TOWN OF DUXBURY
HAZARD MITIGATION PLAN

ADOPTED DECEMBER
17, 2018

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ACKNOWLEGEMENT AND CREDITS

This plan was prepared for the Town of Duxbury by the Metropolitan Area Planning Council (MAPC) under the direction of the Massachusetts Emergency Management Agency (MEMA) and the Massachusetts Department of Conservation and Recreation (DCR). The plan was funded by the Metropolitan Area Planning Council.

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Public Meeting Participants and Community Stakeholders

Special thanks to the public meeting participants and community stakeholders who provided feedback.

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EXECUTIVE SUMMARY

Hazard Mitigation planning is a proactive effort to identify actions that can be taken to reduce the dangers to life and property from natural hazard events. In the communities of the Boston region of Massachusetts, hazard mitigation planning tends to focus most on flooding, the most likely natural hazard to impact these communities. The Federal Disaster Mitigation Act of 2000 requires all municipalities that wish to be eligible to receive FEMA funding for hazard mitigation grants, to adopt a local multi-hazard mitigation plan and update this plan in five year intervals.

PLANNING PROCESS

This is the Town of Duxbury's first Natural Hazard Mitigation Plan. Planning for the Hazard Mitigation Plan was led by the Duxbury Local Hazard Mitigation Planning Team, composed of staff from a number of different Town Departments. This team met on September 20, 2016, March 23, 2018, and November 8, 2018 and discussed where the impacts of natural hazards most affect the Town, goals for addressing these impacts, updates to the Town's existing mitigation measures and new hazard mitigation measures that would benefit the Town.

Public participation in this planning process is important for improving awareness of the potential impacts of natural hazards and to build support for the actions the Town takes to mitigate them. The Town hosted three public meetings. The first was on March 22, 2017 with the Planning Boar, the second on November 14, 2018 with the Planning Board, and the third on November 19, 2018 with the Board of Selectmen, and the draft plan update was posted on the Town's website for public review for two weeks. Key town stakeholders and neighboring communities were notified and invited to review the draft plan and submit comments. There were no public comments.

RISK ASSESSMENT

The Duxbury Hazard Mitigation Plan assesses the potential impacts to the Town from flooding, high winds, winter storms, brush fire, geologic hazards, extreme temperatures, tsunamis, drought, and climate change. Flooding, driven by hurricanes, Nor'easters and other storms, clearly presents the greatest hazard to the Town. These are shown on the map series (Appendix B).

The Duxbury Local Hazard Mitigation Planning Team identified 54 Critical Facilities. These are also shown on the map series and listed in Table 17, identifying which facilities are located within the mapped hazard zones.

A HAZUS-MH analysis provided estimates of damages from Hurricanes of 1% and 0.2% Annual Chance at $38,000,000 million and $1 billion, respectively. Earthquakes of magnitudes 5 and 7 analysis provided $232 million and $2 billion respectively in property damages. Flood damage from both coastal and riverine flooding for the 1% and the 0.2% Annual Chance Flood is $21million and $23 million respectively.

HAZARD MITIGATION GOALS

The Duxbury Local Hazard Mitigation Planning Team identified the following hazard mitigation goals for the Town:

Goal 1: Prevent and reduce the loss of life, injury, public health impacts and property damages resulting from all major natural hazards.

Goal 2: Identify and seek funding for measures to mitigate or eliminate each known significant flood hazard area.

Goal 3: Integrate hazard mitigation planning as an integral factor in all relevant municipal departments, committees and boards.

Goal 4: Prevent and reduce the damage to public infrastructure resulting from all hazards.

Goal 5: Encourage the business community, major institutions and non-profits to work with the Town to develop, review and implement the hazard mitigation plan.

Goal 6: Work with surrounding communities, state, regional and federal agencies to ensure regional cooperation and solutions for hazards affecting multiple communities.

Goal 7: Ensure that future development meets federal, state and local standards for preventing and reducing the impacts of natural hazards.

Goal 8: Take maximum advantage of resources from FEMA and MEMA to educate Town staff and the public about hazard mitigation.

Goal 9: Consider the potential impacts of climate change and incorporate climate mitigation and resilience in all planning efforts.

HAZARD MITIGATION STRATEGY

The Duxbury Local Hazard Mitigation Planning Team identified a number of mitigation measures that would serve to reduce the Town's vulnerability to natural hazard events. Overall, the hazard mitigation strategy recognizes that mitigating hazards for Duxbury will be an ongoing process as our understanding of natural hazards and the steps that can be taken to mitigate their damages changes over time. Climate change and a variety of other factors impact the Town's vulnerability, and local officials will need to work together across municipal lines and with state and federal agencies in order to understand and address these changes. The Hazard Mitigation Strategy will be incorporated into the Town's other related plans and policies.

PLAN REVIEW & UPDATE PROCESS

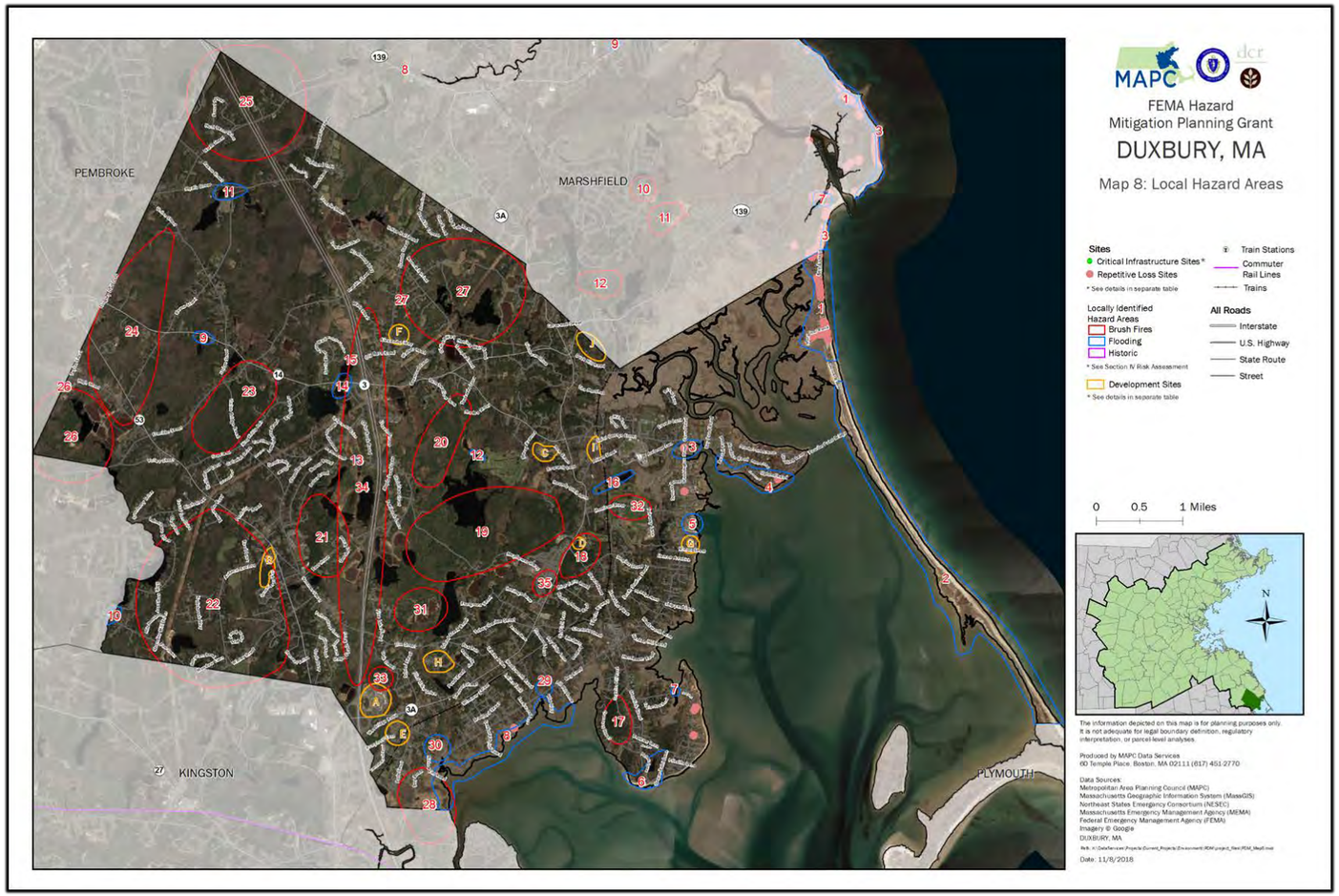
The process for developing Duxbury's Hazard Mitigation Plan 2018 is summarized in **Table 1** below.

Table 1 Plan Review and Update Process

Chapter	Reviews and Updates
III – Public Participation	The Local Hazard Mitigation Planning Team placed an emphasis on public participation for the update of the Hazard Mitigation Plan, discussing strategies to enhance participation opportunities at the first local committee meeting. During plan development, the plan was discussed at two public meetings hosted by the Local Emergency Planning Committee and the Board of Selectmen. The plan was also available on the Town's website for public comment. There were no public comments.
IV – Risk Assessment	MAPC gathered the most recently available hazard and land use data and met with Town staff to identify changes in local hazard areas and development trends. Town staff reviewed critical infrastructure with MAPC staff in order to create an up-to-date list. MAPC also used the most recently available version of HAZUS to assess the potential impacts of flooding, hurricanes and earthquakes using the latest available data.
V - Goals	The Hazard Mitigation Goals were reviewed and endorsed by the Duxbury Local Hazard Mitigation Planning Team.
VI – Existing Mitigation Measures	The list of existing mitigation measures was updated to reflect current mitigation activities in the Town.
VII & VIII – Hazard Mitigation Strategy	Exiting Mitigation were documented and assessed as to whether they were effective. The Plan's hazard mitigation strategy reflects new measures to prevent further loss. The Local Hazard Mitigation Team prioritized all of these measures based on current conditions.
IX – Plan Adoption & Maintenance	This section of the plan was updated with a new on-going plan implementation review and five year update process that will assist the Town in incorporating hazard mitigation issues into other Town planning and regulatory review processes and better prepare the Town for the next comprehensive plan update.

Moving forward into the next five year plan implementation period there will be many more opportunities to incorporate hazard mitigation into the Town's decision making processes. The Town will document any actions taken within this iteration of the Hazard Mitigation Plan on challenges met and actions successfully adopted as part of the ongoing plan maintenance to be conducted by the Duxbury Hazard Mitigation Implementation Team, as described in Section VIII, Plan Adoption and Maintenance.

Figure 1 Existing Features: Critical Facilities, Development Sites, & Local Hazard Areas



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I. INTRODUCTION

PLANNING REQUIREMENTS UNDER THE FEDERAL DISASTER MITIGATION ACT

The Federal Disaster Mitigation Act, passed in 2000, requires all municipalities that wish to continue to be eligible to receive FEMA funding for hazard mitigation grants adopt a local multi-hazard mitigation plan and update this plan in five year intervals. This planning requirement does not affect disaster assistance funding.

Federal hazard mitigation planning and grant programs are administered by the Federal Emergency Management Agency (FEMA) in collaboration with the states. These programs are administered in Massachusetts by the Massachusetts Emergency Management Agency (MEMA) in partnership with the Department of Conservation and Recreation (DCR).

Massachusetts has taken a regional approach and has encouraged the regional planning agencies to apply for grants to prepare plans for groups of their member communities. The Metropolitan Area Planning Council (MAPC) received a grant from the Federal Emergency Management Agency (FEMA) under the Pre-Disaster Mitigation (PDM) Program, to assist the Town of Duxbury in creating its Hazard Mitigation Plan. The local Hazard Mitigation Plan produced under this contract is designed to individually meet the requirements of the Disaster Mitigation Act for each community while listing regional concerns and hazards that impact the Town creating the plan.

WHAT IS A HAZARD MITIGATION PLAN?

Natural hazard mitigation planning is the process of determining how to systematically reduce or eliminate the loss of life and property damage resulting from natural hazards such as floods, earthquakes, and hurricanes. Hazard mitigation means to permanently reduce or alleviate the losses of life, injuries, and property resulting from natural hazards through long-term strategies. These long-term strategies include planning, policy changes, programs, projects, and more.

PREVIOUS FEDERAL/STATE DISASTERS

The Town of Duxbury has experienced 22 natural hazards that triggered federal or state disaster declarations since 1991. These disasters are listed in Figure 2. The majority of these events involved flooding, while eight were due to hurricanes or nor'easters, and seven were due to severe winter weather.

FEMA FUNDED MITIGATION PROJECTS

Duxbury received funding from FEMA and MEMA in 1991/1992 for two sacrificial dune projects on Duxbury Beach to maintain a minimum of sixteen feet NGVD along the entire length of the barrier beach. This also provided flood hazard protection for a large number of properties and is a critical component of safeguarding coastal infrastructure in Duxbury and its neighboring

towns Kingston and Plymouth. However, Duxbury Beach has not qualified for funding for sacrificial dunes or beach nourishment since 1992.[1]

Figure 2: Previous Federal/State Disaster Declarations

Disaster Name (Date of Event)	Type of Assistance	Declared Areas
Hurricane Bob (August 1991)	FEMA Public Assistance Project Grants	Counties of Barnstable, Bristol, Dukes, Essex, Hampden, Middlesex, Plymouth, Nantucket, Norfolk, Suffolk
	Hazard Mitigation Grant Program	Counties of Barnstable, Bristol, Dukes, Essex, Hampden, Middlesex, Plymouth, Nantucket, Norfolk, Suffolk (16 projects)
No-Name Storm (October 1991)	FEMA Public Assistance Project Grants	Counties of Barnstable, Bristol, Dukes, Essex, Middlesex, Plymouth, Nantucket, Norfolk
	FEMA Individual Household Program	Counties of Barnstable, Bristol, Dukes, Essex, Middlesex, Plymouth, Nantucket, Norfolk
	Hazard Mitigation Grant Program	Counties of Barnstable, Bristol, Dukes, Essex, Middlesex, Plymouth, Nantucket, Norfolk, Suffolk (10 projects)
December Blizzard (December 1992)	FEMA Public Assistance Project Grants	Counties of Barnstable, Dukes, Essex, Plymouth, Suffolk
	Hazard Mitigation Grant Program	Counties of Barnstable, Dukes, Essex, Plymouth, Suffolk (7 projects)
March Blizzard (March 1993)	FEMA Public Assistance Project Grants	All 14 Counties
January Blizzard (January 1996)	FEMA Public Assistance Project Grants	All 14 Counties
May Windstorm (May 1996)	State Public Assistance Project Grants	Counties of Plymouth, Norfolk, Bristol (27 communities)
October Flood (October 1996)	FEMA Public Assistance Project Grants	Counties of Essex, Middlesex, Norfolk, Plymouth, Suffolk
	FEMA Individual Household Program	Counties of Essex, Middlesex, Norfolk, Plymouth, Suffolk
	Hazard Mitigation Grant Program	Counties of Essex, Middlesex, Norfolk, Plymouth, Suffolk (36 projects)

[1] Personal Communication, Duxbury Beach Reservation Inc. October 31, 2018

Disaster Name (Date of Event)	Type of Assistance	Declared Areas
(1997)	HUD Community Development Block Grant	Counties of Essex, Middlesex, Norfolk, Plymouth, Suffolk
June Flood (June 1998)	FEMA Individual Household Program	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
	Hazard Mitigation Grant Program	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester (19 projects)
(1998)	HUD Community Development Block Grant	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
March Flood (March 2001)	FEMA Individual Household Program	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
	Hazard Mitigation Grant Program	Counties of Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester (16 projects)
February Snowstorm (Feb 17-18, 2003)	FEMA Public Assistance Project Grants	All 14 Counties
January Blizzard (January 22-23, 2005)	FEMA Public Assistance Project Grants	All 14 Counties
Hurricane Katrina (August 29, 2005)	FEMA Public Assistance Project Grants	All 14 Counties
May Rainstorm/Flood (May 12-23, 2006)	Hazard Mitigation Grant Program	Statewide
April Nor'easter (April 15-27, 2007)	Hazard Mitigation Grant Program	Statewide
Flooding (March, 2010)	SBA Loan; FEMA Public Assistance & Individuals and Households Program	Bristol, Essex, Middlesex, Suffolk, Norfolk, Plymouth, Worcester
	Hazard Mitigation Grant Program	Statewide
Hurricane Earl (September 2010)	FEMA Public Assistance Project Grants	Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, Suffolk, and Worcester
Tropical Storm Irene (August 27-28, 2011)	FEMA Public Assistance	Statewide
Hurricane Sandy (October 27-30, 2012)	FEMA Public Assistance	Statewide
Severe Snowstorm and Flooding (February 8-9, 2013)	FEMA Public Assistance; Hazard Mitigation Grant Program	Statewide

Disaster Name (Date of Event)	Type of Assistance	Declared Areas
Blizzard of 2015 (January 26-28, 2015)	FEMA Public Assistance; Hazard Mitigation Grant Program	Statewide
Winter Storm Riley and Flooding March 3-6, 2018	Hazard Mitigation Grant Program	Statewide

Source: Database Provided by MEMA

COMMUNITY PROFILE

Duxbury is a coastal community of almost 15,500 people located 33 miles southeast of Boston in Plymouth County. It is primarily accessible from the north and south by Route 3 and is bordered by Pembroke on the west, Marshfield on the north, Kingston and Plymouth on the south, and the Atlantic Ocean on the east and southeast.

The town was a center of shipbuilding until the mid-19th century, when ships became too large for the shallow bay. It maintains ties to its seagoing past through a variety of harbor-related activities and programs, including many run by the Duxbury Bay Maritime School in Snug Harbor. Duxbury Bay supports both a recreational and commercial fishing industry, and the town has become well known for its oysters and other shellfish.

Following the shipbuilding era in the town's history, the community became a rural, summer community with its economic base tied to fishing and agriculture. Today, Duxbury is a residential suburb of Boston, with Route 3 serving as its main route to Boston and other points. Many historic and beautiful homes from Pilgrim times and the shipbuilding period remain in Duxbury, and residents cherish the town's historic assets.

The Town is governed by a Town Manager, Board of Selectmen, and Open Town Meeting governmental structure. Duxbury was incorporated in 1637, 17 years after Pilgrims established their colony in Plymouth.

Some of Duxbury's unique characteristics to keep in mind include:

- As a coastal community, the town is directly threatened by high seas and Nor'easter storms that pound the coastline and damage and flood the property and residents living in those areas.
- Flooding in the town is a significant threat to property and the town has problems with water inundation during high rain and storm events, particularly during the spring snowmelt exacerbates flooding due to an elevated water table.
- A defining characteristic of the town are its tree-lined streets. Although these trees are vulnerable to high winds and ice storms, they are a tradeoff the town is willing to have.
- The town has a number of dams that are currently reported to be in good shape. However, should a dam fail at one these locations, it could cause increased risks of flooding downstream.

- The town has proactive municipal officials that frequently share information and coordinate on a regular basis. An example of this was the data collection sessions for this PDM plan, at which representatives of several Town departments were present.
- Duxbury is home to historic structures and sites that are irreplaceable and bring economic value to the town.
- Duxbury contains several major roadways and bridge crossings that provide emergency routes for evacuation and for routes to medical facilities. Some of these transportation resources or infrastructures are frequently at risk of flooding, particularly from ocean storm-related flooding.
- Duxbury has 52 repetitive loss sites that have resulted in 179 claims, due to recurring flooding issues.
- Duxbury would be a good candidate for flood-related grants due to the potential impact to property, transportation emergency routes, and economic/historic resources, and the ability to solve the flooding problems through structural measures such as culvert upgrades, dam and bridge upgrades, or flood proofing. The cost-benefit analysis would likely be in the town's favor.
- Much of the critical infrastructure in the town is located in clusters, and in some cases near areas of floodplain. These facilities are therefore at higher risk of damage.

The Town maintains a website at www.town.duxbury.ma.us

Figure 3: Duxbury Characteristics

Population = 15,444 people
- 4.8% are under age 5
- 26.5% are under age 18
- 16.9% are over age 65
- 7.1% have a disability
- 2.2% are foreign born

Number of Housing Units = 5,937
- 10.7% are renter-occupied housing units
- 17.5% of housing units were built before 1940
- 89.9% of housing units are single family homes

Source: 2016 ACS 5-Year Estimates

II. PLANNING PROCESS AND PUBLIC PARTICIPATION

MAPC employs a six-step planning process based on FEMA's hazard mitigation planning guidance focusing on local needs and priorities, but maintaining a regional perspective matched to the scale and nature of natural hazard events. Public participation is a central component of this process, providing critical information about the local occurrence of hazards while also serving as a means to build a base of support for hazard mitigation activities. MAPC supports participation by the general public and other plan stakeholders through Local Hazard Mitigation Planning Teams, two public meetings hosted by the local Hazard Mitigation Team, posting of the plan to the Town's website, and invitations sent to neighboring communities, Town boards and commissions, the local chamber of commerce, and other local or regional entities to review the plan and provide comment.

PLANNING PROCESS SUMMARY

The six-step planning process outlined below is based on the guidance provided by FEMA in the Local Multi-Hazard Mitigation Planning Guidance. Public participation is a central element of this process, which attempts to focus on local problem areas and identify needed mitigation measures based on where gaps occur in the existing mitigation efforts of the municipality. By working on municipal hazard mitigation plans in groups of neighboring cities and towns, MAPC is able to identify regional opportunities for collaboration and facilitate communication between communities. The planning process is described below.

Figure 4: Six Step Planning Process

1. Map the Hazards – MAPC relies on data from a number of different federal, state, and local sources in order to map the areas with the potential to experience natural hazards. This mapping represents a multi-hazard assessment of the municipality and is used as a set of base maps for the remainder of the planning process. A particularly important source of information is the knowledge drawn from local municipal staff on where natural hazard impacts have occurred. These maps can be found in Appendix B.

2. Assess the Risks & Potential Damages – Working with local staff, critical facilities, infrastructure, vulnerable populations, and other features are mapped and contrasted with the hazard data from the first step to identify those that might represent particular vulnerabilities to these hazards. Land use data and development trends are also incorporated into this analysis. In addition, MAPC develops estimates of the potential impacts of certain hazard events on the community. MAPC drew on the following resources to complete the plan:

    - Town of Duxbury Zoning By-Laws
    - Town of Duxbury, Community Development Plan 2004
    - MAPC, Duxbury Climate Resiliency Assessment and Action Plan 2018
    - MAPC, South Shore Coastal Adaptation Study 2011
    - Kleinfelder Inc., Sea Level Rise Study, 2013
    - Environment America Research and Policy Center, *When It Rains It Pours – Global Warming and the Increase in Extreme Precipitation,* July 2012
    - FEMA, Local Mitigation Plan Review Guide; October 1, 2011
    - FEMA, Flood Insurance Study, Plymouth County, 11/4/2016
    - FEMA Flood Insurance Rate Maps for Plymouth County, MA, 2012
    - FEMA LOMR, Effective 12/13/17
    - MA Office of Coastal Zone Management, Sea Level Rise: Understanding and Applying Trends and Future Scenarios for Analysis and Planning, December 2013
    - MA Office of Dam Safety, Inventory of Massachusetts Dams
    - Massachusetts State Hazard Mitigation Plan, 2013
    - Metropolitan Area Planning Council, GIS Lab, Regional Plans and Data
    - New England Seismic Network, Boston College Weston Observatory, http://aki.bc.edu/index.htm
    - NOAA National Centers for Environmental Information, http://www.ncdc.noaa.gov/
    - Northeast States Emergency Consortium, http://www.nesec.org/
    - US Census, 2010

3. Review Existing Mitigation – Municipalities in the Boston Metropolitan Region have an active history in hazard mitigation as most have adopted flood plain zoning districts, wetlands protection programs, and other measures as well as enforcing the State building code, which has strong provisions related to hazard resistant building requirements. All current municipal mitigation measures must be documented.

4. Develop Mitigation Strategies – MAPC works with the local municipal staff to identify new mitigation measures, utilizing information gathered from the hazard identification, vulnerability assessments, and the community's existing mitigation efforts to determine where additional

work is necessary to reduce the potential damages from hazard events. Additional information on the development of hazard mitigation strategies can be found in Chapter VII.

5. Plan Approval & Adoption – Once a final draft of the plan is complete it is sent to MEMA for the state level review and, following that, to FEMA for approval. Typically, once FEMA has approved the plan, the agency issues a conditional approval (Approval Pending Adoption), with the condition being adoption of the plan by the municipality. More information on plan adoption can be found in Chapter IX and documentation of plan adoption can be found in Appendix D.

6. Implement & Update the Plan – Implementation is the final and most important part of any planning process. Hazard Mitigation Plans must also be updated on a five year basis making preparation for the next plan update an important on-going activity. Chapter IX includes more detailed information on plan implementation.

THE LOCAL HAZARD MITIGATION PLANNING TEAM

MAPC worked with the local community representatives to organize a Local Hazard Mitigation Planning Team for Duxbury. MAPC briefed the local representatives as to the desired composition of that team as well as the need for public participation in the local planning process.

The Local Hazard Mitigation Planning Team is central to the planning process as it is the primary body tasked with developing a mitigation strategy for the community. The local team was tasked with working with MAPC to set plan goals, provide information on the hazards that impact the town, existing mitigation measures, and helping to develop new mitigation measures for this plan update. The Local Hazard Mitigation Planning Team membership can be found below.

René Read	Town Administrator
Valerie Massard	Director of Planning
Peter Buttkus	Director, Public Works
Matthew Clancy	Chief of Police
Kevin Nord	Fire Chief
Scott Lambiase	Building Commissioner/Director of Municipal Services
Joe Grady	Conservation Administrator
Tracy Mayo	Health Agent
Jake Emerson	Harbormaster
Cris Lutazzi	Director, Duxbury Beach Reservation, Inc.

The Duxbury Planning Board and the Duxbury Conservation Commission are the primary entities responsible for regulating development in town. Feedback from the Planning Board and the Conservation Commission was assured through the participation of the Director of Community Development and Planning, Conservation Administrator and the Town Manager, as well as other local public safety officials including the DPW, Building and Health Departments, Facilities Manager, Fire, Police and Harbormaster. In addition, MAPC, the State-designated regional planning authority for Duxbury, works with all agencies that that regulate development in the region, including the listed municipal entities and state agencies, such as the MassDOT and the Department of Conservation and Recreation.

The Local Hazard Mitigation Planning Team met on: September 20, 2016, March 27, 2018, and November 9, 2018. The purpose of the first meeting included review and updates to the hazard mitigation goals, and gathering information on local hazard mitigation issues, and sites or areas related to these. The second meeting focused on verifying information gathered by MAPC staff and discussion of existing mitigation practices and potential new or revised mitigation measures. The third meeting was to provide comments and feedback on the draft plan prior to the public meeting.

The agendas for these meetings are included in Appendix A.

PUBLIC MEETINGS

Public participation in the hazard mitigation planning process is important, both for plan development and for later implementation of the plan. Residents, business owners, and other community members are an excellent source for information on the historic and potential impacts of natural hazard events and particular vulnerabilities the community may face from these hazards. Their participation in this planning process also builds understanding of the concept of hazard mitigation, potentially creating support for mitigation actions taken in the future to implement the plan. To gather this information and educate residents on hazard mitigation, the Town hosted two public meetings, one during the planning process and one after a complete draft plan was available for review.

Natural hazard mitigation plans unfortunately rarely attract much public involvement in the Boston region, unless there has been a recent hazard event. One of the best strategies for overcoming this challenge is to include discussion of the hazard mitigation plan on the agenda of an existing board or commission. With this strategy, the meeting receives widespread advertising and a guaranteed audience of the board or commission members plus those members of the public who attend the meeting. These board and commission members represent an engaged audience that is informed and up to date on many of the issues that relate to hazard mitigation planning in the locality and will likely be involved in plan implementation, making them an important audience with which to build support for hazard mitigation measures. In addition, these meetings frequently receive press coverage, expanding the audience that has the opportunity to hear the presentation and provide comment.

The public had an opportunity to provide input to the Duxbury hazard mitigation planning process during two meetings of the Planning Board on March 22, 2017 and November 14, 2018. It was broadcast live on local cable television. The draft plan update was presented at a Board of Selectmen meeting on November 19, 2018 at Duxbury Town Hall. Both meetings were publicized in accordance with the Massachusetts Public Meeting Law, and an additional notice was published in the local newspaper (the Duxbury Clipper) for the Selectmen's meeting. The agenda each meeting can be found in Appendix C. There were no public comments.

LOCAL STAKEHOLDER INVOLVEMENT

The local Hazard Mitigation Planning Team was encouraged to reach out to local stakeholders that might have an interest in the Hazard Mitigation Plan including neighboring communities, agencies, businesses, nonprofits, and other interested parties. Notice was sent to the following

organizations and neighboring municipalities inviting them to review the Hazard Mitigation Plan and submit comments to the Town:

Town of Pembroke	Selectmen, Planning, DPW and Fire
Town of Kingston:	Selectmen, Planning, DPW, Harbormaster and Fire
Town of Plymouth:	Selectmen, Planning, DPW, Harbormaster and Fire
Town of Marshfield:	Selectmen, Planning, DPW, Harbormaster and Fire
Duxbury Beach Reservation, Inc.	Duxbury Council on Aging
Wildlands Trust of Southeastern MA	Duxbury Planning Board
Old Colony Planning Council	Duxbury Bay Management Commission
South Shore Chamber of Commerce	Sweetser's Bldg., Rob Fawcett
Plymouth Housing Authority	Duxbury Business Association
Duxbury Rural and Historical Society	Duxbury CPC
Duxbury Bay Maritime School	Duxbury Seawall Committee
Long-Point Marina	Duxbury Yacht Club
Bayside Marina Corporation	GATRA
Island Creek Oysters	Jones River Watershed Association
Duxbury Conservation Commission	North and South River Watershed Assoc.
US Coast Guard	MassBays

Duxbury Local Hazard Mitigation Review Team: Town Manager, DPW, Fire, Police & Harbormaster, Facilities, Health, Building and Assessing Depts.

See Appendix C for public meeting notices. The draft Hazard Mitigation Plan 2018 was posted on the Town's website for the second public meeting in November of 2018. Members of the public could access the draft document and submit comments or questions to the Town. There were no public comments.

CONTINUING PUBLIC PARTICIPATION

Following the adoption of the plan update, the planning team will continue to provide residents, businesses, and other stakeholders the opportunity to learn about the hazard mitigation planning process and to contribute information that will update the town's understanding of local hazards. As the annual update and review of the plan are conducted by the Hazard Mitigation Implementation Team, these will be placed on the Town's web site, and any meetings of the Hazard Mitigation Implementation Team will be publicly noticed in accordance with town and state open meeting laws.

PLANNING TIMELINE

Pre-disaster planning for this plan originally began in 2008, through a prior Town Manager and two prior Town Planning Directors. Public participation, circulation of the draft to neighboring communities in 2008, and three Local Committee Meetings on December 23, 2009, May 21, 2009 and December 9, 2009, and a publicly advertised Selectmen's meeting on September 13, 2010 took place prior to submittal of the older draft plan to MEMA in December of 2010. A

series of reviews and a change in FEMA's planning requirements took place, and notice was provided back to the Town of Duxbury that the plan needed additional information to comply with new regulatory guidance, during an interim Planning Director's tenure, in 2014. In 2016 the Town initiated a complete redrafting of the plan coordinated by the current Planning Director with MAPC's assistance. The timeline for this planning effort is summarized below.

September 20, 2016	First meeting of the Duxbury Hazard Mitigation Team
March 22, 2017	First Public Meeting with Duxbury Planning Board
March 27, 2018	Second meeting of the Duxbury Hazard Mitigation Team
November 8, 2018	Third meeting of the Duxbury Hazard Mitigation Team
November 14, 2018	Meeting with the Duxbury Planning Board
November 19, 2018	Second Public Meeting before the Board of Selectmen
November 20, 2018	Draft Plan submitted to MEMA
December 4, 2018	Draft Plan submitted to FEMA
December 17, 2018	Plan submitted to Selectmen for adoption subject to final edits by FEMA
December 21, 2018	After minor edits are made, notice of approval subject to adoption is received from FEMA
December 24, 2018	Adopted plan forwarded to MEMA and FEMA

III. RISK ASSESSMENT

The risk assessment analyzes the potential natural hazards that could occur within the Town of Duxbury as well as the relationship between those hazards and current land uses, potential future development, and critical infrastructure. This section also includes a vulnerability assessment that estimates the potential damages that could result from certain large scale natural hazard events.

In order to determine Duxbury's risk assessment, MAPC gathered the most recently available hazard and land use data and met with Town staff to identify local hazard areas and development trends. MAPC also used FEMA's damage estimation software, HAZUS, which is described in more detail in this section.

OVERVIEW OF HAZARDS AND IMPACTS

The Massachusetts Hazard Mitigation Plan provides an in-depth overview of natural hazards in Massachusetts. Previous state and federal disaster declarations since 1991 are summarized in Figure 2. Figure 5 summarizes the hazard risks for Duxbury. This evaluation takes into account the frequency of the hazard, historical records, and variations in land use. This analysis is based on the vulnerability assessment in the Massachusetts State Hazard Mitigation Plan. The statewide assessment was modified to reflect local conditions in Duxbury using the definitions for hazard frequency and severity listed below. Based on this, the Town developed locally-specific rankings for the frequency and severity of each category of natural hazard in Duxbury.

It should be noted that two of the hazards listed in the 2013 Massachusetts State Hazard Mitigation plan are not applicable to the Town of Duxbury. Due to its size and the development patterns in Duxbury, Major Urban Fires are not applicable. Ice Jams are also not applicable in Duxbury, as coastal Massachusetts experiences somewhat warmer winters and tidal waters are less subject to freezing. The Army Corps Ice Jam Database shows no record of ice jams occurring in Duxbury.

Figure 5: Hazard Risks Summary

Hazard	Frequency		Severity	
	Massachusetts	**Duxbury**	**Massachusetts**	**Duxbury**
Flooding	High	High	Serious	Serious
Dam Failures	Very Low	Very Low	Extensive	Extensive
Coastal Hazards	High	High	Serious	Serious
Tsunami	Very Low	Very Low	Extensive	Extensive
Hurricane/Tropical Storm	Medium	Medium	Serious	Serious
Tornadoes	Medium	Low	Serious	Serious
Thunderstorms	High	High	Minor	Minor
Nor'easter	High	High	Minor	Serious
Winter-Blizzard/Snow	High	High	Minor	Minor
Winter-Ice Storms	Medium	Medium	Minor	Minor

Hazard	Frequency		Severity	
Ice Jams	Low	N/A	Serious	N/A
Earthquakes	Very Low	Very Low	Serious	Serious
Landslides	Low	Low	Minor	Minor
Brush Fires	Medium	Medium	Minor	Minor
Major Urban Fires	Low	N/A	Minor	N/A
Extreme Temperatures	Medium	Medium	Minor	Minor
Drought	Low	Low	Minor	Minor

Source: Massachusetts State Hazard Mitigation Plan, 2013, Modified for Duxbury

Flood-Related Hazards

Flooding was the most prevalent natural hazard identified by local officials in Duxbury. Flooding in town is generally caused by hurricanes, nor'easters, severe rainstorms, and thunderstorms. Global climate change will likely exacerbate these issues and lead to more coastal flooding over time due to the potential for changing rainfall patterns, heavier storms, and higher sea levels.

Regionally Significant Floods

There have been a number of major floods that have affected the Metro Boston region over the last fifty years. Significant historic flood events in Duxbury have included:

- Blizzard of 1978
- January 1979
- April 1987
- October 1991 ("The Perfect Storm")
- December 1992
- October 1996
- June 1998
- March 2001
- April 2004
- May 2006
- April 2007
- April 2004
- March 2010
- December 2010
- March 2013
- January 2018
- March 2018

Town-specific data for previous flooding occurrences are not collected by the Town of Duxbury. The best available local data is from NOAA's National Centers for Environmental Information. Plymouth County, which includes the Town of Duxbury, experienced 47 flood events from 1996 to 2017 (see Figure 6). No deaths or injuries were reported and the total reported property damage in the county was $25.8 million dollars. Data from NOAA for 2018 is not yet available.

On January 4, 2018 Duxbury experienced significant flooding due to a nor'easter. The storm coincided with astronomical high tides and resulted in a surge, recorded at the Boston tide station, of 15.16 feet—higher than the highest surge from the Blizzard of 1978. In March 2018, the Greater Boston Region, and in particular the South Shore, suffered from three major nor'easters that flooded homes and business, crippled infrastructure, and left hundreds of thousands without power. The storm surge from a March 3 nor'easter was so strong that on March 5, part of Duxbury's seawall collapsed into the ocean.

Figure 6: Plymouth County Flood Events, 1996-2017

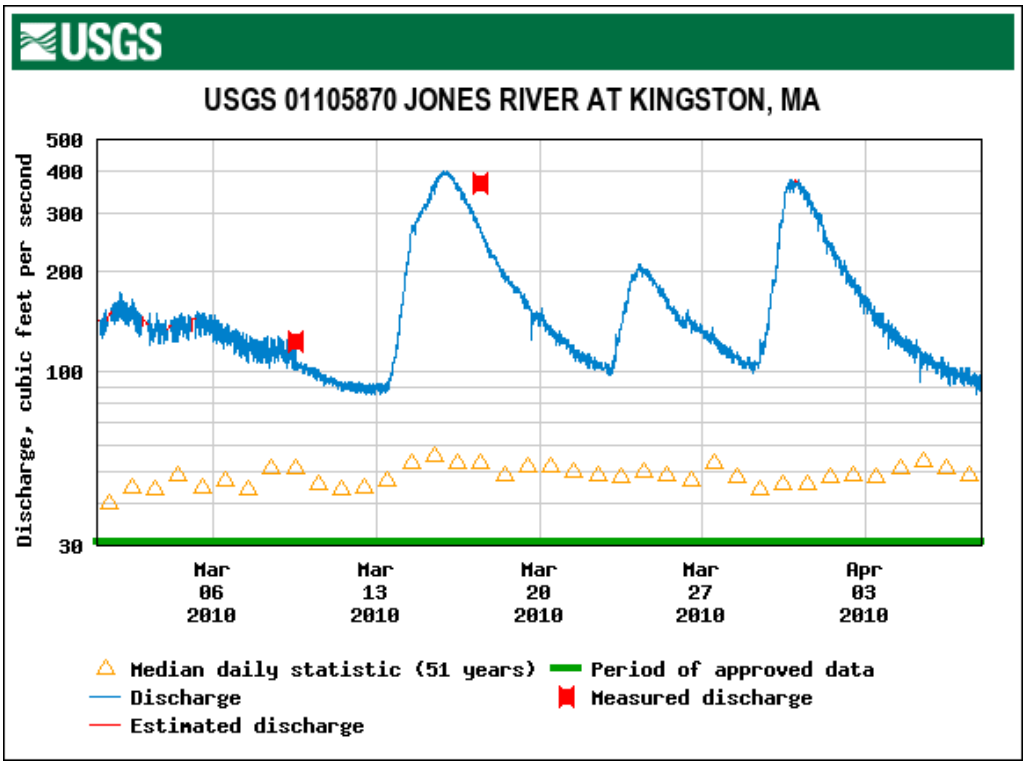
Location	Date	Deaths	Injuries	Property Damage
PLYMOUTH COUNTY	9/18/1996	0	0	0
PLYMOUTH COUNTY	3/5/2001	0	0	0
EASTERN PLYMOUTH	3/28/2005	0	0	0
EASTERN PLYMOUTH/PART OF NORFOLK	10/15/2005	0	0	350,000
WESTERN PLYMOUTH	10/15/2005	0	0	200,000
EASTERN PLYMOUTH/PART OF NORFOLK	10/15/2005	0	0	50,000
WESTERN PLYMOUTH	10/15/2005	0	0	100,000
WESTERN PLYMOUTH	10/15/2005	0	0	140,000
EASTERN PLYMOUTH/PART OF NORFOLK	10/25/2005	0	0	35,000
EASTERN PLYMOUTH/PART OF NORFOLK	12/9/2005	0	0	40,000
SOUTHERN PLYMOUTH	5/13/2006	0	0	500,000
PLYMOUTH COUNTY	5/13/2006	0	0	0
PLYMOUTH COUNTY	6/7/2006	0	0	30,000
PLYMOUTH COUNTY	6/23/2006	0	0	2,000
PLYMOUTH COUNTY	8/20/2006	0	0	5,000
PLYMOUTH COUNTY	10/28/2006	0	0	10,000
PLYMOUTH COUNTY	3/2/2007	0	0	10,000
PLYMOUTH COUNTY	3/17/2007	0	0	8,000
PLYMOUTH COUNTY	4/15/2007	0	0	25,000
PLYMOUTH COUNTY	2/13/2008	0	0	0
PLYMOUTH COUNTY	3/8/2008	0	0	5,000
PLYMOUTH COUNTY	3/8/2008	0	0	0
PLYMOUTH COUNTY	9/27/2008	0	0	50,000
PLYMOUTH COUNTY	5/24/2009	0	0	0
PLYMOUTH COUNTY	8/29/2009	0	0	0
PLYMOUTH COUNTY	3/14/2010	0	0	16,150,000
PLYMOUTH COUNTY	3/29/2010	0	0	8,070,000
PLYMOUTH COUNTY	4/1/2010	0	0	0
PLYMOUTH COUNTY	7/13/2011	0	0	5,000
PLYMOUTH COUNTY	8/10/2012	0	0	30,000
PLYMOUTH COUNTY	5/11/2013	0	0	0

Location	Date	Deaths	Injuries	Property Damage
PLYMOUTH COUNTY	5/11/2013	0	0	0
PLYMOUTH COUNTY	6/7/2013	0	0	0
PLYMOUTH COUNTY	9/3/2013	0	0	0
PLYMOUTH COUNTY	3/30/2014	0	0	0
PLYMOUTH COUNTY	10/22/2014	0	0	0
PLYMOUTH COUNTY	11/17/2014	0	0	0
PLYMOUTH COUNTY	05/31/2015	0	0	0
PLYMOUTH COUNTY	07/28/2015	0	0	15,000
PLYMOUTH COUNTY	09/10/2015	0	0	0
PLYMOUTH COUNTY	10/29/2015	0	0	0
PLYMOUTH COUNTY	05/30/2016	0	0	0
PLYMOUTH COUNTY	04/01/2017	0	0	5,000
PLYMOUTH COUNTY	04/06/2017	0	0	5,000
PLYMOUTH COUNTY	6/24/2017	0	0	1,000
PLYMOUTH COUNTY	10/25/2017	0	0	0
PLYMOUTH COUNTY	10/29/2017	0	0	0
TOTAL		**0**	**0**	**25,841,000**

Source: NOAA, National Centers for Environmental Information

The most severe recent flooding occurred during March 2010 when a total of 14.83 inches of rainfall accumulation was recorded by the National Weather Service (NWS). The weather pattern that consisted of early springtime prevailing westerly winds that moved three successive storms, combined with tropical moisture from the Gulf of Mexico, across New England. Torrential rainfall caused March 2010 to be the wettest month on record.

Figure 6 USGS Flood Gage Discharge Data for the Jones River at Kingston, MA, March 2010



Source: United States Geological Survey 2018

One indication of the extent of flooding is the measured stream discharge at the nearest USGS streamflow gauging station, which is on the Jones River in neighboring Kingston, MA. Figure 2 illustrates that March2010 had two streamflow peaks at 400 cubic feet per second (cfs) in mid-March and 390 cfs in late March. By comparison, the median discharge for March is about 50 cfs. Of the total $25.4 million in flood damages recorded for Plymouth County from1996 to 2017, $24.2 million occurred during the March 2010 flooding (see Figure 5)

Potential damages from flooding in the Town of Duxbury were estimated using FEMA's HAZUS-MH program. The results, shown in Table 20, indicate potential building damages from a 1% Annual Chance Flood (100-year) at $20,66o,000 and from a 0.2% Annual Chance Flood (500-year) at $22,860,000.

Overview of Town-Wide Flooding

The Town of Duxbury is subject to two kinds of flooding: coastal flooding, where wind and tide leads to flooding along the shore and tidal waterways; and inland flooding, where the rate of precipitation or amount of water overwhelms the capacity of natural and structured drainage systems to convey water, causing it to overflow the system. These two types of flooding are often combined as inland flooding is prevented from draining by the push of wind and tide driven water. Both types of flooding can be caused by major storms, known as northeasters (also known as nor'easters) and hurricanes. Nor'easters can occur at any time of the year but they are most common in winter.

The frequency and locations of flood hazard events in Duxbury can be estimated based on the reported loss occurrences for repetitive loss properties and from local knowledge captured through discussion with local staff and the public during identification of local flood hazard areas. Based on these factors, flooding occurs most often along the ocean shoreline, where even a relatively small storm can lead to very high tides and overwash seawalls and dunes, and in a number of low-lying neighborhoods throughout the town. Reported losses on repetitive loss properties indicate that a flood event resulting in property damage occurs on average a little more frequently than once a year, though there have been stretches of up to a couple years over the last 30 years where flooding of this extent did not occur. In particular, winter storms in 1978, 1979, 1987, 1991, 1992, 2005, 2007, 2010, 2013, 2015, and 2018 all led to extensive flood insurance claims in Duxbury's low lying, flood prone areas.

Importantly, coastal flooding and storm surge also causes significant damage to Duxbury Beach, the barrier beach which provides shoreline protection to the Towns of Duxbury, Kingston, and Plymouth. Coastal storms cause overwash on the beach and dunes. Consistent and persistent overwash with coastal storms could cause a permanent breach of the barrier beach and increase high energy wave action into Duxbury Bay if not fully restored each year with beach nourishment and sacrificial dunes.[2]

Inland/Riverine Flooding

[2] Personal Communication, Duxbury Beach Reservation, Inc. October 31, 2018

While coastal flooding is the main concern for Duxbury, the town is impacted by several bodies of water that can flood during storms. These include Keene Brook, the South River Reservoir, and the Chase Reservoir. Flooding is relatively limited in this area and active land conservation and wetland protection measures in this area have limited the exposure of homes and businesses to this type of flooding.

Another type of inland flooding that is an issue for the Duxbury is flooding driven by inadequate stormwater drainage. Particularly an issue in those parts of the town with greater levels of imperviousness, this flooding occurs in areas where the storm drain pipes are inadequately sized compared to the level of stormwater runoff. Exceptionally high tides can also effectively block these storm drain systems, given Duxbury's generally low-lying geography. Combined with the watershed from neighboring towns, the Duxbury area can accumulate a great deal of water in a short amount of time during heavy rains, severe storms, and in the spring season.

Coastal Flooding

Coastal flooding is associated with severe coastal storms that, through the combination of winds and tides, drive tidal waters to higher levels than normally experienced. This can lead to the inundation of low-lying land areas and the overtopping of seawalls. Duxbury has extensive exposure to coastal flooding and flooding along large stretches of its coastline can be a relatively frequent occurrence. All of the repetitive loss sites in Duxbury are located near the Atlantic Ocean, with the greatest concentration along Gurnet Road. This area is particularly vulnerable because coastal flooding occurs in two directions, flooding from the beach side of the road through and over the sea walls, and from inundation from the Great Marsh and Duxbury Bay. Frequent pumping of a low area constructed by the local residents to capture stormwater and floodwater is required in the Gurnet Road portion of Duxbury close to the Marshfield town line, and gaps in the Marshfield sea wall during storm events further contribute to localized flooding along Plymouth Avenue. Other areas repeatedly prone to coastal flooding include the Snug Harbor business district, Mattakeesett public boat landing, King Caesar Road, the low-lying Bay Road, The Gurnet/High Pines on Duxbury Beach. Since 2002, Duxbury and Plymouth County has experienced at least seven Storm Surge/Tide Events causing $405,000 in property damage (Figure 6) however, Duxbury Beach alone sustained over $800,000 in necessary repairs to repair the beach dunes and access road to the residences on the Plymouth side of the barrier beach.

Figure 7 Recent Storm Surge/Tide Events in Plymouth County

Location	Date	Deaths	Injuries	Property Damage
EASTERN PLYMOUTH COUNTY	11/06/2002	0	0	10,000
EASTERN PLYMOUTH COUNTY	01/04/2003	0	0	100,000
EASTERN PLYMOUTH COUNTY	12/06/2003	0	0	10,000
EASTERN PLYMOUTH COUNTY	01/23/2005	0	0	200,000
EASTERN PLYMOUTH COUNTY	05/07/2005	0	0	10,000
EASTERN PLYMOUTH COUNTY	05/24/2005	0	0	10,000
EASTERN PLYMOUTH COUNTY	02/12/2006	0	0	40,000
EASTERN PLYMOUTH COUNTY	08/28/2011	0	0	25,000
TOTAL		0	0	$405,000

Source: NOAA, National Centers for Environmental Information

Seawall Failure and Coastal Erosion

Coastal shorelines are continuously shifting in response to waves, winds, tides, seasonal and climatic variation, engineered or hardened coastal infrastructure, and coastal storms. This dynamic process creates a system of erosion (loss) and/or accretion (gain) of coastal land at a continuous rate over time.[3] Seawall failure and coastal erosion are related issues increasingly impacting towns along the Massachusetts coast. Rising sea levels have led to increased rates of erosion along beaches and coastlines and have undermined seawalls, some of which in the Boston region are many decades old. Seawalls protect the buildings behind them from storm damage and their failure can lead to increased property damage. In some cases however, sea walls disrupt or alter natural shorelines accretion processes and can accelerate shoreline erosion of adjacent beaches. Similarly, intact beaches with dunes dissipate wave energy, protecting buildings behind them. As beaches erode away, this protection is lost. This is the case at Duxbury Beach where coastal storms both nearby and far over that last several years have caused overwash and breach of the barrier beach. Without yearly restoration of the dune height and beach nourishment, a permanent breach is imminent, which could cause significant damage to shoreline infrastructure, both businesses and residents, in Duxbury Bay. The Duxbury Beach Reservation, Inc. has continued to restore and maintain dune height, road repairs, and nourishment to ensure coastal shoreline protection, wildlife habitat, and regional recreational/economic asset. Repairs from coastal storm damage from 2018 alone were over $850,000. A current beach nourishment project underway is over $1.7 million. The project is being supported with a $500,000 Massachusetts Office of Coastal Zone Management grant.

The MA Office of Coastal Zone Management, in partnership with other agencies, measured Massachusetts coastal shifts from the 1800s to 2009. This was performed by delineating and statistically analyzing coastal shorelines through 50 m transects the high water line or landward limit of wave run-up at local high tide along the shore. These high water lines were interpreted from historic maps and satellite data.[4] Duxbury has experienced coastal erosion since the 1800s. Most specifically, the northern portion of Duxbury Beach is indicating coastal landward migration, typically of barrier island process, at the northern portion of the barrier beach. Also, the High Pines area of Duxbury Beach has notable coastal erosion since the mid-1800s. Other areas with notable coastal erosion since the mid-1800s include Long Point, Eagle's Nest, and the shoreline along Bay Road. Coastal Erosion is located in Map 10 of Appendix B.

In April 2010, 500 feet of seawall in neighboring Marshfield collapsed due to erosion undermining its foundation. On March 3, 2018 during Winter Storm Riley, Duxbury experienced sea wall collapse at Gurnet leaving many houses susceptible to extreme coastal flooding and inundation. The Town performed emergency measures by guarding the area with boulders as an interim measure until the seawall can be restored or replaced. FEMA has indicated in their latest rules that reconstruction or repair funding for coastal protection structures like seawalls will only be made available where the damage can be directly attributed to a storm event. Therefore, in order to receive this funding, the Town must continue to maintain records of maintenance and

[3] MA Office of Coastal Zone Management. https://www.mass.gov/service-details/massachusetts-shoreline-change-project
[4] MA Office of Coastal Zone Management: https://www.mass.gov/service-details/massachusetts-shoreline-change-project

repair activities that demonstrate the status of each structure. A drone flight was performed in October of 2018 to document conditions heading into the 2018-19 winter season, and an engineer has been engaged by the Town to document and recommend improvements throughout the 2018 storms into the present as repairs are being planned.

In addition to the sea wall failure, the Gurnet Road at the far southern end and 0.4 miles to the Plymouth town line was breached during Winter Storm Riley. Any access to the residences beyond this point was impeded for more than a month while emergency repairs were made. There is no other access to the Gurnet/Saquish portion of Plymouth.

Dams and Dam Failure

There are 24 Town- and privately-owned dams throughout Duxbury. Dam failure can arise from two types of situations. Dams can fail because of structural problems independent of any storm event. They can also fail following a natural disaster that causes structural damage, such as an earthquake. Dams can fail structurally because of flooding arising from a storm or they can overspill due to flooding.

In the event of a dam failure, the energy of the water stored behind even a small dam can cause loss of life and property damage if there are people or buildings downstream. The number of fatalities from a dam failure depends on the amount of warning provided to the population and the number of people in the area in the path of the dam's floodwaters. An issue for dams in Massachusetts is that many were built in the 19th century without the benefits of modern engineering or construction oversight or consideration of changing weather patterns associated with climate change such as more frequent and/or extreme precipitation events or storms.

The Massachusetts Department of Conservation and Recreation (DCR) Office of Damn Safety (ODS) has three hazard classifications for dams:

High Hazard:	Dams located where failure or mis-operation 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 Hazard:	Dams located where failure or mis-operation may cause loss of life and damage home(s), industrial or commercial facilities, secondary highway(s) or railroad(s) or cause interruption of use or service of relatively important facilities.
Low Hazard:	Dams located where failure or mis-operation may cause minimal property damage to others. Loss of life is not expected.

About 15 smaller dams in Duxbury are not regulated by the ODS or under their jurisdiction. Dams not regulated by ODS are typically those under six feet in height and/or under 15 acre-feet in storage. Of the dams regulated by ODS, only three private dams are classified as "Low Hazard" while the other six dams are classified as "Significant Hazard." Four of those dams are Town-owned and include the Garside Reservoir, Petersons Saw Mill Pond, Mill Pond, and Temple Street Pond Dams. In general, ODS requires that dams rated as low hazards be inspected every ten years, while dams rated as significant hazards must be inspected every five years. Two of Duxbury's dams are susceptible to damage from a Category 1 Hurricane and are susceptible to

flooding with Sea Level Rise in 2038. These include the Blue Fish River Dam and the Wrights Pond Dike (Table 2).

None of the dams in Duxbury were listed in the State Auditor's report that identified dams in unsafe or poor condition.

There have been no dam failures documented in the Town of Duxbury. Based on the record of previous occurrences, dam failure in Duxbury is a very low frequency event as defined by the Massachusetts State Hazard Mitigation Plan, 2013. This hazard may occur less frequently than once in 100 years (less than 1% chance of occurring per year).

Table 2 Duxbury Dams and vulnerability to failure from storms and flooding

Dam	Owner	Hazard Severity with Failure	Current FEMA Flood Risk	Hurricane Surge Storm Zone	2038 SLR Depth (ft.)
Bluefish River Dam	Private	N/A	1%	Cat 1	>6-8
Lower Chandler Pond Dam	Duxbury	Significant	1%	____	____
Garside Reservoir	Duxbury	Significant	1%	____	____
Peterson's Saw Mill Pond Dam	Duxbury	Significant	1%	____	____
Boys & Girls Camp #3 Dam	Private	Significant	1%	____	____
Round Pond Dam	Private	Low	1%	____	____
Pine Lake Dam	Private	Low	1%	____	____
Mill Pond Dam	Duxbury	Significant	1%	____	____
Boys & Girls Camp #1 Dam	Private	Significant	1%	____	____
Temple Street Pond Dam	Duxbury	Significant	1%	____	____
Merry Memorial Dam	Private	N/A	1%	____	____
Wright Reservoir Dam	Private	Low	1%	____	____
Boys & Girls Club #2 Dam	Private	N/A	1%	____	____
Golden Reservoir Dam	Duxbury	N/A	___	____	____
Merry Reservoir Dam	Private	N/A	1%	____	____
Pit Pond Dam	Private	N/A	___	____	____
Mcissac & Williams #1 Dam	Private	N/A	1%	____	____
Mcissac & Williams #3 Dam	Private	N/A	1%	____	____
Pink #2 Dam	Private	N/A	1%	____	____
Mcissac & Williams Dam	Private	N/A	1%	____	____
Reed #2 Dam	Duxbury	N/A	1%	____	____
Keith & Adams Reservoir Dam	Private	N/A	____	____	____

Crowell Reservoir Dam	Private	N/A	____	____	____
Dam	**Owner**	**Hazard Severity with Failure**	**Current FEMA Flood Risk**	**Hurricane Surge Storm Zone**	**2038 SLR Depth (ft.)**
Wrights Pond Dike	Duxbury	N/A	1%	Cat 1	0-2
Mayflower St. Pond Dam	Duxbury	N/A		____	____
Upper Chandler Pond Dam	Private	Low	1%	____	____

Potential Flood Hazard Areas

Information on potential flood hazard areas was taken from several sources. The first was the National Flood Insurance Rate Maps (FIRM). The FIRM flood zones are shown on Map 3 in Appendix B and their definitions are listed below. In addition, information on areas subject to flooding was provided by local officials.

Flood Insurance Rate Map Zone Definitions

Zone A (1% annual chance): Zone A is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the Flood Insurance Study (FIS) by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no BFEs (base flood elevations) or depths are shown within this zone. Mandatory flood insurance purchase requirements apply.

Zone AE and A1-A30 (1% annual chance): Zones AE and A1-A30 are the flood insurance rate zones that correspond to the 100-year floodplains that are determined in the FIS by detailed methods. In most instances, BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply.

Zone X500 (0.2% annual chance): Zone X500 is the flood insurance rate zone that corresponds to the 500-year floodplains that are determined in the Flood Insurance Study (FIS) by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no BFEs (base flood elevations) or depths are shown within this zone.

Zone VE (1% annual chance): Zone VE is the flood insurance rate zone that corresponds to the 100-year coastal floodplains that have additional hazards associated with storm waves. BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply.

The 18 "Locally Identified Areas of Flooding" described in Figure 8: Locally Identified Areas of Flooding were identified by town staff as areas where flooding is known to occur. All of these areas do not necessarily coincide with the flood zones from the FIRM maps. Some may be areas that flood due to inadequate drainage systems or other local conditions rather than location within a flood zone. The numbers correspond to the numbers on Map 8, "Local Hazard Areas."

Figure 8: Locally Identified Areas of Flooding

Map ID	Name	Description
1	Gurnet Road	Also known as Cable Hill, this area experiences flooding along the coast that is primarily impacted by nor'easter storms. The area experiences heavy wave overwash from the sea during storms, along with back water and still water flooding. Damages have included loss of homes and residents were evacuated at times. There is a 400-foot long sea wall running along the coast here, but portions of the wall are missing or in disrepair in at least two sections. Officials estimate that there is flooding here two or three times per year and a need to condemn homes at least once every ten years. (Please see narrative on coastal flooding.)
2	Duxbury Beach	The Duxbury Beach Reservation, Inc., the nonprofit that owns and manages the beach, is currently trying to raise $5 million to elevate the height of the sacrificial dune. Flooding and impact from wave damage are concerns along Duxbury Beach, a barrier beach making up the most eastern side of town across from Duxbury Harbor. The beach is the only means of travel to the Gurnet and Saquish Point, approximately 250 home sites in Plymouth near Duxbury's southeastern town line. In addition to being the sole access route for Saquish Point residents, the beach also acts as a flood barrier for Plymouth, Kingston, and Duxbury Bays, attenuating high waves as they move toward Duxbury to the west. The beach is maintained on a regular basis. In 1991/1992, FEMA/MEMA funded two sacrificial dune projects to maintain a minimum of sixteen feet NGVD along the entire length of the beach and provide flood hazard protection for a large number of properties.
3	Washington and St. George Streets	Still water and high tides cause roadway flooding at this spot, hindering access to homes and through the area by vehicles. There are also two homes in this area that have been flooded in the past.
4	King Caesar Road	Flooding is caused by tidal wave action from the south.
5	Snug Harbor	This commercial district in town is a flooding concern with the roads, homes, and businesses in the area all being subject to damage during extremely high tides and storm events.
6	Patten Lane	This flooding concern is impacted by tidal wave action along the coast that causes erosion to the dunes and damage through the channel outlet during nor'easters and other storm events.
7	Marshall Street Bridge	This flooding area is of particular note because flooding of the bridge jeopardizes critical access to the Standish Shore neighborhood (approximately 120 homes). As with most areas of town, this area is impacted by extreme storm events.
8	Bay Road Neighborhoods	This flooding concern comprises several smaller neighborhoods that exist along Bay Road, Landing Road area in particular is open to the ocean and FIRMs predict severe damage from large storm events that hit this area.

Map ID	Name	Description
9	Congress Street	Riverine water overtopping the roadway causes flooding in this area. The culvert structure beneath the roadway is an insufficient size to handle the flow from the unnamed brook below it during heavy rainstorms.
10	Lake Shore Drive	This flood hazard area is at the outlet end of the Lower Chandler Mill Pond on the town's line with Pembroke.
11	Keene Mill and Keene Brook	Overtopping of the roadway during heavy rainfalls causes flooding in this area.
12	North Hill Dam	Owned by Stan Merry, the dam can be a flood hazard if the dam fails. The dam has largely been maintained and has had some reconstruction work done. It is believed to be in good shape now.
13	Chase Reservoir	Flooding here is due to complications from the dam at the reservoir. The dam has partially failed in the past and been repaired. It is believed to be in fair condition at present.
14	South River Reservoir	This is a Town-owned dam, which has failed previously and also caused overtopping of Route 14. The dam was repaired and is reported to be in good condition now. Overtopping of this dam also causes flooding on Plantation Drive (15). The dam, though currently considered to be sound, may not be capable of handling the volume. There is a control weir installed on the dam to alleviate those concerns and to aid in overtopping.
15	Plantation Drive	Flooding occurs when the South River overtops the dam. The structure cannot handle the volume of the dam, which does have a control weir installed.
16	Blue Fish River	Flooding is the result of the inundation of saltwater, which backs upstream almost to Route 3A during high tides/high rain events.
29	Wirt Way	In March 2018, during Winter Storm Riley, storm inundation crossed Bay Road adjacent to Wirt Way flooding neighborhoods on the landward side of Bay Road.
30	Island Creek outlet	In March 2018, during Winter Storm Riley, storm inundation flooded Island Creek at Bay Road outlet, causing new areas of flooding in the neighborhood upstream of the Island Creek outlet.

Repetitive Loss Structures

As defined by the National Flood Insurance Program (NFIP), a repetitive loss property is any property for which the NFIP has paid two or more flood claims of $1,000 or more in any given 10-year period since 1978. There are 52 repetitive loss properties in Duxbury: almost all are residential properties impacted by coastal flooding. These repetitive loss properties had a total of 179 losses between 1978 and the end of 2017, totaling $3,328,924 in damages. Figure 9 summarizes the number and type of repetitive loss structures located within Duxbury and the number of losses and total claims associated with them.

Figure 9: Summary of Repetitive Losses and Claims

	Single Family Residential	Other
Number of Properties	50	2
Number of Losses	175	4
Total Claims	$3,309,919	$19,006

Source: Department of Conservation and Recreation, FEMA Repetitive Loss data

Based on the record of previous occurrences, flooding and coastal hazard events in Duxbury are high frequency events as defined by the 2013 Massachusetts State Hazard Mitigation Plan. These hazards may occur more frequently than once in five years, or a greater than 20% chance per year.

Wind-Related Hazards

Wind-related hazards include hurricanes, tropical storms, and tornadoes, as well as high winds during nor'easters and thunderstorms. As with many communities, falling trees that result in downed power lines and power outages are an issue in Duxbury. Information on wind-related hazards can be found on Map 5 in Appendix B.

Hurricanes and Tropical Storms

A hurricane is a violent wind and rainstorm with wind speeds of 74-200 miles per hour. A hurricane is strongest as it travels over the ocean and is particularly destructive to coastal property as the storm hits the land. The Town of Duxbury's entire area is vulnerable to hurricanes, which occur between June and November. A tropical storm has similar characteristics, but wind speeds are below 74 miles per hour.

Since 1900, 39 tropical storms have impacted New England (NESEC). Massachusetts has experienced approximately 32 tropical storms, nine Category 1 hurricanes, five Category 2 hurricanes, and one Category 3 hurricane. A hurricane or storm track is the line that delineates the path of the eye of a hurricane or tropical storm.

As shown in Map 5 in Appendix A, a tropical storm tracked through Duxbury in 1896 over the Town Hall and the neighboring cluster of now historic landmarks. Another tropical storm tracked over western Duxbury in 2004. Duxbury also experiences the impacts of hurricanes and tropical storms regardless of whether the storm track passes directly through the town, and numerous hurricanes have affected the eastern Massachusetts communities (

Table **3**) The hazard mapping indicates that the 100-year wind speed in Duxbury is 120 miles per hour (see Appendix B).

Table 3: Hurricane Records for Massachusetts, 1938-2017

Hurricane Event	Date
Great New England Hurricane*	September 21, 1938

Hurricane Event	Date
Great Atlantic Hurricane*	September 14-15, 1944
Hurricane Doug	September 11-12, 1950
Hurricane Carol*	August 31, 1954
Hurricane Edna*	September 11, 1954
Hurricane Diane	August 17-19, 1955
Hurricane Donna	September 12, 1960
Hurricane Gloria	September 27, 1985
Hurricane Bob	August 19, 1991
Hurricane Earl	September 4, 2010
Tropical Storm Irene	August 28, 2011
Hurricane Sandy	October 29-30, 2012

*Category 3, Source: National Oceanic and Atmospheric Administration

Hurricane intensity is measured according to the Saffir/Simpson scale, which categorizes hurricane intensity linearly based upon maximum sustained winds, barometric pressure, and storm surge potential. These are combined to estimate potential damage. The following gives an overview of the wind speeds, surges, and range of damage caused by different hurricane categories:

Figure 10: Saffir/Simpson Scale

Scale No. (Category)	Winds (mph)	Surge (feet)	Potential Damage
1	74 - 95	4 - 5	Minimal
2	96 - 110	6 - 8	Moderate
3	111 - 130	9 - 12	Extensive
4	131 - 155	13 - 18	Extreme
5	> 155	>18	Catastrophic

Source: NOAA

Hurricanes typically have regional impacts beyond their immediate tracks. Falling trees and branches are a significant problem because they can result in power outages when they fall on power lines or block traffic and emergency routes. Hurricanes are a town-wide hazard in Duxbury. Potential hurricane damages to Duxbury have been estimated using HAZUS-MH. Total damages are estimated at $38 million for a Category 2 hurricane and $163 million for a Category 4 hurricane. Other potential impacts, including displaced households, sheltering needs, and debris generation, are detailed in Table 18.

Based on records of previous occurrences, hurricanes in Duxbury are a medium frequency event as defined by the 2013 Massachusetts State Hazard Mitigation Plan. This hazard occurs from once in 5 years to once in 50 years, or a 2% to 20% chance per year.

Tornados

A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud. These events are spawned by thunderstorms and occasionally by hurricanes, and may occur singularly or in multiples. They develop when cool air overrides a layer of warm air, causing the warm air to rise rapidly. Most vortices remain suspended in the atmosphere. Should they touch down, they become a force of destruction. Some ingredients for tornado formation include:

- Very strong winds in the mid and upper levels of the atmosphere
- Clockwise turning of the wind with height (from southeast at the surface to west aloft)
- Increasing wind speed with altitude in the lowest 10,000 feet of the atmosphere (i.e. 20 mph at the surface and 50 mph at 7,000 feet)
- Very warm, moist air near the ground with unusually cooler air aloft
- A forcing mechanism such as a cold front or leftover weather boundary from previous shower or thunderstorm activity

Tornado damage severity is measured by the Fujita Tornado Scale, in which wind speed is not measured directly but rather estimated from the amount of damage. As of February 1, 2007, the National Weather Service began rating tornados using the Enhanced Fujita-scale (EF-scale), which allows surveyors to create more precise assessments of tornado severity. The EF-scale is summarized below:

Figure 11: Enhance Fujita Scale

Fujita Scale			Derived		Operational EF Scale	
F Number	**Fastest ¼ mile (mph)**	**3-second gust (mph)**	**EF Number**	**3-second gust (mph)**	**EF Number**	**3-second gust (mph)**
0	40 – 72	45 – 78	0	65 – 85	0	65 – 85
1	73 – 112	79 – 117	1	86 – 109	1	86 – 110
2	113 – 157	118 – 161	2	110 – 137	2	111 – 135
3	158 – 207	162 – 209	3	138 – 167	3	136 – 165
4	208 – 260	210 – 261	4	168 – 199	4	166 – 200
5	261– 318	262 – 317	5	200 – 234	5	Over 200

Source: Massachusetts State Hazard Mitigation Plan, 2013

The frequency of tornados in eastern Massachusetts is low; on average, there are six tornadoes that touchdown somewhere in the Northeast region every year. The strongest tornado in Massachusetts history was the Worcester Tornado in 1953 (NESEC).

The most recent significant tornado events in Massachusetts were in Springfield in June 2011 and in Revere in 2014. The Springfield tornado caused significant damage and resulted in four deaths. The Revere tornado touched down in Chelsea just south of Route 16 and moved north into Revere's business district along Broadway and ended near the intersection of Routes 1 and 60. The path was approximately two miles long and 3/8 mile wide, with wind speeds up to 120 miles per hour. Approximately 65 homes had substantial damages and 13 homes and businesses were

uninhabitable. In August of 2018 an EF1 tornado hit the town center of Webster, destroying at least two buildings and damaging others

Remains from the deadly 1953 Worcester tornado touched down in Duxbury, having blown over 75 miles across Massachusetts. Since 1958 there have been 10 additional tornadoes in surrounding Plymouth County recorded by the Tornado History Project. One of these was a F2 tornado, and four were F1 tornados. The 10 tornadoes resulted in a total of one fatality and two injuries and $119 thousand to $1.15 million in damages, as summarized in Table 4.

Table 4: Tornado Records for Plymouth County

Date	Fujita	Fatalities	Injuries	Width	Length	Damage
9/7/1958	0	1	1	10	0.1	$500-$5000
7/4/1964	1	0	0	10	2.3	$50K-$500K
6/9/1965	0	0	0	10	0.1	<$50
11/18/1967	2	0	0	17	.1	$50-$500
8/9/1968	1	0	0	100	1	$500-$5000
9/16/1986	1	0	0	50	.1	$50K-$500K
7/10/1989	1	0	1	23	.1	$5K-$50K
7/10/1989	0	0	0	23	.1	$5K-$50K
8/20/1997	0	0	0	10	0.1	$5K-$50K
7/24/2012	0	0	0	15	.03	$3K

Source: The Tornado History Project

Buildings constructed prior to current building codes may be more vulnerable to damages caused by tornadoes. Evacuation of impacted areas may be required on short notice. Sheltering and mass feeding efforts may be required along with debris clearance, search and rescue, and emergency fire and medical services. Key routes may be blocked by downed trees and other debris, and widespread power outages are also typically associated with tornadoes.

Although tornadoes are a potential town-wide hazard in Duxbury, tornado impacts are relatively localized compared to severe storms and hurricanes. Damages from any tornado in Duxbury would greatly depend on the track of the tornado. Generally, the more densely developed areas would likely be subject to more damage in the event of a tornado.

Based on the record of previous occurrences since 1950, Tornado events in Duxbury are a low frequency event as defined by the 2013 Massachusetts State Hazard Mitigation Plan. This hazard may occur from once in 50 years to once in 100 years.

Nor'easters

A northeast coastal storm, known as a nor'easter, is typically a large counter-clockwise wind circulation around a low-pressure center. Featuring strong northeasterly winds blowing in from the ocean over coastal areas, nor'easters are relatively common in the winter months in New England occurring one to two times a year. The storm radius of a nor'easter can be as much as 1,000 miles

and these storms feature sustained winds of 10 to 40 mph with gusts of up to 70 mph. These storms are accompanied by heavy rains or snows, depending on temperatures. Previous occurrences of Nor'easters include the following listed in the Massachusetts State Hazard Mitigation Plan 2013:

- February 1978 Blizzard of 1978
- October 1991 Severe Coastal Storm ("Perfect Storm")
- December 1992 Great Nor'easter of 1992
- January 2005 Blizzard/Noreaster
- October 2005 Coastal Storm/Nor'easter
- April 2007 Severe Storms, Inland & Coastal Flooding/Nor'easter
- January 2011 Winter Storm/Nor'easter
- October 2011 Severe Storm/Nor'easter

Many of the historic flood events identified in the previous section were precipitated by nor'easters, including the "Perfect Storm" event in 1991. The recent blizzards in winter 2018, as well as those in December 2010, February 2013, and January 2015, were large nor'easters that caused significant snowfall amounts.

Duxbury is vulnerable to both the wind and precipitation that accompanies nor'easters. High winds can cause damage to structures, fallen trees, and downed power lines, leading to power outages. Intense rainfall can also overwhelm drainage systems, causing localized flooding of rivers and streams as well as urban stormwater ponding and localized flooding. Fallen tree limbs coupled with heavy snow accumulation and intense rainfall can impede local transportation corridors and block access for emergency vehicles.

The entire Town of Duxbury could be at risk from the wind, rain, or snow impacts from a nor'easter, depending on the track and radius of the storm, but inland areas would not be subject to coastal hazards.

Based on the record of previous occurrences, nor'easters in Duxbury are high frequency events as defined by the 2013 Massachusetts State Hazard Mitigation Plan. This hazard may occur more frequently than once in 5 years (greater than 20% per year).

Severe Thunderstorms

While less severe than the other types of storms discussed, thunderstorms can lead to localized damage and represent a hazard risk for communities. A thunderstorm typically features lightning, strong winds, and rain and/or hail. Thunderstorms sometime give rise to tornados. On average, these storms are only around 15 miles in diameter and last for about 30 minutes. A severe thunderstorm can include winds of close to 60 mph and rain sufficient to produce flooding. The town's entire area is potentially subject to severe thunderstorms.

The best available data on previous occurrences of thunderstorms in Duxbury is for Plymouth County through the National Centers for Environmental Information. Between the years 1978 and 2017, records indicate four thunderstorm events in Plymouth County and five specific to Duxbury (Table 5). These storms resulted in a total of $65,000 in property damages. There were no injuries or deaths reported.

Table 5: Plymouth County Thunderstorm Events, 1995-2017

LOCATION	BEGIN_DATE	EVENT_TYPE	MAGNITUDE (KTS)	DEATHS	INJURIES	DAMAGE
Plymouth County	10/30/1979	Thunderstorm	0	0	0	0
Plymouth County	7/20/1981	Thunderstorm	0	0	0	0
Plymouth County	6/27/1983	Thunderstorm	0	0	0	0
Plymouth County	6/12/1991	Thunderstorm	0	0	0	5,000
Duxbury	6/22/1997	Thunderstorm	50	0	0	
Duxbury	07/23/2011	Thunderstorm	50	0	0	30,000
Duxbury	07/18/2012	Thunderstorm	50	0	0	10,000
Duxbury	02/25/2016	Thunderstorm	50	0	0	10,000
Duxbury	07/23/2016	Thunderstorm	50	0	0	10,000
TOTAL				**0**	**0**	**$65,000**

Source: NOAA, National Centers for Environmental Information; Magnitude refers to maximum wind speed (kts)

Severe thunderstorms are a town-wide hazard for Duxbury. The town's vulnerability to severe thunderstorms is similar to that of nor'easters. High winds can cause falling trees and power outages, as well as obstruction of key routes and emergency access. Heavy precipitation may also cause localized flooding, both riverine and urban drainage related. While there are no existing town estimates for damages from thunderstorms in Duxbury, the best available data for Plymouth County (Table 11) shows that from 1995 to 2017 thunderstorms resulted in $65,000 in property damages. There were no reported injuries or deaths.

Based on the record of previous occurrences, severe thunderstorms in Duxbury are high frequency events as defined by the 2013 Massachusetts State Hazard Mitigation Plan. This hazard may occur more frequently than once in 5 years (greater than 20% per year).

Winter Storms

Winter storms, including heavy snow, blizzards, and ice storms, are the most common and most familiar of the region's hazards that affect large geographic areas. The majority of blizzards and ice storms in the region cause more inconvenience than they do serious property damage, injuries, or deaths. However, periodically, a storm will occur which is a true disaster, and necessitates intense large-scale emergency response.

Blizzards and Heavy Snow

A blizzard is a winter snowstorm with sustained or frequent wind gusts to 35 mph or more, accompanied by falling or blowing snow reducing visibility to or below ¼ mile. These conditions must be the predominant condition over a 3-hour period. Extremely cold temperatures are often associated with blizzard conditions, but are not a formal part of the definition. The hazard created by the combination of snow, wind and low visibility significantly increases, however, with temperatures below 20 degrees.

Winter storms are a combination hazard because they often involve wind, ice and heavy snowfall. The National Weather Service defines "heavy snow fall" as an event generating at least 4 inches of snowfall within a 12-hour period. Winter storms are often associated with a nor'easter event, a large counter-clockwise wind circulation around a low-pressure center often resulting in heavy snow, high winds, and rain.

The Northeast Snowfall Impact Scale (NESIS) developed by Paul Kocin of The Weather Channel and Louis Uccellini of the National Weather Service (Kocin and Uccellini, 2004) characterizes and ranks high impact northeast snowstorms. These storms have large areas of 10 inch snowfall accumulations and greater. NESIS has five categories: Extreme, Crippling, Major, Significant, and Notable. NESIS scores are a function of the area affected by the snowstorm, the amount of snow, and the number of people living in the path of the storm. The largest NESIS values result from storms producing heavy snowfall over large areas that include major metropolitan centers. The NESIS categories are summarized below in Table 6.

Table 6: NESIS Categories

Category	NESIS	Value Description
1	1 – 2.499	Notable
2	2.5 – 3.99	Significant
3	4 – 5.99	Major
4	6 – 9.99	Crippling
5	10+	Extreme

Source: Massachusetts State Hazard Mitigation Plan, 2013

The most significant winter storm in recent history was the "Blizzard of 1978," which resulted in over 3 feet of snowfall and multiple day closures of roadways, businesses, and schools. According to NOAA, Duxbury has experienced 17 Blizzards since 1978. These occurred in:

- February 1978
- March 1993
- January 1996
- March 2001
- December 2003
- January 2004
- January 2005
- April 2007
- December 2010
- January 2011
- February 2013
- January 2014
- January 2015
- February 2015
- January 2016
- Feburary 2016

- March 2018

The Town of Duxbury does not keep local records of winter storms. Data for Plymouth County, which includes Duxbury, is the best available data to help understand previous occurrences and impacts of heavy snow events. According to National Climate Data Center (NCDC) records, from Eastern Plymouth County experienced 40 heavy snowfall events 1997 to 2018, resulting in $108 thousand in property damage but no deaths or injuries. See Table 7 for and heavy snow events and impacts in Plymouth County.

Table 7: Heavy Snow Events and Impacts in Eastern Plymouth County, 1997-2016

Date	Deaths	Injuries	Property Damage
1/11/1997	0	0	0
2/16/1997	0	0	0
3/31/1997	0	0	0
4/1/1997	0	0	0
12/24/1998	0	0	0
1/14/1999	0	0	0
2/25/1999	0	0	0
3/15/1999	0	0	0
1/13/2000	0	0	0
2/18/2000	0	0	0
1/20/2001	0	0	0
3/5/2001	0	0	0
3/26/2001	0	0	0
12/5/2002	0	0	0
3/16/2004	0	0	0
2/24/2005	0	0	0
12/13/2007	0	0	0
12/16/2007	0	0	0
1/27/2008	0	0	0
12/19/2008	0	0	3,000
12/31/2008	0	0	0
1/18/2009	0	0	0
1/19/2009	0	0	0
2/3/2009	0	0	0
3/2/2009	0	0	0
12/19/2009	0	0	0

Date	Deaths	Injuries	Property Damage
12/20/2010	0	0	0
1/26/2011	0	0	0
1/21/2012	0	0	0
2/8/2013	0	0	0
3/7/2013	0	0	0
1/2/2014	0	0	0
1/21/2014	0	0	0
2/5/2014	0	0	0
2/15/2014	0	0	5,000
2/2/2015	0	0	0
2/8/2015	0	0	0
3/5/2015	0	0	0
2/5/2016	0	0	100,000
4/4/2016	0	0	0
Total	**0**	**0**	**$108,000**

Source: NOAA, National Centers for Environmental Information

Blizzards are considered high frequency events based on past occurrences, as defined by the Massachusetts State Hazard Mitigation Plan, 2013. This hazard occurs more than once in five years, with a greater than 20 percent chance of occurring each year.

Ice Storms

The ice storm category covers a range of different weather phenomena that collectively involve rain or snow converted to ice in the lower atmosphere leading to potentially hazardous conditions on the ground. Hail size typically refers to the diameter of the hailstones. Warnings and reports may report hail size through comparisons with real-world objects that correspond to certain diameters:

Table 8: Hail Size Comparisons

Description	Diameter (inches)
Pea	0.25
Marble or mothball	0.50
Penny or dime	0.75
Nickel	0.88
Quarter	1.00
Half dollar	1.25
Walnut or ping pong ball	1.50

Description	Diameter (inches)
Golf ball	1.75
Hen's egg	2.00
Tennis ball	2.50
Baseball	2.75
Tea cup	3.00
Grapefruit	4.00
Softball	4.50

While ice pellets and sleet are examples of these, the greatest hazard is created by freezing rain conditions, which is rain that freezes on contact with hard surfaces leading to a layer of ice on roads, walkways, trees, and other surfaces. The conditions created by freezing rain can make driving particularly dangerous and emergency response more difficult. The weight of ice on tree branches can also lead to falling branches damaging electric lines.

Town-specific data for previous ice storm occurrences are not collected by the Town of Duxbury. The best available local data is for Plymouth County through the National Climatic Data. Plymouth County, which includes the Town of Duxbury, has experienced no ice storm events since 1950 and one hail event on June 27, 2000. Ice storms and hail are considered to be low frequency events based on past occurrences, as defined by the Massachusetts State Hazard Mitigation Plan. This hazard occurs once in 50 years to once in 100 years, with a 1-2% chance of occurring each year.

The impacts of winter storms are often related to the weight of snow and ice, which can cause roof collapses and also causes tree limbs to fall which can in turn cause property damage and potential injuries.

Winter storms are a potential town-wide hazard in Duxbury, where the average annual snowfall is 36 - 48 inches (see Map 6 in Appendix B). Duxbury's vulnerability is primarily related to restrictions to travel on roadways, temporary road closures, school closures, and potential restrictions on emergency vehicle access. The Town works to clear roads and carries out general snow removal operations to ensure vehicle access is maximized. Commuter rail operations may also be impacted, as they were in the 2015 blizzard which caused the closure of the MBTA system for one day and limited services on several commuter rail lines for several weeks. Another winter storm vulnerability is power outages due to fallen trees and utility lines.

Geologic Hazards

Geologic hazards include earthquakes and landslides. The Massachusetts Building Code requires new construction comply with seismic standards, there are still many structures that pre-date the most recent building code. Information on geologic hazards in Duxbury can be found on Map 4 in Appendix B.

Earthquakes

Damage in an earthquake stems from ground motion, surface faulting, and ground failure in which weak or unstable soils, such as those composed primarily of saturated sand or silts, liquefy. The effects of an earthquake are mitigated by distance and ground materials between the epicenter and a given location. An earthquake in New England affects a much wider area than a similar earthquake in California due to New England's solid bedrock geology (NESEC).

Seismologists use a magnitude scale (Richter Scale) to express the seismic energy released by each earthquake. The typical effects of earthquakes in various ranges are summarized below.

Figure 12: Richter Scale and Effects[5]

Richter Magnitudes	Earthquake Effects
Less than 3.5	Generally not felt, but recorded
3.5- 5.4	Often felt, but rarely causes damage
Under 6.0	At most slight damage to well-designed buildings; can cause major damage to poorly constructed buildings over small regions.
6.1-6.9	Can be destructive in areas up to about 100 km. across where people live
7.0- 7.9	Major earthquake; can cause serious damage over larger areas
8 or greater	Great earthquake; can cause serious damage in areas several hundred meters across.

According to the State Hazard Mitigation Plan, New England experiences an average of five earthquakes per year. From 1668 to 2016, 408 earthquakes were recorded in Massachusetts (NESEC). Most have originated from the La fault in Quebec or from the Cape Anne fault located off the coast of Rockport. The region has experienced larger earthquakes, including a magnitude 5.0 earthquake in 1727 and a 6.0 earthquake that struck in 1755 off the coast of Cape Anne. More recently, a pair of damaging Malbaie earthquakes occurred near Ossipee, NH in 1940, and a 4.0 earthquake centered in Hollis, Maine in October 2012 was felt in the Boston area. Historical records of some of the more significant earthquakes are shown in Table 9.

Table 9: Historical Earthquakes in Massachusetts or Surrounding Area

Location	Date	Magnitude
MA - Cape Ann	11/10/1727	5
MA - Cape Ann	12/29/1727	NA
MA - Cape Ann	2/10/1728	NA
MA - Cape Ann	3/30/1729	NA
MA - Cape Ann	12/9/1729	NA

[5] Nevada Seismological Library (NSL), 20

Location	Date	Magnitude
MA - Cape Ann	2/20/1730	NA
MA - Cape Ann	3/9/1730	NA
MA – Boston	6/24/1741	NA
MA - Cape Ann	6/14/1744	4.7
MA – Salem	7/1/1744	NA
MA - Off Cape Ann	11/18/1755	6
MA - Off Cape Cod	11/23/1755	NA
MA – Boston	3/12/1761	4.6
MA - Off Cape Cod	2/2/1766	NA
MA – Offshore	1/2/1785	5.4
MA - Wareham/Taunton	12/25/1800	NA
MA - Woburn	10/5/1817	4.3
MA - Marblehead	8/25/1846	4.3
MA - Brewster	8/8/1847	4.2
MA - Boxford	5/12/1880	NA
MA - Newbury	11/7/1907	NA
MA - Wareham	4/25/1924	NA
MA - Cape Ann	1/7/1925	4
MA - Nantucket	10/25/1965	NA
MA - Boston	12/27/74	2.3
VA - Mineral	8/23/11	5.8
MA - Nantucket	4/12/12	4.5
ME - Hollis	10/17/12	4.0
CT-Wauregan	1/12/2015	3.3
CT-Wauregan	1/12/2015	2.6
NH-East Kingston	2/15/2018	2.7

Source: Boston HIRA

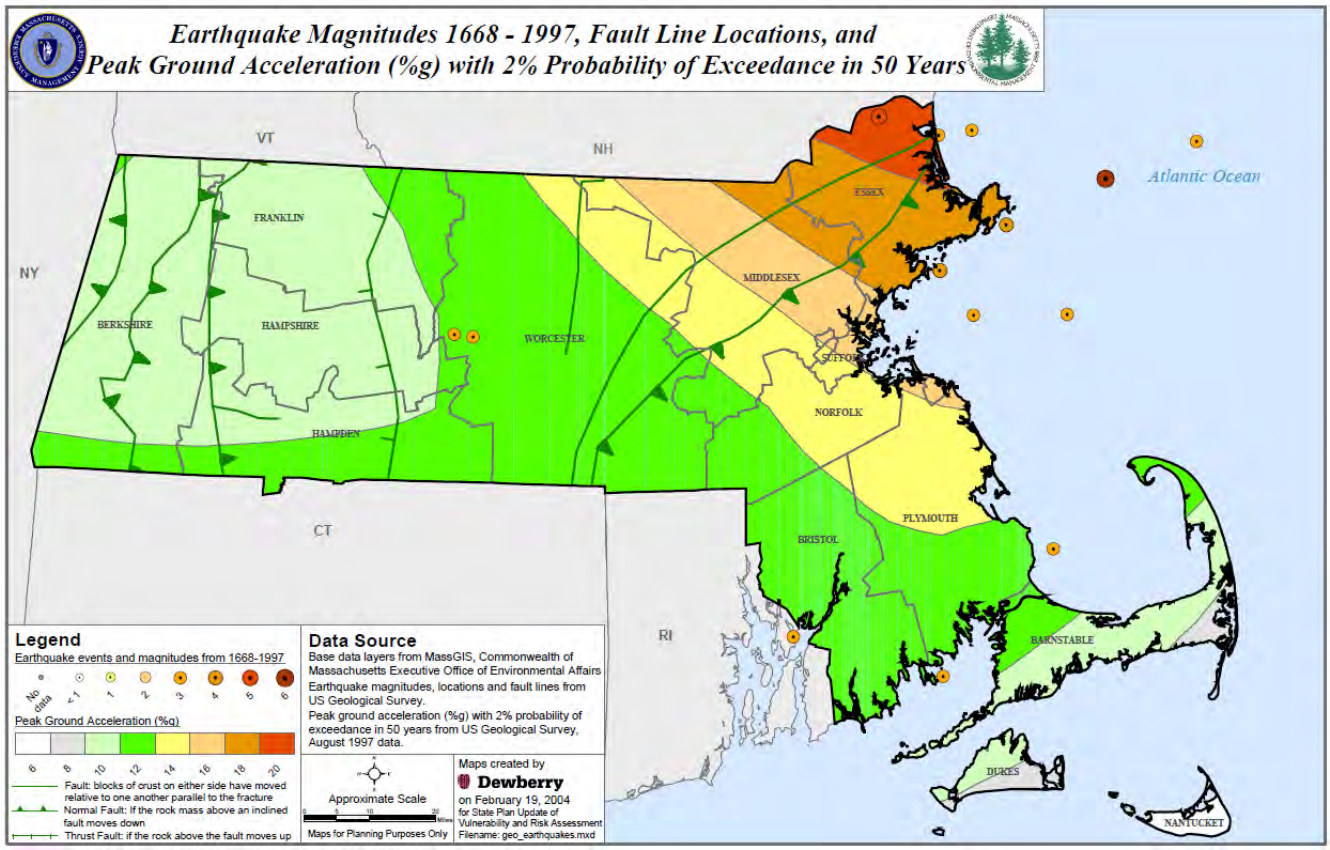
One measure of earthquake risk is ground motion, which is measured as maximum peak horizontal acceleration, expressed as a percentage of gravity (1 g). The range of peak ground acceleration in Massachusetts is from 10g to 20g, with a 2% probability of exceedance in 50 years. Duxbury is in the middle part of the range for Massachusetts, making it a relatively moderate area of earthquake risk within the state, although the state as a whole is considered to have a low risk of earthquakes compared to the rest of the country (Figure 13)

Although New England has not experienced a damaging earthquake since 1755, seismologists state that a serious earthquake occurrence is possible. There are five seismological faults in

Massachusetts, but there is no discernible pattern of previous earthquakes along these fault lines. Earthquakes occur without warning and may be followed by aftershocks. Older buildings and infrastructure were constructed without specific earthquake resistant design features.

Earthquakes are a hazard with multiple impacts beyond the obvious building collapse. Buildings may suffer structural damage which may or may not be readily apparent. Earthquakes can cause major damage to roadways, making emergency response difficult. Water lines and gas lines can break, causing flooding and fires. Another potential vulnerability is equipment within structures. For example, a hospital may be structurally engineered to withstand an earthquake, but if the equipment inside the building is not properly secured, the operations at the hospital could be severely impacted during an earthquake. Earthquakes can also trigger landslides.

Figure 13 State of Massachusetts Earthquake Probability Map



Earthquakes are a potential town-wide hazard in Duxbury. The town has many older buildings that pre-date current building code which could be vulnerable in the event of a severe earthquake. Potential earthquake damages to Duxbury have been estimated using HAZUS-MH. Total building damages are estimated at $232 million for a 5.0 magnitude earthquake and $2.3 billion for a 7.0 magnitude earthquake. Other potential impacts are detailed in Figure 12.

According to the Boston College Weston Observatory, in most parts of New England, there is a one in ten chance that a potentially damaging earthquake will occur in a 50 year time period.

The Massachusetts State Hazard Mitigation Plan classifies earthquakes as very low frequency events that occur less frequently than once in 100 years, or a less than 1% per year.

Landslides

According to the United States Geological Society (USGS), a landslide describes a process that results in movement of rock, soil, fill, or combination downward and outward by falling, toppling, sliding, spreading or flowing.[6] Although gravity acting on an over steepened slope is the primary reason for a landslide, there are other contributing factors. Among the contributing factors are: erosion by rivers or ocean waves over steepened slopes; rock and soil slopes weakened through saturation by snowmelt or heavy rains; earthquakes create stresses that make weak slopes fail; and excess weight from accumulation of rain or snow, and stockpiling of rock or ore, from waste piles, or from man-made structures.

Landslides can result from human activities that destabilize an area or can occur as a secondary impact from another natural hazard such as flooding. In addition to structural damage to buildings and the blockage of transportation corridors, landslides can lead to sedimentation of water bodies. Typically, a landslide occurs when the condition of a slope changes from stable to unstable. Natural precipitation such as heavy snow accumulation, torrential rain and run-off may saturate soil creating instability enough to contribute to a landslide. The lack of vegetation and root structure that stabilizes soil can destabilize hilly terrain.

There is no universally accepted measure of landslide extent but it has been represented as a measure of the destructiveness. Figure 14 below summarizes the estimated intensity for a range of landslides. For a given landslide volume, fast moving rock falls have the highest intensity while slow moving landslides have the lowest intensity.

Figure 14: Estimated Landslide Intensity

Estimated Volume (m^3)	Expected Landslide Velocity		
	Fast moving landslide (Rock fall)	Rapid moving landslide (Debris flow)	Slow moving landslide (Slide)
<0.001	Slight intensity		
<0.5	Medium intensity		
>0.5	High intensity		
<500	High intensity	Slight intensity	
500-10,000	High intensity	Medium intensity	Slight intensity
10,000 – 50,000	Very high intensity	High intensity	Medium intensity
>500,000		Very high intensity	High intensity

[6] U.S. Dept. of Interior U.S. Geological Society. Landslide Types and Processes. Fact Sheet 2003-3072

>>500,000			Very high intensity

Source: *A Geomorphological Approach to the Estimation of Landslide Hazards and Risks in Umbria, Central Italy*, M. Cardinali et al, 2002

All of Duxbury is classified as having a low risk for landslides (see Map 4, Appendix B). The town does not have records of any damages caused by landslides in Duxbury. Should a landslide occur in the future, the type and degree of impacts would be highly localized. The town's vulnerabilities could include damage to structures, transportation and other infrastructure, and localized road closures. Potential damages would depend on the extent of impact and be based on how many properties were affected. Injuries and casualties, while possible, would be unlikely given the low extent and impact of landslides in Duxbury. Based on past occurrences and the Massachusetts Hazard Mitigation Plan, landslides are low frequency events that can occur once in 50 to 100 years (a 1% to 2% chance of occurring each year).

Tsunami

An additional natural hazard associated with earthquakes are tsunamis. Tsunamis are created when the epicenter of an earthquake, the area of the fault where a sudden rupture occurs, is beneath the ocean floor. This can sometimes create immense sea waves if the earthquake causes upward or downward movement of the sea floor.[7] According to the National Centers for Environmental Information, there are Tsunami's reported in the Northeast area of the United States. The 2013 Massachusetts Natural Hazard Mitigation Plan reports tsunamis have a very low frequency with extensive and catastrophic severity across the coast of Massachusetts. Duxbury has a very low risk frequency of tsunami but if it were to occur, the damage would likely be extensive and catastrophic.

Fire-Related Hazards

A brush fire is an uncontrolled fire occurring in a forested or grassland area. In the Boston Metro region, these fires rarely grow to the size of a wildfire as seen more typically in the western U.S. As their name implies, these fires typically burn no more than the underbrush of a forested area. There are three different classes of wild fires:

- Surface fires are the most common type and burn along the floor of a forest, moving slowly and killing or damaging trees;
- Ground fires are usually started by lightning and burn on or below the forest floor;
- Crown fires spread rapidly by wind, jumping along the tops of trees.

Wildfire season can begin in March and usually ends in late November. The majority of wildfires typically occur in April and May, when most vegetation is void of any appreciable moisture, making them highly flammable. Once "green-up" takes place in late May to early June, the fire danger usually is reduced somewhat. A wildfire differs greatly from other fires by its extensive size, the speed at which it can spread out from its original source, its potential to unexpectedly change direction, and its ability to jump gaps such as roads, rivers and fire breaks.

[7] MA Emergency Management Agency, State *Hazard Mitigation Plan*, 2013

These fires can present a hazard where there is the potential for them to spread into developed or inhabited areas, particularly residential areas where sufficient fuel materials might exist to allow the fire the spread into homes. Protecting structures from fire poses special problems, and can stretch firefighting resources to the limit. If heavy rains follow a fire, other natural disasters can occur, including landslides, mudflows, and floods. If the wild fire destroys the ground cover, then erosion becomes one of several potential problems.

The Duxbury Fire Department has occasionally had to respond to brush fires. In February 2018, firefighters stopped a brush fire that had started along the powerlines before it reached a shed and caused further damage. The fire was not extensive and no restoration was required.

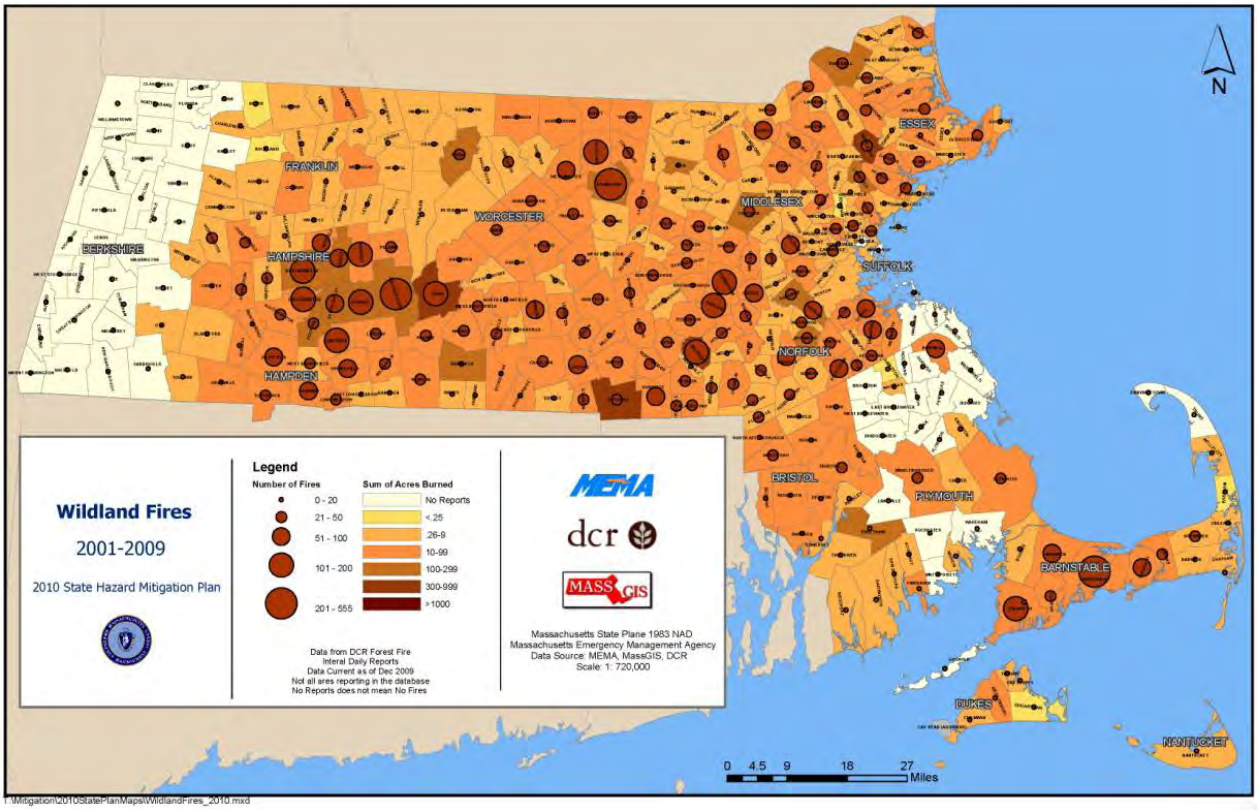
Duxbury Potential Brush Fire Hazard Areas

The following areas of town were identified as having the highest potential for brush fires based either on higher concentration of brush or forest, or large stands of phragmites. The numbers correspond to the numbers on Appendix B Map 8, "Local Hazard Areas."

- Miles Standish Park (17)
- Depot Street, Lapham Woods (18)
- Mayflower Street, Town Forest (19)
- Waiting Hill (20)
- Behind Chandler School on Duxbury Bog (21)
- Autumn Lane, O'Neil Farm, beneath high tension wires (22)
- King Phillips Path, Lansing Bennett Forest (23)
- Summer and Congress streets, border with Pembroke (24)
- North Street, by Marshfield and Pembroke lines (25)
- Pine Brook area (26)
- Wright Reservation, high tension wires (27)
- Bay Farm area, along border with Kingston (28)
- Cranberry Bogs by Island Creek (31)
- Harrison Street at the open space and forested areas (32)
- Oak Street
- Route 3 North and South between exits 10-12. (34)

Figure 15: Massachusetts Wildfires, 2001-2009

Source: Massachusetts State Hazard Mitigation Plan



Wildfires in Massachusetts are measured by the number of fires and the sum of acres burned. The most recent data available for wildfires in Massachusetts (shown in Figure 15) indicates that there were no wildfire reports for Duxbury from 2001-2009, however the Town of Duxbury responded to 103 incidences of fire-related hazards in Duxbury from 2013-2018. These are listed in Table 10.

Table 10 Fire Department reported and responded incidences of fire-related hazards 2013-2018

Date	Incident#	Address	Type
1/31/2013	2013-000188	BEAVERBROOK LN	Brush or brush-and-grass mixture fire
4/6/2013	2013-000711	BLODGETT AVE	Brush or brush-and-grass mixture fire
4/7/2013	2013-000721	BARSES LN	Forest, woods or wildland fire
4/17/2013	2013-000787	RTE 3 SB N/EXIT 11	Forest, woods or wildland fire
4/19/2013	2013-000803	TREMONT ST	Brush or brush-and-grass mixture fire
4/29/2013	2013-000852	TAYLOR ST	Forest, woods or wildland fire
5/1/2013	2013-000863	TREMONT ST	Natural vegetation fire, other
5/2/2013	2013-000868	UNION ST	Brush or brush-and-grass mixture fire

Date	Incident#	Address	Type
5/7/2013	2013-000903	SIMMONS DR	Brush or brush-and-grass mixture fire
5/15/2013	2013-000949	TREMONT ST	Natural vegetation fire, other
7/7/2013	2013-001283	WOODLAND WAY	Forest, woods or wildland fire
8/18/2013	2013-001553	ROUTE 3 N/B	Brush or brush-and-grass mixture fire
11/25/2013	2013-002098	ROUTE 3 SOUTH	Brush or brush-and-grass mixture fire
3/22/2014	2014-000474	VALLEY ST	Brush or brush-and-grass mixture fire
4/12/2014	2014-000589	WELLINGTON LN	Forest, woods or wildland fire
4/14/2014	2014-000601	GURNET RD	Natural vegetation fire, other
4/25/2014	2014-000670	RAC HEL'S LN	Natural vegetation fire, other
5/11/2014	2014-000755	ROSEWOOD CT	Brush or brush-and-grass mixture fire
5/12/2014	2014-000763	LAKESHORE DR	Forest, woods or wildland fire
6/3/2014	2014-000899	DEPOT ST	Natural vegetation fire, other
6/22/2014	2014-001026	VALLEY ST	Brush or brush-and-grass mixture fire
6/30/2014	2014-001077	RTE 3 NB EXIT 10-11	Brush or brush-and-grass mixture fire
7/6/2014	2014-001120	CRESCENT ST	Brush or brush-and-grass mixture fire
7/11/2014		LAKESHORE DR	Brush or brush-and-grass mixture fire
8/17/2014	2014-001401	WEST ST	Forest, woods or wildland fire
9/21/2014	2014-001612	WASHINGTON ST	Brush or brush-and-grass mixture fire
1/12/2015	2015-000075	SURREY LANE	Brush or brush-and-grass mixture fire
4/16/2015	2015-000813	TEMPLE ST	Brush or brush-and-grass mixture fire
5/4/2015	2015-000924	WINDY HILL LN	Forest, woods or wildland fire
5/5/2015	2015-000928	WINDY HILL	Forest, woods or wildland fire
5/14/2015	2015-000985	OAK ST	Brush or brush-and-grass mixture fire
5/16/2015	2015-000996	FRANKLIN ST	Natural vegetation fire, other
5/17/2015	2015-001002	JAMES ROAD	Brush or brush-and-grass mixture fire
5/26/2015	2015-001039	GLENN RD	Brush or brush-and-grass mixture fire
5/27/2015	2015-001045	SUMMER ST	Brush or brush-and-grass mixture fire
5/30/2015	2015-001061	SUMMER ST	Natural vegetation fire, other
7/1/2015	2015-001298	RTE 3 NB EXIT 10-11	Brush or brush-and-grass mixture fire
7/1/2015	2015-001297	SUMMER ST	Brush or brush-and-grass mixture fire
7/20/2015	2015-001439	RTE 3 NB EXIT 11-12	Grass fire
7/23/2015	2015-001469	RTE 3 SB between 12 and 11	Grass fire
8/2/2015	2015-001545	KING PHILLIPS PATH	Brush or brush-and-grass mixture fire
8/3/2015	2015-001560	LAKE SHORE DR	Brush or brush-and-grass mixture fire
9/3/2015	2015-001774	CHURCH ST	Natural vegetation fire, other

Date	Incident#	Address	Type
9/22/2015	2015-001914	RTE 3 NB EXIT 10-11	Brush or brush-and-grass mixture fire
10/28/2015	2015-002144	STOCKADE PATH	Natural vegetation fire, other
12/1/2015	2015-002356	JAMES RD	Brush or brush-and-grass mixture fire
3/13/2016	2016-000537	BIRCH ST	Brush or brush-and-grass mixture fire
3/19/2016	2016-000573	RTE 3 NB EXIT 10-11	Forest, woods or wildland fire
3/22/2016	2016-000592	DUXBURY BEACH RD	Brush or brush-and-grass mixture fire
4/10/2016	2016-000749	BUCKBOARD RD	Brush or brush-and-grass mixture fire
4/17/2016	2016-000786	UNION BRIDGE RD	Brush or brush-and-grass mixture fire
4/18/2016	2016-000797	TREETOP LN	Brush or brush-and-grass mixture fire
4/22/2016	2016-000814	RTE 3 NB N EXIT 11	Brush or brush-and-grass mixture fire
4/24/2016	2016-000834	ALLENS LN	Forest, woods or wildland fire
5/1/2016	2016-000869	PRENCE ST	Brush or brush-and-grass mixture fire
5/23/2016	2016-001017	OAK ST	Natural vegetation fire, other
6/15/2016	2016-001144	CHANDLER MILL DR	
6/19/2016	2016-001167	STANDISH ST	
6/24/2016	2016-001195	BACK RIVER WAY	Natural vegetation fire, other
6/29/2016	2016-001229	RTE 3 SB EXIT 10-11	Grass fire
7/4/2016	2016-001277	DEPOT ST	Brush or brush-and-grass mixture fire
7/23/2016	2016-001396	MAYFLOWER ST	Brush or brush-and-grass mixture fire
7/24/2016	2016-001409	MAYFLOWERST	Brush or brush-and-grass mixture fire
7/24/2016	2016-001403	ROUTE 130	Brush or brush-and-grass mixture fire
7/27/2016	2016-001428	MAYFLOWER ST	Brush or brush-and-grass mixture fire
8/28/2016	2016-001634	TREMONT ST	Forest, woods or wildland fire
9/14/2016	2016-001743	RTE 3 NBS EXIT 10	Brush or brush-and-grass mixture fire
9/14/2016	2016-001745	TREMONT ST	Natural vegetation fire, other
9/18/2016	2016-001772	PINE POINT RD	Natural vegetation fire, other
9/22/2016	2016-001802	RTE 3 NB EXIT 10-11	Brush or brush-and-grass mixture fire
9/25/2016	2016-001820	BAY RD	Brush or brush-and-grass mixture fire
3/4/2017	2017-000408	RTE 3 NB EXIT 10-11	Brush or brush-and-grass mixture fire
3/5/2017	2017-000414	SCREENHOUSELN	Brush or brush-and-grass mixture fire
3/17/2017	2017-000489	RTE 3 NB N EXIT 11	Brush or brush-and-grass mixture fire
3/20/2017	2017-000518	WASHINGTON ST	Brush or brush-and-grass mixture fire
3/21/2017	2017-000525	STANDISH ST	Brush or brush-and -grass mixture fire
4/11/2017	2017-000664	HIDDEN ACRES DR	Brush or brush-and-grass mixture fire

Date	Incident#	Address	Type
4/11/2017	2017-000667	PLANTATIONDR	Brush or brush-and-grass mixture fire
4/15/2017	2017-000708	KEENE ST	Brush or brush-and-grass mixture fire
4/15/2017	2017-000707	PENNY LN	Forest, woods or wildland fire
4/15/2017	2017-000711	WRIGHT CT	Forest, woods or wildland fire
4/17/2017	2017-000725	TREMONT ST	Brush or brush-and-grass mixture fire
6/21/2017	2017-001167	WASHINGTON ST	Natural vegetation fire, other
7/4/2017	2017-001291	PARTRIDGE RD	Brush or brush-and-grass mixture fire
7/22/2017	2017-001409	TREMONT ST	Natural vegetation fire, other
7/23/2017	2017-001413	DEPOT ST	Grass fire
8/23/2017	2017-001617	PINE LAKE RD	Forest, woods or wildland fire
8/24/2017	2017-001620	CHERRY LN	Forest, woods or wildland fire
8/25/2017	2017-001628	CHERRY LN	Forest, woods or wildland fire
9/26/2017	2017-001845	MAYFLOWER ST	Grass fire
10/21/2017	2017-002024	BIANCA RD	Forest, woods or wildland fire
2/7/2018	2018-000333	HARRISON ST	Brush or brush-and-grass mixture fire
2/10/2018	2018-000350	HARRISON ST	Brush or brush-and-grass mixture fire
2/28/2018	2018-000451	UNION BRIDGE RD	Brush or brush-and-grass mixture fire
3/6/2018	2018-000731	TREMONT ST	Brush or brush-and-grass mixture fire
3/12/2018	2018-000782	HARRISON ST	Brush or brush-and-grass mixture fire
3/12/2018	2018-000785	HARRISON ST	Brush or brush-and-grass mixture fire
4/24/2018	2018-001171	TEMPLE ST	Brush or brush-and-grass mixture fire
5/23/2018	2018-001386	RTE 3 SB N EXIT 11	Brush or brush-and-grass mixture fire
5/25/2018	2018-001402	CRESCENT ST	Natural vegetation fire, other
7/8/2018	2018-001774	SUMMER ST	Brush or brush-and-grass mixture fire
9/4/2018	2018-0	ELM ST	Brush or brush-and-grass mixture fire
9/5/2018	2018-002215	ELM ST	Forest, woods or wildland fire

Potential damages from wildfires in Duxbury would depend on the extent and type of land affected. Duxbury has over 6,000 acres of forested area and over 3,000 acres of protected open space. Much of this land area contains the Southeastern Massachusetts Pine Barren Forest, known for its sandy soils, scrub oak and pitch pine, a fire-dominated forest which naturally relies on fires for regeneration. Though fires in Duxbury's Pine Barren Forest are few and far between, there is a high potential for loss of residences which are often nestled within the forested areas. The Chief of the Duxbury Fire Department has significant concern on Duxbury's vulnerability and risk of loss with fire-related hazards:

> "Among the only trees that thrive in this region's sandy soil are pitch pine and scrub oak; both species are susceptible to fire but pitch pine's resin-rich needles are especially so.

> With the added fuel from ground covered with dried pinecones, needles, leaves, and twigs, these forests can produce some of the fastest-moving fires in the country. In recent decades, there has been intense residential development surrounding state forests and parks. Dozens of structures have been lost in Southeastern MA., in the 1957 and 1964 fires. Today, even a medium-size wildfire in southeastern Massachusetts would likely destroy hundreds of homes and possibly result in loss of life."[8]

The Duxbury Fire Chief noted that public education, permitting and monitoring of open air burning, and "prescribed burns" of the Pine Barren Forest can help to mitigate future fires and minimize extensive loss. There could be the need for post-fire revegetation to restore a burned property which could cost from a few thousand dollars to tens of thousands for an extensive area. However, there are no data on actual wildfire damages.

Potential vulnerabilities to wildfires include damage to structures and other improvements, and impacts on natural resources such as town conservation land. Smoke and air pollution from wildfires can be a health hazard, especially for sensitive populations including children, the elderly, and those with respiratory and cardiovascular diseases.

Based on past occurrences and the Massachusetts Hazard Mitigation Plan 2013, brushfires are of medium frequency, events that occur from once in five years to once in 50 years (2% to 20% probability per year). However, given the extensive forest, tree species composition, and numerous response to brush fires in the last five years, brushfires are a high hazard for Duxbury.

Extreme Temperatures

Extreme temperatures occur when either high temperature or low temperatures relative to average local temperatures occur. These can occur for brief periods of time and be acute, or they can occur over long periods of time when there is a prolonged period of excessively hot or cold weather.

Duxbury has four well-defined seasons. The seasons have several defining factors, with temperature one of the most significant. Extreme temperatures can be defined as those far outside of the normal seasonal ranges for Massachusetts. The average temperature for Massachusetts winter (December to February) is 31.8°F and the summer (June to August) average is 71°F. Extreme temperatures are a town-wide hazard.

Extreme Cold

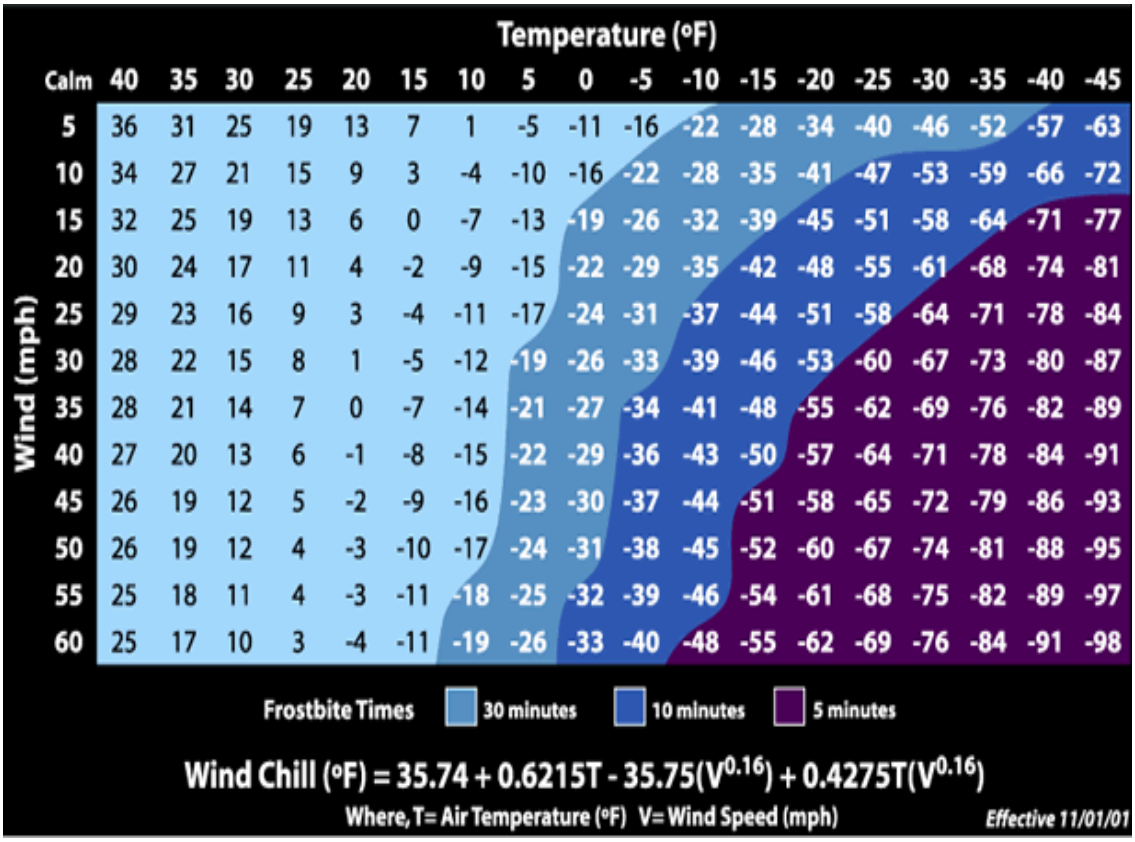
For extreme cold, temperature is typically measured using Wind Chill Temperature Index, which is provided by the National Weather Service (NWS). The latest version of the index was implemented in 2001 and it meant to show how cold conditions feel on unexposed skin. The index is provided in Figure 16 below.

[8] Personal Communication. Chief Nord, Duxbury Fire Department, October 30, 2018.

Extreme cold is relative to the normal climatic lows in a region. Temperatures that drop decidedly below normal and wind speeds that increase can cause harmful wind chill factors. The wind chill is the apparent temperature felt on exposed skin due to the combination of air temperature and wind speed. Extreme cold is a dangerous situation that can result in health emergencies for susceptible people, such as those without shelter or who are stranded or who live in homes that are poorly insulated or without heat. The elderly and people with disabilities are often most vulnerable. In Duxbury, 16.9% of the people are over 65 years old, and 3.5% of the population have a disability.

Other damages related to extreme cold in Duxbury relate to the freezing of the bay, which can cause heaves and structural damage to piers, docks and marina structures on the waterfront, including the Powder Point Bridge pilings and other bridges in these bay waters. Access to iced-over waters is prevented during these freezes, affecting shellfishing and fishing activities, and damaged infrastructure must be repaired with closures or significantly reduced usage until these repairs are made.

Figure 16: Wind Chill Temperature Index and Frostbit Risk



Source: National Weather Service

The Town of Duxbury does not collect data for previous occurrences of extreme cold. The best available local data are for Plymouth County, through the National Centers for Environmental Information (NCDC). There are two extreme cold events on record which caused no deaths, injuries, or property damage (see Figure 17). Extreme cold events occur between once in five years to once in 50 years, or a 2% to 20% chance of occurring each year.

Figure 17: Plymouth County Extreme Cold and Wind Chill Occurrences[9]

Date	Deaths	Injuries	Damage
2/16/2015	0	0	0
2/14/2016	0	0	0

Extreme Heat

While a heat wave for Massachusetts is defined as three or more consecutive days above 90°F, another measure used for identifying extreme heat events is through a Heat Advisory from the NWS. These advisories are issued when the heat index (Figure 18) is forecast to exceed 100 degrees Fahrenheit (F) for two or more hours; an excessive heat advisory is issued if forecast predicts the temperature to rise above 105°F.

Figure 18: Heat Index Chart

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

Category	Heat Index	Health Hazards
Extreme Danger	130 °F – Higher	Heat Stroke or Sunstroke is likely with continued exposure.
Danger	105 °F – 129 °F	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Extreme Caution	90 °F – 105 °F	Sunstroke, muscle cramps, and/or heat exhaustions possible with prolonged exposure and/or physical activity.
Caution	80 °F – 90 °F	Fatigue possible with prolonged exposure and/or physical activity.

Source: National Weather Service

Extreme heat poses many health risks. Prolonged exposure to high temperatures can cause heat-related illnesses, such as heat cramps, heat exhaustion, heat stroke, and in severe cases, death. Heat exhaustion is the most common heat-related illness and if untreated, it may progress to heat stroke. Prolonged heat exposure can also exacerbate pre-existing conditions, including respiratory illnesses, cardiovascular disease, and mental illnesses.

[9] NOAA, National Centers for Environmental Information

Senior adults are at particularly high risk to heat for several reasons. They may not adjust to sudden changes in temperature as quickly as younger people, they are more likely to have a chronic medical condition whose symptoms may be exacerbated by heat, and they are more likely to be taking prescription medications that affect their ability to control body temperature.[10,11] In Duxbury, 16.9% of the people are over 65 years old

Power failures can occur during heat waves, where intense heat spikes electricity demand and aging infrastructure. This occurred in June 2017 in the Town of Belmont, MA where intense heat cause a spike in electricity demand. With its aging infrastructure, the combination of these factors led to equipment failure.[12] Loss of electricity not only impair a resident's ability to cool, but can cause significant medical emergency for those who require electronic medical equipment or from food-borne illnesses from contaminated food, ingested after loss of refrigeration.

The Town of Duxbury does not collect data on excessive heat occurrences. The best available local data are for Plymouth County through the National Centers for Environmental Information. From 1950 to 2017, there is one recorded excessive heat event, with no deaths or injuries, and no property damage resulting from excessive heat (see Figure 19).

Historically, extreme temperature events are a medium frequency event based on past occurrences, as defined by the Massachusetts State Hazard Mitigation Plan. Extreme heat events occur between once in five years to once in 50 years, or a 2% to 20% chance of occurring each year. However, with our changing climate, extreme heat will likely become a more frequent experience. According to the Northeast Climate Science Center, Duxbury in the South Coastal Basin could experience 19 days over 90° by 2050 and 37 days over 90° by the end of the century. This is based on an average five days over 90° today.[13]

Figure 19: Plymouth County Extreme Heat Occurrences

Date	Deaths	Injuries	Damage
7/6/2010	0	0	0

Source: NOAA, National Centers for Environmental Information

MAPC performed a heat island analysis to ascertain the areas most at risk to extreme heat. A heat island is defined as an area whose temperature ranges more than 1.8-.54° F greater during the daytime or up to 22° F greater in the evening than the surrounding areas.[14] MAPC used LANDSAT satellite imagery at 30 m resolution to ascertain land surface temperatures during the

[10] Gamble, J. L., Hurley, B. J., Schultz, P. A., Jaglom, W. S., Krishnan, N., & Harris, M. (2013). Climate Change and Older Americans: State of the Science. Environmental Health Perspectives, 121(1), 15–22. http://doi.org/10.1289/ehp.1205223
[11] Center for Disease Control and Prevention. Natural Disasters and Severe Weather. https://www.cdc.gov/disasters/extremeheat/older-adults-heat.html
[12] Wicked Local Belmont "Power Outage in Belmont Affects 2,000 Customers" June 14, 2017. http://belmont.wickedlocal.com/news/20170612/power-outage-in-belmont-affects-2000-customers.

[13] *Northeast Climate Science Center. UMass Amherst. Massachusetts Climate Change Projections. www.resilentma.org*

[14] U.S. Environmental Protection Agency. https://www.epa.gov/heat-islands

daytime in the warmest months of 2016. In Duxbury, there are two very small areas in of Town whose land surface temperature is in the top 5% of Metropolitan Boston region (Appendix B Map 9).

Today, extreme temperatures are a medium frequency event based on past occurrences, as defined by the Massachusetts State Hazard Mitigation Plan, 2013. Both extreme temperature events occur between once in five years to once in 50 years, or a 2 percent to 20 percent chance of occurring each year.

Drought

Drought is a temporary irregularity in precipitation and differs from aridity since the latter is restricted to low rainfall regions and is a permanent feature of climate. Drought is a period characterized by long durations of below normal precipitation. Drought conditions occur in virtually all climatic zones yet its characteristics vary significantly from one region to another, since it is relative to the normal precipitation in that region. Drought can affect agriculture, water supply, aquatic ecology, wildlife, and plant life.

Five levels of drought have been developed to characterize drought severity: Normal, Advisory, Watch, Warning, and Emergency. These drought levels are based on the conditions of natural resources and are intended to provide information on the current status of water resources. The levels provide a basic framework from which to take actions to assess, communicate, and respond to drought conditions. They begin with a normal situation where data are routinely collected and distributed, move to heightened vigilance with increased data collection during an advisory, to increased assessment and proactive education during a watch. Water restrictions might be appropriate at the watch or warning stage, depending on the capacity of each individual water supply system. A warning level indicates a severe situation and the possibility that a drought emergency may be necessary. A drought emergency is one in which mandatory water restrictions or use of emergency supplies is necessary. Drought levels are used to coordinate both state agency and local response to drought situations.

In Massachusetts, droughts are caused by the prevalence of dry northern continental air and a decrease in coastal- and tropical-cyclone activity. During the 1960's, a cool drought occurred because dry air from the north caused lower temperatures in the spring and summer of 1962-65. Average annual precipitation in Massachusetts is 44 inches per year, and during the 1965 drought, the statewide precipitation total of 30 inches was 68 percent of average. The drought was so severe, the Quabbin Reservoir was 20 feet below its current level today.[15] In 2016, nearly half of Massachusetts was in extreme drought conditions with 15 inches of deficit rainfall (Figure 20), the worst drought since 1965. The drought geographically affected 6.5 million

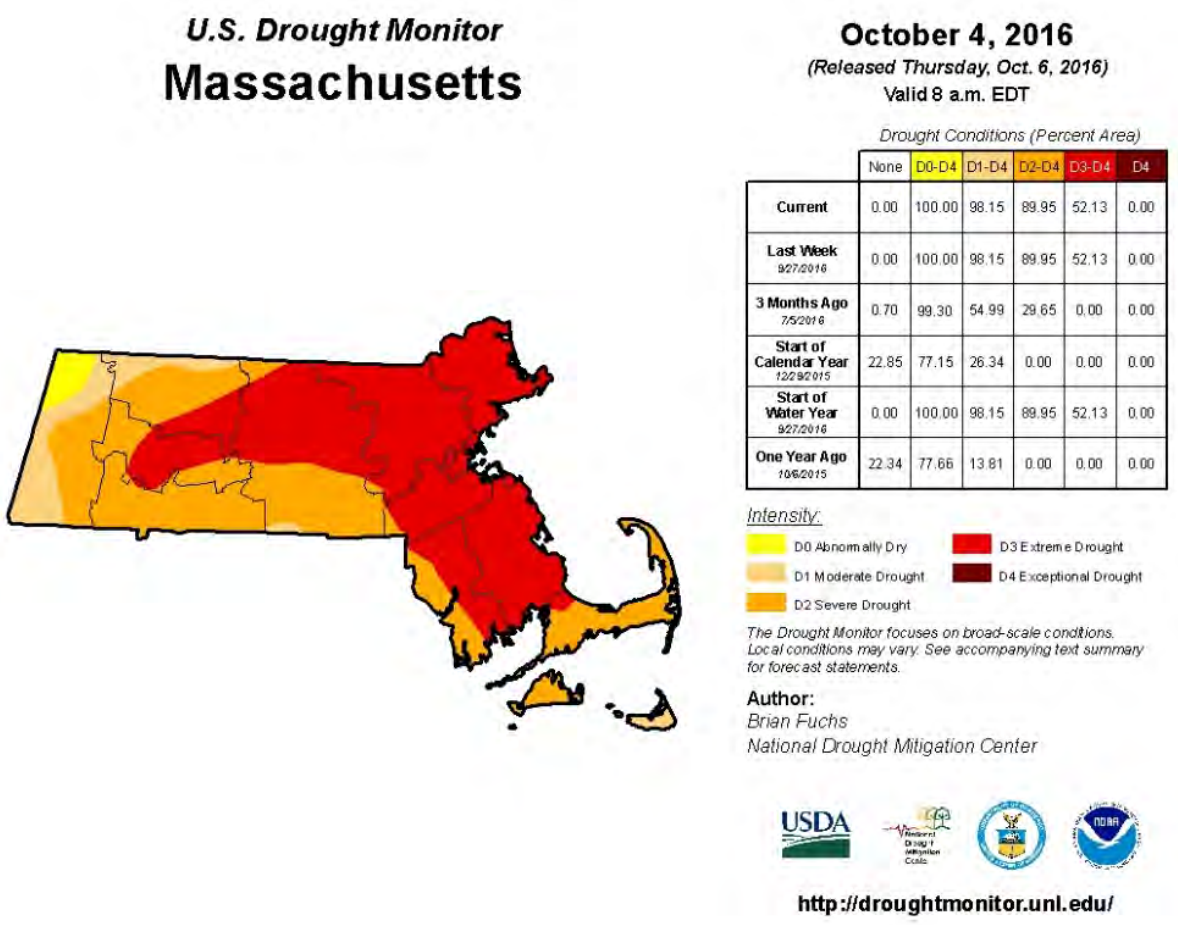
[15] Lathrop, Janet. Putting New England's Drought into Perspective. https://www.umass.edu/newsoffice/article/putting-new-england%E2%80%99s-drought-perspective

people, forced communities to buy drinking water from the Massachusetts Water Resources Authority,[16] and prompting State aid to farmers for crop losses.

Average annual precipitation in Massachusetts is 44 inches per year, with approximately three to four inch average amounts each month of the year. Regional monthly precipitation ranges from zero to 17 inches. Statewide annual precipitation ranges from 30 to 61 inches. Thus, in the driest calendar year (1965), the statewide precipitation total of 30 inches was 68% of average.

Although Massachusetts is relatively small, it has a number of distinct regions that experience significantly different weather patterns and react differently to the amounts of precipitation they receive. The DCR precipitation index divides the state into six regions: Western, Central, Connecticut River Valley, Northeast, Southeast, and Cape and Islands. Duxbury is located in the Southeast Region. In Duxbury, drought is a potential town-wide hazard.

Figure 20 Drought Conditions in Massachusetts, 2016



[16] https://www.boston.com/weather/local-news/2016/09/15/more-than-half-of-massachusetts-now-experiencing-an-extreme-drought

Five levels of drought have been developed to characterize drought severity: Normal, Advisory, Watch, Warning, and Emergency. These drought levels are based on the conditions of natural resources and are intended to provide information on the current status of water resources. The levels provide a basic framework from which to take actions to assess, communicate, and respond to drought conditions. They begin with a normal situation where data are routinely collected and distributed, move to heightened vigilance with increased data collection during an advisory, to increased assessment and proactive education during a watch. Water restrictions might be appropriate at the watch or warning stage, depending on the capacity of each individual water supply system. A warning level indicates a severe situation and the possibility that a drought emergency may be necessary. A drought emergency is one in which mandatory water restrictions or use of emergency supplies is necessary. Drought levels are used to coordinate both state agency and local response to drought situations.

As dry conditions can have a range of different impacts, a number of drought indices are available to assess these various impacts. Massachusetts 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. Drought level is determined monthly based on the number of indices which have reached a given drought level. Drought levels are declared on a regional basis for each of six regions in Massachusetts. County by county or watershed-specific determinations may also be made.

A determination of drought level is based on seven indices:

1. Standardized Precipitation Index (SPI) reflects soil moisture and precipitation.
2. Crop Moisture Index (CMI) reflects soil moisture conditions for agriculture.
3. Keetch Byram Drought Index (KBDI) is designed for fire potential assessment.
4. Precipitation Index is a comparison of measured precipitation amounts to historic normal precipitation.
5. The Groundwater Level Index is based on the number of consecutive month's groundwater levels are below normal (lowest 25% of period of record).
6. The Stream flow Index is based on the number of consecutive months that stream flow levels are below normal (lowest 25% of period of record).
7. The Reservoir Index is based on the water levels of small, medium and large index reservoirs across the state, relative to normal conditions for each month.

Determinations regarding the end of a drought or reduction of the drought level focus on two key drought indicators: precipitation and groundwater levels. These two factors have the greatest long-term impact on stream flow, water supply, reservoir levels, soil moisture and potential for forest fires.

Previous Occurrences

Duxbury does not collect data relative to drought events, however, rainfall data collected by the Duxbury Water Department indicates that 2016 had the lowest amount of rainfall than any other year from 1998-2018 (Figure 23). Because drought tends to be a regional natural hazard, this plan references state data as the best available data for drought. The statewide scale is a composite of six regions of the state. Regional composite precipitation values are based on monthly values from six stations, and three stations in the smaller regions (Cape Cod/Islands and West).

Drought Emergency

Drought emergencies have been reached infrequently, with five events occurring in the period between 1850 and 2018: in 1883, 1911, 1941, 1957, and 1965-1966. The 1965-1966 drought period is viewed as the most severe drought to have occurred in modern times in Massachusetts because of its long duration. On a monthly basis over the 162-year period of record, there is a one percent chance of being in a drought emergency.

Drought Warning

Drought warning levels not associated with drought emergencies have occurred five times, in 1894, 1915, 1930, 1985, and 2016. On a monthly basis over the 162-year period of record, there is a two percent chance of being in a drought warning level. Duxbury was under a drought warning from July to December 2016.

Drought Watch

Drought watches not associated with higher levels of drought generally have occurred in three to four years per decade between 1850 and 1950. In the 1980s, there was a lengthy drought watch level of precipitation between 1980 and 1981, followed by a drought warning in 1985. A frequency of drought watches at a rate of three years per decade resumed in the 1990s (1995, 1998, 1999). In the 2000s, drought watches occurred in 2001, 2002, and 2016. The overall frequency of being in a drought watch is 8% on a monthly basis over the 162-year period of record.

Figure 21 depicts the incidents of drought levels' occurrence in Massachusetts from 1850 to 2012 using the Standardized Precipitation Index (SPI) parameter alone. On a monthly basis, the state would have been in a Drought Watch to Emergency condition 11% of the time between 1850 and 2012. Table 11: Chronology of Major Droughts in Massachusetts summarizes the chronology of major droughts since the 1920s.

Table 11: Chronology of Major Droughts in Massachusetts

Date	Area Affected	Recurrence Interval (years)	Remarks
1929-32	Statewide	10 to >50	Water-supply sources altered in 13 communities. Multistate.
	Statewide	15 to >50	More severe in eastern and extreme western Massachusetts. Multistate.
1957-59	Statewide	5 to 25	Record low water levels in observation wells, northeastern Massachusetts.
1961-69	Statewide	35 to >50	Water-supply shortages common. Record drought. Multistate.
1980-83	Statewide	10 to 30	Most severe in Ipswich and Taunton River basins; minimal effect in Nashua River basin. Multistate.
1985-88	Housatonic River Basin	25	Duration and severity unknown. Streamflow showed mixed trends elsewhere.

2016-17	Statewide	N/A	Drought declaration began in July 2016 with a Drought Watch which was upgraded to a Drought Warning in August 2016. The Central and Northeast regions were the most severely affected.

Drought Emergency

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Figure 21: Statewide Drought Levels using SPI Thresholds, 1850-2012

(Source: Mass. State Drought Management Plan 2013)

Under a severe long term drought, the Town of Duxbury could be vulnerable to restrictions on water supply. Potential damages of a severe drought could include losses of landscaped areas if outdoor watering is restricted and potential loss of business revenues if water supplies were severely restricted for a prolonged period. As this hazard has never occurred to such a severe degree in Duxbury, there are no data or estimates of potential damages, but under a severe long term drought scenario it would be reasonable to expect a range of potential damages from several million to tens of millions of dollars. Another potential vulnerability of droughts could be increased risk of wildfires.

Probability of Future Occurrences

The state has experienced emergency droughts five times between 1850 and 2016. Even given that regional drought conditions may occur at a different interval than state data indicates, droughts remain primarily regional and state phenomena in Massachusetts. Emergency drought conditions over the 162-year period of record in Massachusetts are a low frequency natural hazard event that can occur from once in 50 years to once in 100 years (1% to 2% chance per year), as defined by the 2013 Massachusetts State Hazard Mitigation Plan.

Changing precipitation patterns and the number of extreme weather events per year is difficult to project into the future.[17,18] The Northeast Climate Science Center does report an anticipated increase in rainfall for Massachusetts in the spring and winter months and their climate projection models suggest that the frequency of high-intensity rainfall events will also increase.[19] Consequently, warming temperatures can cause greater evaporation in the summer and fall, as well as earlier snow melt, leading to periods of either drought or extreme snowfall. The Northeast Climate Science Center projects a small decrease in average summer precipitation into the century; this combined with projected higher temperatures could increase the frequency of episodic droughts in the future.[20],[21]

Impacts of Climate Change

Climate change is the most compelling environmental, economic, and social issue of our time. Duxbury contains a rich fabric of cultural and natural assets the community through time has had the foresight to protect. Duxbury Beach is a critically important resource affording shoreline protection to the Town and neighboring communities, supporting threatened species and species of conservation concern habitat, enabling diverse recreation opportunities, and supporting economic vitality. Further it protects the shellfish growing areas that support a robust oyster and shellfish commercial economy in Duxbury.

Many of the natural hazards that Duxbury has historically experienced are likely to be exacerbated by climate change in future years. Duxbury routinely experiences coastal flooding

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[17] Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston," June 2016

[18] Horton, R., G. Yohe, W. Easterling, R. Kates, M. Ruth, E. Sussman, A. Whelchel, D. Wolfe, and F. Lipschultz, 2014: Ch. 16: Northeast. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 16-1-nn

[19] Northeast Climate Center UMass Amherst. Massachusetts Climate Change Projections. December 2017.

[20] Northeast Climate Center UMass Amherst. Massachusetts Climate Change Projections. December 2017.

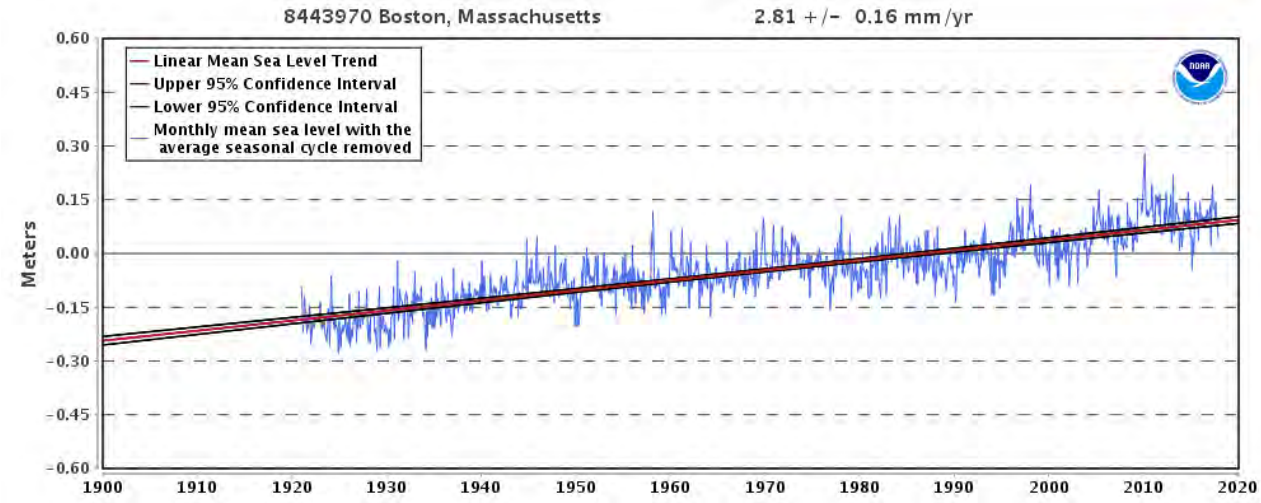
[21] MAPC. 2018. Duxbury Climate Vulnerability Assessment and Action Plan.

and inundation with even just a lunar high tide. Projected sea level rise and changes in intensity of storm and precipitation events compel the need to assess the vulnerability of Duxbury's people and places as well as plan for protecting its future. Extreme heat poses risk to public health, infrastructure deterioration, and natural systems and agriculture that function to support the community of Duxbury. We address projected climate change conditions in order to comprehensively address natural hazard mitigation now and into the future, specifically for sea level rise, precipitation changes, and temperature changes.

Sea Level Rise

Over the last century, sea level rise has risen by 11 inches (Figure 22 Observed Sea Level Rise from Boston Tide Station and Research Advisory Group (BRAG) anticipates that the rate of increase will accelerate, anticipating an additional eight inches by 2030.[22,23] Warming temperatures contribute to sea level rise in several ways. First, warm water expands to take up more space. Second, rising temperatures are melting land-based ice which enters the oceans as meltwater. Other contributions to sea level rise include land subsidence and gravitational pull. Land subsidence is a drop in elevation in response to the last glacial period, when pressure from the heavy ice compressed the land causing land areas around the glacier to curl upward in that time period and gravitational pull. With glacial retreat, the land is very slowly reshaping its elevation (returning to an isostatic balance) causing some portions of the east coast to rebound (rise), and some areas to subside (sink).[24]

Figure 22 Observed Sea Level Rise from Boston Tide Station



Boston Tide Station from 1921-2016 which indicates over 11 inches of sea level rise in the last century.

There are several models and projections for sea level rise available. The majority derive results that are relatively similar based upon some key assumptions, such as emission scenarios.

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[22] U.S. Environmental Protection Agency. 2016. Climate Change Indicators in the United States, 2016. Fourth meditation. EPA 430-R-16-004. www.epa/gov/climate-indicators.
[23] Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston," June 2016
[24] Upton, J. Sinking Atlantic Coastline Meets Rapidly Rising Seas. Scientific American. April 2016.

In 2013, Kleinfelder performed sea level rise and storm surge modeling for the towns of Scituate, Marshfield, and Duxbury, projecting scenarios in 25, 50, and 75 years. Sea level rise was estimated using NOAA Technical Report *Global Sea Level Rise Scenarios for the United States National Climate Assessment* (December 2012) and storm surge was modeled using the hydrodynamic Sea, Lake, and Overland Surge from Hurricanes Model (SLOSH) developed by the National Weather Service.

In 2018, we anticipate completion of a more comprehensive SLR and storm surge analysis for Duxbury through the *Massachusetts Department of Transportation Coastal Transportation Vulnerability Assessment*. Comprised of the widely-accepted Advanced Circulation (ADCIRC) probabilistic model, this analysis is a high-resolution, hydrodynamic, probabilistic model that calculates probable future water flows as a result of tides, elevations, waves, winds, rivers, and various storms, accounting for inland storm runoff interaction with the coastal water activity at their interface in the model, with respect to state roads. It was used in Boston Harbor, called the Boston Harbor Flood Risk Model (BH-FRM) and is one of the most detailed projections for coastal flooding available.[25] Finally, the Northeast Climate Science Center at UMass Amherst completed a SLR analysis for the Commonwealth in December 2017. This analysis is based upon the one used for Boston Harbor in *Climate Ready Boston* and a method recently used in Southern California.[26] This is a probabilistic model that projects changes in sea level based upon existing tide gauges. For Duxbury, the closest analysis is the Boston tide gauge.

Table 12 Total Relative Sea Level Rise projections in Boston and South Shore for the "Highest" emission scenarios.

	2030	2050	2070	2100
Boston BH_FRM [27]	8.00 in.	1.50 ft.	3.10 ft.	7.40 ft.
South Shore [28]	8.04 in.	1.85 ft.	3.39 ft.	6.52 ft.
Boston Tide Gauge[29]	1.2 ft.	2.4 ft.	4.2 ft.	7.6 ft.

The Kleinfelder model was calculated using the "highest" emission scenario as directed through consensus with the municipalities and other local and statewide experts. This analysis is illustrated in Appendix B Map 11. The other models report both medium and high emission scenarios, but the highest emission scenarios are reported for total relative sea level rise in **Table 12.**

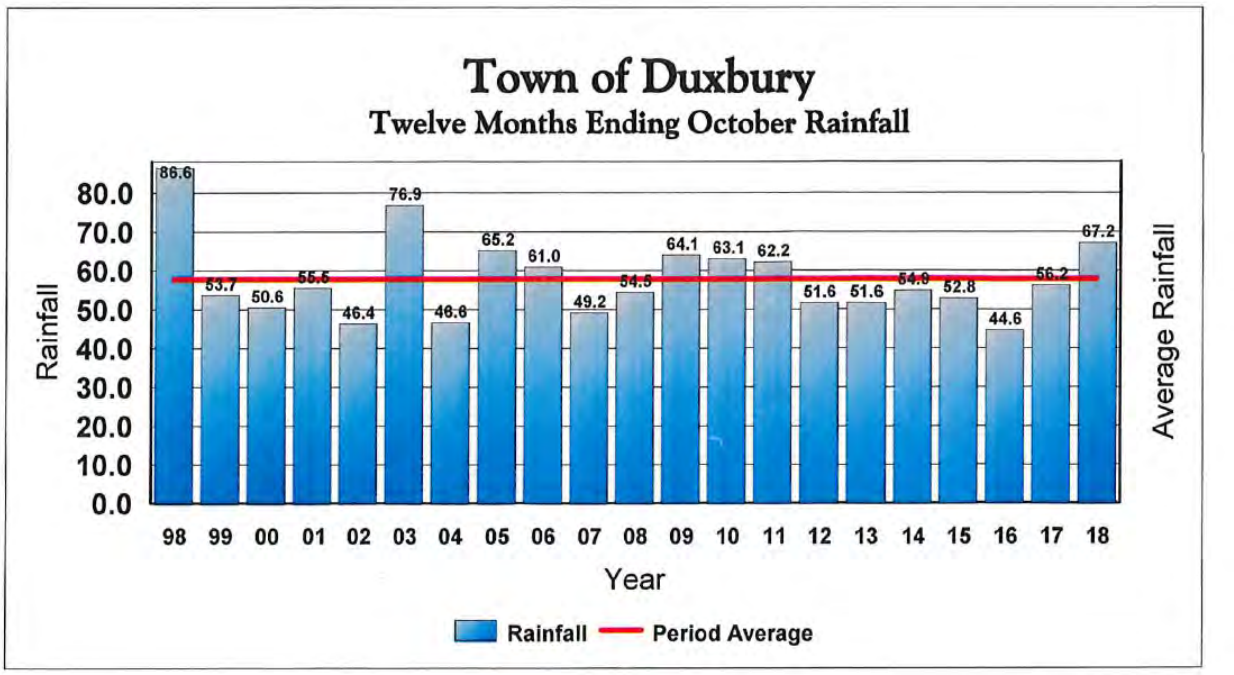
Extreme Precipitation

In the last 50 years, precipitation in the Northeast US increased 71% in the amount of rain that falls in the top 1% of storm events.[30] Locally the Town of Duxbury receives approximately 57.8

[25] Bosma, K., Douglas, E., Kirshen, P., McArthur, K., and Miller, S. MassDOT-FHWA Pilot Project Report. Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options for the Central Artery. June 2015.
[26] Northeast Climate Science Center. UMass Amherst. Massachusetts Climate Change Projections. December 2017.
[27] Douglas, E.M., Kirshen, P.H., Bosma, K., et al. 2017. Simulating the Impacts and Assessing the Vulnerability of the Central Artery/Tunnel System to Sea level Rise and Increased Coastal Flooding. J Extreme Events 3 (4): 1650013 (28 pages).
[28] *"Sea Level Rise Study. The Towns of Marshfield, Duxbury, Scituate, MA". 2013. Kleinfelder.*
[29] Northeast Climate Science Center. UMass Amherst. "Massachusetts Climate Change Projections". December 2017

inches of rainfall annually based on measurements collected from the Duxbury Water Department from 1998-2018 (**Figure 23**) with 1998 and 2003 being the years with the greatest amount of precipitation.

Figure 23 Duxbury Water Department Rainfall Data 1998-2018



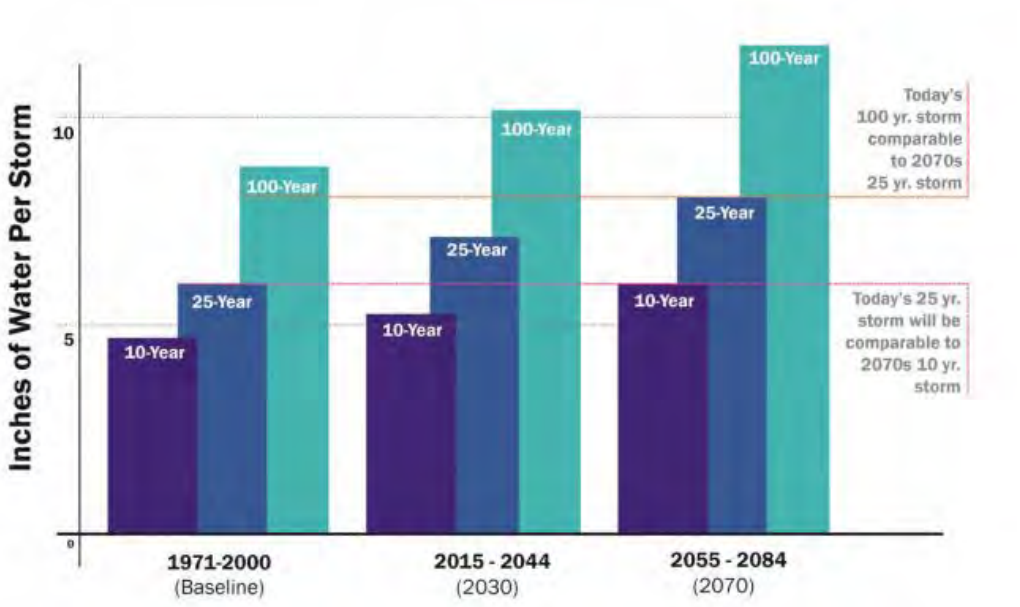
Projections for future Northeastern US precipitation suggest an increase in total precipitation, changes in precipitation patterns, and increased frequency of extreme storms such as hurricanes and nor'easters. Local precipitation projection models indicate that the frequency of these events and the amount of precipitation occurring during these events is likely to increase. For example, a 100-year storm is defined as a storm that would have a 1% chance of occurring in any given year. Historically this could create 8.9 inches of rain, but models project that amount could increase to 10 inches of rain by 2044 and 11.7 inches of rain by 2084 (
Figure **24**).[31,32]

[30] Horton, R., G. Yohe, W. Easterling, R. Kates, M. Ruth, E. Sussman, A. Whelchel, D. Wolfe, and F. Lipschultz, 2014: Ch. 16: Northeast. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 16-1-nn.

[31] City of Cambridge, *Climate Change Vulnerability Assessment*, (City of Cambridge, 2015), Temperature and Precipitation Projections (http://www.cambridgema.gov/CDD/Projects/Climate/~/media/A9D382B8C49F4944BF64776F88B68D7A.ashx)

[32] Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston," June 2016

Figure 24 Precipitation Projects and Storm Frequency



Precipitation projections. Modeling from Kleinfelder and ATMOS indicates more rain in any given storm event above the baseline into the end of the century. Source: Cambridge Climate Vulnerability Assessment 2015. Kleinfelder based on ATMOS projections November 2015

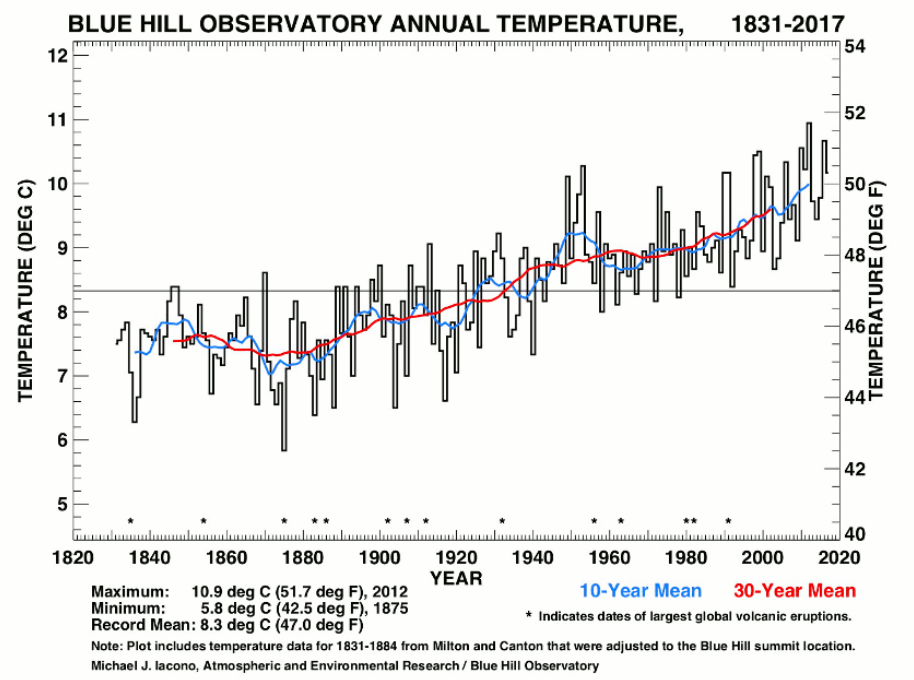
The actual amount of increased precipitation and number of extreme weather events per year is difficult to project into the future. The Northeast Climate Science Center reports an anticipated increase in rainfall for Massachusetts in the spring and winter months, and their climate projection models suggest that the frequency of high-intensity rainfall events will also increase. Consequently, warming temperatures can cause greater evaporation in the summer and fall, as well as earlier snowmelt, leading to periods of either drought or extreme snowfall. The Northeast Climate Science Center projects a small decrease in average summer precipitation into the century; this combined with projected higher temperatures could increase the frequency of episodic droughts and decrease stream flow during the summer. Finally, scientists anticipate the Boston region will continue to experience significant snow events through 2100, though at this time, winter precipitation will be more rain than snow due projected warmer winters. [33]

Extreme Heat

According to the National Ocean and Atmospheric Administration and NASA, 2017 was the second warmest year on record and according to the EPA's US Climate Change Indicators report, the period from 2006-2015 was the warmest decade since temperature has been measured.[34,35] Data from the Blue Hill Observatory in Milton (Figure 25) located 30 miles from

[33] Northeast Climate Science Center. UMass Amherst. Massachusetts Climate Change Projections. December 2017
[34] https://www.washingtonpost.com/news/energy-environment/wp/2018/01/18/2017-was-among-the-planets-hottest-years-on-record-government-scientists-report/?utm_term=.77bff825293d
[35] U.S. Environmental Protection Agency. 2016. Climate Change Indicators in the United States, 2016. Fourth meditation. EPA 430-R-16-004. www.epa/gov/climate-indicators.

Figure 25 Observed Temperature Change



Duxbury, reflects this trend. Future temperature projections for the Northeast indicate an increasing likelihood of heat waves, measured by the likely number of days over 90 and 100. The South Coastal Basin, where Duxbury lies, may be cooler than other inland or dense urban areas in the Commonwealth due to the presence of offshore winds and this is demonstrated by differences in temperature projections. The South Coastal Basin could experience 8-13 days over 90° by 2030 and 9-57 days over 90° by the end of the century. Metro Boston may experience 20-40 days over 90° by 2030 and 90 days over 90° by the end of the century. In addition to warming summer temperatures, winters are already warming and scientists project that to nontinue by an increase of 2°- 6° in 2030 and an increase of 4°-12° by the end of the century.[36]

Even small changes in temperatures can have a dramatic effect, such as changing precipitation patterns and extending the growing season. The implications of warmer winters and summers are a shift in the growing season and freeze/thaw cycle for the northeast. The Northeast has already seen a significant deviation from the long-term average growing season beginning in the late 1980s with nearly 10 days longer growing season.[37] Future projected warming translates into a climate similar to North Carolina and Virginia in the mid-century or to Alabama toward the end of the century.[38] These shifts in temperature will have an important effect on food production, natural systems, species and vector borne disease migration, and public health. In addition, they will affect energy use for heating and cooling.

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[36] Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston," June 2016

[37] U.S. Environmental Protection Agency. 2016. Climate Change Indicators in the United States, 2016. Fourth meditation. EPA 430-R-16-004. www.epa/gov/climate-indicators.

[38] Climate Ready Boston, "The Boston Research Advisory Group Report: Climate Change and Sea Level Rise Projections for Boston," June 201

Table 13 South Coastal Basin area (SC) projected increases in average temperature in degrees Fahrenheit.

	Baseline 1961–2010	2030	2050-2070	2090-2100
SC Annual Average	50˚	52˚-58˚	52˚-58˚	53˚-60˚
SC Winter Average	31˚	33˚-35˚	33˚-39˚	34˚-40˚
SC Summer Average	69˚	71˚-73˚	71˚-78˚	72˚-81˚

Source: Northeast Climate Science Center. UMass Amherst. Massachusetts Climate Change Projections. December 2017

LAND USE AND DEVELOPMENT TRENDS

Existing Land Use

The most recent land use statistics available from the state are from aerial photography done in 2005. Table 14 shows the acreage and percentage of land in 29 categories. Because the town has an extensive system of protected open space, forest makes up over 42% of land in Duxbury. If the five residential categories are aggregated, residential uses make up about 22% of the area of the town (3,361 acres). Commercial and industrial combined make up less than 1% of Duxbury, or 83 acres.

Table 14: 2005 Land Use

Land Use Type	Acres	Percent
Forest	6534.6	42.4%
Low Density Residential	2734.5	17.8%
Forested Wetland	1521.6	9.9%
Saltwater Wetland	1041.1	6.8%
Non-Forested Wetland	634.4	4.1%
Very Low Density Residential	515.4	3.3%
Cranberry Bog	487.5	3.2%
Water	402.1	2.6%
Saltwater Sandy Beach	280.8	1.8%
Golf Course	177.2	1.2%
Transportation	175.8	1.1%
Urban Public/Institutional	170.1	1.1%
Pasture	121.0	0.8%
Multi-Family Residential	105.1	0.7%
Cropland	91.8	0.6%
Powerline/Utility	79.8	0.5%
Commercial	79.6	0.5%
Participation Recreation	77.0	0.5%
Open Land	68.6	0.4%
Brushland/Successional	23.8	0.2%
Cemetery	23.6	0.2%
Nursery	14.7	0.1%
Waste Disposal	12.0	0.1%

Land Use Type	Acres	Percent
Transitional	10.0	0.1%
Marina	7.6	0.0%
High Density Residential	5.1	0.0%
Industrial	3.3	0.0%
Water-Based Recreation	1.2	0.0%
Medium Density Residential	1.0	0.0%

Source: MassGIS

Economic Elements

The Town of Duxbury has multiple neighborhood business districts, though commercial uses make up only about 0.5% of the municipality's land area. Hall's Corner is Duxbury's main commercial area, and it contains a mixture of retail stores (including the Foodie's grocery store), dining options, and offices. Other smaller commercial areas include Snug Harbor, Cox Corner, Millbrook Landing, Bennett's Area, and Kings Town Way. Of all the neighborhood business districts, Snug Harbor is most impacted by flooding and will be most susceptible to the impacts of sea level rise.

Historic, Cultural, and Natural Resource Areas

Duxbury has a plethora of historic, cultural, and natural resource areas that give the town its unique character. The second municipality to be incorporated in Massachusetts (in 1637), Duxbury has many historic homes like the John Alden House and King Caesar House. Most of the buildings with historical significance were built during the Shipbuilding Era (late 1700s to mid-1800s) and Summer Tourism Era (mid-1800s to mid-1900s).

Duxbury, the second municipality to be incorporated in Massachusetts in 1637, is rich with cultural assets contributing significant culture and beauty to the Town. Duxbury has 792 historic assets registered in the Massachusetts Historic Structures Inventory, the earliest dating to 1632, the Myles Standish (Chestnut Street) burial ground and many first period colonial homes such as the 1700 John Alden House. Other notable historic assets beloved by the community and visitors alike are Snug Harbor, Powder Point Bridge, the Girl Scout House, the King Caesar House, the Nathaniel Winsor, Jr. House and the Bradford House. The iconic Powder Point Bridge was built in 1891, about 30 years before local families came together to purchase Duxbury Beach and protect it from development pressure.

Duxbury has the Duxbury Rural & Historical Society, a local non-profit located at the historic Nathaniel Winsor, Jr. house, which maintains four historic properties, archival library, museum collections, and 150 acres of conservation land. The society runs approximately 70 programs, events, and rentals a year and reported that 2017 was its most successful year to date.[39] The Town also has a Historical Commission, established in 1975, to "Identify, document, and protect,

[39] http://duxburyhistory.org/about-us-2/

Duxbury's historic resources, to increase public awareness of Duxbury's heritage and the value of historic preservation." The Historical Commission also oversees the Demolition Delay Bylaw for any structure over 75 years old. [83] Since 2002, the Town of Duxbury has approved and implemented 23 historic preservation projects using Community Preservation Act funds. The Town's Local Historic District Commission has been actively adding single-parcel Local Historic Districts in 2016, 2017 and 2018, with more planned for 2019. There is demonstrated community value to Duxbury's historic and cultural assets and these are important to consider in future planning, growth, and natural hazard mitigation/ climate change resilience.[40]

Duxbury is a coastal community shaped by its extensive natural assets that define the values and cultural richness of the Town. With 37 miles of tidal shoreline, 1,200 acres of salt marshes, over 3,500 acres of protected open space, and prime forest land, Duxbury is well-served by the ecological services and resilience these natural features provide. Intact natural systems support clean drinking water, clean air, important agricultural and recreation amenities, flood control, beautification, economic benefits and carbon sequestration. Since 1963, Duxbury has been aggressive in acquiring and protecting land for its drinking water[41] and this effort has restored many endangered and sensitive wildlife habitats. Some conservation lands include North Hill Marsh & Wildlife Sanctuary, Lansing Bennett Forest, and cranberry bogs.

The Town contains 10,356 acres of BioMap2 Core Habitat and Critical Natural Landscape and nearly 70% of that total area is protected.[42] BioMap2 is a program created by the MA Department of Fish and Game Natural Heritage and Endangered Species Program (NHESP) and The Nature Conservancy to map important natural resource areas that will protect biodiversity and the nature of Massachusetts in the face of climate change. The large expanse of intact natural lands, ensures strong ecosystem function to protect the community from the impacts of climate change. These areas also support 17 rare, endangered or threatened wildlife species or natural communities. This includes the over 200 acres along 4 miles of coastal, sandy dunes on Duxbury Beach owned by the Duxbury Beach Reservation, Inc. who manages the Endangered Species Program for the Piping Plover, Least Tern, and others. Core Habitats are areas required to sustain rare wildlife and their exemplary natural ecosystems and habitat. Critical Natural Landscape describes areas that support these exemplary ecosystems or habitats to endure stressors from climate change or development.

Development Trends

A low density suburb approaching buildout, Duxbury's population grew dramatically between 1960 and 1990, largely due to the completion of Route 3 in 1963. Little developable land remains in Duxbury today as a great deal of the open space in town has been permanently protected and one-acre zoning prevents much growth from occurring. New growth in Duxbury is primarily limited to teardowns and redevelopment.

Development trends throughout the metropolitan region are tracked by MAPC's Development Database "MassBuilds," which provides an inventory of new development over the last decade.

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[40] MAPC.2018 Duxbury Climate Vulnerability Assessment and Action Plan
[41] Duxbury Conservation Commission. 2017. *Duxbury Open Space and Recreation Plan.*
[42] Natural Heritage and Endangered Species Program. Conserving the Biodiversity of Massachusetts in a Changing World- Duxbury. 2012. http://maps.massgis.state.ma.us/dfg/biomap/pdf/town_core/Duxbury.pdf

The database tracks both completed developments and those currently under construction. The developments listed in this database, plus others that have been provided by Duxbury's Planning Director, are shown in Table 15. Since 2009, over 400 housing units and 36,000 square feet of commercial space has been constructed, approved, or under review.

Table 15: Summary of New and Pending Developments in Duxbury, 2009-2018

Developments Completed (Year Completed)	Housing Units	Commercial Square Feet	Project Type
Island Creek Village (2017)	238	0	40B project with multifamily housing, both affordable and market rate
Duxbury Woods (2015)	40	0	Luxury townhouses
Duxbury Farms (2015)	20	0	Single family homes
Duxbury Estates (2015)	44	0	Small multifamily condo units, age-restricted
Duxbury Maritime School (2009)	0	27,000	DBMS campus with classrooms, offices, and sailing programs – redevelopment planned to older portions of building
Duxbury Yacht Club (2009)	0	9,300	Expansion of Yacht Club for warehouse and shipping
Developments in Planning/ Construction	**Housing Units**	**Commercial Square Feet**	**Project Type**
Freeman Farms (in construction)	17	0	Single family homes
Nash Road (in construction)	5	0	Single family homes
Webster Point (approved)	20	0	40B project with multifamily housing, both affordable and market rate
Feinberg Bog (approved)	6	0	Townhouse condos, half are affordable
Dogwood Drive (approved)	10	0	Single family homes
The Paddock (approved)	5	0	Single family homes; 5 are new
Total	**405**	**36,300**	

Potential Future Development

MAPC consulted with municipal planning staff to determine areas that may be developed in the future, based on the Town's comprehensive planning efforts and current trends and projects. These areas are described below:

- **Kingston Way (B)** - Possible expansion of a family-owned commercial turkey processor.
- **Railroad Avenue and Alden Street (I)** - Possible redevelopment location but no applications have been filed to date.
- **Island Creek Oysters (K)** - No new construction at this time but rezoned to commercial (formerly Battelle Laboratories); will reuse existing buildings for office and agricultural uses, including serving oysters at a raw bar.
- **Lincoln Street (L)** - 40B being bid out for development by the Duxbury Affordable Housing Trust (units TBD).

In order to characterize any change in the town's vulnerability associated with new developments, a GIS mapping analysis was conducted which overlaid the development sites in relation to natural hazards, including FEMA Flood Zones, Kleinfelder Sea Level Rise in 2038, and Locally Identified Hazards such as Brush Fires, Local Flooding, and Other Hazards. The analysis shows that four sites are located in flood zones, two are located in areas locally identified for brush fires, and one is located vulnerable to sea level rise in 2038. All of the developments are in the areas defined as "Low Landslide Incidence." Other hazards are categorized at the same level throughout town. For snowfall, all of Duxbury is in the zone of 36 to 48 inches average annual snowfall. With respect to wind, there is no variation across all sites; the hazard map depicts the entire town of Duxbury with a 100-year wind speed of 120 miles per hour (See hazard maps in Appendix B).

Table 16 shows the relationship of these parcels to the aforementioned hazards. This information is provided so that planners can ensure that development proposals comply with flood plain zoning and that careful attention is paid to drainage issues.

Table 16: Relationship of Potential Development to Hazard Areas

Map ID	Development	type	Locally ID Hazard	FEMA	SLR 2038
A	30 Tremont Street Island Creek Village	Development	--	A	--
B	Kingston Way	Development	Brush Fire		--
C	McLean's Way	Development	--	--	--
D	Littleton Way	Development	Brush Fire	A	--
E	Brewster Commons	Development	--	--	--
F	Lincoln Street	Development	--	--	--
G	Island Creek Oysters	Development	--	A, AE	Yes
H	Freeman Farm	Development	--	A	--
I	Railroad Ave., Alden and St. George streets	Development	--	--	--
J	Webster Point Village	Development	--	--	--

CRITICAL INFRASTRUCTURE IN HAZARD AREAS

Critical infrastructure includes facilities that are important for disaster response and evacuation (such as emergency operations centers, fire stations, water pump stations, etc.) and facilities where additional assistance might be needed during an emergency (such as nursing homes, elderly housing, day care centers, etc.). There are 53 facilities identified in Duxbury. Twelve of these facilities are located in brush fire areas, none are located in a FEMA flood zone or sea level rise in 2038. Two facilities are susceptible to hurricane storm surge. These are listed in Table 17 and are shown on the maps in Appendix B.

Explanation of Columns in Table 17

Column 1: ID #: The first column is an ID number which appears on the maps that are part of this plan. See Appendix B.
Column 2: Name: The second column is the name of the site.
Column 3: Type: The third column indicates what type of site it is.
Column 4: FEMA Flood Zone: This column addresses the risk of flooding based upon historic and potential current flooding according to the FEMA Flood Insurance Rate Maps (FIRM maps). If there is an entry in this column, it indicates the type of flood zone as follows:
Zone AE (1% annual chance) - Zones AE is the flood insurance rate zone that correspond to the 100-year floodplains that are determined in the FIS by detailed methods. In most instances, BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply.
Zone AO (1% chance zone) Areas subject to inundation by 1-percent-annual-chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between one and three feet. Average flood depths derived from detailed hydraulic analyses are shown in this zone. Mandatory flood insurance purchase requirements and floodplain management standards apply.
Zone VE (1% annual chance) - Zone VE is the flood insurance rate zone that corresponds to the 100-year coastal floodplains that have additional hazards associated with storm waves. BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply.
Column 5: Sea Level Rise 2038. This column illustrates future flooding associated with sea level rise in 2038 as modeled by Kleinfelder 2013, using the NOAA Technical Report *Global Sea Level Rise Scenarios for the United States National Climate Assessment* (December 2012)
Column 6: Locally-Identified Hazard: The locally identified hazard areas were identified by Local Steering Committee as areas where flooding, brush fires, or other hazards occur. These areas do not necessarily coincide with the flood zones from the FIRM maps. They may be areas that flood due to inadequate drainage systems or other local conditions rather than location within a flood zone. The numbers correspond to the numbers on Map 8, "Hazard Areas."
Column 7: Hurricane Surge Category: The seventh column indicates whether or not the site is located within a hurricane surge area and the category of hurricane estimated to be necessary to cause inundation of the area. The following explanation of hurricane surge areas was taken from the US Army Corps of Engineers web site: "Hurricane storm surge is an abnormal rise in sea level accompanying a hurricane or other intense storm. Along a coastline a hurricane will cause waves on top of the surge. Hurricane Surge is estimated with the use of a computer model called SLOSH. SLOSH stands for Sea Lake and Overland Surge from Hurricanes. The SLOSH models are created and run by the National Hurricane Center. The SLOSH model results are merged with ground elevation data to determine areas that will be subject to flooding from various categories of hurricanes. Hurricane categories are defined by the Saffir-Simpson Scale." See http://www.sam.usace.army.mil/hesdata/General/hestasks.htm. According to the Saffir-Simpson Scale, the least damaging storm is a Category 1 (winds of 74-95 miles per hour) and the most damaging storm is a Category 5 (winds greater than 155 miles per hour).

Table 17 Duxbury Critical Infrastructure and Natural Hazards

Map ID	NAME	TYPE	FEMA Flood Zone	SLR 2038	Locally ID Hazard	Hurricane Surge
1	Bay Farm Montessori Academy	School	--	--	--	--
2	Good Shepherd Christian Academy	School	--	--	--	--
3	Chandler Elementary School	School	--	--	--	--
4	Alden School	School	--	--	--	Cat 4
5	Duxbury Middle School	School	--	--	--	--
6	Duxbury High School	School	--	--	--	--
7	Fire Department	Fire Station	--	--	--	--
8	Fire Department Sta. 2	Fire Station	--	--	--	--
9	Animal Shelter	Municipal	--	--	--	--
10	Sand/Salt Shed	Municipal	--	--	--	--
11	Salt Shed	Municipal	--	--	--	--
12	Salt Shed	Municipal	--	--	--	--
13	First Parish	Church	--	--	--	--
14	Town Hall	Municipal	--	--	--	--
15	DPW	Municipal	--	--	--	--
16	Selectmen's Office	Municipal	--	--	--	--
17	DPW Barn	Municipal	--	--	--	--
18	Mayflower Crematory	Crematory	--	--	Brush Fire--	--
19	Mayflower Cemetery	Cemetery	--	--	--	--
20	Transfer Station	Municipal	--	--	--	--
21	Council on Aging	Senior Center	--	--	Brush Fire--	--
22	Holy Family Church	Church	--	--	--	--
23	Mayflower 1 Well	Well	--	--	Brush Fire	--
24	Mayflower 2 Well	Well	--	--	Brush Fire	--
25	Police Station	Police Station	--	--	--	--
26	Duxbury Free Public Library	Municipal	--	--	--	--
27	Birch Street Water Storage Tank	Water Storage Tank	--	--	--	--
28	Police Repeater	Communication Tower	--	--	Brush Fire	--
29	Captain Hill Stand pipe	Water Stand Pipe	--	--	Brush Fire	--

Map ID	NAME	TYPE	FEMA Flood Zone	SLR 2038	Locally ID Hazard	Hurricane Surge
30	Scada Antenna	Communication Tower	--	--	Brush Fire	--
31	Society of Devine Word	Church	--	--	Brush Fire	--
32	Bay Path Nursing Home	Elder Housing	--	--	--	--
33	Village at Duxbury	Elder Housing	--	--	Brush Fire	--
34	Duxbury House	Special Needs	--	--	--	--
35	Mass Highway DPW Barn District 5	Municipal	--	--	--	--
36	Berry Brook School	School	--	--	Brush Fire	--
37	Pied Piper Pre-School	Child Care	--	--	--	--
38	High Street United Methodist Church	Church	--	--	--	--
39	Learn and Play Pre-School	Child Care	--	--	--	--
40	Pilgrim Child Care	Child Care	--	--	--	--
41	Pilgrim Church	Church	--	--	--	--
42	Ellison Center for the Arts Pre-School	Child Care	--	--	--	--
43	Depot Street Water Pump Station	Water Pump Station	--	--	Brush Fire	--
44	Partridge Road Pump Station	Water Pump Station	--	--	--	--
45	Evergreen 1 Water Pump Station	Water Pump Station	--	--	--	--
46	Evergreen 2 Water Pump Station	Water Pump Station	--	--	--	--
47	Tremont 2 Water Pump Station	Water Pump Station	--	--	--	--
48	Tremont 1 Water Pump Station	Water Pump Station	--	--	--	--
49	Lake Shore Drive Water Pump Station	Water Pump Station	--	--	--	--
50	Snug Harbor Shared Septic	Shared Septic	--	--	Brush Fire--	--
51	Lovers Lane Shared Septic	Shared Septic	--	Yes	--	--
52	Long Point Marine	Marina	AE	Yes	--	Cat 1
53	Powder Point Bridge	Bridge	VE	Yes	--	--

54	Blue Fish Shared Septic	Shared Septic	AE	Yes	--	Cat 1,2,3

VULNERABILITY ASSESSMENT

The purpose of the vulnerability assessment is to estimate the extent of potential damages from natural hazards of varying types and intensities. A vulnerability assessment and estimation of damages was performed for hurricanes, earthquakes, and flooding. The methodology used for hurricanes and earthquakes was the HAZUS-MH software. The methodology for flooding was developed specifically to address the issue in many of the communities where flooding was not solely related to location within a floodplain.

Introduction to HAZUS-MH

HAZUS- MH (multiple-hazards) is a computer program developed by FEMA to estimate losses due to a variety of natural hazards. The following overview of HAZUS-MH is taken from the FEMA website. For more information on the HAZUS-MH software, go to http://www.fema.gov/plan/prevent/hazus/index.shtm

> "HAZUS-MH is a nationally applicable standardized methodology and software program that contains models for estimating potential losses from earthquakes, floods, and hurricane winds. HAZUS-MH was developed by the Federal Emergency Management Agency (FEMA) under contract with the National Institute of Building Sciences (NIBS). Loss estimates produced by HAZUS-MH are based on current scientific and engineering knowledge of the effects of hurricane winds, floods and earthquakes. Estimating losses is essential to decision-making at all levels of government, providing a basis for developing and evaluating mitigation plans and policies as well as emergency preparedness, response and recovery planning.
>
> HAZUS-MH uses state-of-the-art geographic information system (GIS) software to map and display hazard data and the results of damage and economic loss estimates for buildings and infrastructure. It also allows users to estimate the impacts of hurricane winds, floods and earthquakes on populations."

There are three modules included with the HAZUS-MH software: hurricane wind, flooding, and earthquakes. There are also three levels at which HAZUS-MH can be run. Level 1 uses national baseline data and is the quickest way to begin the risk assessment process. The analysis that follows was completed using Level 1 data. Level 1 relies upon default data on building types, utilities, transportation, etc. from national databases as well as census data. While the databases include a wealth of information on the Town of Duxbury, it does not capture all relevant information. In fact, the HAZUS training manual notes that the default data is "subject to a great deal of uncertainty."

However, for the purposes of this plan, the analysis is useful. This plan is attempting to generally indicate the possible extent of damages due to certain types of natural disasters and to allow for a comparison between different types of disasters. Therefore, this analysis should be considered to be a starting point for understanding potential damages from the hazards.

Estimated Damages from Hurricanes

The HAZUS-MH software was used to model potential damages to the community from a 100-year and 500-year hurricane event; storms that are 1% and 0.2% likely to happen in a given year, and roughly equivalent to a Category 2 and Category 4 hurricane. The damages caused by these hypothetical storms were modeled as if the storm track passed directly through the town, bringing the strongest winds and greatest damage potential.

Though there are no recorded instances of a hurricane equivalent to a 500-year storm passing through Massachusetts, this model was included in order to present a reasonable "worst case scenario" that would help planners and emergency personnel evaluate the impacts of storms that might be more likely in the future, as we enter into a period of more intense and frequent storms.

Table 18: Estimated Damages from Hurricanes

	100-Year	500-Year
Building Characteristics		
Estimated total number of buildings	5,932	
Estimated total building replacement value (2014 $)	$2,341,000,000	
Building Damages		
# of buildings sustaining minor damage	674	1,776
# of buildings sustaining moderate damage	80	532
# of buildings sustaining severe damage	4	91
# of buildings destroyed	4	69
Population Needs		
# of households displaced	0	28
# of people seeking public shelter	0	15
Debris		
Building debris generated (tons)	1,816	8,988
Tree debris generated (tons)	3,886	8,646
# of truckloads to clear building debris	72	359
Value of Damages		
Total property damage (buildings and content)	$38,299,980	$1,162,776,540
Total losses due to business interruption	$1,687,830	$14,632,600

Estimated Damages from Earthquakes

The HAZUS-MH earthquake module allows users to define an earthquake magnitude and model the potential damages caused by that earthquake as if its epicenter had been at the geographic center of the study area. For the purposes of this plan, two earthquakes were selected: magnitude 5.0 and a magnitude 7.0. Historically, major earthquakes are rare in New England, though a magnitude 5 event occurred in 1963.

Table 19: Estimated Damages from Earthquakes

	Magnitude 5.0	Magnitude 7.0
Building Characteristics		
Estimated total number of buildings	5,932	
Estimated total building replacement value (2014 $)	$2,341,000,000	
Building Damages		
# of buildings sustaining slight damage	1,747	237
# of buildings sustaining moderate damage	877	1,415
# of buildings sustaining extensive damage	215	1,799
# of buildings completely damaged	51	2,463
Population Needs		
# of households displaced	93	2,282
# of people seeking public shelter	49	1,184
Debris		
Building debris generated (tons)	40,000	340,000
# of truckloads to clear debris (@ 25 tons/truck)	1,480	13,760
Value of Damages		
Total property damage	$232,170,000	$2,093,300,000
Total losses due to business interruption	$38,740,000	$251,196,000

Estimated Damages from Riverine and Coastal Flooding

The HAZUS-MH flood risk module was used to estimate damages to the municipality at the 100 and 500 return periods. These return periods correspond to flooding events that have a 1% and a 0.2% likelihood of occurring in any given year.

Table 20: Estimated Damages from Flooding

	100-Year	500-Year
Building Characteristics		
Estimated total number of buildings	5,932	
Estimated total building replacement value	$2,854,000,000	
Building Damages		
# of buildings sustaining slight damage (<10%)	15	9
# of buildings sustaining moderate damage (10-50%)	22	22
# of buildings sustaining substantial damage (>50%)	0	1
Population Needs		
# of households displaced	11	16
# of people seeking public shelter	536	648
Value of Damages		
Total property damage (buildings and content)	$20,660,000	$22,860,000
Total losses due to business interruption	$17,380,000	$14,440,000

IV. HAZARD MITIGATION GOALS

The Duxbury Local Hazard Mitigation Planning Team determined the following goals for this Hazard Mitigation Plan and approved them at a meeting on March 27, 2018. All of the goals are reflective of the Town's priorities and concerns relative to natural hazard mitigation. They are all considered critical for the Town and they are not listed in order of importance.

Goal 1: Prevent and reduce the loss of life, injury, public health impacts and property damages resulting from all major natural hazards.

Goal 2: Identify and seek funding for measures to mitigate or eliminate each known significant flood hazard area.

Goal 3: Integrate hazard mitigation planning as an integral factor in all relevant municipal departments, committees and boards.

Goal 4: Prevent and reduce the damage to public infrastructure resulting from all hazards.

Goal 5: Encourage the business community, major institutions and non-profits to work with the Town to develop, review and implement the hazard mitigation plan.

Goal 6: Work with surrounding communities, state, regional and federal agencies to ensure regional cooperation and solutions for hazards affecting multiple communities.

Goal 7: Ensure that future development meets federal, state and local standards for preventing and reducing the impacts of natural hazards.

Goal 8: Take maximum advantage of resources from FEMA and MEMA to educate Town staff and the public about hazard mitigation.

Goal 9: Consider the potential impacts of climate change and incorporate climate mitigation and resilience in all planning efforts.

V. EXISTING MITIGATION MEASURES

The existing protections in the Town of Duxbury are a combination of zoning, land use, and environmental regulations, public education, infrastructure maintenance and infrastructure improvement projects. Infrastructure maintenance generally addresses localized drainage clogging problems, or seawall/revetment/dune repairs, while large scale capacity problems may require pipe replacement, invert elevation modifications, utility and road elevation, or large scale seawall/revetment improvements and replacements. These more expensive projects are subject to the capital budget process and lack of funding is one of the biggest obstacles to completion of some of these. The existing mitigation measures in the Town of Duxbury are described below and summarized in Table 21 below.

FLOOD-RELATED MITIGATION MEASURES

Duxbury employs a number of practices to help minimize potential flooding and impacts from flooding, and to maintain existing drainage infrastructure. Existing town-wide mitigation measures include the following:

National Flood Insurance Program (NFIP) – Duxbury participates in the NFIP with 286 policies in force as of March 31, 2018. FEMA maintains a database on flood insurance policies and claims that can be found on FEMA's website at https://bsa.nfipstat.fema.gov/reports/1011.htm.

The following information is provided for the Town of Duxbury:

Flood insurance policies in force (as of March 31, 2018)	286
Coverage amount of flood insurance policies	$81,681,900
Premiums paid	$407,432
Total losses (all losses submitted regardless of the status)	460
Closed losses (Losses that have been paid)	355
Open losses (Losses that have not been paid in full)	37
CWOP losses (Losses that have been closed without payment)	68
Total payments (Total amount paid on losses)	$5,825,080

The Town complies with the NFIP by enforcing floodplain regulations, maintaining up-to-date floodplain maps, and providing information to property owners and builders regarding floodplain and building requirements.

Public Works Operations/Maintenance Activities – The Public Works Department actively maintains the Duxbury's storm drain system. The following specific activities serve to maintain the capability of the drainage system through the reduction of sediment and litter build up and proper maintenance and repair.

- *Street sweeping* – The town streets are swept two to three times per year. Other downtown areas such as the main business district can be swept more frequently as needed from May through September. Poor draining streets can also be swept as needed following rainstorms.

- *Catch basin cleaning* – The Town of Duxbury contracts to have catch basin cleaning done each year, with all catch basins in town being cleaned each year.
- *Roadway treatments* – The Town uses a mixture of one part sand to one part salt for de-icing purposes to minimize the amount of sand that enters catch basins and streams.
- *Other* – Continued repair and rehabilitation of check valves and back-flow preventers.

Public Safety – the town recently acquired a high water rescue truck from a military surplus in January of 2018 to facilitate rescues and responses during flood emergencies.

Zoning Regulations – The Town's zoning regulations include a section on Subdivisions Rules and Regulations, which contain a number of requirements that address flood hazard mitigation. Some of these provisions also relate to other hazards. The zoning by-law also includes provisions for Flood Hazard Areas, Ground Water Protection Districts, Site Plan Approval, and Open Space Requirements.

Wetlands Protection Act – Duxbury enforces the State Wetlands Protection Act through the permitting authority of the Conservation Commission. Enforcement of the Act serves to protect the Town's shores, ponds, rivers, and wetlands for, among other reasons, flood control, erosion and sedimentation control, and storm damage prevention. It also prevents any new development in a VE Zone.

Living Shoreline capital improvements on Duxbury Beach. Since its creation, the Duxbury Beach Reservation, Inc has worked with the Town of Duxbury to restore, maintain, and steward the coastal sandy barrier beach/dune habitat along Duxbury beach. These include large scale sacrificial dunes and beach nourishment projects over the last several decades.

DAM FAILURE MITIGATION MEASURES

DCR dam safety regulations – All dams are subject to the Division of Conservation and Recreation's dam safety regulations. The dams must be inspected regularly and reports filed with the DCR Office of Dam Safety.

Permits required for construction – State law requires a permit for the construction of any dam.

The Comprehensive Emergency Management Plan – The CEMP addresses dam safety.

WIND HAZARD MITIGATION MEASURES

Massachusetts State Building Code – The town enforces the Massachusetts State Building Code whose provisions are generally adequate enough to mitigate most wind damage. The code's provisions are the most cost-effective mitigation measure against tornados given the extremely low probability of occurrence. If a tornado were to occur, the potential for severe damages would be extremely high.

Tree-Trimming– Duxbury's Land and Natural Resources Department within the Department of Public Works and Tree Warden conducts tree trimming where necessary. It also responds to

downed tree limbs caused by winds, lightning strike reports and other weather related incidents. The local electric company, Eversource, conducts regular tree trimming.

WINTER-RELATED HAZARD MITIGATION MEASURES

Snow disposal – The town does not do any snow disposal except for removing snow at the library.

Roadway Treatments – The town uses a mixture of sand and salt with a bit more salt in the mix. This is done to minimize the amount of sand that enters catch basins and streams.

FIRE-RELATED HAZARD MITIGATION MEASURES

Burn Permits – Duxbury Fire Department requires a written permit for outdoor burning, which includes explanation of the related regulations and precautions for the permit-holder to take. The permit-holder must call the fire department on the proposed burn day to confirm weather conditions are suitable for outdoor burning.

Subdivision/Development Review – The Fire Department participates in the review of new subdivisions and development projects.

Forest Fire Response- The Duxbury Fire Department has three vehicles to manage forest fires. These include two Maxim Brush Breaker Vehicles that carry 750 gallons of water with gasoline-powered pumps and fire hoses. They also have a Ford F550 Brat that was obtained by a federal grant in 2015 that has a 300 gallon water tank with a pump in order to fit in tight areas to fight forest fires.

GEOLOGIC HAZARD MITIGATION MEASURES

Massachusetts State Building Code – The State Building Code contains a section on designing for earthquake loads (780 CMR 1612.0). Section 1612.1 states that the purpose of these provisions is "to minimize the hazard to life to occupants of all buildings and non-building structures, to increase the expected performance of higher occupancy structures as compared to ordinary structures, and to improve the capability of essential facilities to function during and after an earthquake". This section goes on to state that due to the complexity of seismic design, the criteria presented are the minimum considered to be "prudent and economically justified" for the protection of life safety. The code also states that absolute safety and prevention of damage, even in an earthquake event with a reasonable probability of occurrence, cannot be achieved economically for most buildings.

Section 1612.2.5 sets up seismic hazard exposure groups and assigns all buildings to one of these groups according to a Table 1612.2.5. Group II includes buildings which have a substantial public hazard due to occupancy or use and Group III are those buildings having essential facilities which are required for post-earthquake recovery, including fire, rescue and police stations, emergency rooms, power-generating facilities, and communications facilities.

MULTIHAZARD MITIGATION MEASURES

Comprehensive Emergency Management Plan (CEMP) – Every community in Massachusetts is required to have a Comprehensive Emergency Management Plan. These plans address mitigation, preparedness, response and recovery from a variety of natural and man-made emergencies. These plans contain important information regarding flooding, hurricanes, tornadoes, dam failures, earthquakes, and winter storms. Therefore, the CEMP is a mitigation measure that is relevant to all of the hazards discussed in this plan.

Communications Equipment – Duxbury has full coverage of the Town with emergency services radio. The Town is addressing compatibility issues that will allow for regional dispatch during emergency events. Incident command units are available through Plymouth County and MEMA.

Emergency Power Generators – The Town maintains emergency power generators for warming and cooling stations, shelters and critical public infrastructure (water well pumps, package wastewater treatment facilities, police and fire). Currently plowing and debris clearing to provide access is required in advance of hauling of individual portable generators to some water pumps and package plants, and additional generator needs have been identified in recent storm events, including lack of generators at Town Hall (which houses DPW, Facilities and the Town Manager).

Massachusetts State Building Code – The Massachusetts State Building Code contains many detailed regulations regarding wind loads, earthquake resistant design, flood-proofing, and snow loads.

Local and Regional Emergency Management–The Town of Duxbury has an Emergency Management Agency staffed by a Director and Deputy Director, located at the Fire Department. This agency oversees the implementation of the Comprehensive Emergency Management Plan for natural and man-made disasters. Duxbury also participates in the Pilgrim Area Local Emergency Planning Committee (or LEPC) with the neighboring Towns of Kingston and Marshfield.
This committee, comprised of public officials, specialists, media, and others collaborate on emergency management and coordinate with the local and state Emergency Management Agencies, police, and Boards of Health.

Public Information & Outreach – The Town provides information to residents and business owners relating to a range of potential natural hazards, most especially with regard to flooding, hurricanes, and nor'easters. They also participate in "Reverse 911" for emergency communication to residents through BlackBoard Connect and provide Town-wide email updates. The Duxbury Fire Department maintains an active Twitter Feed with a significant following, particularly during natural-hazard related emergencies that has been recognized the Commonwealth of Massachusetts Governor Baker. In addition, Duxbury maintains up to date flood information on its website, particularly as it is related to residents in flood zones.

Inter-Municipal Coordination and Cooperation – The Town of Duxbury is contributing up to $75,000 towards emergency repairs to the Canal Street Bridge (aka the "Rainbow Bridge) in Marshfield this year in order to maintain safe access for plows, fire trucks, school buses, and emergency response and repairs to the Gurnet/Saquish region of Duxbury, Marshfield and Plymouth. This bridge is located in Marshfield but is one of three failing bridges that provide access to this area, the other two being the Powder Point Bridge (failing – town will approach Town Meeting in 2019 to fund repairs and restoration, as it is limited to 4 tons) and the state-owned Beach Street Bridge in Marshfield slated for closure and repairs in 2019. The Town

actively participates in regional meetings with the CZM, Cape Cod region and MAPC South Shore communities to learn about mitigation activities in other towns and states, and to look for ways to cooperate regionally to help mitigate hazards described in this plan. Previous coordination has included modeling of sea level rise for zoning, planning and public education related to the same.

Table 21 Existing Natural Hazard Mitigation Measures in Duxbury

Summary of Existing Mitigation Measures
FLOOD HAZARD MITIGATION
The town participates in the NFIP and has adopted the effective FIRM maps. The town actively enforces the floodplain regulations.
Street Sweeping
Catch Basin Cleaning
Roadway Treatments
Enforcement of the State Building Code
Community Preservation Act
Infrastructure Improvements
Regulations, By-Laws and Plans (Flood Hazard Areas, Open Space Requirements, Drinking Water Protection Districts, Wetlands Bylaw, NPDES)
Living Shoreline Improvements-Sacrificial dunes, beach nourishment
DAM FAILURE HAZARD MITIGATION
DCR Dam Safety Regulations
State Permits Required for Dam Construction
Comprehensive Emergency Management Plan
WIND RELATED HAZARDS
Massachusetts State Building Code
Tree Trimming
WINTER RELATED HAZARDS
Snow Removal
Roadway Treatments
BRUSH FIRE RELATED HAZARDS
Permits Required for Outdoor Burning
Subdivision Review by Fire Department
Comprehensive Emergency Management Plan
Vehicles with Water Storage Tank to manage forest fires
GEOLOGIC/EARTHQUAKE HAZARDS
Massachusetts State Building Code
WINTER RELATED HAZARDS
Roadway Treatments
Snow Disposal (At Library)
MULTIPLE HAZARD MITIGATION
Comprehensive Emergency Management Plan
Radio Communications
Emergency Power Generators
Massachusetts Building Code
Local and Regional Emergency Management
Public Outreach-Blackboard Connect

Inter-municipal coordination and cooperation

MITIGATION CAPABILITIES AND LOCAL CAPACITY FOR IMPROVEMENTS

Under the Massachusetts system of "Home Rule," the Town of Duxbury is authorized to adopt and from time to time amend a number of local bylaws and regulations that support the town's capabilities to mitigate natural hazards. These include Zoning Bylaws, Subdivision and Site Plan Review Regulations, Wetlands Bylaws, Health Regulations, Public Works regulations, and local enforcement of the State Building Code. Local Bylaws may be amended each year at the annual Town Meeting to improve the town's capabilities, and changes to most regulations simply require a public hearing and a vote of the authorized board or commission. The Town of Duxbury has recognized several existing mitigation measures that require implementation or improvements, and has the capacity based on these Home Rule powers within its local boards and departments to address these.

Several departments including Planning, Building, Facilities Management, Public Works and Conservation will address the many planned infrastructure projects. New strategies including paving reduction and drought resistant planting will be stewarded by the Conservation Commission. Many projects, including public education, encouragement of building elevation, open space planning, and incorporating climate issues into capital and other planning documents will be jointly pursued by departments and town leadership.

Moving forward into the next five year plan implementation period there will be many more opportunities to incorporate hazard mitigation into the Town's decision making processes. The challenges the Town faces in implementing these measures are primarily due to limited funding and available staff time. This plan should help the Town prioritize the best use of its limited resources for enhanced mitigation of natural hazards.

VI. HAZARD MITIGATION STRATEGY

What is Hazard Mitigation?

Hazard mitigation means to permanently reduce or alleviate the losses of life, injuries and property resulting from natural hazards through long-term strategies. These long-term strategies include planning, policy changes, education programs, infrastructure projects and other activities. FEMA currently has three mitigation grant programs: the Hazards Mitigation Grant Program (HGMP), the Pre-Disaster Mitigation program (PDM), and the Flood Mitigation Assistance (FMA) program. The three links below provide additional information on these programs.

- https://www.fema.gov/hazard-mitigation-grant-program
- https://www.fema.gov/pre-disaster-mitigation-grant-program
- https://www.fema.gov/flood-mitigation-assistance-grant-program

Hazard Mitigation Measures can generally be sorted into the following groups:[43]

- Prevention: Government administrative or regulatory actions or processes that influence the way land and buildings are developed and built. These actions also include public activities to reduce hazard losses. Examples include planning and zoning, building codes, capital improvement programs, open space preservation, and stormwater management regulations.

- Property Protection: Actions that involve the modification of existing buildings or infrastructure to protect them from a hazard or removal from the hazard area. Examples include acquisition, elevation, relocation, structural retrofits, flood proofing, storm shutters, and shatter resistant glass.

- Public Education & Awareness: Actions to inform and educate citizens, elected officials, and property owners about the potential risks from hazards and potential ways to mitigate them. Such actions include outreach projects, real estate disclosure, hazard information centers, and school-age and adult education programs.

- Natural Resource Protection: Actions that, in addition to minimizing hazard losses also preserve or restore the functions of natural systems. These actions include sediment and erosion control, stream corridor restoration, watershed management, forest and vegetation management, and wetland restoration and preservation.

- Structural Projects: Actions that involve the construction of structures to reduce the impact of a hazard. Such structures include storm water controls (e.g., culverts), floodwalls, seawalls, retaining walls, and safe rooms.

- Emergency Services Protection: Actions that will protect emergency services before, during, and immediately after an occurrence. Examples of these actions include protection

[43] *FEMA Local Multi-Hazard Mitigation Planning Guidance*

of warning system capability, protection of critical facilities, and protection of emergency response infrastructure.

Introduction to Recommended Mitigation Measures

Description of the Mitigation Measure – The description of each mitigation measure is brief and cost information is given only if cost data were already available from the community. The cost data represent a point in time and would need to be adjusted for inflation and for any changes or refinements in the design of a particular mitigation measure.

Priority – As described above and summarized in Table 23, the designation of high, medium, or low priority was done considering potential benefits and estimated project costs, as well as other factors in the STAPLEE analysis.

Implementation Responsibility – The designation of implementation responsibility was done based on a general knowledge of what each municipal department is responsible for. It is likely that most mitigation measures will require that several departments work together and assigning staff is the sole responsibility of the governing body of each community.

Time Frame – The time frame was based on a combination of the priority for that measure, the complexity of the measure and whether or not the measure is conceptual, in design, or already designed and awaiting funding. Because the time frame for this plan is five years, the timing for all mitigation measures has been kept within this framework. The identification of a likely time frame is not meant to constrain a community from taking advantage of funding opportunities as they arise.

Potential Funding Sources – This column attempts to identify the most likely sources of funding for a specific measure. The information on potential funding sources in this table is preliminary and varies depending on a number of factors. These factors include whether or not a mitigation measure has been studied, evaluated or designed, or if it is still in the conceptual stages. MEMA and DCR assisted MAPC in reviewing the potential eligibility for hazard mitigation funding. Each grant program and agency has specific eligibility requirements that would need to be taken into consideration. In most instances, the measure will require a number of different funding sources. Identification of a potential funding source in this table does not guarantee that a project will be eligible for, or selected for funding. Upon adoption of this plan, the local team responsible for its implementation should begin to explore the funding sources in more detail.

Additional information on funding sources – The best way to determine eligibility for a particular funding source is to review the project with a staff person at the funding agency. The following websites provide an overview of programs and funding sources.

Army Corps of Engineers (ACOE or USACE) – The website for the North Atlantic district office is http://www.nae.usace.army.mil/. The ACOE provides assistance in a number of types of projects including shoreline/streambank protection, flood damage reduction, flood plain management services and planning services.

Massachusetts Emergency Management Agency (MEMA) – MEMA coordinates FEMA hazard mitigation grants. https://www.mass.gov/orgs/massachusetts-emergency-management-agency.

Abbreviations Used in Table 22

FEMA Mitigation Grants includes:
- FMA = Flood Mitigation Assistance Program.
- HMGP = Hazard Mitigation Grant Program.
- PDM = Pre-Disaster Mitigation Program

ACOE = Army Corps of Engineers (aka USACE)
DHS/EOPS = Department of Homeland Security/Emergency Operations
DEP (SRF) = Department of Environmental Protection (State Revolving Fund)
USDA = United States Department of Agriculture
Mass DOT = Massachusetts Department of Transportation
DCR = MA Department of Conservation and Recreation
TOD= Town of Duxbury
EEA=MA Executive Office of Energy and Environmental Affairs
CPA= Community Preservation Act
CZM= Massachusetts Office of Coastal Zone Management

Table 22: Recommended Mitigation Measures

Mitigation Measure	Priority	Lead Implementation	Timeframe	Estimated Cost Range	Potential Funding Sources
Flooding					
1. Maintain Duxbury Beach to a minimum elevation of 16.5 feet NGVD	High	Planning/ Duxbury Beach Reservation, Inc.	2019-2023	$1 to $2 million a year	MEMA, FEMA, Army Corps of Engineers, NOAA/NFWF
2. Congress Street study and culvert replacement	High	DPW	2018-2020	$35,000	Town, FEMA, grants
3. Development of sacrificial dune on Plymouth Avenue	High	DPW/Conservation	2018-2020	$2 million	Town General Fund, FEMA grant, CZM, NOAA/NFWF
4. Dam management and maintenance plan	Medium	DPW	2021-2023	$75,000/yr. for five years + staff time	Town General Fund, FEMA, MEMA

Mitigation Measure	Priority	Lead Implementation	Timeframe	Estimated Cost Range	Potential Funding Sources
5. Land acquisition program in flood areas, potentially along the coast	High & NFIP	Conservation Commission	2018-2023	>$1 million	EEA, CPA
6. Regulatory revisions for stormwater management	High & NFIP	Planning / Natural Resources	2018-2020	Town Staff Time or $20,000 consultant	Town General Fund, MET, EOEEA Smart Growth Grants
7. Updated FIRM mapping and bylaws	High & NFIP	Planning / Public Works	2018-2020	Town staff time	Town General Fund
8. Provide public information on NFIP compliance	Medium & NFIP	Planning / Public Works	2018-2023	Town staff time and material	Town General Fund
9. Seawall restoration and improvement	High	DPW/Planning	2018-2023	$26 million	Tax, betterment, FEMA Disaster
10. Perform Coastal Erosion/Accretion Littoral Study	High	Planning	2018-2019	$75,000	CZM, EEA, MAPC
Geologic Hazards (Earthquakes, Landslides)					
10. Assess earthquake vulnerability of all public buildings and implement upgrades if feasible	Low	DPW	2022	$50,000	Town General Fund
Fire-Related Hazards					
11. Increase public information and awareness about fire hazards	Medium	Fire	2018-2023	Staff time	Town General Fund
Winter Hazards					
12. Assess municipal structures for susceptibly to snow loads	Medium	Building Dept.	2018-2023	$50,000	Town General Fund

Mitigation Measure	Priority	Lead Implementation	Timeframe	Estimated Cost Range	Potential Funding Sources
13. Acquire adequate emergency generators for public safety (water pumps, package plant pumps, town hall)	High	Facilities, DPW	2018-2020	>$2 million	Town General Fund, FEMA grants
Drought					
14. Promote drought tolerant landscaping and site design measures	Medium	Building Department	2019-2023	Staff Time	Staff Time/Town general operating budget
Extreme Temperatures					
15. Encourage site design to increase tree plantings near buildings, increase the percentage of tree used in parking areas and along public ways	Medium	Planning /Conservation	2018-2023	Staff Time	Staff time/Town general operating budget
Climate Change					
16. Implement the Town of Duxbury Climate Vulnerability Assessment and Action Plan and incorporate these recommendations into Comprehensive Planning for the Town	High	Multiple Departments	2018-2023	TBD	EEA, CZM, CPA, TOD,
17. Establish and maintain a Climate Resilience Task Force that works across departments and commissions for a multi-disciplinary approach toward climate resilience.		Town Administrator, Planning	2018-2023	Staff Time	TOD

Mitigation Measure	Priority	Lead Implementation	Timeframe	Estimated Cost Range	Potential Funding Sources
18. Incorporate climate resilience into all local and regional plans as well as capital improvement plans.		Planning, Conservation	2018-2023	Staff Time	TOD
19. Hire a consultant to evaluate in greater detail Duxbury's susceptibility to salt water intrusion of its aquifer.		Planning, DPW, Town Administrator	2020	$100,000	NOAA/NFWF, EEA, CZM, DEP, USGS
20. Monitor health of submerged aquatic vegetation such as eelgrass beds, and salt marshes, and restore as necessary.		Conservation	2019-2023	$75,000	EEA, MDFW, MassBays, Boston University
21. Collaborate with the residents and businesses in the near- and long-term most vulnerable areas to examine potential zoning, regulatory, incentive, mitigation or cooperative-based approaches on sea level rise.	High	Planning	2019-2023	$50,000	MAPC, CZM, EEA
22. Explore zoning that prohibits building in high hazard areas.	High	Planning, Conservation	2019-2023	$20,000	MAPC, EEA, TOD

Process for Setting Priorities for Mitigation Measures

The last step in developing the Town's mitigation strategy is to assign a level of priority to each mitigation measure so as to guide the focus of the Town's limited resources towards those actions with the greatest potential benefit. At this stage in the process, the Local Hazard Mitigation Planning Team had limited access to detailed analyses of the cost and benefits of any given mitigation measure, so prioritization is based on the local team members' understanding of

existing and potential hazard impacts and an approximate sense of the costs associated with pursuing any given mitigation measure.

Priority setting was based on local knowledge of the hazard areas, including impacts of hazard events, the extent of the area impacted, and the relation of a given mitigation measure to the Town's goals. In addition, the local Hazard Mitigation Planning Team also took into consideration factors such as the number of homes and businesses affected, whether or not road closures occurred and what impact closures had on delivery of emergency services and the local economy, anticipated project costs, whether any environmental constraints existed, and whether the Town would be able to justify the costs relative to the anticipated benefits.

Table 23 below demonstrates the prioritization of the Town's recommended hazard mitigation measures. For each mitigation measure, the geographic extent of the potential benefiting area is identified as is an estimate of the overall benefit and cost of the measures. The benefits, costs, and overall priority were evaluated in terms of:

Estimated Benefits	
High	Action will result in a significant reduction of hazard risk to people and/or property from a hazard event
Medium	Action will likely result in a moderate reduction of hazard risk to people and/or property from a hazard event
Low	Action will result in a low reduction of hazard risk to people and/or property from a hazard event
Estimated Costs	
High	Estimated costs greater than $100,000
Medium	Estimated costs between $10,000 to $100,000
Low	Estimated costs less than $10,000 and/or staff time
Priority	
High	Action very likely to have political and public support and necessary maintenance can occur following the project, and the costs seem reasonable considering likely benefits from the measure
Medium	Action may have political and public support and necessary maintenance has potential to occur following the project
Low	Not clear if action has political and public support and not certain that necessary maintenance can occur following the project

Table 23 Prioritization of Recommended Mitigation Measures for a Hazard Mitigation Strategy

Mitigation Measure	Geographic Coverage	Estimate Cost	Estimated Benefit	2018 Priority
Flooding				
1. Maintain Duxbury Beach to a minimum elevation of 16.5 feet NGVD	Protects the shoreline of Duxbury, Plymouth, and Kingston Bays	High	High	High
2. Congress Street study and culvert replacement	West Duxbury	Medium	Medium	High
3. Development of sacrificial dune on Plymouth Avenue	Gurnet	High	High	High
4. Dam management and maintenance plan	Townwide	Low	Medium	Medium
5. Land acquisition program in flood areas, potentially along the coast	Townwide	High	High	High & NFIP
6. Regulatory revisions for stormwater management	Townwide	Low	High	High & NFIP
7. Updated FIRM mapping and bylaws	Coastal Zone	Low	Medium	High & NFIP
8. Provide public information on NFIP compliance	Townwide	Low	Medium	Medium & NFIP
9. Seawall restoration and improvement	Gurnet, Coastal Zone	High	High	High
Geologic Hazards (Earthquakes, Landslides)				
10. Assess earthquake vulnerability of all public buildings and implement upgrades if feasible	Townwide	Low	Low	Low
Fire-Related Hazards				
11. Increase public information and awareness about fire hazards	Townwide	Low	Medium	Medium
Winter Hazards				
12. Assess municipal structures for susceptibly to snow loads	Townwide	Medium	Low	Medium

Mitigation Measure	Geographic Coverage	Estimate Cost	Estimated Benefit	2018 Priority
13. Acquire adequate emergency generators for public safety (water pumps, package plant pumps, town hall)	Townwide	???	???	???
Drought				
14. Promote drought tolerant landscaping and site design measures	Townwide	Low	Medium	Medium
Extreme Temperatures				
15. Encourage site design to increase tree plantings near buildings, increase the percentage of tree used in parking areas and along public ways	Townwide	Low	Medium	Medium
Climate Change				
16. Implement the Town of Duxbury Climate Vulnerability Assessment and Action Plan	Townwide	High	High	High
17. Establish and maintain a Climate Resilience Task Force that works across departments and commissions for a multi-disciplinary approach toward climate resilience.	Townwide	Low	Low	Medium
18. Incorporate climate resilience into all local and regional plans as well as capital improvement plans.	Townwide	Low	Medium	High
19. Hire a consultant to evaluate in greater detail Duxbury's susceptibility to salt water intrusion of its aquifer.	Townwide	Medium	Low	Medium
20. Monitor health of submerged aquatic vegetation such as eelgrass beds, and salt marshes, and restore as necessary.	Coastal Zone	Medium	Medium	Medium

Mitigation Measure	Geographic Coverage	Estimate Cost	Estimated Benefit	2018 Priority
21. Collaborate with the residents and businesses in the near- and long-term most vulnerable areas to examine potential zoning, regulatory, incentive, mitigation, or cooperative-based approaches on sea level rise.	Coastal Zone	Medium	Medium	High
22. Explore zoning that prohibits building in high hazard areas.	Coastal Zone	Medium	Medium	Medium

Regional and Inter-Community Considerations

Some hazard mitigation issues are strictly local. The problem originates primarily within the municipality and can be solved at the municipal level. Other issues are inter-community and require cooperation between two or more municipalities. There is a third level of mitigation which is regional and may involve a state, regional or federal agency or three or more municipalities.

Regional Partners

In many communities, mitigating natural hazards, particularly flooding, is more than a local issue. The drainage systems that serve these communities are a complex system of storm drains, roadway drainage structures, pump stations and other facilities owned and operated by a wide array of agencies including but not limited to the Town of Duxbury, the Department of Conservation and Recreation (DCR), and Massachusetts Department of Transportation (MassDOT). The planning, construction, operations, and maintenance of these structures are integral to the flood hazard mitigation efforts of communities. As such, these agencies must be considered the community's regional partners in hazard mitigation. These agencies also operate under the same constraints as communities do, including budgetary and staffing constraints and numerous competing priorities. In the sections that follow, the plan includes recommendations for activities where cooperation with these other agencies may be necessary. Implementation of these recommendations will require that all parties work together to develop solutions.

Overview of Regional Facilities within Duxbury

Major facilities owned, operated and maintained by federal, state, regional or private entities in Duxbury include:

- Massachusetts Routes 3, 3A, 14, 53, and 139 (MassDOT)
- Duxbury Beach (Duxbury Beach Reservation, Inc.)
- Myles Standish Monument State Reservation (DCR)
- Gurnet – Shared Drinking and Wastewater Systems with the Town of Marshfield.

- Powder Point Bridge- Access point for the Saquish neighborhood in the Town of Plymouth located at the terminus of Duxbury Beach. This is the only point of access and egress during emergencies. The neighborhood is highly vulnerable to coastal flooding.
- Kingston Bay-Bay system shared with the Town of Kingston, important for boating regulation, boating management, commercial fish industry, and water quality to uphold the Clean Water Act.

Inter-Community Considerations

1. *Living and Hardened Shoreline Environment* – The coastal shoreline of the South Shore area is a dynamic environment where forces of erosion and deposition of sand are constantly at work changing the beach profile. This process disregards municipal boundaries as sand and other materials are moved along the coast. Shoreline protection measures such as living shorelines, dunes, beaches, sea walls, jetties, and others have an impact on this process with the potential of building up sand in some areas while stripping it away from others. Municipalities along the South Shore should work to understand how these processes are at work locally and consider mutually beneficial means of protecting their shore side communities from the impacts of storm damage. Collaboration on coastal shoreline protection, such as seawalls, beach nourishment, and marshes is critical for mitigating coastal flood hazards and infrastructure damage.

2. *Duxbury Beach*- Duxbury Beach, a barrier beach, protects the shorelines of Duxbury, Kingston, and Plymouth Bays from high energy waves during coastal storm events. Its protection and nourishment is critcal in minimizing coastal shoreline erosion and infrastructure damage from flooding natural hazards. The three communities should collaborate on mitigating coastal flood damage and invest in nourishment and other flood and erosion control measures.

3. *Shared Water Systems*-The Gurnet neighborhood is serviced by the Town of Marshfield for wastewater and drinking water. This neighborhood is in a AE Zone and highly vulnerable to intense wave energy and coastal storms. Collaboration between the Towns of Duxbury and Marshfield on the maintenance and resilience of these is systems is critical.

4. *Stormwater Management in Kingston Bay*
Duxbury lies along Kingston Bay, an important area for living shorelines, commercial fishing, and recreational boating. The Towns of Kingston and Duxbury should continue to collaborate and coordinate on stormwater management strategies for National Pollution Discharge Elimination Program for the Clean Water Act to uphold the commercial, recreational, and natural systems important for the economy and shoreline protection of both communities.

VII. PLAN ADOPTION AND MAINTENANCE

PLAN ADOPTION

The Duxbury Hazard Mitigation Plan 2018 was adopted by the Board of Selectmen, subject to final edits required by FEMA on December 17, 2018. See Appendix D for documentation. The plan was approved by FEMA on December 21, 2018 for a five-year period that will expire on December 21, 2023.

PLAN MAINTENANCE

The Town of Duxbury Hazard Mitigation Team meets annually every September to review and update the Hazard Mitigation Plan. MAPC worked with the Duxbury Hazard Mitigation Planning Team to prepare this plan. After approval of the plan by FEMA, this group will continue to meet annually to function as the Hazard Mitigation Implementation Team, with the Director of Planning designated as the coordinator. Additional members could be added to the local implementation team from businesses, non-profits and institutions. The Town will encourage public participation during the next 5-year planning cycle. As updates and a review of the plan are conducted by the Hazard Mitigation Implementation Team, these will be placed on the Town's web site, and any meetings of the Hazard Mitigation Implementation Team will be publicly noticed in accordance with town and state open meeting laws.

IMPLEMENTATION AND EVALUATION SCHEDULE

Mid-Term Survey on Progress– The coordinator of the Hazard Mitigation Implementation Team will prepare and distribute a survey in year three of the plan. The survey will be distributed to all of the local implementation group members and other interested local stakeholders. The survey will poll the members on any changes or revisions to the plan that may be needed, progress and accomplishments for implementation, and any new hazards or problem areas that have been identified.

This information will be used to prepare a report or addendum to the local hazard mitigation plan in order to evaluate its effectiveness in meeting the plan's goals and identify areas that need to be updated in the next plan. The Hazard Mitigation Implementation Team, coordinated by the Town Planner, will have primary responsibility for tracking progress, evaluating, and updating the plan.

Begin to Prepare for the next Plan Update -- FEMA's approval of this plan is valid for five years, by which time an updated plan must be approved by FEMA in order to maintain the town's approved plan status and its eligibility for FEMA mitigation grants. Given the lead time needed to secure funding and conduct the planning process, the Hazard Mitigation Implementation Team will begin to prepare for an update of the plan in year three. This will help the Town avoid a lapse in its approved plan status and grant eligibility when the current plan expires.

The Hazard Mitigation Implementation Team will use the information from the Mid-Term progress review to identify the needs and priorities for the plan update and seek funding for the plan update process. Potential sources of funding may include FEMA Pre-Disaster Mitigation grants and the Hazard Mitigation Grant Program. Both grant programs can pay for 75% of a planning project, with a 25% local cost share required.

Prepare and Adopt an Updated Local Hazard Mitigation Plan –Once the resources have been secured to update the plan, the Hazard Mitigation Implementation Team may decide to undertake the update themselves, contract with the Metropolitan Area Planning Council to update the plan or to hire another consultant. However the Hazard Mitigation Implementation Team decides to update the plan, the group will need to review the current FEMA hazard mitigation plan guidelines for any changes. The Duxbury Hazard Mitigation Plan Update will be forwarded to MEMA and DCR for review and to FEMA for approval.

INTEGRATION OF THE PLANS WITH OTHER PLANNING INITIATIVES

Upon approval of the Duxbury Hazard Mitigation Plan 2018 by FEMA, the Local Hazard Mitigation Team will provide all interested parties and implementing departments with a copy of the plan and will initiate a discussion regarding how the plan can be integrated into that department's ongoing work. At a minimum, the plan will be reviewed and discussed with the following departments:

- Fire
- Emergency Management
- Facilities
- Police/Harbormaster
- Public Works
- Planning
- Conservation
- Health
- Building

Other groups that will be coordinated with include large institutions, Chambers of Commerce, land conservation organizations and watershed groups. These include the Snug Harbor Business District, Duxbury Beach Reservation, Inc., MassBays, and others. The plans will also be posted on the community's website with the caveat that local team coordinator will review the plan for sensitive information that would be inappropriate for public posting. The posting of the plan on a web site will include a mechanism for citizen feedback such as an e-mail address to send comments.

The Hazard Mitigation Plan will be integrated into other town plans and policies as they are updated and renewed, including the Duxbury Master Plan "Envision Duxbury", Open Space and Recreation Plan, Comprehensive Emergency Management Plan, Capital Investment Program, and Climate Vulnerability Assessment and Action Plan.

IX. LIST OF REFERENCES

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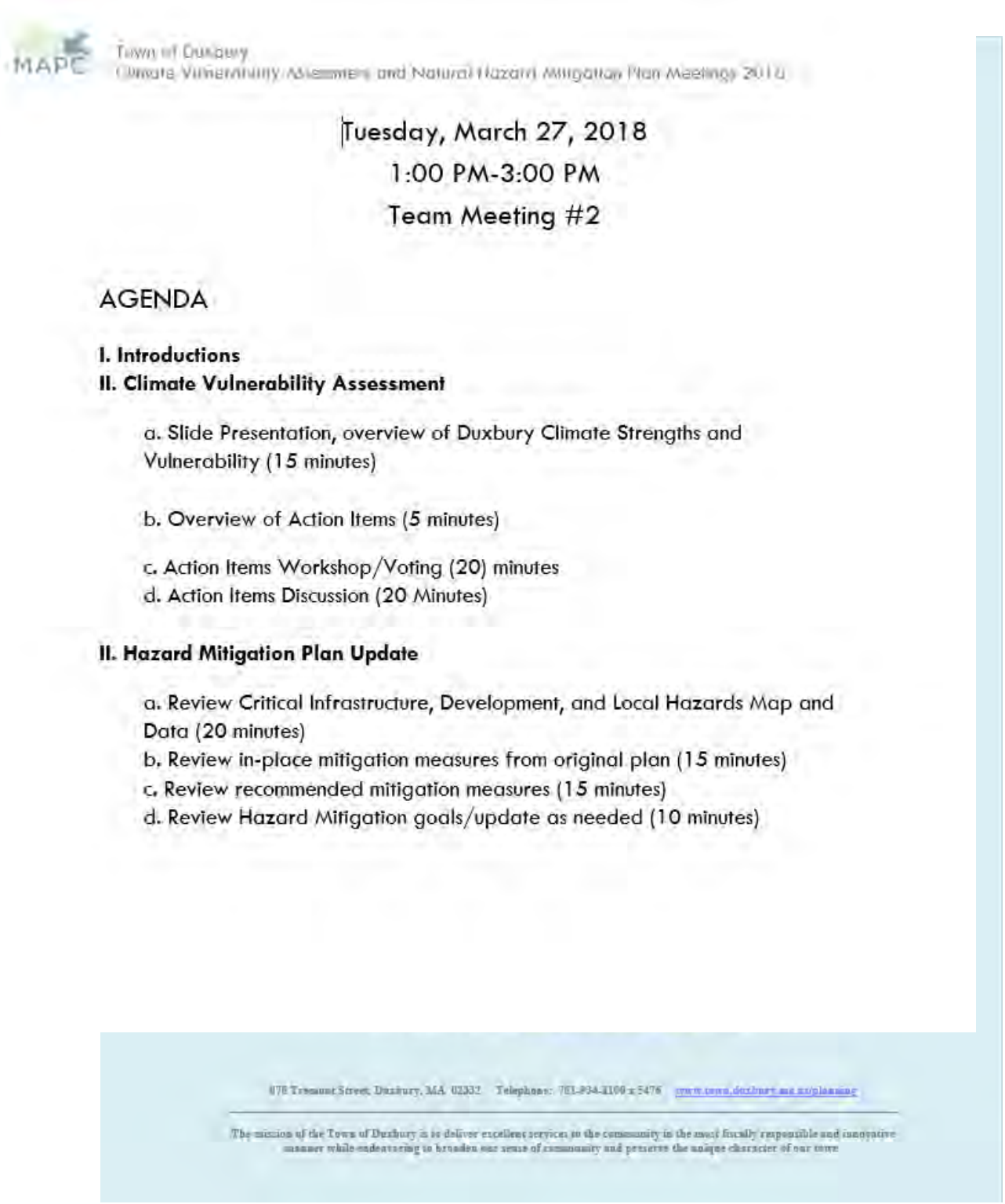
Appendix A Local Team Meetings



MAPC Town of Duxbury
Climate Vulnerability Assessment and Natural Hazard Mitigation Plan Meetings 2018

Tuesday, March 27, 2018
1:00 PM-3:00 PM
Team Meeting #2

AGENDA

I. Introductions
II. Climate Vulnerability Assessment

a. Slide Presentation, overview of Duxbury Climate Strengths and Vulnerability (15 minutes)

b. Overview of Action Items (5 minutes)

c. Action Items Workshop/Voting (20) minutes
d. Action Items Discussion (20 Minutes)

II. Hazard Mitigation Plan Update

a. Review Critical Infrastructure, Development, and Local Hazards Map and Data (20 minutes)
b. Review in-place mitigation measures from original plan (15 minutes)
c. Review recommended mitigation measures (15 minutes)
d. Review Hazard Mitigation goals/update as needed (10 minutes)

878 Tremont Street, Duxbury, MA 02332 Telephone: 781-934-1100 x 5478 www.town.duxbury.ma.us/planning

The mission of the Town of Duxbury is to deliver excellent services to the community in the most fiscally responsible and innovative manner while endeavoring to broaden our sense of community and preserve the unique character of our town

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Date: October 30, 2018 at 1:36:38 PM EDT
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Subject: DRT Meeting - ASPR 397 Washington, Hazard Mitigation Plan

Hi all,

There will be a DRT meeting next Thursday, November 8 at 9 AM. On the agenda is a discussion of the 2018 Hazard Mitigation Plan, and an ASPR for 397 Washington Street. Attached please find information for both items. Let me know if you can't make it; the mural room is occupied so we will meet in Scott's office.

Best,
Ashley

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www.town.duxbury.ma.us/planning<http://www.town.duxbury.ma.us/planning>

<ASPRplan_397Washington.pdf>
<Dux Hazard Mitigation Plan 2018 Pending Approval.doc>

Appendix B Hazard Mapping

The MAPC GIS (Geographic Information Systems) Lab produced a series of maps for each community. Some of the data came from the Northeast States Emergency Consortium (NESEC). More information on NESEC can be found at http://www.serve.com/NESEC/. Due to the various sources for the data and varying levels of accuracy, the identification of an area as being in one of the hazard categories must be considered as a general classification that should always be supplemented with more local knowledge.

The map series consists of eight maps as described below. The maps in this appendix are necessarily reduced scale versions for general reference.

Map 1.	Population Density
Map 2.	Potential Development
Map 3.	Flood Zones
Map 4.	Earthquakes and Landslides
Map 5.	Hurricanes and Tornadoes
Map 6.	Average Snowfall
Map 7.	Composite Natural Hazards
Map 8.	Hazard Areas
Map 9	Areas of Extreme Heat
Map 10	Costal Shoreline Change
Map 11	Sea Level Rise with Category 1 Hurricane Storm Surge

Map1: Population Density – This map uses the US Census block data for 2010 and shows population density as the number of people per acre in seven categories with 60 or more people per acre representing the highest density areas.

Map 2: Land Use – This map depicts existing land use, based on the MacConnell Land Use map series from University of Massachusetts, available from MassGIS . The map displays 33 categories of land use based on interpretation of aerial photos. For more information on how the land use statistics were developed and the definitions of the categories, please go to http://www.mass.gov/mgis/lus.htm

Map 3: Flood Zones – The map of flood zones used the FEMA NFIP Flood Zones as depicted on the FIRMs (Federal Insurance Rate Maps) for Norfolk County dated July 17, 2012 as its source. This map is not intended for use in determining whether or not a specific property is located within a FEMA NFIP flood zone. The currently adopted FIRMS for Duxbury are kept by the Town. For more information, refer to the FEMA Map Service Center website http://www.msc.fema.gov. The definitions of the flood zones are described in detail on this site as well. The flood zone map for each community also shows critical infrastructure and repetitive loss areas.

Map 4: Earthquakes and Landslides – This information came from NESEC. For most communities, there was no data for earthquakes because only the epicenters of an earthquake are mapped.

The landslide information shows areas with either a low susceptibility or a moderate susceptibility to landslides based on mapping of geological formations. This mapping is highly general in

nature. For more information on how landslide susceptibility was mapped, refer to http://pubs.usgs.gov/pp/p1183/pp1183.html.

Map 5: Hurricanes and Tornadoes – This map shows a number of different items. The map includes the storm tracks for both hurricanes and tropical storms, if any occurred in this community. This information must be viewed in context. A storm track only shows where the eye of the storm passed through. In most cases, the effects of the wind and rain from these storms were felt in other communities even if the track was not within that community. This map also shows the location of tornadoes with a classification as to the level of damages. What appears on the map varies by community since not all communities experience the same wind-related events. These maps also show the 100 year wind speed.

Map 6: Average Snowfall - - This map shows the average snowfall. It also shows storm tracks for nor'easters, if any storms tracked through the community.

Map 7: Composite Natural Hazards - This map shows four categories of composite natural hazards for areas of existing development. The hazards included in this map are 100 year wind speeds of 110 mph or higher, low and moderate landslide risk, FEMA Q3 flood zones (100 year and 500 year) and hurricane surge inundation areas. Areas with only one hazard were considered to be low hazard areas. Moderate areas have two of the hazards present. High hazard areas have three hazards present and severe hazard areas have four hazards present.

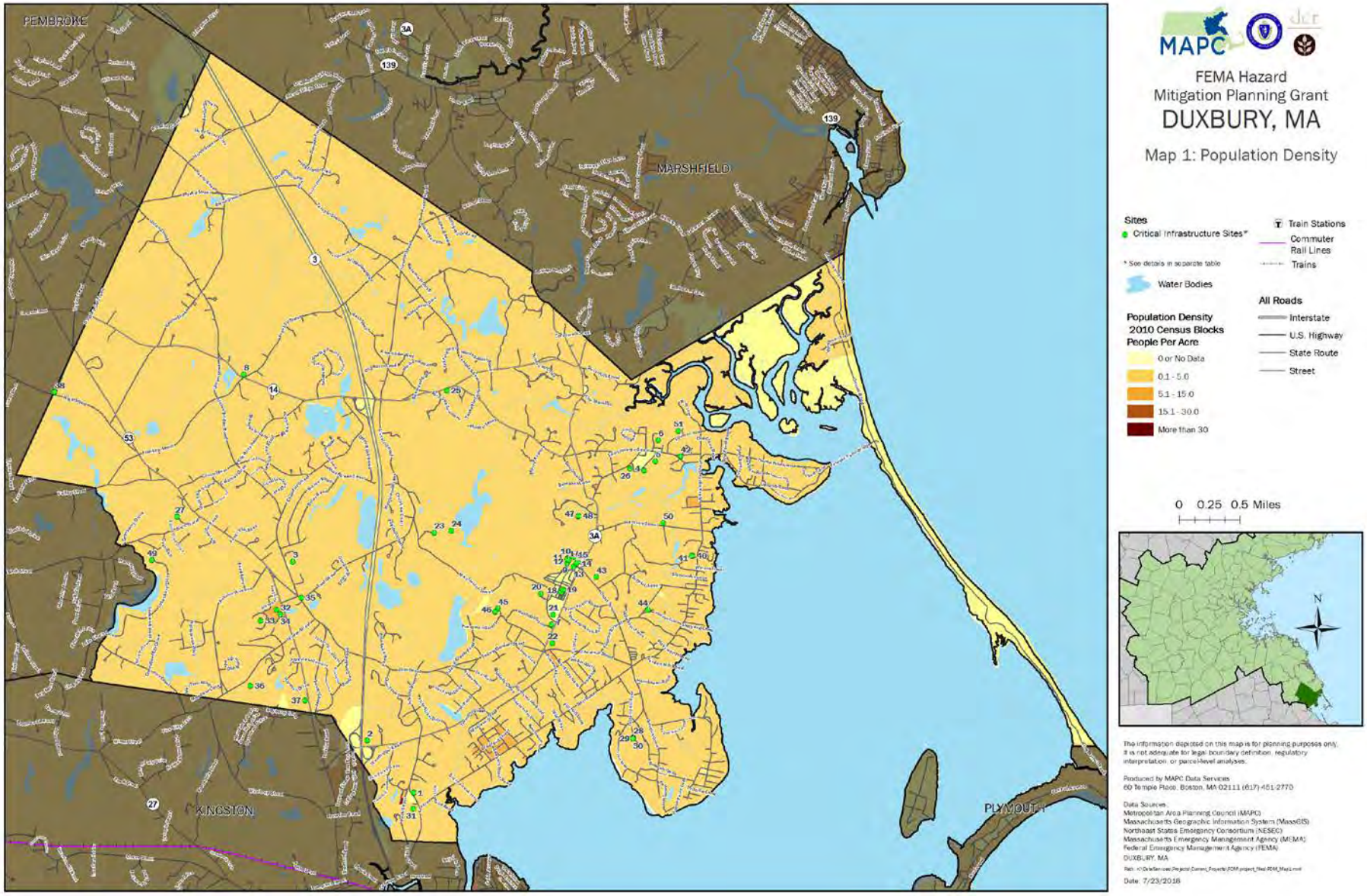
Map 8: Hazard Areas – For each community, locally identified hazard areas are overlaid on an aerial photograph dated April, 2009. The source of the aerial photograph is Mass GIS. This map also shows potential future developments, and critical infrastructure sites. MAPC consulted with town staff to determine areas that were likely to be developed or redeveloped in the future.

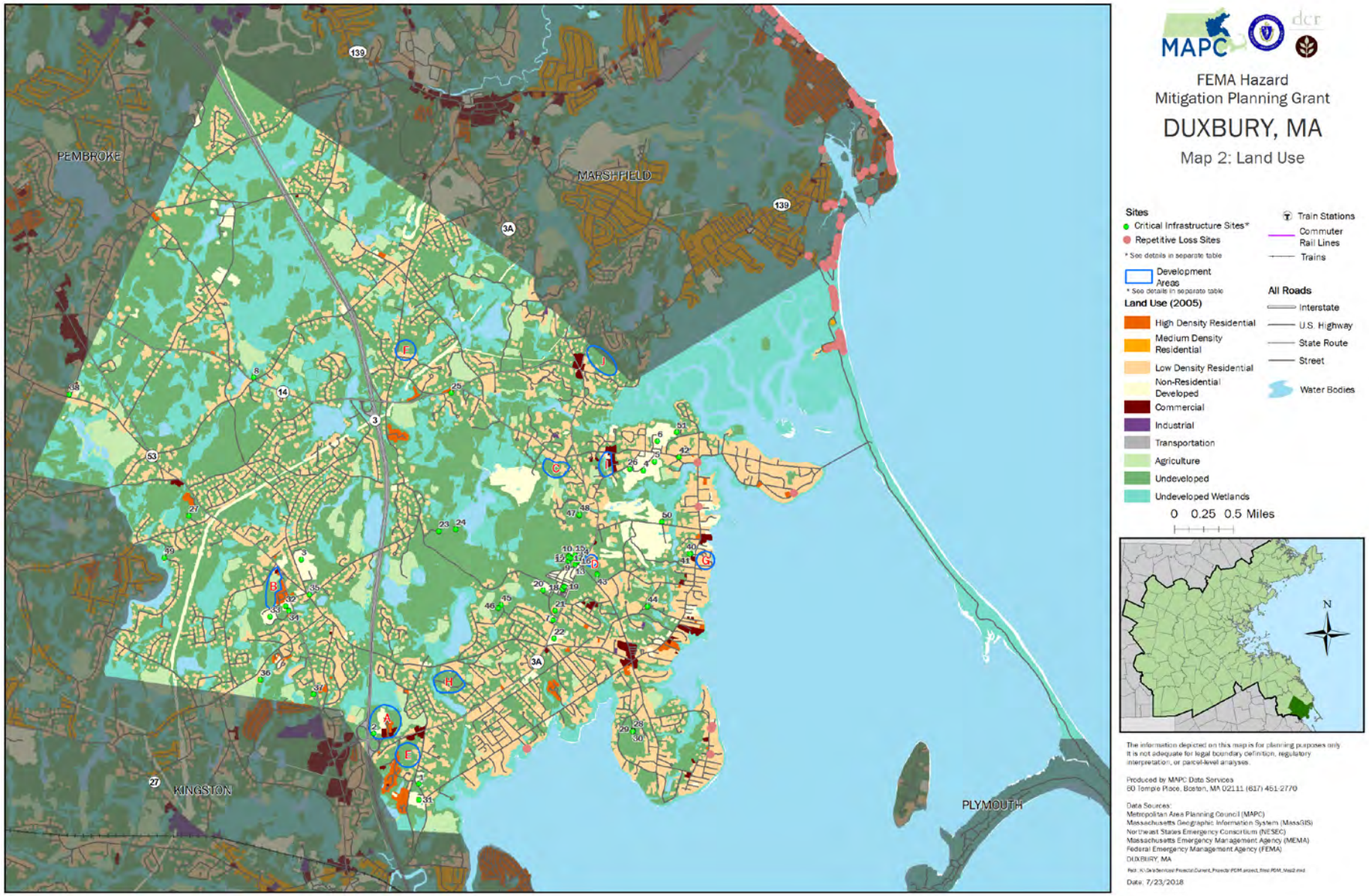
Map 9: Extreme Heat- MAPC uses LANDSAT 30m spatial resolution satellite data to extract land surface temperature to assess a community's exposure to present-day extreme heat and any vulnerabilities to rising temperatures with climate change. The extreme heat analysis uses date from 2016 with satellite images on days of 90° or higher at Logan Airport, July 13 and August 30, 2016 and created land surface temperature using a methodology development by Walawender, Hajto, and Iwaniuk (2012) called Landsat TRS Tools. This map illustrates the hottest areas in the top fifth percentile for the 101 towns in Metropolitan Boston.

Map 10: Coastal Shoreline Change- The MA Office of Coastal Zone Management (CZM) worked with the United States Geological Survey and the Woods Hold Coastal and Marine Science Center to document trends and erosion/accretion dynamics of Massachusetts shorelines. Ocean shorelines were delineated using historical data, aerial ortho-imagery and LIDAR using 50 meter transects along the entire coast of Massachusetts.

Map 11: Sea Level Rise- In 2013, Kleinfelder performed sea level rise and storm surge modeling for the towns of Scituate, Marshfield, and Duxbury, projecting scenarios in 25, 50, and 75 years. Sea level rise was estimated using NOAA Technical Report *Global Sea Level Rise Scenarios for the United States National Climate Assessment* (December 2012) and storm surge was modeled using the hydrodynamic Sea, Lake, and Overland Surge from Hurricanes Model (SLOSH) developed by

the National Weather Service. This map illustrates Sea Level Rise depth in 2038 with a Category 1 Hurricane Storm Surge.


PEMBROKE
MARSHFIELD
KINGSTON
PLYMOUTH
MAPC
FEMA Hazard
Mitigation Planning Grant
DUXBURY, MA
Map 1: Population Density
Sites
Critical Infrastructure Sites*
* See details in separate table
Water Bodies
Train Stations
Commuter Rail Lines
Trains
All Roads
Interstate
U.S. Highway
State Route
Street
Population Density
2010 Census Blocks
People Per Acre
0 or No Data
0.1 - 5.0
5.1 - 15.0
15.1 - 30.0
More than 30
0 0.25 0.5 Miles
N
The information depicted on this map is for planning purposes only. It is not adequate for legal boundary definition, regulatory interpretation, or parcel-level analyses.
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources:
Metropolitan Area Planning Council (MAPC)
Massachusetts Geographic Information System (MassGIS)
Northeast States Emergency Consortium (NESEC)
Massachusetts Emergency Management Agency (MEMA)
Federal Emergency Management Agency (FEMA)
DUXBURY, MA
Date: 7/23/2018


MAPC
dcr
FEMA Hazard
Mitigation Planning Grant
DUXBURY, MA
Map 2: Land Use
PEMBROKE
MARSHFIELD
KINGSTON
PLYMOUTH
Sites
Critical Infrastructure Sites*
Repetitive Loss Sites
* See details in separate table
Development Areas
* See details in separate table
Land Use (2005)
High Density Residential
Medium Density Residential
Low Density Residential
Non-Residential Developed
Commercial
Industrial
Transportation
Agriculture
Undeveloped
Undeveloped Wetlands
Train Stations
Commuter Rail Lines
Trains
All Roads
Interstate
U.S. Highway
State Route
Street
Water Bodies
0 0.25 0.5 Miles
N
The information depicted on this map is for planning purposes only. It is not adequate for legal boundary definition, regulatory interpretation, or parcel-level analyses.
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources:
Metropolitan Area Planning Council (MAPC)
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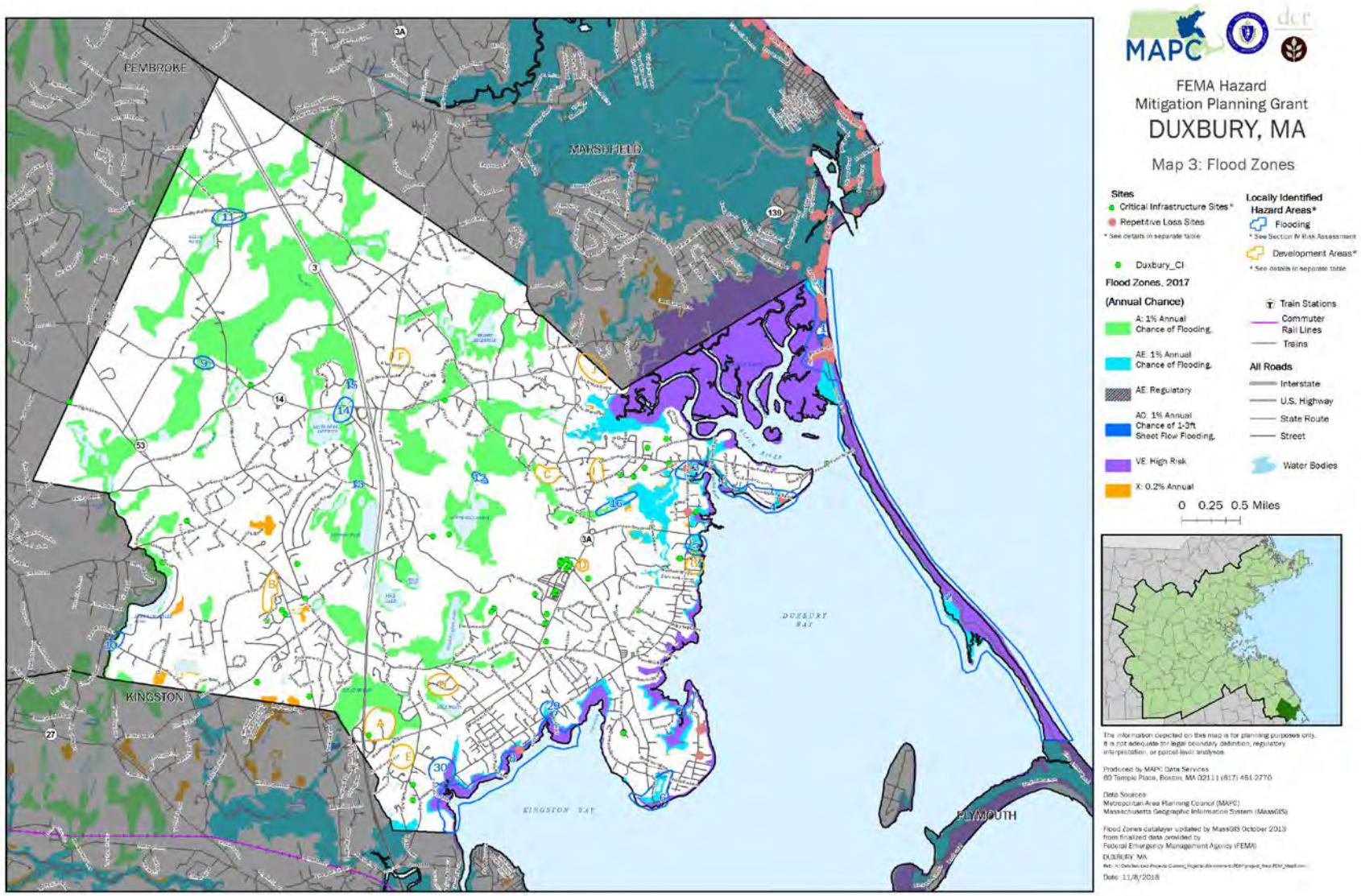
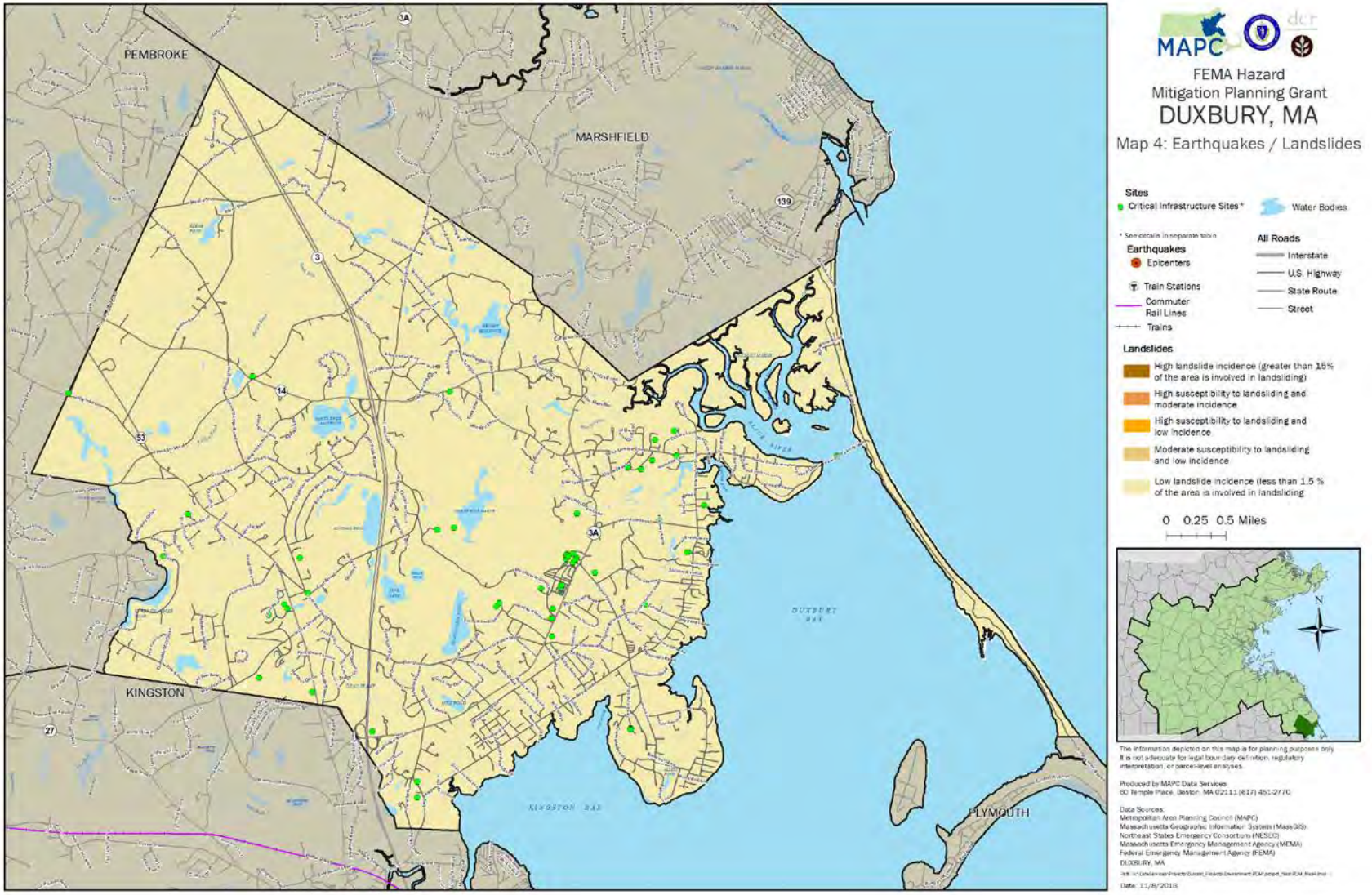
Northeast States Emergency Consortium (NESEC)
Massachusetts Emergency Management Agency (MEMA)
Federal Emergency Management Agency (FEMA)
DUXBURY, MA
Date: 7/23/2018


PEMBROKE
MARSHFIELD
KINGSTON
PLYMOUTH
DUXBURY BAY
KINGSTON BAY
MAPC
FEMA Hazard
Mitigation Planning Grant
DUXBURY, MA
Map 3: Flood Zones
Sites
Critical Infrastructure Sites*
Repetitive Loss Sites
* See details in separate table
Duxbury_CI
Flood Zones, 2017
(Annual Chance)
A: 1% Annual Chance of Flooding.
AE: 1% Annual Chance of Flooding.
AE: Regulatory
AO: 1% Annual Chance of 1-3ft Sheet Flow Flooding.
VE: High Risk
X: 0.2% Annual
Locally Identified Hazard Areas*
Flooding
* See Section IV Risk Assessment
Development Areas*
* See details in separate table
Train Stations
Commuter Rail Lines
Trains
All Roads
Interstate
U.S. Highway
State Route
Street
Water Bodies
0 0.25 0.5 Miles
The information depicted on this map is for planning purposes only. It is not adequate for legal boundary definition, regulatory interpretation, or parcel-level analyses.
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources:
Metropolitan Area Planning Council (MAPC)
Massachusetts Geographic Information System (MassGIS)
Flood Zones datalayer updated by MassGIS October 2013 from finalized data provided by Federal Emergency Management Agency (FEMA)
DUXBURY_MA
Date: 11/8/2018


PEMBROKE
MARSHFIELD
KINGSTON
PLYMOUTH
MAPC
dcr
FEMA Hazard
Mitigation Planning Grant
DUXBURY, MA
Map 4: Earthquakes / Landslides
Sites
Critical Infrastructure Sites*
Water Bodies
* See details in separate table
Earthquakes
Epicenters
Train Stations
Commuter Rail Lines
Trains
All Roads
Interstate
U.S. Highway
State Route
Street
Landslides
High landslide incidence (greater than 15% of the area is involved in landsliding)
High susceptibility to landsliding and moderate incidence
High susceptibility to landsliding and low incidence
Moderate susceptibility to landsliding and low incidence
Low landslide incidence (less than 1.5 % of the area is involved in landsliding
0 0.25 0.5 Miles
N
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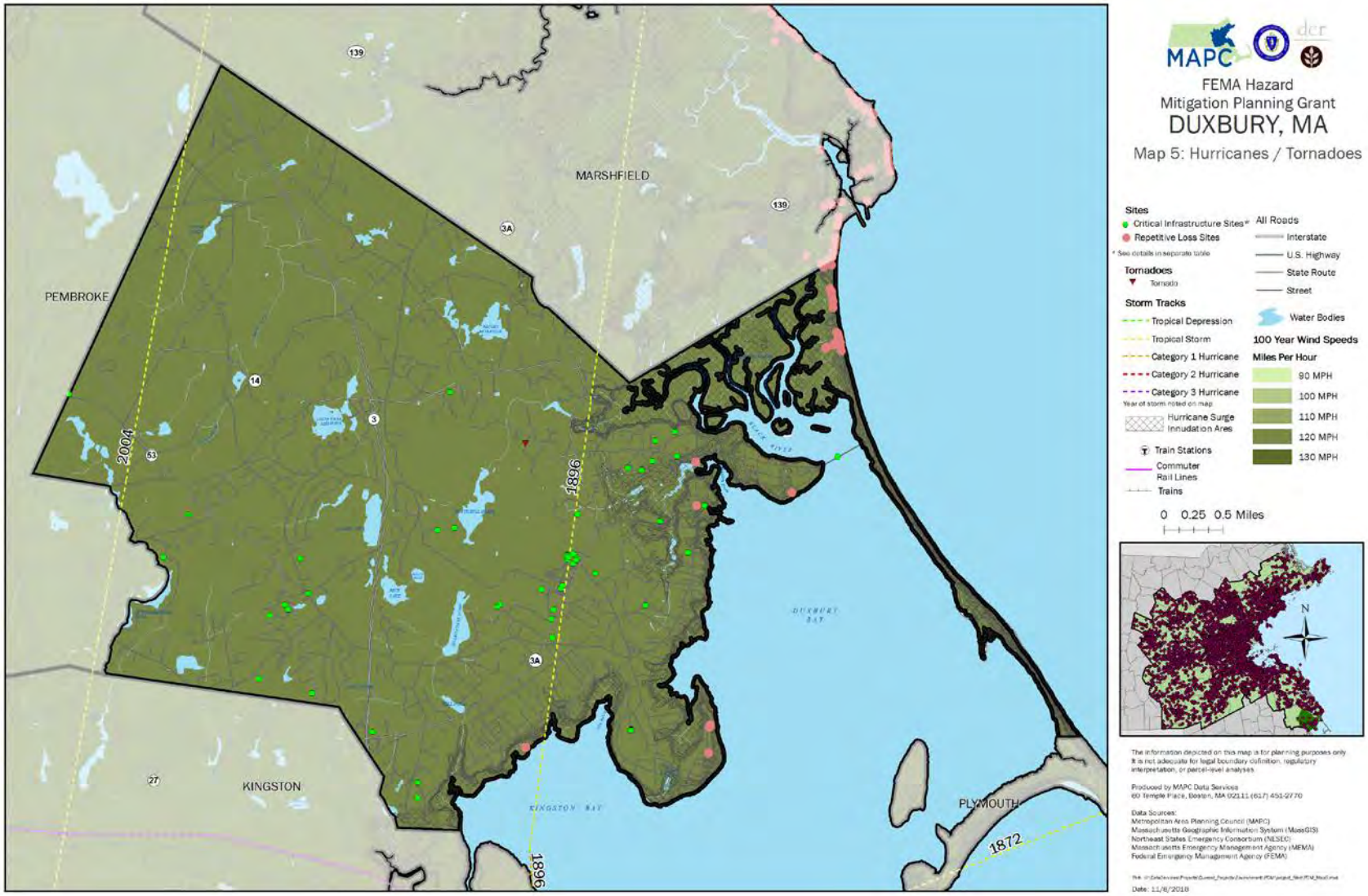
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources:
Metropolitan Area Planning Council (MAPC)
Massachusetts Geographic Information System (MassGIS)
Northeast States Emergency Consortium (NESEC)
Massachusetts Emergency Management Agency (MEMA)
Federal Emergency Management Agency (FEMA)
DUXBURY, MA
Date: 11/8/2018


MAPC
FEMA Hazard
Mitigation Planning Grant
DUXBURY, MA
Map 5: Hurricanes / Tornadoes
MARSHFIELD
PEMBROKE
KINGSTON
PLYMOUTH
2004
1896
1898
1872
Sites
Critical Infrastructure Sites*
Repetitive Loss Sites
* See details in separate table
Tornadoes
Tornado
Storm Tracks
Tropical Depression
Tropical Storm
Category 1 Hurricane
Category 2 Hurricane
Category 3 Hurricane
Year of storm noted on map
Hurricane Surge Inundation Area
Train Stations
Commuter Rail Lines
Trains
All Roads
Interstate
U.S. Highway
State Route
Street
Water Bodies
100 Year Wind Speeds
Miles Per Hour
90 MPH
100 MPH
110 MPH
120 MPH
130 MPH
0 0.25 0.5 Miles
N
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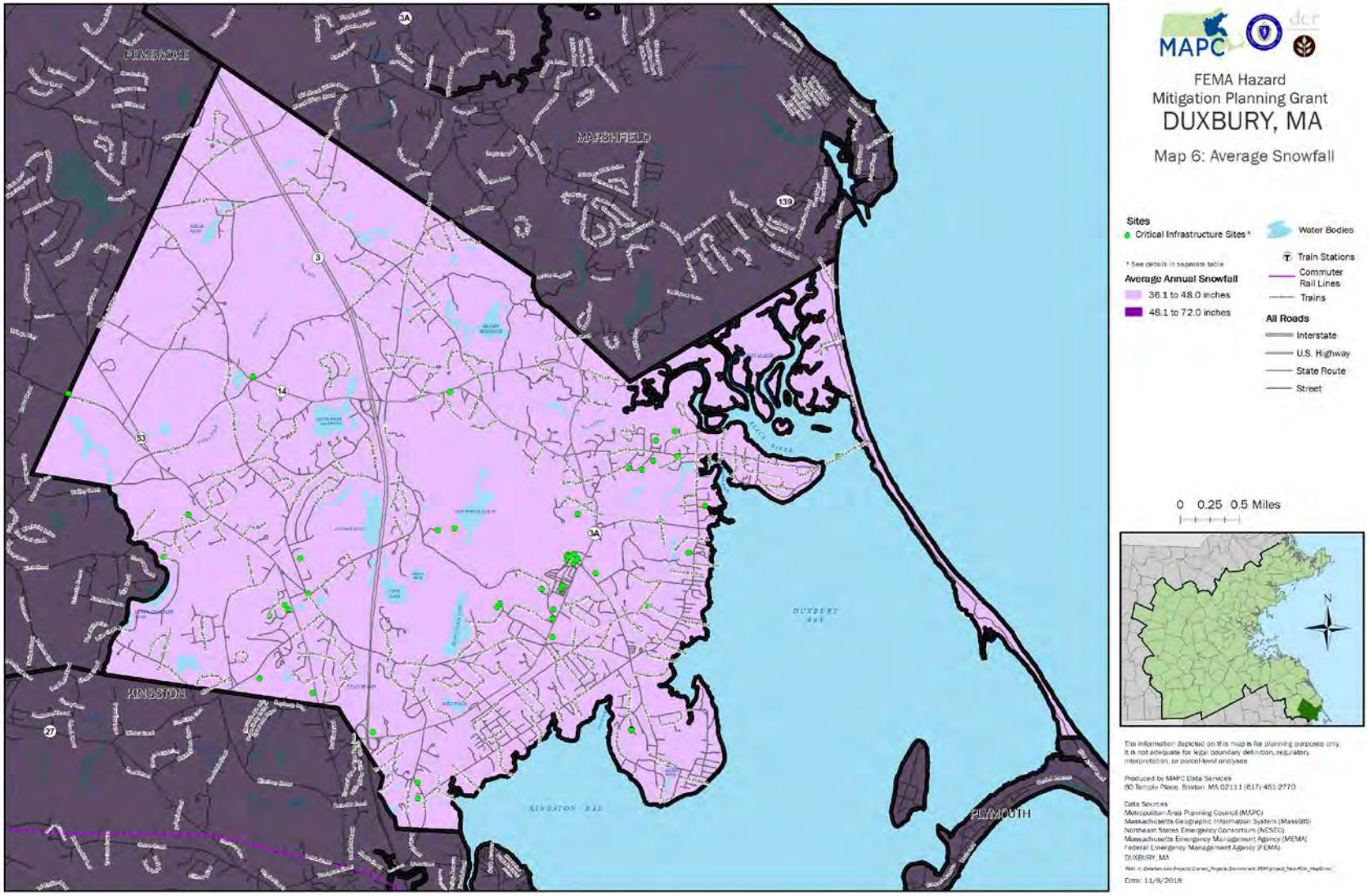
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources:
Metropolitan Area Planning Council (MAPC)
Massachusetts Geographic Information System (MassGIS)
Northeast States Emergency Consortium (NESEC)
Massachusetts Emergency Management Agency (MEMA)
Federal Emergency Management Agency (FEMA)
Date: 11/8/2018


PEMBROKE
MARSHFIELD
KINGSTON
PLYMOUTH
DUXBURY BAY
KINGSTON BAY
MAPC
FEMA Hazard
Mitigation Planning Grant
DUXBURY, MA
Map 6: Average Snowfall
Sites
Critical Infrastructure Sites *
* See details in separate table
Average Annual Snowfall
36.1 to 48.0 inches
48.1 to 72.0 inches
Water Bodies
Train Stations
Commuter Rail Lines
Trains
All Roads
Interstate
U.S. Highway
State Route
Street
0 0.25 0.5 Miles
N
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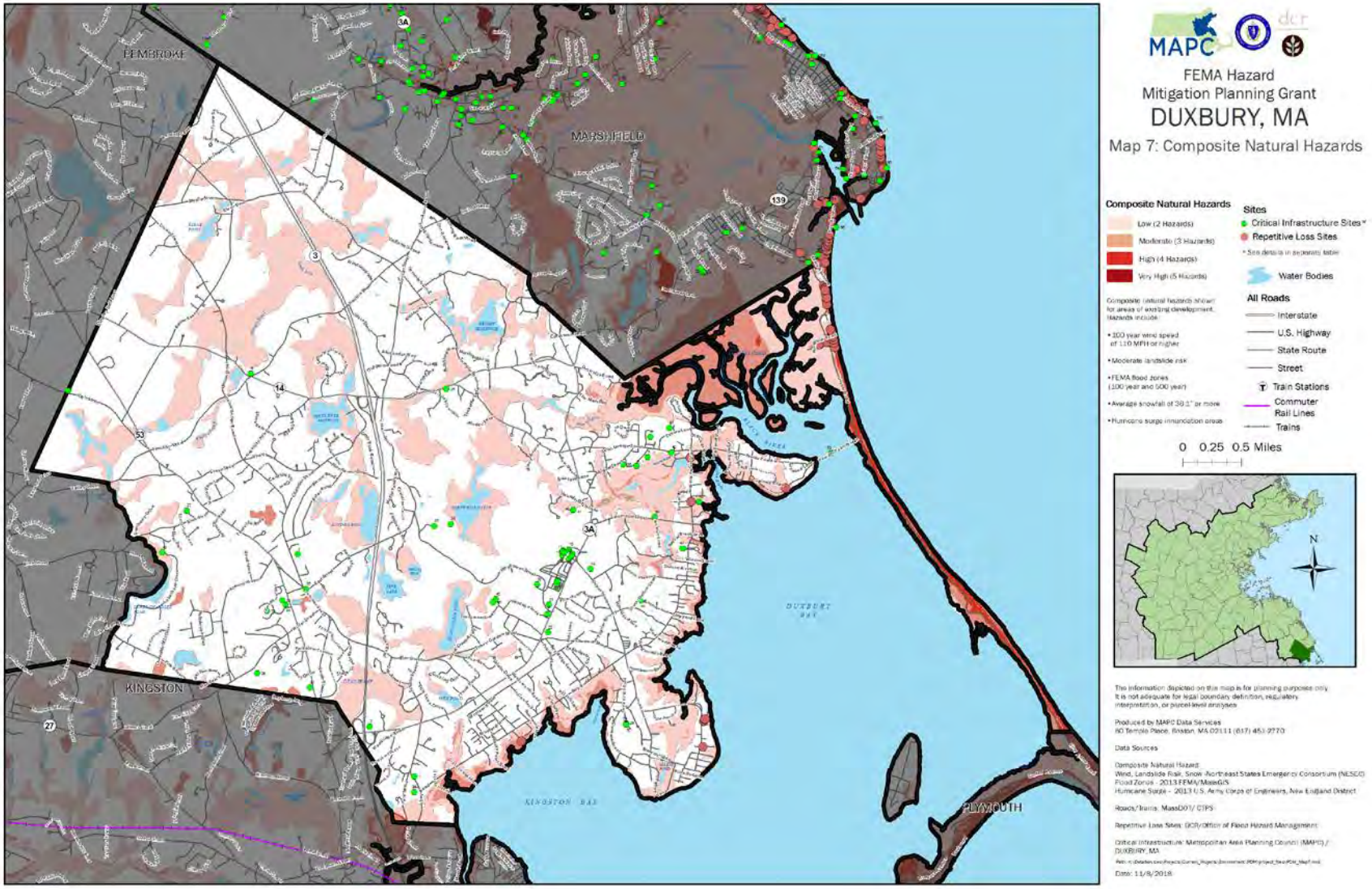
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources
Metropolitan Area Planning Council (MAPC)
Massachusetts Geographic Information System (MassGIS)
Northeast States Emergency Consortium (NESEC)
Massachusetts Emergency Management Agency (MEMA)
Federal Emergency Management Agency (FEMA)
DUXBURY, MA
Date: 11/8/2018


PEMBROKE
MARSHFIELD
KINGSTON
PLYMOUTH
MAPC
FEMA Hazard
Mitigation Planning Grant
DUXBURY, MA
Map 7: Composite Natural Hazards
Composite Natural Hazards
Low (2 Hazards)
Moderate (3 Hazards)
High (4 Hazards)
Very High (5 Hazards)
Sites
Critical Infrastructure Sites*
Repetitive Loss Sites
Water Bodies
All Roads
Interstate
U.S. Highway
State Route
Street
Train Stations
Commuter Rail Lines
Trains
0 0.25 0.5 Miles
N
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources
Date: 11/8/2018


PEMBROKE
MARSHFIELD
KINGSTON
PLYMOUTH
MAPC
dcr
FEMA Hazard
Mitigation Planning Grant
DUXBURY, MA
Map 8: Local Hazard Areas
Sites
Critical Infrastructure Sites*
Repetitive Loss Sites
* See details in separate table
Locally Identified
Hazard Areas
Brush Fires
Flooding
Historic
* See Section IV Risk Assessment
Development Sites
* See details in separate table
Train Stations
Commuter
Rail Lines
Trains
All Roads
Interstate
U.S. Highway
State Route
Street
0 0.5 1 Miles
N
The information depicted on this map is for planning purposes only.
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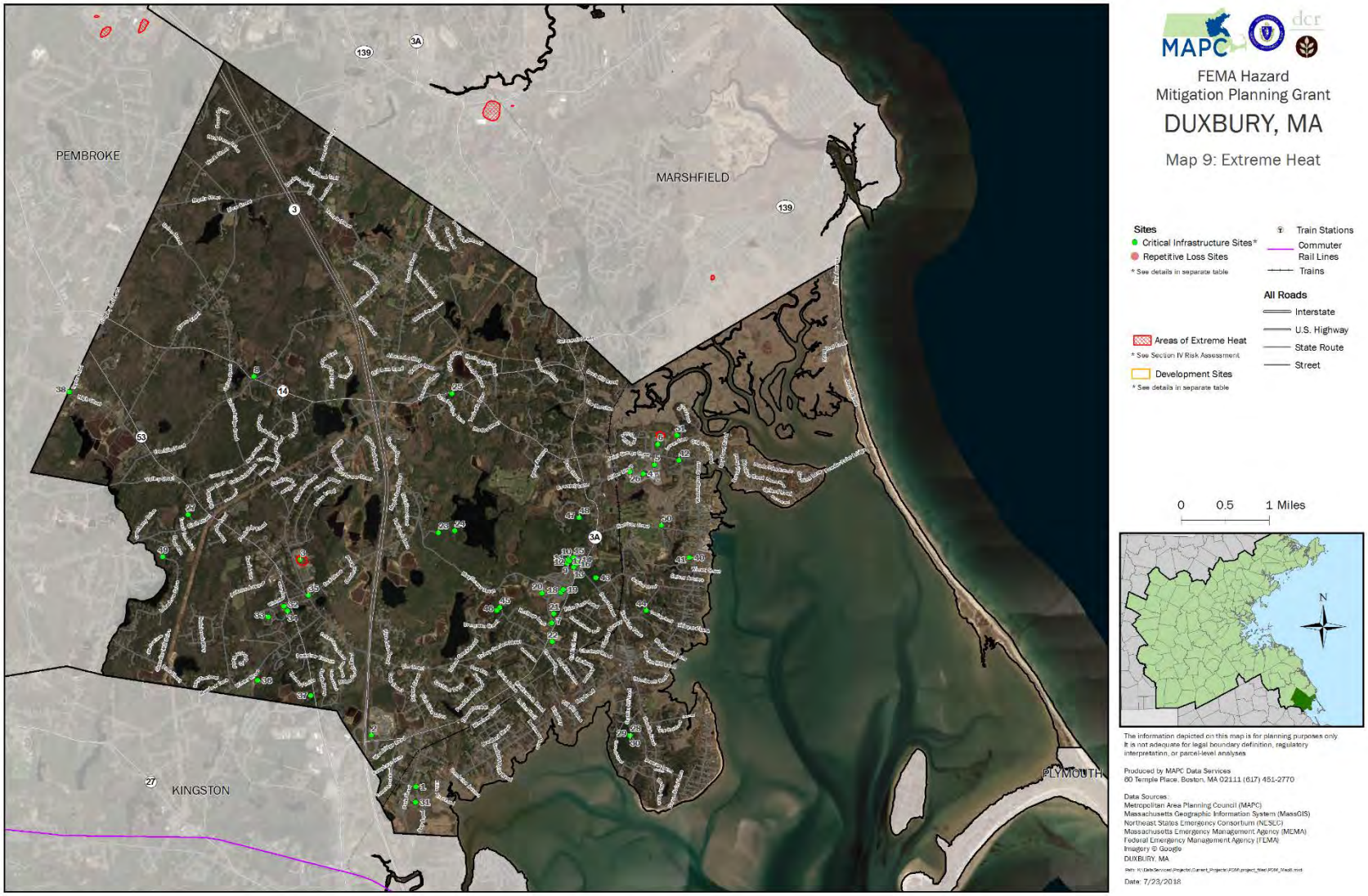
interpretation, or parcel-level analyses
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources:
Metropolitan Area Planning Council (MAPC)
Massachusetts Geographic Information System (MassGIS)
Northeast States Emergency Consortium (NESEC)
Massachusetts Emergency Management Agency (MEMA)
Federal Emergency Management Agency (FEMA)
Imagery © Google
DUXBURY, MA
Date: 7/23/2018


PEMBROKE
MARSHFIELD
KINGSTON
PLYMOUTH
MAPC
dcr
FEMA Hazard
Mitigation Planning Grant
DUXBURY, MA
Map 9: Extreme Heat
Sites
Critical Infrastructure Sites*
Repetitive Loss Sites
* See details in separate table
Train Stations
Commuter Rail Lines
Trains
All Roads
Interstate
U.S. Highway
State Route
Street
Areas of Extreme Heat
* See Section IV Risk Assessment
Development Sites
* See details in separate table
0 0.5 1 Miles
N
The information depicted on this map is for planning purposes only. It is not adequate for legal boundary definition, regulatory interpretation, or parcel-level analyses
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources:
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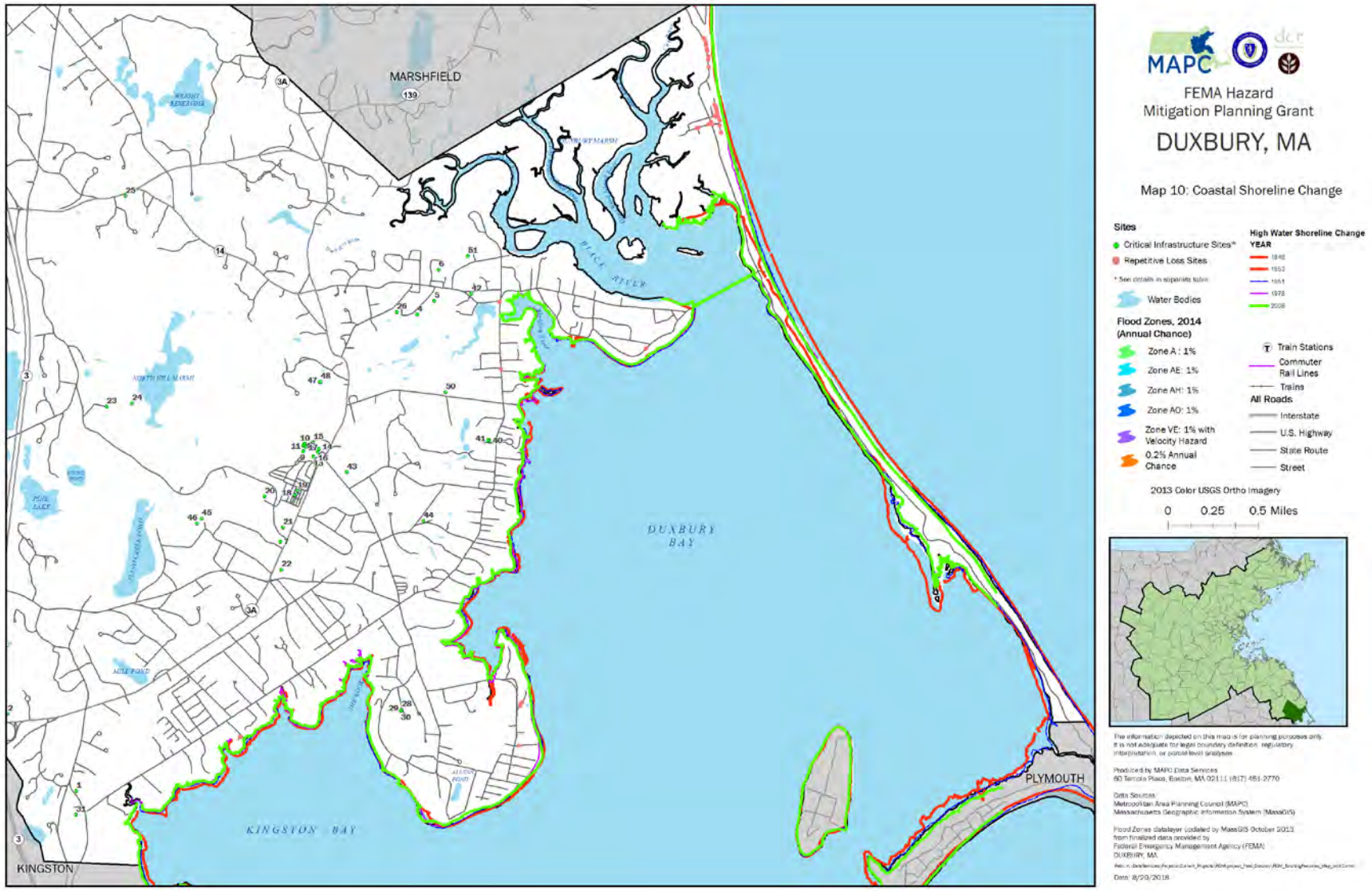
Massachusetts Emergency Management Agency (MEMA)
Federal Emergency Management Agency (FEMA)
Imagery © Google
DUXBURY, MA
Date: 7/23/2018


MARSHFIELD
PLYMOUTH
KINGSTON
KINGSTON BAY
DUXBURY BAY
PLACE RIVER
MAPC
FEMA Hazard
Mitigation Planning Grant
DUXBURY, MA
Map 10: Coastal Shoreline Change
Sites
Critical Infrastructure Sites*
Repetitive Loss Sites
* See details in separate table
Water Bodies
Flood Zones, 2014
(Annual Chance)
Zone A : 1%
Zone AE: 1%
Zone AH: 1%
Zone AO: 1%
Zone VE: 1% with
Velocity Hazard
0.2% Annual
Chance
High Water Shoreline Change
YEAR
1848
1953
1951
1978
2008
Train Stations
Commuter
Rail Lines
Trains
All Roads
Interstate
U.S. Highway
State Route
Street
2013 Color USGS Ortho Imagery
0 0.25 0.5 Miles
The information depicted on this map is for planning purposes only.
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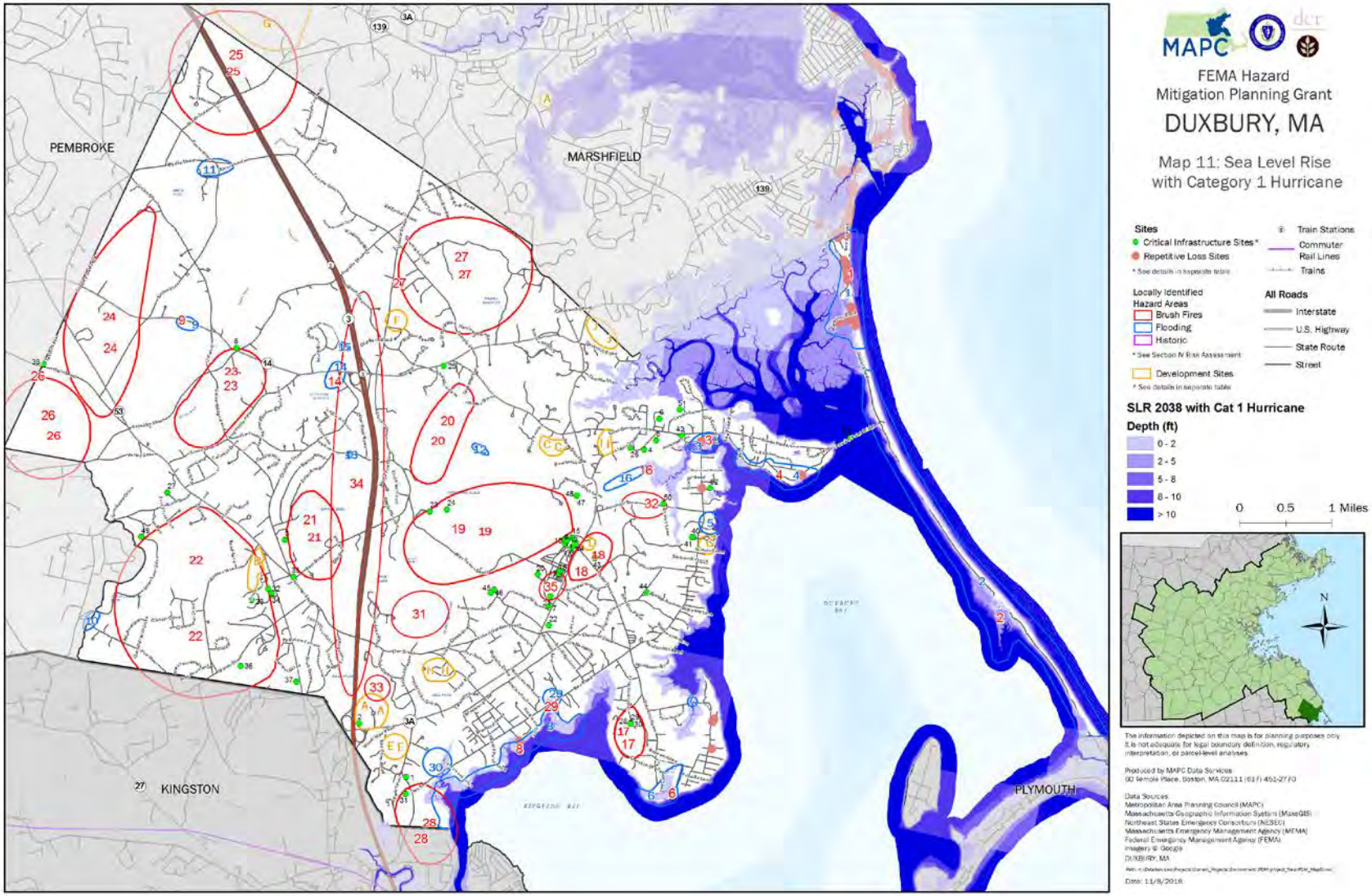
interpretation, or parcel-level analyses
Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources
Metropolitan Area Planning Council (MAPC)
Massachusetts Geographic Information System (MassGIS)
Flood Zones datalayer updated by MassGIS October 2013
from finalized data provided by
Federal Emergency Management Agency (FEMA)
DUXBURY, MA.
Date: 8/20/2018


PEMBROKE
MARSHFIELD
KINGSTON
PLYMOUTH
MAPC
dcr
FEMA Hazard
Mitigation Planning Grant
DUXBURY, MA
Map 11: Sea Level Rise
with Category 1 Hurricane
Sites
Critical Infrastructure Sites*
Repetitive Loss Sites
* See details in separate table
Train Stations
Commuter Rail Lines
Trains
Locally Identified Hazard Areas
Brush Fires
Flooding
Historic
* See Section IV Risk Assessment
Development Sites
* See details in separate table
All Roads
Interstate
U.S. Highway
State Route
Street
SLR 2038 with Cat 1 Hurricane
Depth (ft)
0 - 2
2 - 5
5 - 8
8 - 10
> 10
0
0.5
1 Miles
N
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Produced by MAPC Data Services
60 Temple Place, Boston, MA 02111 (617) 451-2770
Data Sources:
Metropolitan Area Planning Council (MAPC)
Massachusetts Geographic Information System (MassGIS)
Northeast States Emergency Consortium (NESEC)
Massachusetts Emergency Management Agency (MEMA)
Federal Emergency Management Agency (FEMA)
Imagery © Google
DUXBURY, MA
Date: 11/8/2018

Appendix C Public Participation

HAZARD MITIGATION PLAN PUBLIC MEETING

Natural hazards can have serious impacts on the Town of Duxbury and its residents



The Duxbury Hazard Mitigation Plan is being prepared to help the town reduce its vulnerability to natural hazards such as flooding, hurricanes and winter storms. Please join the Town for a presentation about the Hazard Mitigation Plan at a public meeting hosted by the Planning Board.

Date: **Wednesday, March 22, 2017**
Time: **7:00 PM**
Location: **Duxbury Town Hall, Mural Room**
878 Tremont Street, Duxbury, MA

For more information, please contact Martin Pillsbury at mpillbury@mapc.org

MAPC
METROPOLITAN AREA PLANNING COUNCIL

Meeting Notice

Town of Duxbury, Massachusetts

Pursuant to MGL Chapter 30A, §18-25
All meeting notices and agenda must be filed and time stamped in the Town Clerk's Office and posted at least 48 hours prior to the meeting (excluding Saturdays, Sundays and Holidays)

TOWN CLERK'S STAMP
TOWN CLERK
2017 MAR 17 AM 7:38
DUXBURY, MASS.

Board: ***Planning Board***

Meeting Location: ***Town Hall, 878 Tremont Street, Mural Room***

Day & Date of Meeting: ***Wednesday, March 22, 2017*** **Time:** ***7:00 PM***

Posted by: ***Brian Glennon, Chairman***

AGENDA

7:00 PM — Call Meeting to Order / Open Forum

A. Hazard Mitigation Plan Public Meeting (MAPC / Martin Pillsbury)

B. ANR Plan of Land, 0 North Street & Keene Street / Baldwin

C. Performance Guarantee and Lot Release: McLean's Way Definitive Subdivision / Reinhalter

D. Discussion of Concept Plan: 232 Surplus Street / JRM Investment Realty 2010, LLC

E. Discussion of Annual Town Meeting 2017 / 2018:
- Ground-Mounted Solar Regulations
- Access Standards
- Grading / Stormwater Containment

F. Planning Director Report:
- Comprehensive Plan
- Recodification
- Zoning Maps
- Other

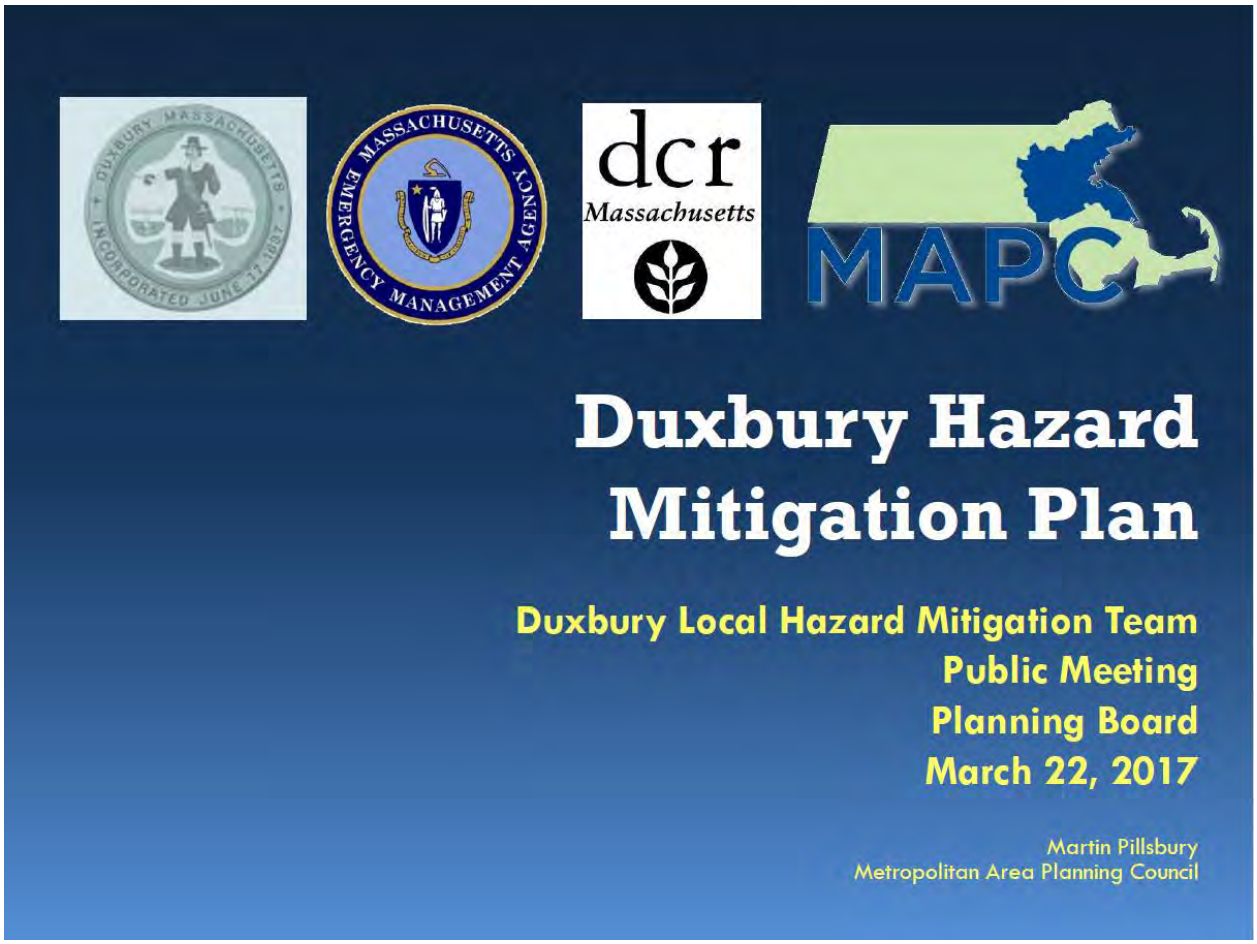
G. Discussion of Process / Planning Board Subcommittees for Comprehensive Plan Update and Zoning Bylaw Recodification

H. Other Business
- FYI Items
- Other

9:00 PM — Adjourn

NEXT PLANNING BOARD MEETING:
Wednesday, April 12, 2017 at 7:00 PM,
Duxbury Town Hall, Mural Room
878 Tremont Street

The listings of matters are those reasonably anticipated by the chair which may be discussed at the meeting. Not all items listed may in fact be discussed and other items not listed may also be brought up for discussion to the extent permitted by law.


Duxbury Hazard Mitigation Plan
Duxbury Local Hazard Mitigation Team
Public Meeting
Planning Board
March 22, 2017
Martin Pillsbury
Metropolitan Area Planning Council

From: Ashley MacMillan
To: Alicia Babcock, Seawall Committee; Anne Antonellis Duxbury Business Association; Bayside Marine Corporation; Brian Cherry; Charles Kilmer; Chief Clancy; Chief Kevin M. Nord; Chris Sherman; Chuck Leonard DBMS; Cris Luttazi; DFD Captains; Douglas Hart, DYC; Duxbury Rural and Historical Society; Eugene Fulmine, Pembroke DPW; Frank Gay GATRA; Greg Marshfield Planner; Jake Emerson; Joanne Moore; Joe Grady; Joe Messina (jmessina@princelobel.com); Jonathan Beder Plymouth DPW; Jones River Watershed Association; Karen Grey Wildlands Trust; Kingston Board of Selectmen; Kingston Dept. of Public Works; Kingston Fire Department; Kingston Harbormaster; Kingston Planning Board; Linda Brodie (lkbrodie@gmail.com); Long Point Marina; Mark Cutter, USCG; Marshfield Selectmen; Matthew Heins, Pembroke Planning; Michael Dimeo, Marshfield Harbormaster; Nancy O'Connor; North & South River Watershed Association; Pam DiBona, MassBays; Pembroke Board of Selectmen (selectmen@townofpembrokemass.org); Pembroke Fire Chief Michael Hill (mhill@pembrokefire.org); Pembroke Police Chief Richard Wall (rwall@pembrokepolice.org); Pembroke Town Administrator (ethorne@townofpembrokemass.org); Peter Buttkus; Peter Forman, South Shore Chamber of Commerce; Plymouth Board of Selectmen; Plymouth Harbormaster; Plymouth Housing Authority; René Read; Richard Klein, USCG; Rob Fawcett (robfawcett@yahoo.com); Robin Carver Plymouth Planner; Schofield, Darci; Scott Lambiase; Seawall Committee; Stanley Eldridge, Plymouth Fire Chief; Stephen Dunn; Susan Ossoff; Tom Reynolds Marshfield DPW; Tracy Mayo; Valerie Massard; William Hocking, Marshfield Fire; bglennon@cumberlandgulf.com (bglennon@cumberlandgulf.com); Cindy Fiorini (claddfiorini@gmail.com); David Litti (dlitti@msullc.com); George Wadsworth (jgweds@aol.com); Jennifer Turcotte (jturcotte@sts-me.com); John Bear; Scott Casagrande (scottcasagrande@borhelinsurance.com)
Subject: Duxbury Hazard Mitigation Plan 2018
Date: Monday, November 5, 2018 9:41:25 AM
Attachments: image001.wmz
image002.png
oledata.mso
DuxburyHazardMitigationPlan2018.pdf

---

bury
tts

November 5, 2018
via email

RE: Hazard Mitigation Plan

Dear Stakeholders,

Attached please find the 2018 Hazard Mitigation Plan for the Town of Duxbury prepared through the Metropolitan Area Planning Council (MAPC). This draft is currently pending adoption and your feedback is welcome. Please submit any comments or questions to me in the Planning Office at (781) 934-1100 ext. 5475, massard@town.duxbury.ma.us, or through correspondence to the address below.

To review the document online, please click on the following link:
https://www.town.duxbury.ma.us/sites/duxburyma/files/uploads/duxbury_pdm_draft_10.30.18online.pdf

Warm Regards,
Valerie Massard, AICP, CFM
Planning Director, Town of Duxbury

cc: Town of Pembroke: Selectmen, Planning, DPW and Fire
Town of Kingston: Selectmen, Planning, DPW, Harbormaster and Fire
Town of Plymouth: Selectmen, Planning, DPW, Harbormaster and Fire
Town of Marshfield: Selectmen, Planning, DPW, Harbormaster and Fire

Duxbury Beach Reservation, Inc.	Duxbury Council on Aging
Wildlands Trust of Southeastern MA	Duxbury Planning Board
Old Colony Planning Council	Duxbury Bay Management Commission
South Shore Chamber of Commerce	Sweetser's Bldg., Rob Fawcett
Plymouth Housing Authority	Duxbury Business Association
Duxbury Rural and Historical Society	Duxbury Community Preservation Committee
Duxbury Bay Maritime School	Duxbury Seawall Committee
Long-Point Marina	Duxbury Yacht Club
Bayside Marina Corporation	GATRA
Island Creek Oysters	Jones River Watershed Association
Duxbury Conservation Commission	North and South River Watershed Association
US Coast Guard	MassBays

Duxbury Local Hazard Mitigation Review Team: Town Manager, DPW, Fire, Police & Harbormaster, Facilities Maintenance, Health, Planning, Conservation, Building and Assessing Depts.

and D. Schofield, MAPC

TOWN CLERK'S STAMP
TOWN CLERK
2018 NOV -8 PM 1:49
DUXBURY, MASS.

Meeting Notice
REVISED

Town of Duxbury, Massachusetts

Pursuant to MGL Chapter 30A, §18-25
All meeting notices and agenda must be filed and time stamped in the Town Clerk's Office and posted at least 48 hours prior to the meeting (excluding Saturdays, Sundays and Holidays)

Board: *Planning Board*

Meeting Location: *Duxbury Town Hall, 878 Tremont Street, Mural Room, lower level*

Day & Date of Meeting: *Wednesday, November 14, 2018* **Time:** *7:00 PM*

Posted by: *Scott Casagrande, Chairman*

AGENDA

7:00 PM Call Meeting to Order / Open Forum / Committee Liaison Reports

A. **Approval Not Required: 124 Evergreen Street;** *Applicant proposes to carve off 3 new buildable lots.*

B. **Approval Not Required: 1 & 7 Modoc Street;** *Applicant proposes to adjust the lot line between two existing parcels.*

C. **7:15 PM – Administrative Site Plan Review and ZBA Referral; Special Permit: 397 Washington Street;** *Applicant proposes to convert the building to mixed-use: a real-estate office with apartments on the upper level, with updated signage, landscaping, and lighting.*

D. **Comprehensive Plan Update, Phase 2:** *Presentation by MAPC*

E. **Discussion - Zoning Bylaw for Medical Marijuana/Siting of Facilities**

F. **Discussion/Update: Hazard Mitigation Plan**

G. **Other Business:**

Performance Guarantee Reduction: Nash Road, JRM Investment Realty
Minutes
Construction Estimates October 2018
Engineering Invoices (if received)
FYI Items/Correspondence
Planning Board Meeting Schedule 2019
New Business for Next Planning Board Agenda

NEXT PLANNING BOARD MEETING:
Wednesday, November 28, 2018 at 7:00 PM
Duxbury Town Hall, 878 Tremont Street,
Mural Room, lower level

The listings of matters are those reasonably anticipated by the chair which may be discussed at the meeting. Not all items listed may in fact be discussed and other items not listed may also be brought up for discussion to the extent permitted by law.

Meeting Notice

Town of Duxbury, Massachusetts

Pursuant to MGL Chapter 30A, §18-25
All meeting notices and agenda must be filed and time stamped in the Town Clerk's Office and posted at least 48 hours prior to the meeting (excluding Saturdays, Sundays and Holidays)

TOWN CLERK'S STAMP
TOWN CLERK
2018 NOV 19 AM 10:20
DUXBURY, MASS.

Committee: **Board of Selectmen** ***LOCATION CHANGE***

Meeting Location: ***Senior Center – Ellison Room – 10 Mayflower Street***

Day & Date of Meeting: ***Monday, November 19, 2018*** **Time:** ***6:00 p.m.***

Posted by: ***N. O'Connor***

AGENDA
(Originally posted 11/15/18 @ 3:29pm)
Revised 11/19/18

I **CALL TO ORDER**

II **EXECUTIVE SESSION**

6:00pm For the purpose of discussing pending litigation since an open meeting may have a detrimental effect on the litigating position of the Town, if the Chair so declares, regarding:
Johnson vs Town of Duxbury

6:15pm For the purpose of discussing pending litigation since an open meeting may have a detrimental effect on the litigating position of the Town, if the Chair so declares, regarding:
Town of Duxbury v. Quakewrap and C.W. White Marine

III **OPEN FORUM**

IV **NEW BUSINESS**

Recognition of Firefighters Alex Merry and Jack Ahern for their Service in North Carolina
Recognition of Call Firefighter Pieter Van Slyck on his years of service

7:01 p.m. Tax Classification Hearing - presented by Steve Dunn, Assessor

7:15 p.m. – Public Hearing re: Hazard Mitigation Plan

Discussion pertaining to potential zoning amendment relating to the regulation of medical marijuana treatment centers.

Discussion pertaining to Ch. 61A land – 1065 Summer Street

Discussion and review of Annual Liquor License Renewals along with CV/Entertainment licenses

Discussion regarding Declaration of Surplus items – Fire Department

(Continued on next page/back)

The listings of matters are those reasonably anticipated by the chair which may be discussed at the meeting. Not all items listed may in fact be discussed and other items not listed may also be brought up for discussion to the extent permitted by law.

Appendix D Local Adoption

Certificate to Document Adoption of the
Hazard Mitigation Plan Update
By the Board of Selectmen

TOWN OF DUXBURY, MASSACHUSETTS

CERTIFICATE OF ADOPTION
BOARD OF SELECTMEN
TOWN OF DUXBURY, MASSACHUSETTS

A RESOLUTION ADOPTING THE

TOWN OF DUXBURY HAZARD MITIGATION PLAN 2018

WHEREAS, the *Town of Duxbury Hazard Mitigation Plan 2018* contains several potential future projects to mitigate potential impacts from natural hazards in the Town of Duxbury, and

WHEREAS, duly-noticed public meetings were held by Planning Board on March 22, 2017 and by the Board of Selectmen on November 19, 2018.

WHEREAS, the Town of Duxbury authorizes responsible departments and/or agencies to execute their responsibilities demonstrated in the plan, and

NOW, THEREFORE BE IT RESOLVED that the Town of Duxbury Board of Selectmen adopts the *Town of Duxbury Hazard Mitigation Plan 2018,* in accordance with M.G.L. 40 §4 or the charter and bylaws of the Town of Duxbury.

ADOPTED AND SIGNED this Date: December 17, 2018

Theodore J. Flynn, Chair

David J. Madigan, Clerk

Shawn Dahlen, Vice Chair

878 Tremont Street, Duxbury, MA 02332-4499 (781) 934-1107

"The Mission of the Town of Duxbury is to deliver excellent services to the community in the most fiscally responsible and innovative manner while endeavoring to broaden our sense of community and preserve the unique character of our town.