995, Second Assessment - Climate Change 1995: A Report of the Intergovernmental Panel on Climate Change, IPCC, Geneva, Switzerland.

O'Connell, J.F., 2003, New Shoreline Change Data Reveal Massachusetts is Eroding, WHOI Sea Grant and Cape Cod Cooperative Extension, Marine Extension Bulletin, March, 2003.

O'Neill, J.F., Thieler, E.R., and Schupp, C. 2002, New Shoreline Change Data and Analysis for the Massachusetts Shore, with Emphasis on Cape Cod and the Islands: Mid1800s - 1994, Environment Cape Cod, Vol. 5, No. 1.

Thieler, E.R., O'Neill, J.F., and Schupp, C. 2002, The Massachusetts Shoreline Change Project: 1800s - 1994, Technical Report, U.S.G.S. Administrative Report, Woods Hole, MA.

Funding for the Cape Cod Pre-disaster Mitigation Planning grant was provided to the Cape Cod Commission by the Federal Emergency Management Agency under the DMA 2000 Initiative through the Massachusetts Emergency Management Agency. This map was produced through the Cape Cod Commission's Geographic Information Systems Department for the Pre-disaster Mitigation Project, January, 2004, based on data analysis, graphs and text provided by Jim O'Connell, Woods Hole Oceanographic Institution Sea Grant Program and Cape Cod Cooperative Extension. A description of the methods used in the data analysis for this project can be found in Thiesler, O'Connell and Schupp (2002) - see references above. Comments and suggestions are welcome at the Cape Cod Commission office or contact ps@capecodcommission.org. This map is illustrative and all depicted boundaries are approximate.



Hurricane Surge Inundation Areas

Note: Missing Data for Grand Island Area
Source: US Army Corps of Engineers / Cape Cod Commission

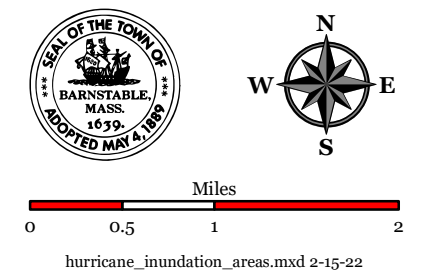
- Category 1 Hurricane
- Category 2 Hurricane
- Category 3 Hurricane
- Category 4 Hurricane

- Fire District / Village Lines
- Major Roads
- Town Boundary
- Shoreline
- Water Bodies (May be obscured)

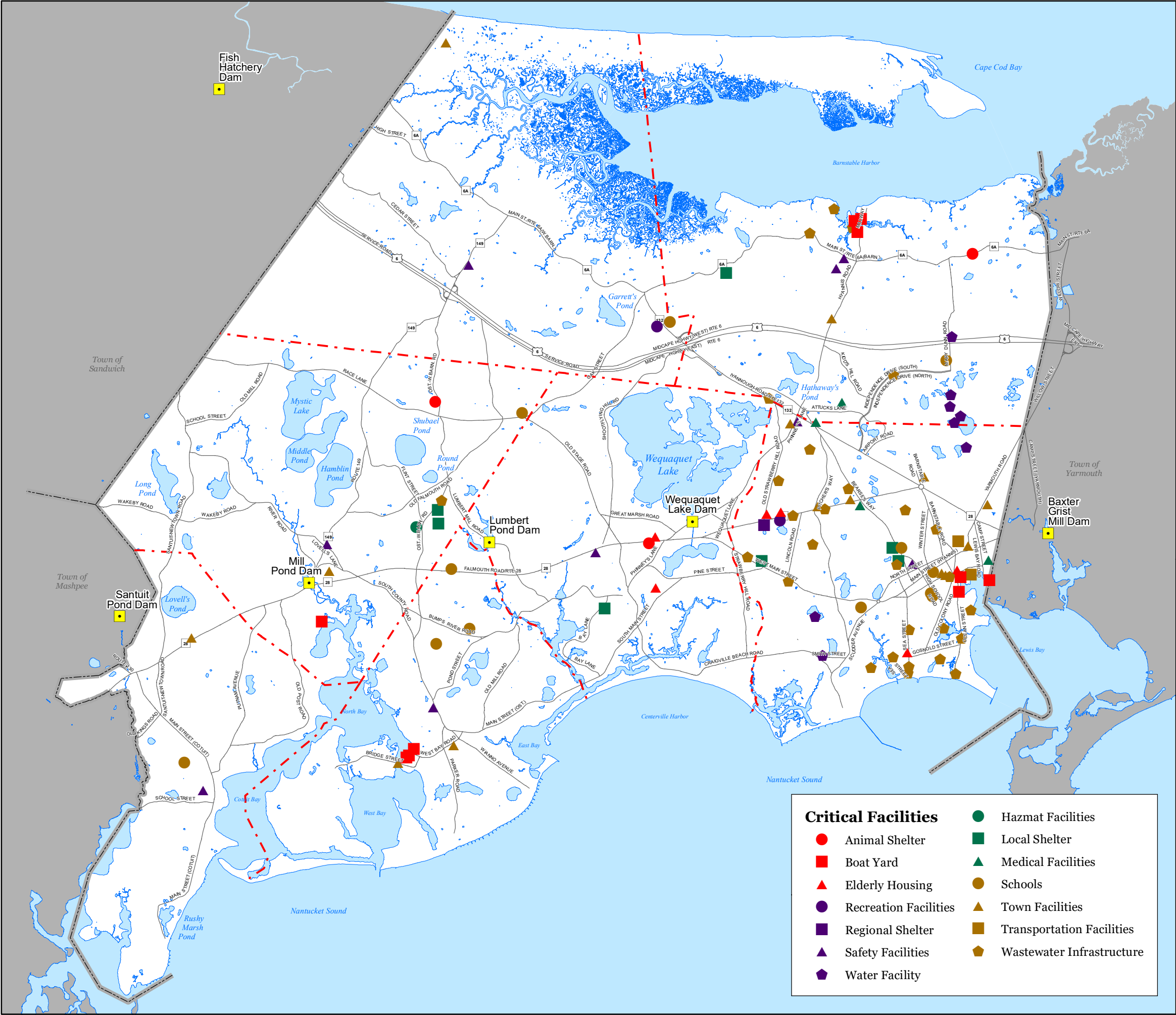
**TOWN OF
BARNSTABLE
MASSACHUSETTS**

2021 Hazard Mtigation
Plan Update

**Hurricane
Inundation Areas
Figure 2**



**TOWN OF BARNSTABLE
GEOGRAPHIC INFORMATION
SYSTEMS UNIT**



Dams (MassGIS)
■ Significant Hazard

Fire District / Village Lines

Major Roads

Town Boundary

Shoreline

Water Bodies (May be obscured)

**TOWN OF
BARNSTABLE
MASSACHUSETTS**

2021 Hazard Mitigation
Plan Update

Dams
Figure 3

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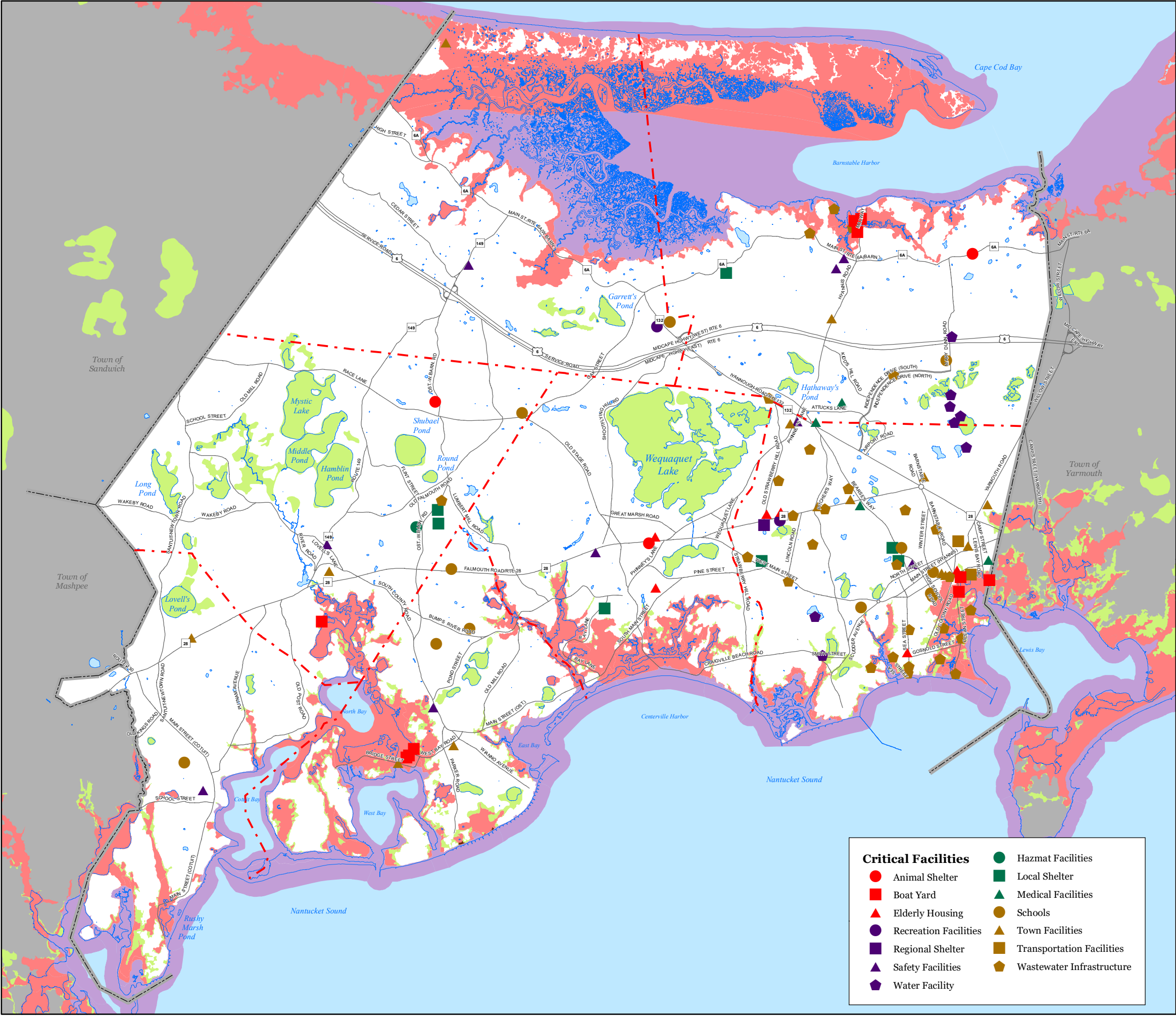
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**TOWN OF BARNSTABLE
GEOGRAPHIC INFORMATION
SYSTEMS UNIT**



Special Flood Hazard Areas (SFHAs) Subject to Inundation by the 1% Annual Chance Flood

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equalled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood.

Zone AE - Base Flood Elevations determined.

Zone AO - Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined.

Zone AH - Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.

Zone VE - Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

Other Flood Areas

Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

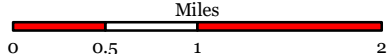

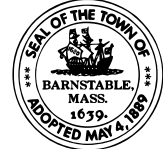
NOTE: The flood zones shown here represent the 2009 Preliminary Revised FEMA Flood Insurance Rate Maps. These maps are preliminary and have not yet been adopted. These are preliminary data that may be subject to appeal and may change before final adoption and cannot be used for making final determinations.

- Fire District / Village Lines
- Major Roads
- Town Boundary
- Shoreline
- Water Bodies (May be obscured)

TOWN OF BARNSTABLE MASSACHUSETTS

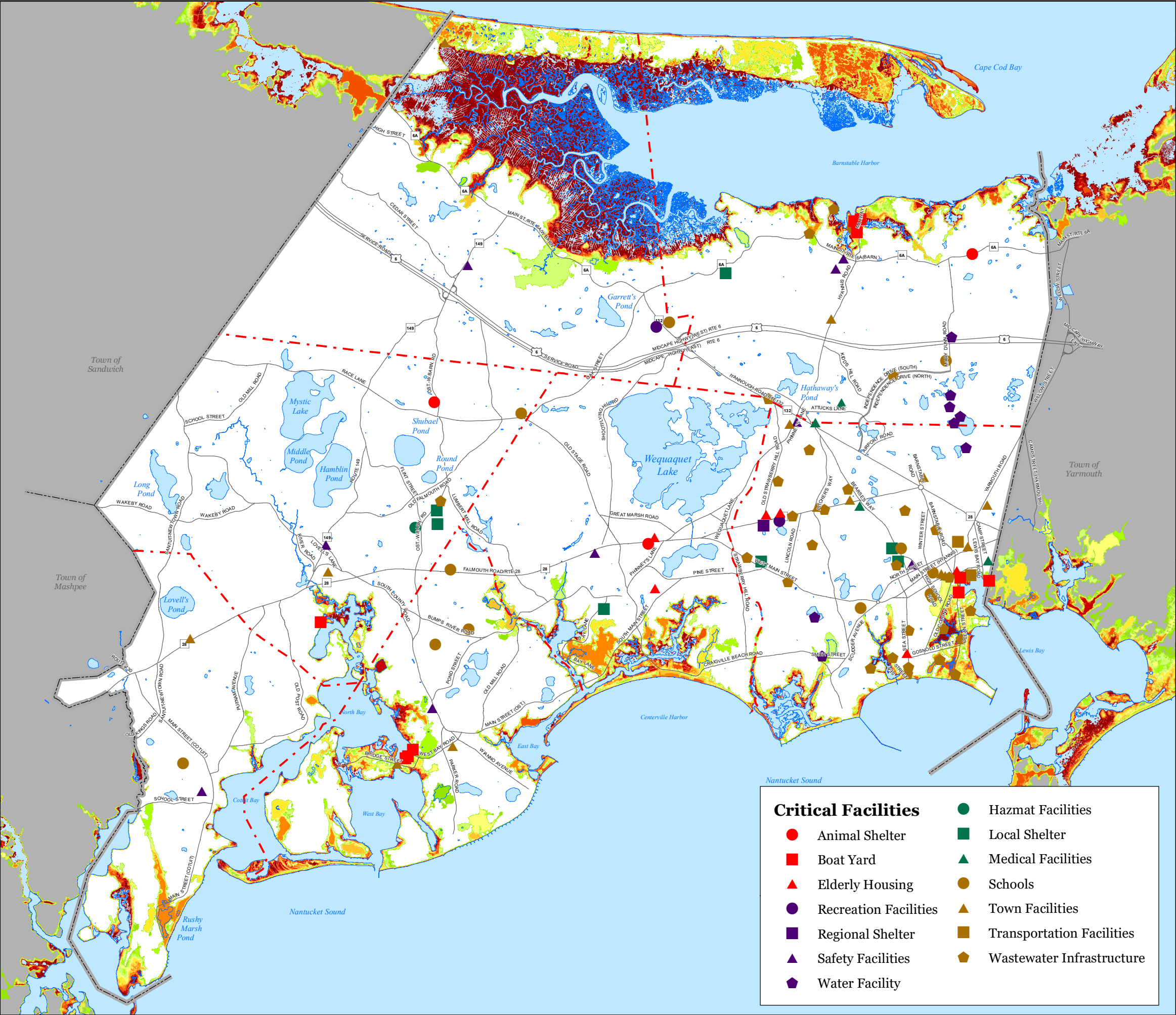
2021 Hazard Mitigation Plan Update

Flood Zones Figure 4



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**TOWN OF BARNSTABLE
GEOGRAPHIC INFORMATION
SYSTEMS UNIT**



Potential Extent of MHHW with Sea Level Rise

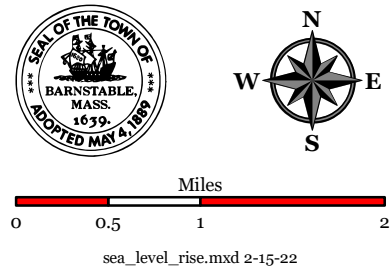
- Mean Higher High Water (MHHW)
- MHHW + 1 ft Sea Level Rise
- MHHW + 2 ft Sea Level Rise
- MHHW + 3 ft Sea Level Rise
- MHHW + 4 ft Sea Level Rise
- MHHW + 5 ft Sea Level Rise
- MHHW + 6 ft Sea Level Rise
- MHHW + 7 ft Sea Level Rise
- MHHW + 8 ft Sea Level Rise
- MHHW + 9 ft Sea Level Rise
- MHHW + 10 ft Sea Level Rise

- Fire District / Village Lines
- Major Roads
- Town Boundary
- Shoreline
- Water Bodies (May be obscured)

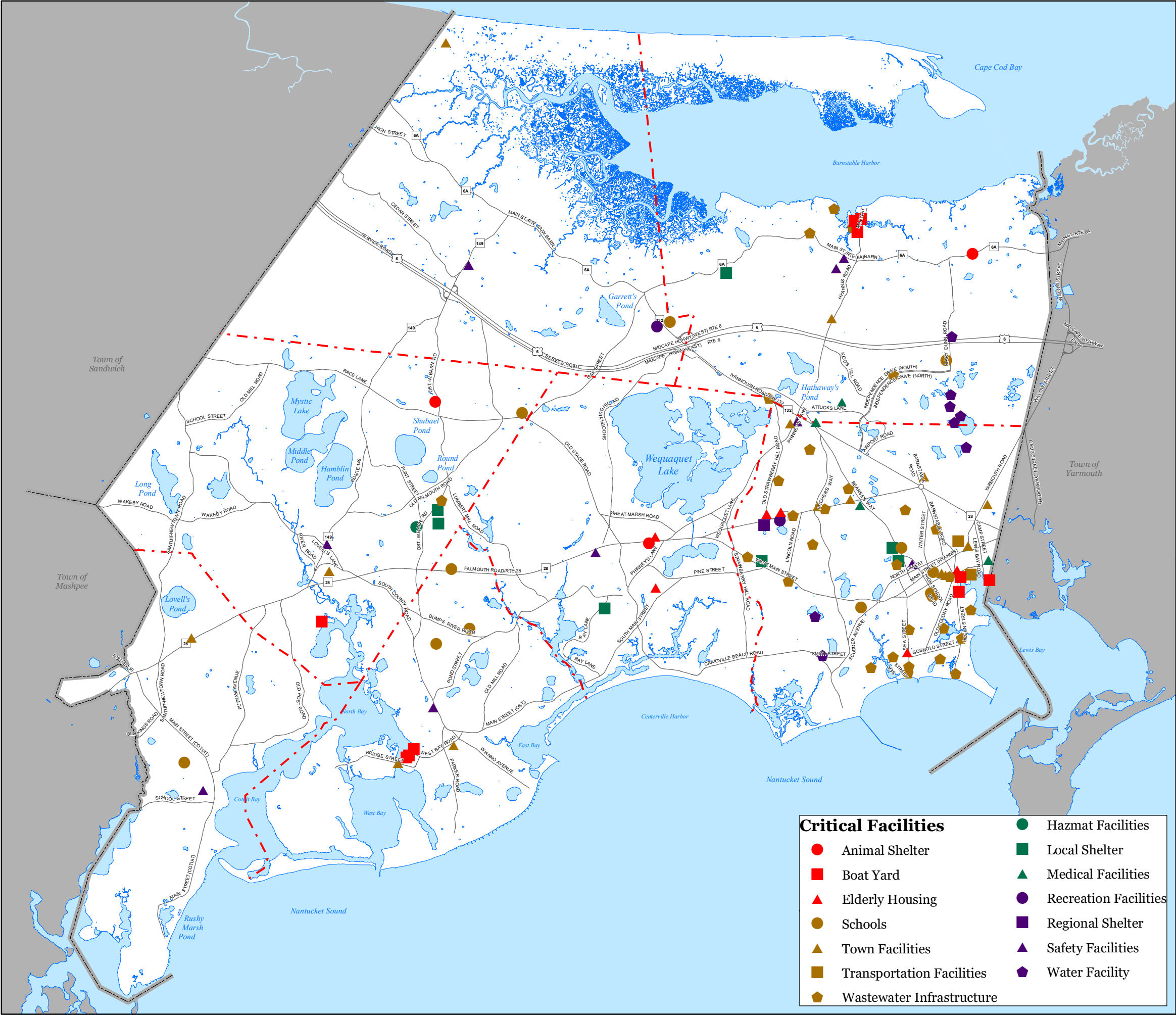
TOWN OF
BARNSTABLE
MASSACHUSETTS

2021 Hazard Mitigation
Plan Update

Sea level Rise
Figure 5



TOWN OF BARNSTABLE
GEOGRAPHIC INFORMATION
SYSTEMS UNIT



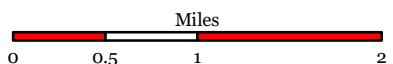
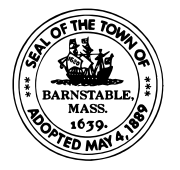
- Fire District / Village Lines
- Major Roads
- Town Boundary
- Shoreline
- Water Bodies (May be obscured)

TOWN OF BARNSTABLE MASSACHUSETTS

2021 Hazard Mitigation Plan Update

Critical Facilities

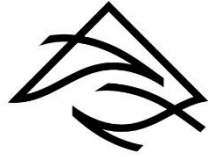
Figure 6



critical_facilities.mxd 2-15-22

**TOWN OF BARNSTABLE
GEOGRAPHIC INFORMATION
SYSTEMS UNIT**

APPENDIX B: BARNSTABLE TOWN COUNCIL RESOLUTION



**Woodard
& Curran**

woodardcurran.com