Town of Braintree Climate Vulnerability Assessment and Action Plan

December 2017

Prepared for
Town of Braintree
1 John F. Kennedy Memorial Drive
Braintree, Massachusetts 02184
www.townofbraintreegov.org
Joseph C. Sullivan, Mayor

Prepared by
Metropolitan Area Planning Council
60 Temple Place, 6th Floor
Boston, Massachusetts 02111
www.mapc.org

ACKNOWLEDGEMENTS

The project was conducted by the Metropolitan Area Planning Council (MAPC) with funding from MAPC's Planning for MetroFuture Technical Assistance program, the Barr Foundation, the Commonwealth of Massachusetts Community Compact and District Local Technical Assistance programs, and the Town of Braintree.

METROPOLITAN AREA PLANNING COUNCIL

Officers

President	Keith Bergman
Vice President	Erin Wortman
Secretary	Sandra Hackman
Treasurer	Taber Keally
Executive Director	Marc D. Draisen

Project Manager/Senior Environmental Planner	Anne Herbst
Regional Planner	Genea Foster
GIS/Data Analysis	Eliza Wallace
	Ryan Melendez
	Emily Long

TOWN OF BRAINTREE

Mayor	Joseph C. Sullivan
Project Manager/Conservation Planner	Kelly Phelan

STEERING COMMITTEE MEMBERS

James Arsenault, Sharmila Biswas, Bob Campbell, Lou Dutton, Michael Cavanaugh, Mary Beth McGrath, David McKenna, Sean Murphy, Stephen O'Brien, Kelly Phalen, Christine Stickney, Mark Thompson

TABLE OF CONTENTS

TABLES

FIGURES

INTRODUCTION

The devastating effects of Hurricanes Harvey, Irma, and Maria highlight the imperative to plan now for future storms. As detailed in the *Climate Change Background* section of this report, we are already experiencing warmer temperatures, increased precipitation, and rising seas. Precipitation in the Boston area has increased by 10% in the past fifty years. Recently released design storm figures (NOAA 14) for the 10-year, 24-hour storm are 15% higher than those issued in 1961. Climate projections for this century include increased frequency and intensity of rain storms, rising seas, and more frequent days with extreme heat.

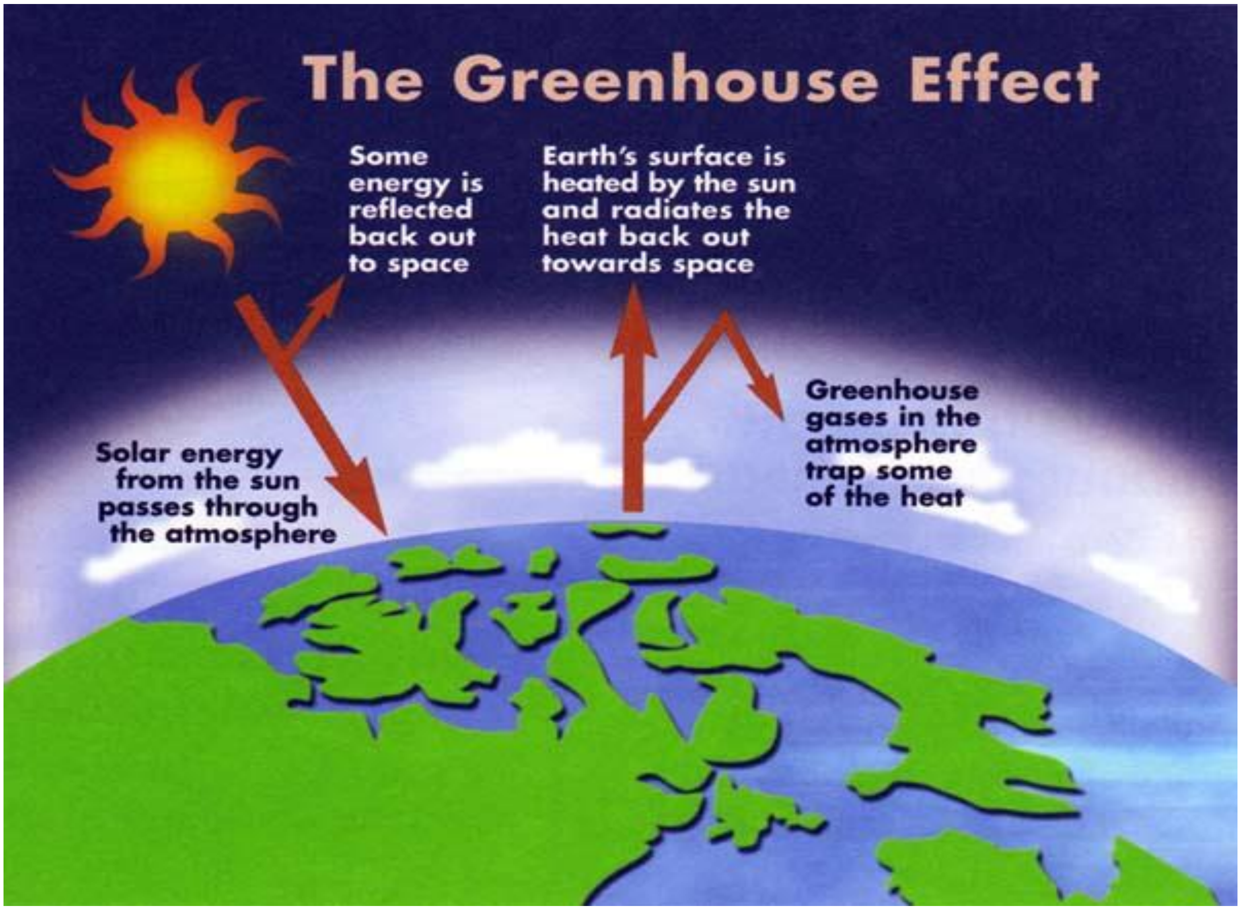
The March 2010 rains caused millions of dollars in damages in Braintree. As rainfall amounts increase, rain events similar to 2010 will become more frequent. A one-thousand year event would nearly double the rainfall experienced over three days in March 2010. As is evident from the recent hurricanes, damage and suffering from such an extreme event is inevitable. Indeed, flooding or extreme heat, and the resultant potential for power outages can have severe and cascading effects during far lesser storms than a one-in-one-thousand year occurrence.

Yet we can take steps to increase community resilience and limit future damages. Many of today's municipal investments and decisions have long legacies that will influence future vulnerabilities. Advance planning can save money, while inaction, or actions that don't anticipate future conditions, may lead to higher costs in the future. An example of effective planning comes from the reports that Florida properties experienced much less damage from Hurricane Irma than from Hurricane Andrew in 1992. This is attributed to critical improvements made to the building code as a result of lessons learned from Hurricane Andrew. This report identifies future climate vulnerabilities and suggests strategies that can reduce the risk of harm to people and properties, and help speed recovery when inevitable future storms occur.

CLIMATE CHANGE BACKGROUND

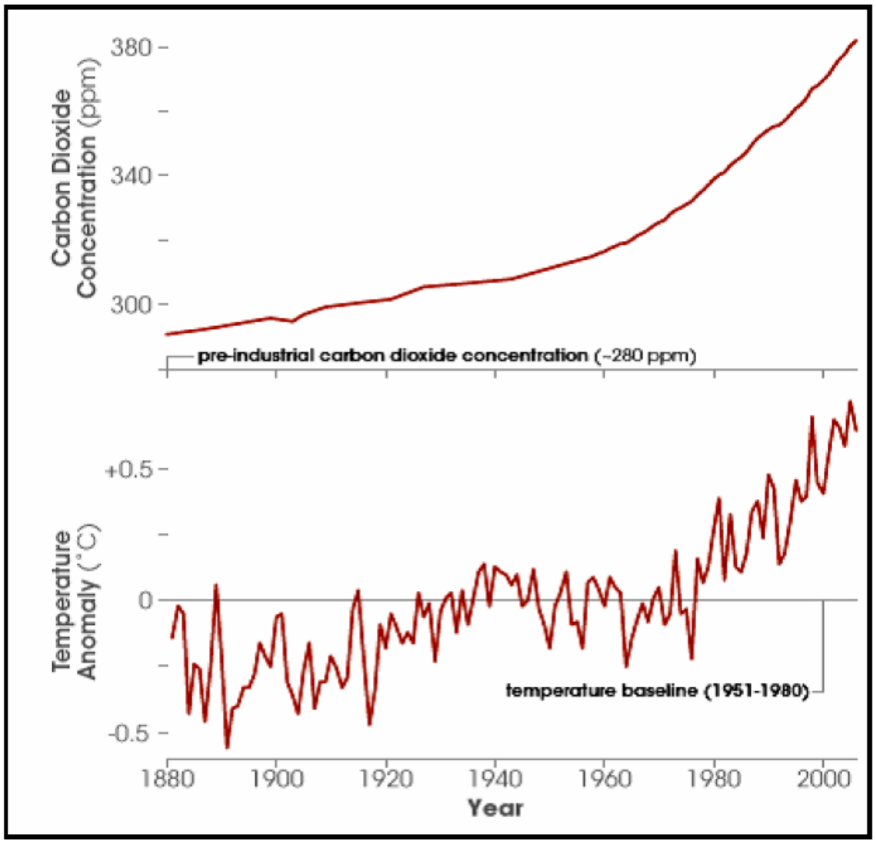
Our climate has always been regulated by gases, including carbon dioxide, methane, and nitrous oxide, that blanket the earth. These gases trap heat that would otherwise be reflected out to space; without them our planet would be too cold to support life. We refer to these gases as "greenhouse gases" (GHGs) for their heat trapping capacity. Changes in GHG concentrations occur naturally, due to such events as volcanic eruptions, and variations in solar energy entering the atmosphere.

In the past century, human activity associated with industrialization has contributed to a growing concentration of GHGs in our atmosphere. The combustion of fossil fuels, our primary energy source in the age of industrialization, releases GHGs into the atmosphere. As shown in Figure 1, there is a correlation between increases in carbon dioxide concentrations and global temperature. There is by now widespread consensus among scientists regarding the warming of our climate and its causes. As stated in the Third United States Climate Report (2014): "Global climate is changing and this change is apparent across a wide range of observations. The global warming of the past 50 years is primarily due to human activities." (Chapter 2, page 12)



The following sections will review climate changes that have been observed to date, and projections of future changes. Climate change impacts are not evenly distributed across the globe. The focus of this report is on impacts relevant to Braintree. We utilize data for the Northeast United States and, where possible, the Boston region. For those interested in more background on climate science, the U. S. National Climate Assessment 2014 provides a very readable review. It can be downloaded at: http://nca2014.globalchange.gov/downloads.

Figure 1. Global Temperature and CO2 Trends



Source: MA Climate Change Adaptation Report 2011

Climate Change: Observations, Projections, Impacts

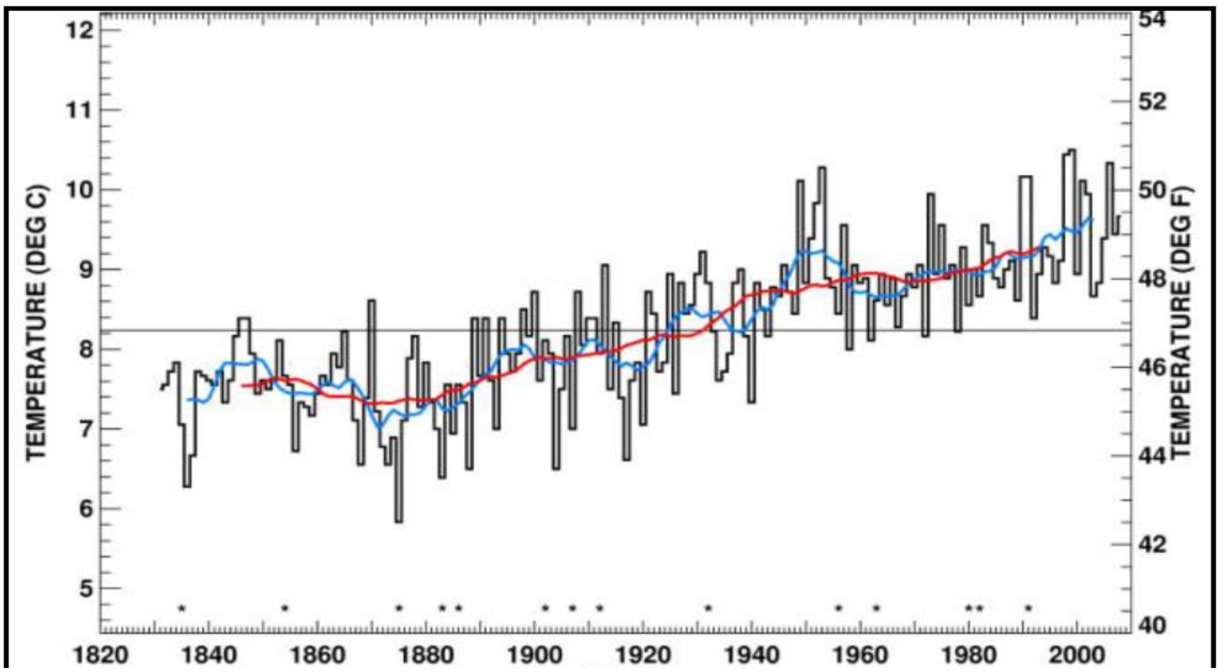
Climate change observations come from a variety of data sources that have measured and recorded changes in recent decades and centuries. Climate change projections, however, predict future climate impacts and by their nature cannot be observed or measured. As a result of the inherent uncertainty in predicting future conditions, climate projections are generally expressed as a range of possible impacts. There are two primary sources of uncertainty. Scientists project future impacts by developing models; the range of projected impacts will be smaller or larger depending on the level of confidence in a given climate model. The other source of uncertainty is that our future GHG emission levels are unknown. GHG levels reflect global emissions. While the international community is investing substantial efforts in reducing GHG emissions, it is not possible to predict future emissions levels with any certainty. As a result, climate projections often include multiple scenarios, or a range of results, reflecting a range of future GHG levels in the atmosphere.

Temperature

Temperature has been increasing along with GHG concentrations in the past century. According to the US National Climate Assessment 2014, temperatures in the Northeast United States have increased by almost two degrees Fahrenheit between 1895 and 2011. Data from the Blue Hill Observatory in Milton (Figure 2) located three miles from Braintree, reflects this trend.

Figure 2. Observed Temperature Change

For the Northeast United States: temperature increased by almost 2 degrees, between 1895 and 2011 (US National Climate Assessment 2014)



Blue Hill Observatory Annual Temperature, 1831-2008

Source: Michael J. Iacono (from MA Climate Change Adaptation Report 2011)

Future temperature projections for the Boston Harbor Basin (Figure 3) are shown below. The projections show an increase in average temperatures and an increasing likelihood of heat waves, as indicated by the increased number of days over 90 and 100 degrees each year. Increasing temperatures will have important impacts on human health. Heat is the number one cause of U.S. weather fatalities over the past decade (EPA/NOAA). Heat waves are often accompanied by poor air quality, exacerbating chronic respiratory and cardiovascular conditions.

Figure 3. Projected Temperature Change for the Boston Harbor Basin

Parameter (Temperature F°)	Observed Baseline (1971-2000)	Predicted 2020-2049	Predicted 2040-2069	Predicted 2060-2089	Predicted 2080-2099
Annual temperature	50°	52-54°	53-56°	53-98°	54-61°
Winter temperature	30°	32-34°	33-37°	33-39°	34-40°
Spring Temperature	48°	49-51°	50-53°	50-56°	51-57°
Summer temperature	70°	72-74°	72-77°	73-80°	73-82°
Fall Temperature	53°	55-57°	57-59°	56-62°	56-64°
Days over 90 (days/year)	8	13-23	16-37	17-57	19-75
Days over 100 (days/year)	0.05	.29-2	.37-4	.52-9	.6-16

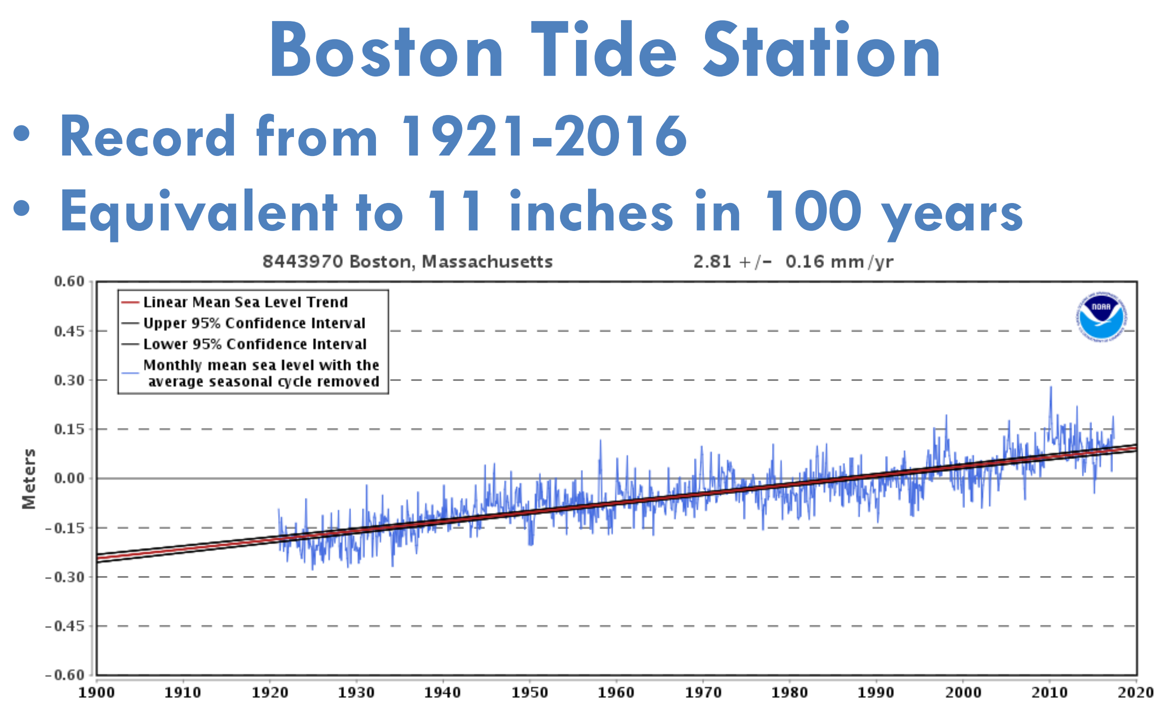
Source: Northeast Climate Science Center, UMass-Amherst, 2017

Rising temperatures will impact natural systems; expected impacts include changes in species and the composition of forest and wetland habitats, an increase in invasive species and pests, and a longer growing season. Rising temperatures also drive other impacts including changes in precipitation patterns, and sea level rise.

Sea Level Rise

Records from the Boston Tide Station show nearly one foot of sea level rise in the past century (Figure 4). Warming temperatures contribute to sea level rise in two ways. First, warm water expands to take up more space. Second, rising temperatures are melting land-based ice which enters the oceans as melt water. The third, quite minor, contributor to sea level rise in New England is not related to climate change. New England is still experiencing a small amount of land subsidence (drop in elevation) in response to the last glacial period.

Figure 4. Observed Sea Level Rise

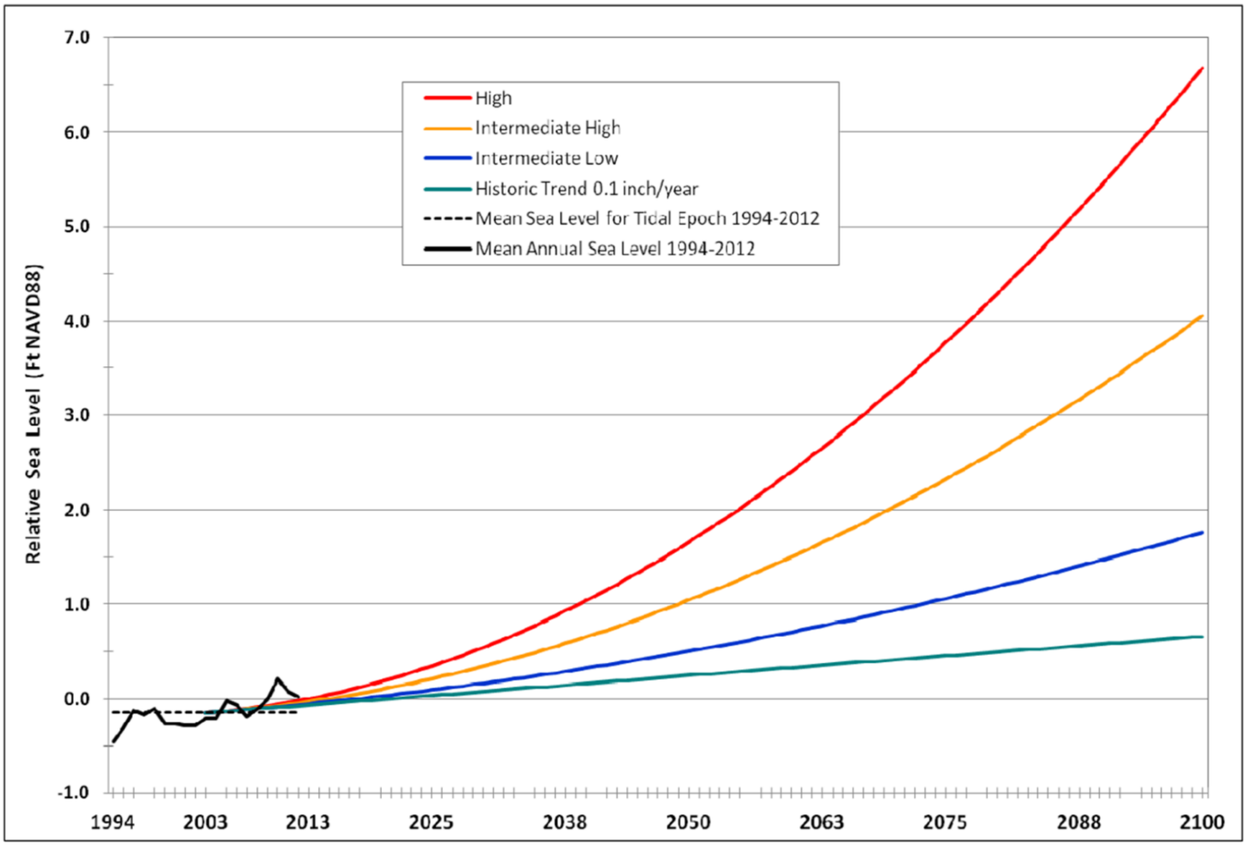


Source: NOAA

The Massachusetts Office of Coastal Zone Management (CZM) adjusted global predictions for future sea level rise, taking into account local subsidence. As is evident in Figure 5, the range of projections for the future is quite wide, particularly approaching the end of this century. The High scenario includes ocean warming and a calculation of maximum glacier and ice sheet melt. The Intermediate High scenario averages higher predictions but includes lesser ice sheet melting. The Intermediate Low considers lower sea level rise scenarios and limited ice melt. The Historic Trend reflects a continuation of the current rate of sea level rise.

The CZM estimate for the Boston Harbor does not take into account more recent research that suggests the Boston Harbor is included in a region that may experience greater than average sea level rise. CZM cautions that the Historic and Intermediate Low scenarios may "considerably underestimate actual sea level rise", particularly for time horizons beyond 25 years. Although Braintree has limited coastal shoreline, the tidal segment of the Fore and Monatiquot Rivers may experience the impacts typically projected for sea level rise, including flooding, erosion, and loss of salt marsh and other coastal habitats.

Figure 5. Projected Sea Level Rise for Greater Boston Harbor



Source: Sea Level Rise: Understanding and Applying Trends and Future Scenarios for Analysis and Planning, Massachusetts Office of Coastal Zone Management, December 2013.

Precipitation

Precipitation in Massachusetts has increased by approximately 10% in the fifty-year period from 1960 to 2010 (Figure 6). Moreover, for the Northeast US, according to the U.S. National Climate Assessment, 2014, in the past fifty years there has been a 71% increase in the amount of rain that falls in the top 1% of storm events. As the atmosphere warms, it can hold more water; this leads to an increase in large rainfall events.

Projections for future precipitation suggest an increase in total precipitation, but also changes in precipitation patterns. Rain amounts are projected to increase in the winter and spring, but decrease in the summer (Figure 7). As a result, despite overall increasing precipitation levels, summer droughts may be a consequence of climate change. In addition, as noted, it is expected that we will experience a greater number of large rain events. Another potential source of uncommon, but significant, rain events is hurricanes. According to the National Oceanic and Atmospheric Administration (NOAA), hurricanes may become more intense, with a projected 10-15% increase in rainfall by the end of the century.

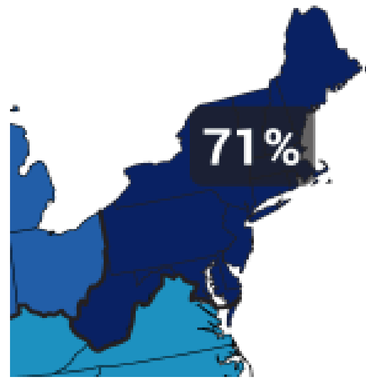
As we experienced in 2016, drought can strain water supplies and stress plant and aquatic communities. Increasing winter/spring precipitation, along with warmer weather resulting in more rain rather than snow, is expected to create additional flooding early in the year, and low-flow in rivers and streams in the summer.

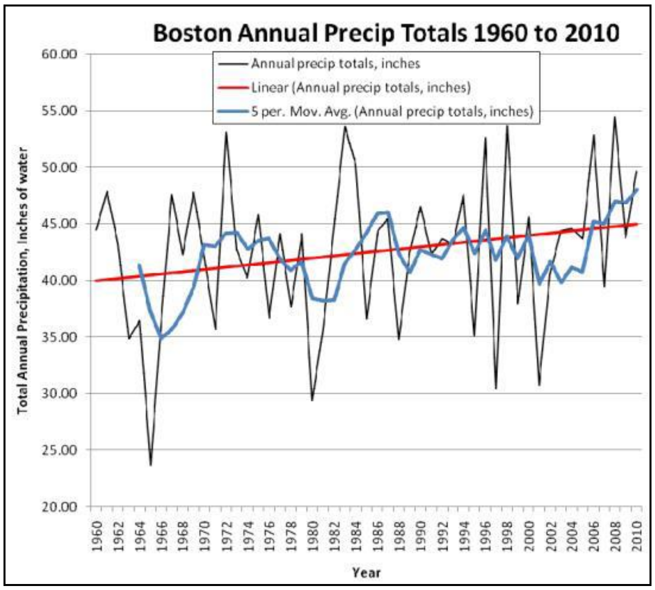
Figure 6. Observed Precipitation Change

For the Northeast United States:

- **71% increase in the amount of rain that falls in the top 1% events from 1958 – 2012.**

Source: US National Climate Assessment 2014





For the Boston area: 10% increase over the past 50 years

Source: MA Climate Change Adaptation Report 2011

The observed changes in precipitation are also reflected in changing precipitation frequency estimates. Precipitation frequency estimates, used to derive design storm standards, were published in 1961 by the U.S. Commerce Department in a document known as TP-40 (Technical Paper 40). The National Oceanic and Atmospheric Administration (NOAA Atlas 14) and the Northeast Regional Climate Center (NRCC) at Cornell University have recently published updated estimates. The TP-40 100-year storm calculated in 1961 is now approximately equal to a 30-year storm as calculated by NRCC and NOAA Atlas 14 (MWRA p. 67). TP-40 figures are less precise, reflecting data available at the time. The NOAA 14 and NRCC figures are specific to Braintree.

Table 1. Design Storm Estimates

Braintree	TP-40	NOAA Atlas 14	NRCC
10-year, 24-hour storm	4.5”	5.24”	4.91”
100-year, 24-hour storm	6.5”	8.16”	8.72”

Figure 7. Projected Precipitation Change

Parameter	Current Conditions (1961-1990)	Predicted Change by 2050		Predicted Change by 2100	
		Low	High	Low	High
Annual precipitation	41 inches	+ 5%	+ 8%	+ 7%	+ 14%
Winter precipitation	8 inches	+ 6%	+ 16%	+ 12%	+ 30%
Summer precipitation	11 inches	- 3%	-1%	0%	-1%

Source: MA Climate Change Adaptation Report 2011

The cities of Boston and Cambridge projected future conditions for the 10-year, 24-hour design storm as part of their climate vulnerability assessments. Their projections for increased precipitation are shown in Table 2.

Table 2. 10-year 24-hour Design Storm Projections

Boston Water and Sewer Commission	Baseline (1948-2012)	Precipitation		
		2035	2060	2100
Medium emission scenario	5.24”	5.55”	5.76”	6.08”
High emission scenario		5.6”	6.03”	6.65”
Cambridge	**(1971-2000)**	**2015-2044**	**2055-2084**	
	4.9”	5.6”	6.4”	

Source: Climate Ready Boston, Boston Research Advisory Group Report, 2016

Why Do a Climate Vulnerability Assessment?

This climate vulnerability assessment is an effort to determine which Braintree community assets --- people, natural resources, and physical infrastructure --- may be susceptible to harm from climate change. Climate vulnerability assessments generally consider:

- Exposure – whether climate changes will have a negative effect on various assets in the community.
- Sensitivity – if affected by climate change, how much damage, or loss of function will occur.
- Adaptive Capacity - sensitivity will be lessened, or heightened, by the degree to which there may be ways for the community asset to cope, compensate, or be modified, to adjust to climate changes.

Once vulnerabilities are identified, they can be prioritized according to the perceived risk they present. Generally, this involves considering the probability of damage to an asset and the consequences of damage. As an example, flooding to a sewer pump station and open space might be equally likely, but the pump station would presumably have higher priority as the consequence of failure is more severe. This strategy for considering risk is illustrated in Figure 8.

Figure 8. Risk Analysis

		Probability		
Consequence		Low	Medium	High
	Low	Least Risk	M-L	M
	Medium	M-L	Medium Risk	M-H
	High	M	M-H	Greatest Risk

For the most part, projected climate impacts do not create brand new concerns, rather they are an intensification, increased frequency, or geographic expansion, of existing challenges including flooding, heat waves and drought. As a result, Braintree already has significant experience and expertise to bring to these challenges. Further, many initiatives to address climate impacts provide benefits to the Town (tree planting, open space preservation), can help address Town obligations (MS4 permit compliance), or combat previously identified problems (flooding). Although disruptive storms may occur at any time, most of the predicted climate changes are happening relatively slowly over time. Identifying future vulnerabilities now gives the Town of Braintree time to plan for; and enact; projects and policy changes that will make for a more resilient community in the future.

Socioeconomic Vulnerability

Just as some locations in Braintree will be more vulnerable to climate impacts than others, it is also the case that climate change will not affect all residents of Braintree equally. In the context of climate change, vulnerable populations include a higher proportion of individuals who may be more susceptible to climate impacts, and who may have more difficulty adapting to, preparing for, and recovering from extreme weather events. Socioeconomic vulnerability refers to socioeconomic characteristics, such as income and race/ethnicity that influence vulnerability to climate change. Socioeconomic vulnerability influences susceptibility to illness or injury and capacity to meet ones basic needs following extreme weather. Individuals can simultaneously experience multiple socioeconomic vulnerabilities that can magnify the extent to which they are affected by climate change.

Low-income communities often have limited access to healthcare services and have higher rates of uninsured people. Low-income people are often more susceptible to financial shocks, which can occur after extreme weather, and which can have long-lasting impacts on financial security and the ability to secure safe shelter and meet medical needs. Furthermore, people who lack financial resources may have limited access to transportation. This can impair their ability to relocate to emergency shelters or away from areas susceptible to climate impacts. Social isolation can also influence vulnerability, as it limits access to critical information, municipal resources, and social support systems that can bolster emergency response. People at the most risk for social isolation include those living alone and people with limited English language proficiency. People of color and undocumented immigrants may also experience social isolation due to historically strained or tenuous relationships with government officials and first responders.

Environmental conditions can also exacerbate the impact of severe weather. Neighborhood environmental quality has been found to be strongly associated with socioeconomic composition. Environmental justice communities – neighborhoods with a high concentration of low-income people, people of color, and people with limited English language proficiency – are often more vulnerable to climate impacts. This is because of the higher prevalence of environmental burdens (i.e., noxious and industrial land uses), which lead to worsened environmental quality and higher incidence of chronic diseases. Housing conditions are also an important facet of environmental vulnerability. Not only are low-income people more likely to live in substandard housing, it is more financially challenging for them to make their homes more resilient to climate change and to fix damage caused by extreme weather.

SOCIOECONOMIC CONDITIONS IN BRAINTREE

Demographic information helps identify populations that may be particularly affected by climate change. It can also provide opportunities to build upon existing strengths in order to enhance resiliency. Understanding a community's character, socioeconomic makeup, and environmental features is important to fully understanding the implications of climate impacts on the town's population.

Age

Braintree's population has been growing since 1990, and will continue to grow over the coming decades. In 2010, Braintree's population was nearly 36,000, with 6,000 individuals over 65 years of age (Census 2010). According to MAPC's "Stronger Region" scenario, in which Metro Boston will retain a vibrant economy even as baby-boomers retire, MAPC projects that by 2030, Braintree's total population will increase by 12% to 40,000. Over the same period, Braintree's population will age. MAPC projects that by 2030, the senior population will increase by 48% (Figure 9). As of 2010, approximately 27% of Braintree's households consisted of people living alone (US Census, 2010). Seniors were disproportionately represented in this population, accounting for 43% ± 4% of residents living alone (ACS 2011-2015). One block group in North Braintree has nearly one-third of its resident age 65 and over (Figure 10). Seniors represent more than 20% of the population in several other block groups.

Figure 9. Current Population and Projections

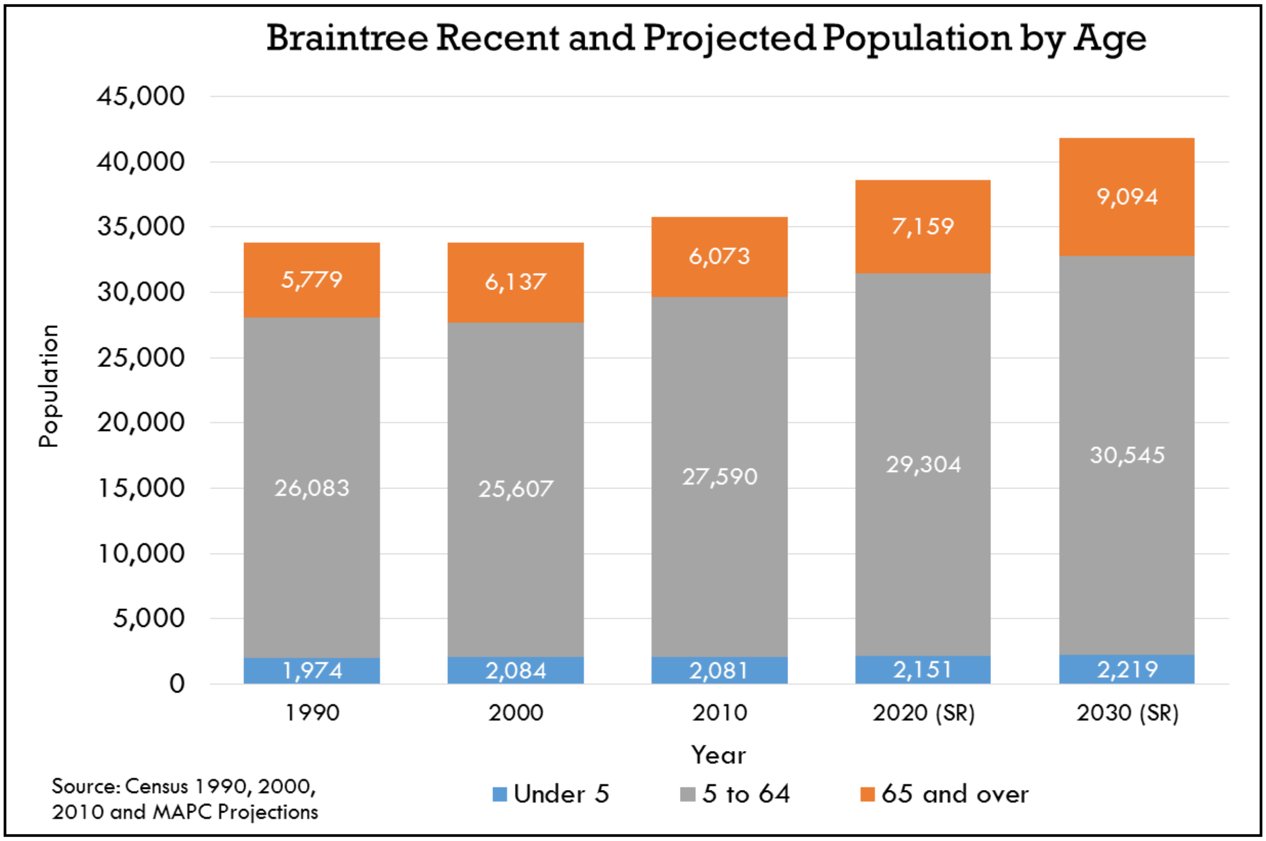
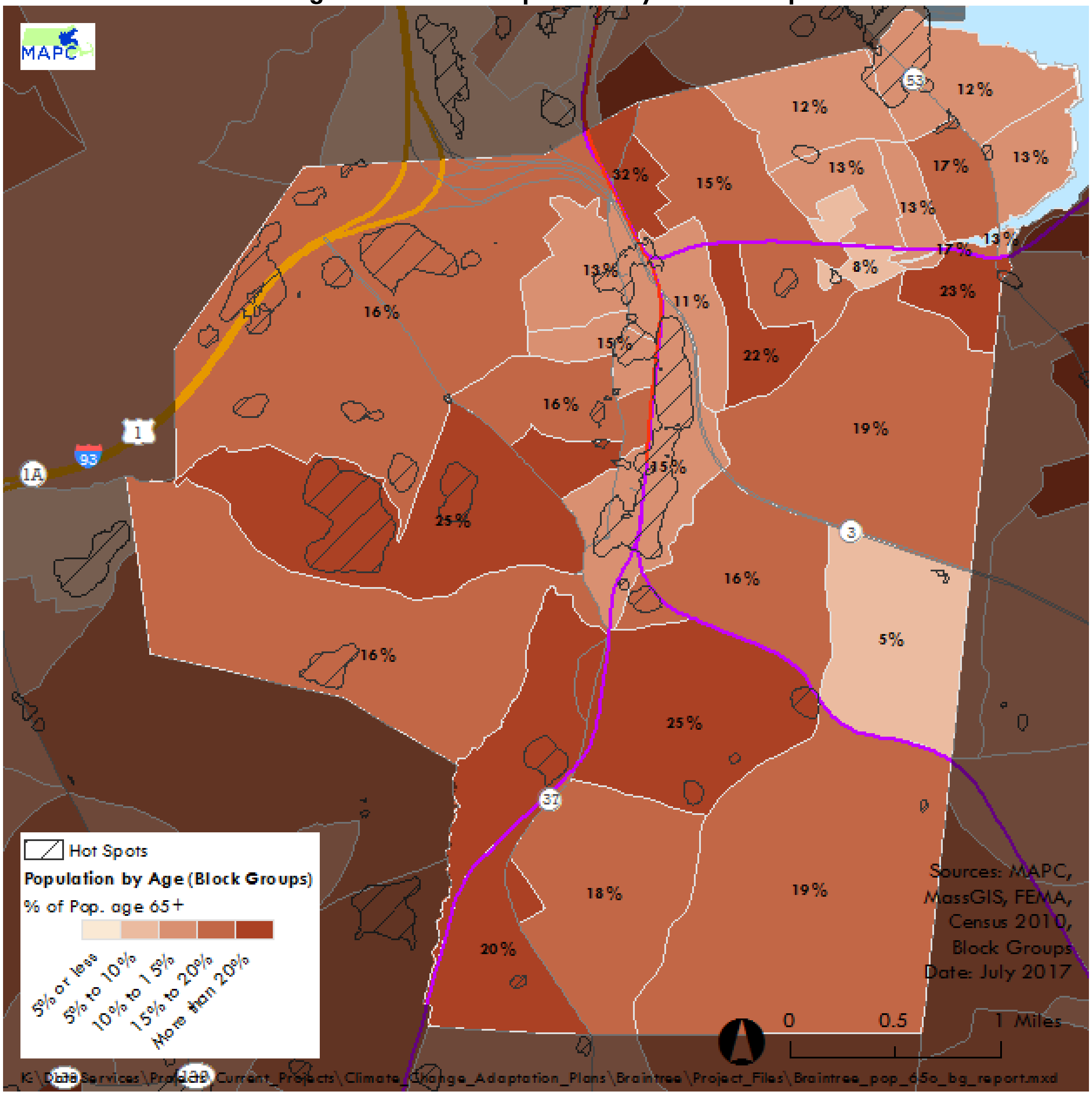


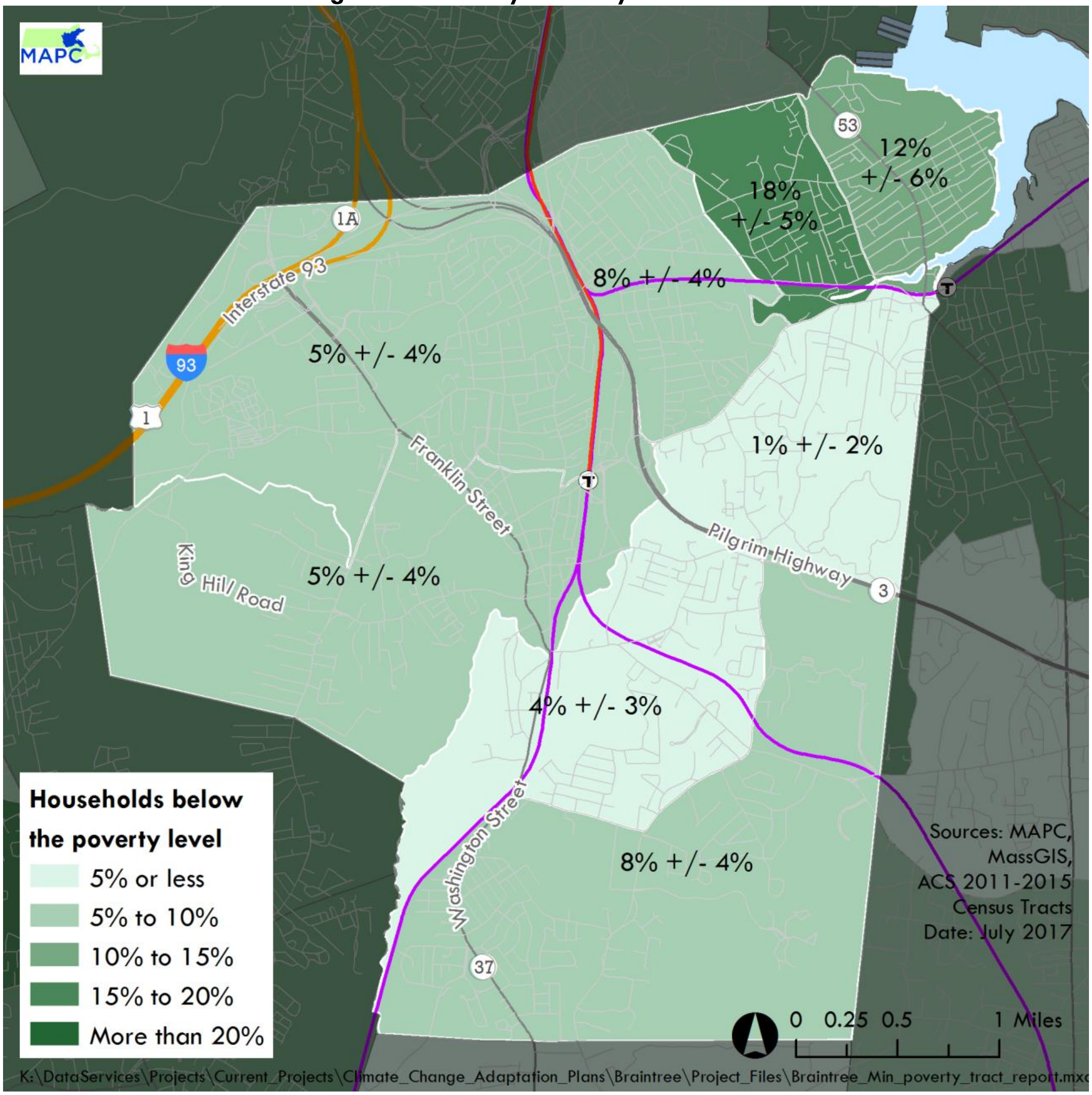
Figure 10. Senior Population by Block Group



Income

The median household income in Braintree is \$84,776 ± \$4,318 as compared with \$75,389 ± \$428 for Metro Boston (ACS 2011-2015). While Braintree as a whole is wealthier than Metro Boston, segments of the population still struggle to meet their basic needs. According to the US Census (2015), a household income of \$24,257 or less for a family of four is considered living in poverty. According to the ACS, 8% (±1.5%) of Braintree households are living in poverty. Figure 11 shows concentrations households in poverty by census tract. A much higher proportion of residents in East Braintree are living in poverty as compared to the rest of the town.

Figure 11. Poverty Rates by Census Tract



Race and Ethnicity

Braintree is becoming more diverse. In 2000, people of color were 6.7% of the total population. By 2010 that number had more than doubled to 14.8%. In 2010, 7.5% of the population identified as Asian, 2.6% percent as Black, 2.5% as Latino, and the remaining 2.4% as multi-racial, or another race. Figure 12 shows minority populations by 2010 census block group. Figure 13 shows country of origin for the Asian population in Braintree.

Figure 12. Percentage of People of Color by Block Group

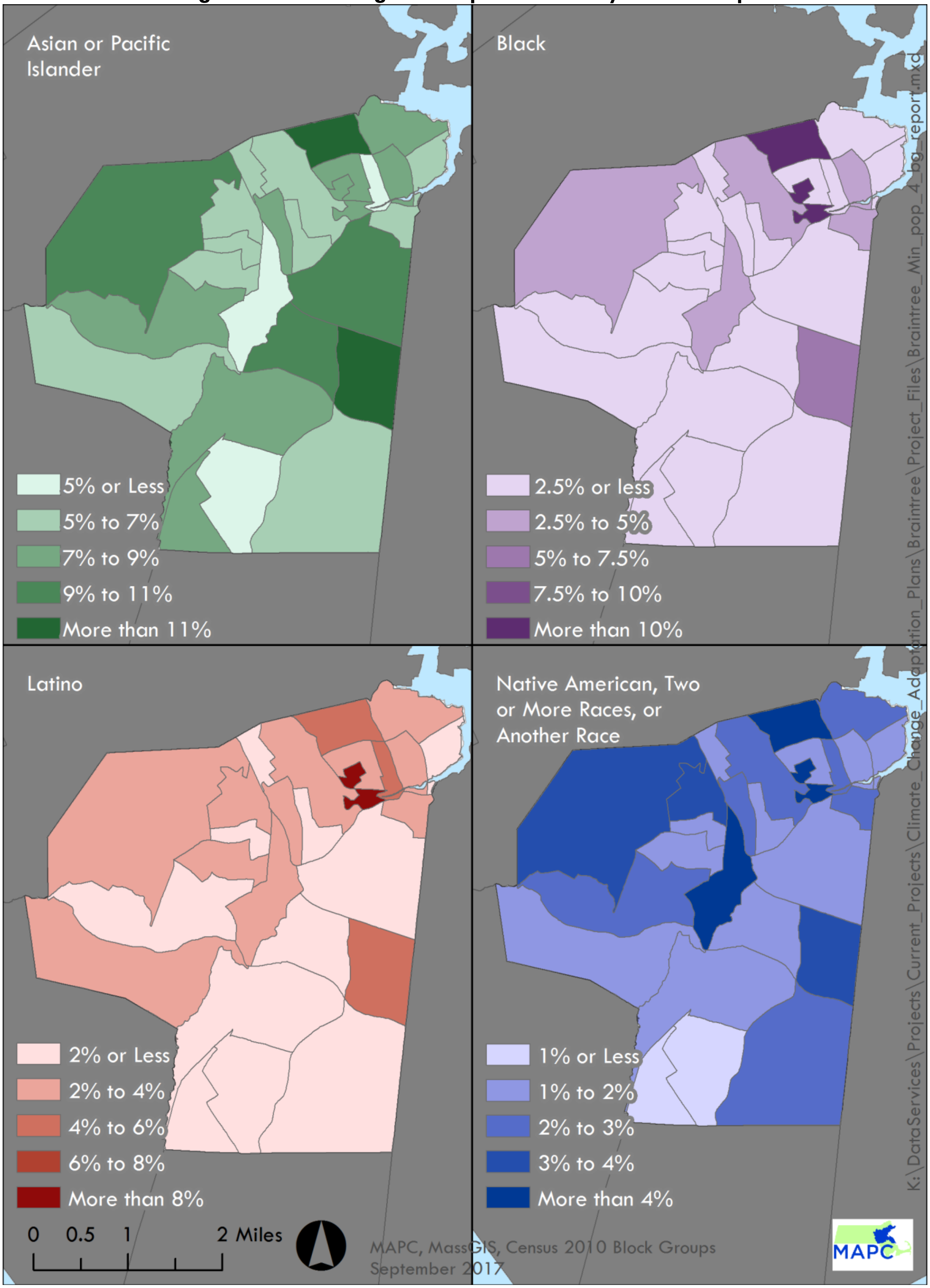
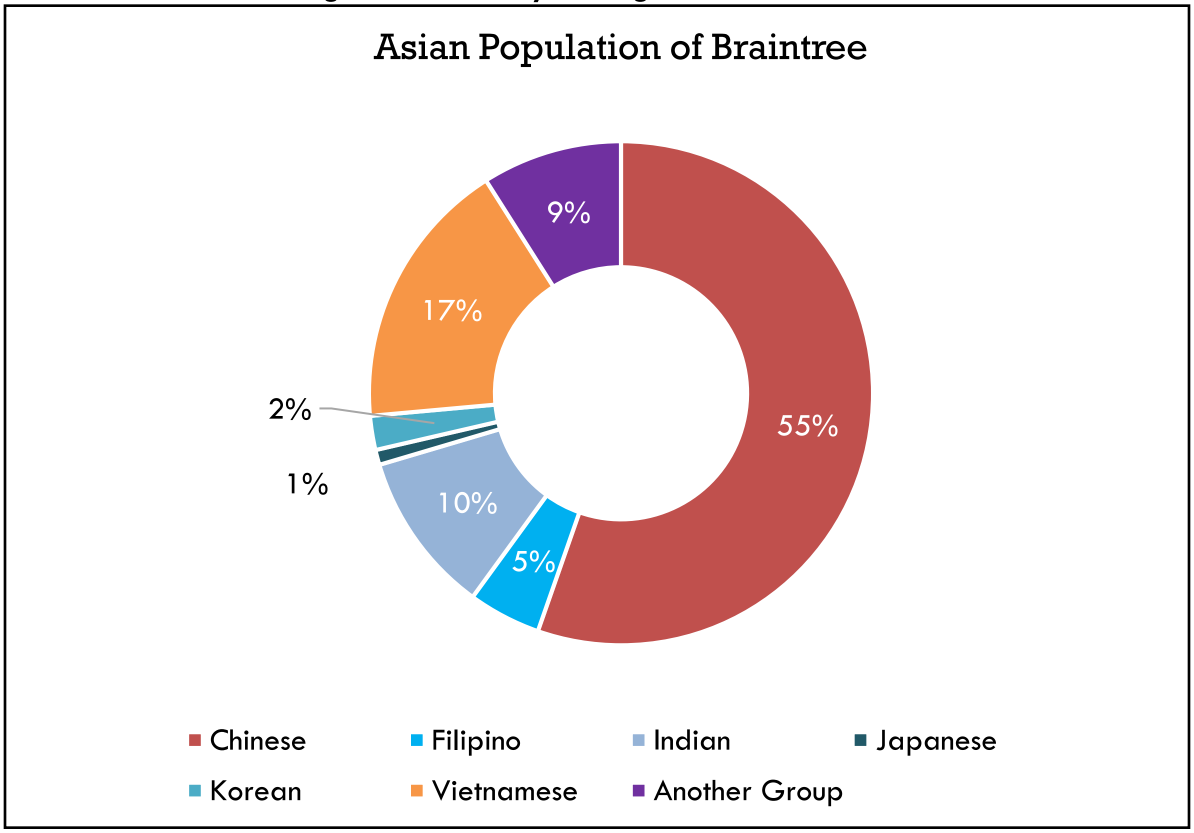


Figure 13. Country of Origin for Asian Residents

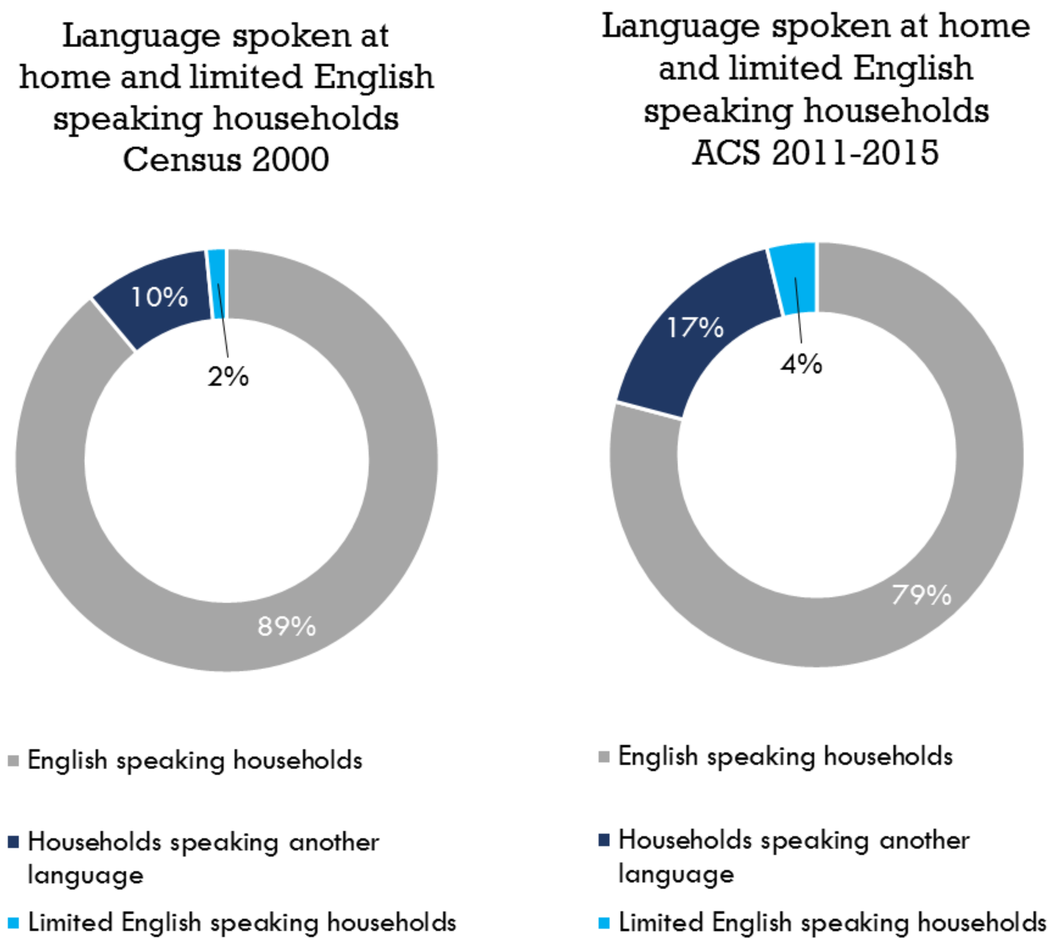


Language and Linguistic Isolation

The percentage of Braintree households that speak a language other than English in the home has increased over time. According to the 2000 Census, 12% of households spoke a language other than English, and by 2011-2015, that proportion increased to 21% (ACS). As the percent of households speaking another language at home has increased, the proportion of limited English speaking households has increased as well. "Limited English speaking households", formerly known as "Linguistically isolated households", have no household members age 14 or older who speak English very well. Other languages spoken at home include: Chinese languages (1,216 ± 294), and Spanish or Spanish Creole (681 ± 250). According to the ACS, Braintree residents who speak Asian languages are less likely to speak English very well than others who speak a language other than English in the home. Reliable data regarding geographic distribution of based on language and linguistic isolation are not available.

Our demographic analysis indicates that a number of identified vulnerable populations have been growing, or are projected to grow over time. These include seniors, young children, individuals living alone, people of color, and people with limited English language proficiency. The demographic analysis provides indications of where higher concentrations of vulnerable residents may be located, yet it is important to recognize that residents with heightened vulnerability to climate impacts reside throughout the town.

Figure 14. Language and Linguistic Isolation



Climate Impacts on Public Health

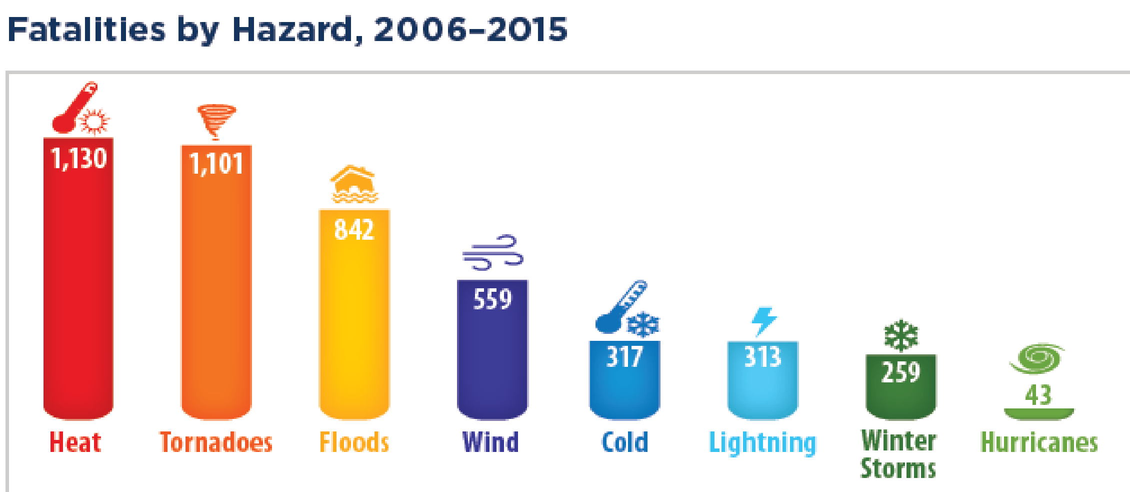
Climate change is expected to have an impact on public health across socioeconomic status and geography. Extreme weather events can increase stress, which can worsen or cause new physical and mental health conditions. An individual's vulnerability to the public health impacts of climate change is influenced by personal behaviors, environmental quality, housing quality, social connectivity, and access to resources. Socioeconomic characteristics may limit access to information, medical equipment, and healthcare. Low-income people and linguistically-isolated households are most vulnerable to this threat.

Seniors, young children, people with disabilities, and people with pre-existing health conditions, are most physically vulnerable to the health impacts of climate change. Individuals with physical mobility constraints, such as people with disabilities and seniors, may need additional assistance with emergency response. In Braintree, approximately 12% ± 1% of the civilian non-institutionalized population has a disability (ACS 2011-2015). As the population in Braintree ages, it is likely that the percentage of the population with a disability will rise. In Massachusetts, over 20% of the age 65 to 74 population has a disability, that figure jumps to nearly 50% for those 75 and older. By comparison, just over 10% of adults ages 35 to 64 have a disability. Reliable data regarding the geographic distribution of residents with disabilities is not available.

Extreme Heat

The projected increase in extreme heat and heat waves is the source of one of the key health concerns related to climate change. Heat was the leading cause of weather fatalities in the United States over the past decade (Figure 15). As noted earlier, the Northeast Climate Science Center projects 19 to 75 days over 90°F, and .6 to 16 days over 100°F annually, by the end of this century.

Figure 15. United States Weather Fatalities

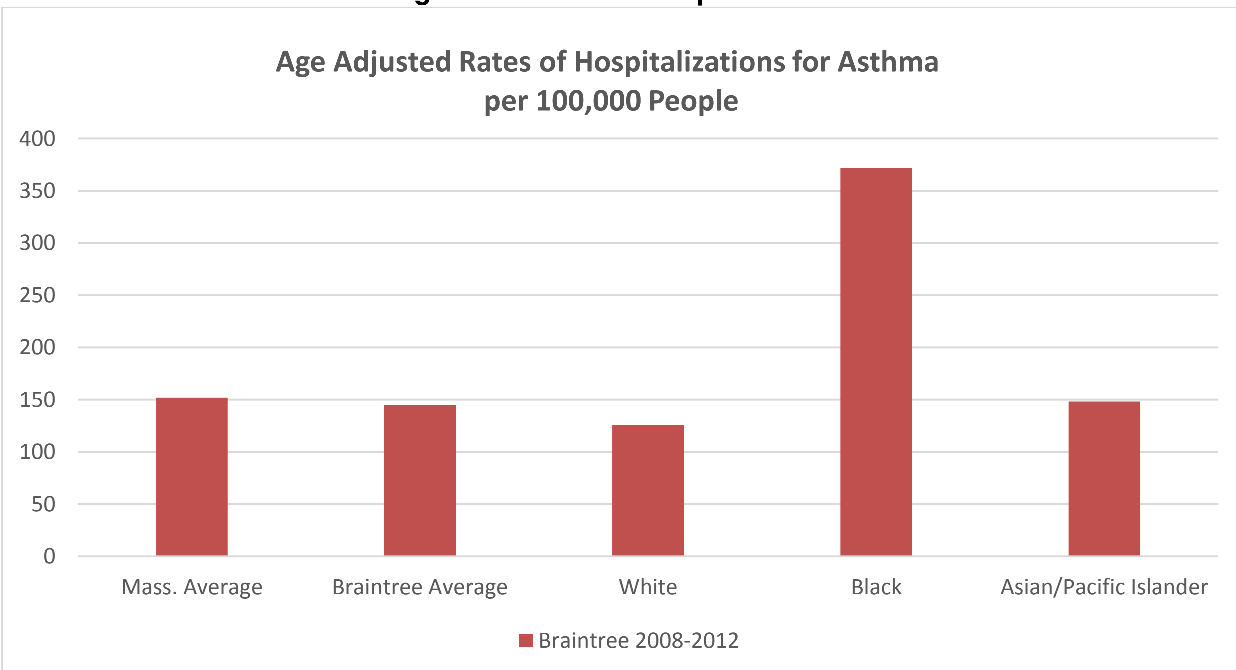


Source: EPA and NOAA

Prolonged exposure to high temperatures can cause heat-related illnesses, such as heat cramps, heat exhaustion, heat stroke, and death. Heat exhaustion is the most common heat-related illness and if untreated, it may progress to heat stroke. People who perform manual labor, particularly those who work outdoors, are at increased risk for heat-related illnesses. Prolonged heat exposure can also exacerbate pre-existing conditions, including respiratory illnesses, cardiovascular disease, and mental illnesses. The senior population is often at elevated risk due to a high prevalence of pre-existing and chronic conditions. People who live in older housing stock (as is often the case with public housing), and in housing without air conditioning have increased vulnerability to heat-related illnesses. Power failures are more likely to occur during heat waves, affecting the ability of residents to remain cool during extreme heat. Individuals with pre-existing conditions and those who require electric medical equipment may be at increased risk during a power outage. Loss of refrigeration can result in food-borne illnesses if contaminated food is ingested.

Extreme heat can contribute to greater levels of ground level air pollution and allergens. The poor air quality and high humidity that often accompany heat waves can aggravate asthma and other pre-existing cardiovascular conditions. Anyone who does outdoor physical activity during hot days with poor air quality is at increased risk for respiratory illness. Low-income people and people of color may also be at increased risk because these populations have a higher prevalence of chronic disease. While Braintree residents are hospitalized for asthma at a lower rate than that of Massachusetts residents as a whole, hospitalizations for Black residents are considerably higher than for White residents. Rates for Asian/Pacific Islander residents are also higher than for White residents (Figure 16). Data for asthma hospitalization rates for Latinos were not available.

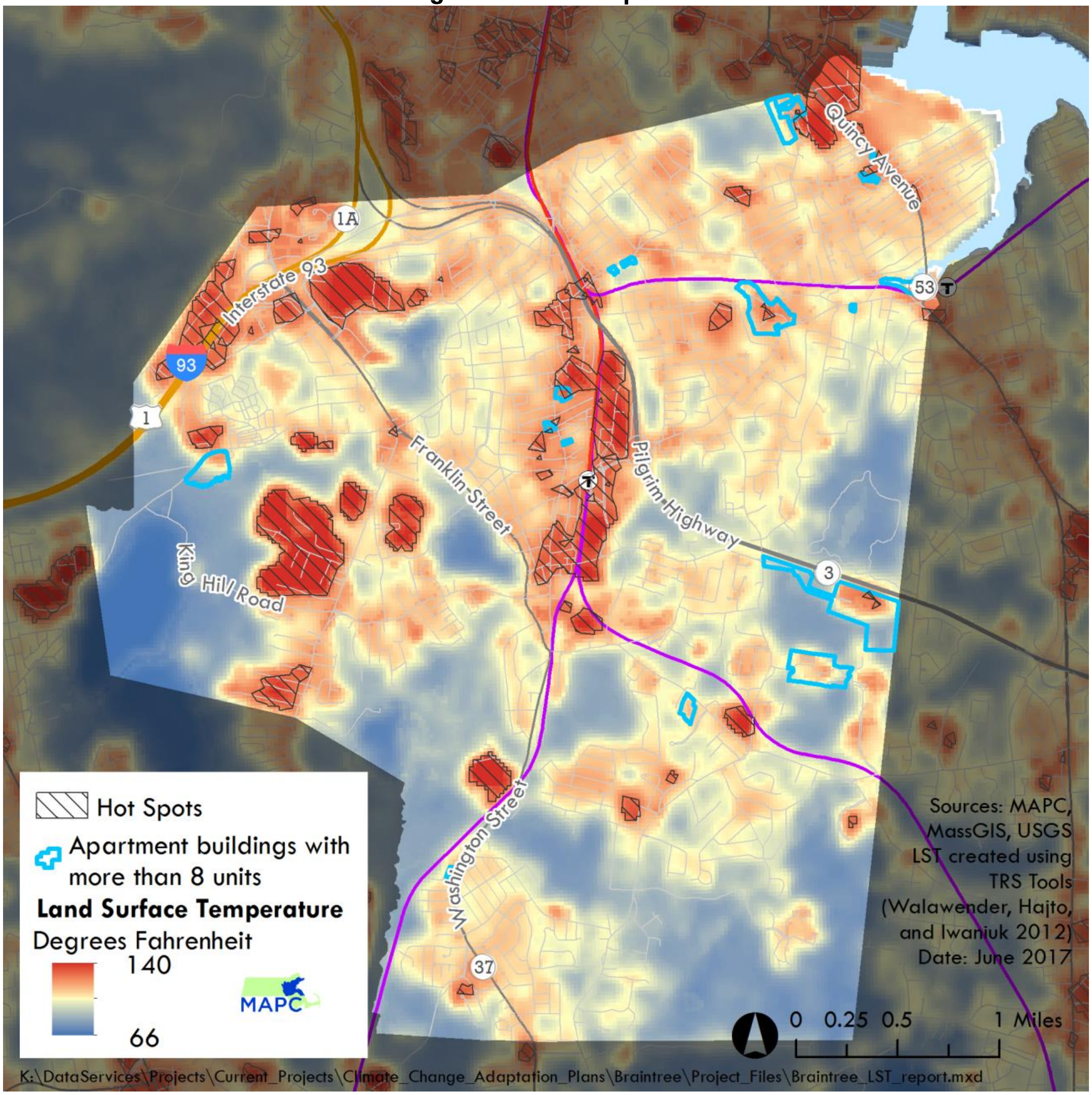
Figure 16. Asthma Hospitalizations



Source: DPH, MassCHIP

Due to what is termed the "heat island effect", areas with less shade and more dark surfaces (pavement and roofs) will experience even hotter temperatures; these surfaces absorb heat during the day and release it in the evening, keeping nighttime temperatures warmer as well. Figure 17 displays land surface temperature derived from satellite imagery on July 13, 2016, when the high temperature at Logan Airport was 92°F. It is important to note that air temperature just several feet above the ground varies from ground temperature. The range of land surface temperatures is much greater than that of air temperatures. Black pavements can attain temperatures far higher than the air temperature several feet above the ground. In contrast, vegetation or water can be much cooler than air temperatures. Thus the air temperature people

Figure 17. Heat Impacts



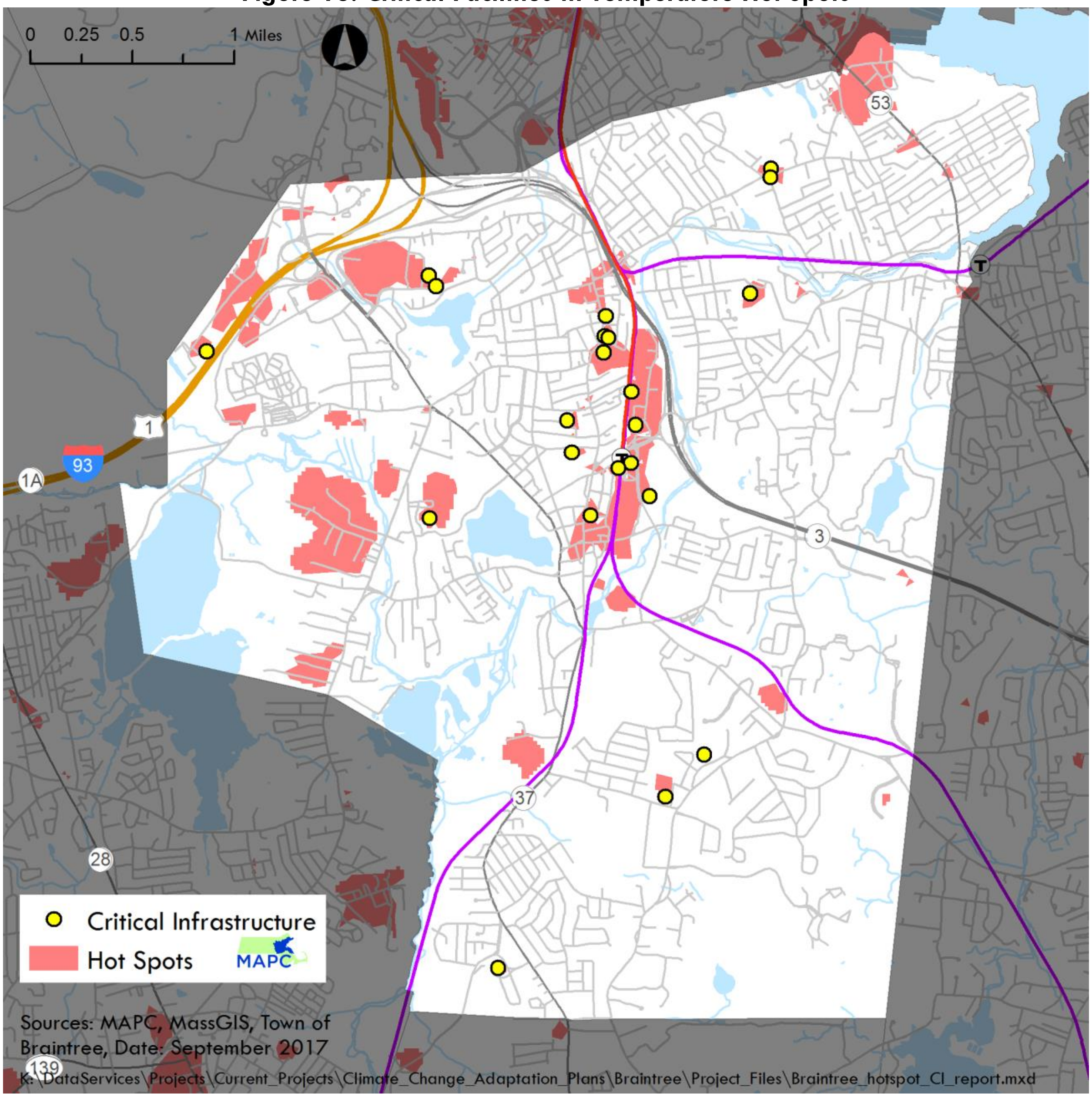
Land Surface Temperature on July 13th, 2016, when high temperature at Logan Airport was 92 degrees Fahrenheit.

experience will not be as hot as the hottest temperatures shown, nor as cool as the coolest areas shown.

The temperature display reveals that the hottest areas in Braintree coincide, for the most part, with locations that are zoned for commercial and industrial use. Given the generally suburban nature of the residential areas in Braintree, this is not surprising. There are, however, several residential locations, including Lenox Farms, the McCusker Drive area, Skyline Drive, and the area between Washington Street and the Braintree MBTA station that, while not as hot as the commercial and industrial areas, nevertheless are identified as "hot spots: part of the hottest 5% of land area in the MAPC region.

Residential areas adjacent to business or industrial areas will be hotter than other locations. Notably, all of the Braintree public schools, with the exception of Highlands and Morrison Elementary Schools, are located in hot spots, as are Thayer Academy, the Thayer Academy South Athletic Campus, and the Archbishop Williams Stadium. Figure 18, and the accompanying Table 3, identify critical facilities from the Braintree Hazard Mitigation Plan and from MassGIS, in hot spot locations.

Figure 18. Critical Facilities in Temperature Hot Spots



"Hot spots" identify the hottest 5% of land in the MAPC region.

Table 3. Critical Facilities in Temperature Hot Spots

Facility	Location
Ross Elementary School	20 Hayward Street
Mary Flaherty School	99 Lakeside Drive
East Middle School	305 River Street
Hollis Elementary School	482 Washington Street
Monatiquot Elementary School	25 Brow Avenue
Thayer Academy	745 Washington Street
St Francis Of Assisi	850 Washington Street
Braintree High	128 Town Street
SEAMASS Transfer Station	257 Ivory Street
Railyards	Ivory Street
Liberty Elementary School	49 Proctor Road
South Middle School	232 Peach Street
Northeast Specialty Hospital	2001 Washington Street
Fire Station # 3	1 Hayward Street
Verizon Telephone Exchange	505 Washington Street
Hugs Plus	460 Washington Street
Kinder-Care School	10 Webster Road
Braintree Medical Facility Center	340 Wood Road
Heliport	South Shore Plaza
Electric Substation	South Shore Plaza Road
Braintree MBTA Station	Ivory Street
University Of Phoenix-Boston	100 Grossman Drive

Increased Precipitation and Flooding

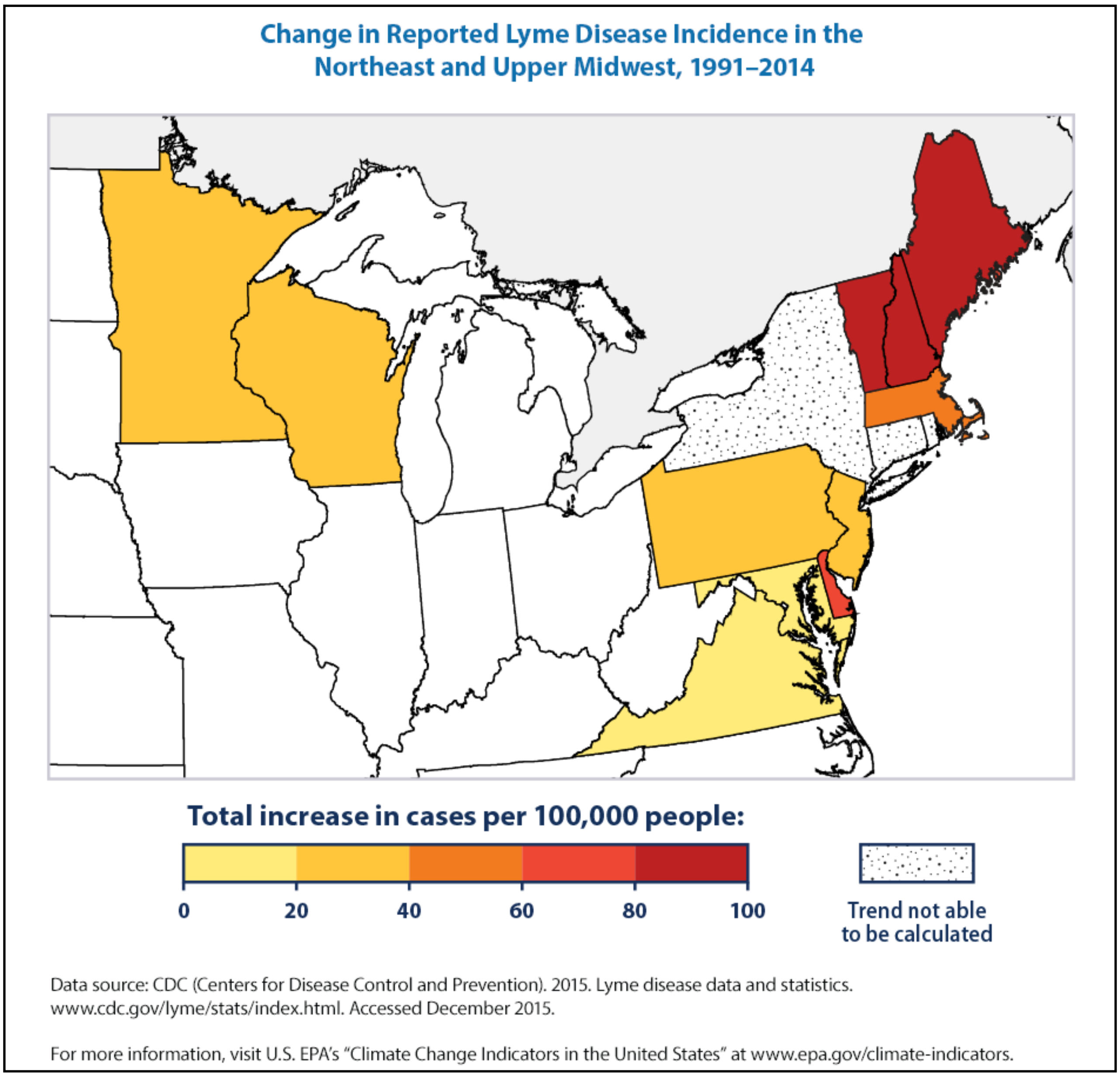
As previously noted, climate change is expected to bring increased precipitation and changing precipitation patterns to Massachusetts. Heavier winter and spring storms can cause localized flooding and water damage to buildings and the formation of mold. Mold triggers allergies and respiratory illnesses, such as asthma. Some strains of mold release airborne toxins, called mycotoxins, which can cause mold toxicity. Mold toxicity can influence the function of internal organs, the nervous system, and the immune system.

Heavy precipitation and flooding can also lead to health-threatening water contamination, including bacteria, viruses, and chemicals that cause gastrointestinal diseases, dermatological conditions, toxicity/poisoning, and other illnesses. Heavy precipitation can cause pollutants to be washed into water bodies and can also overwhelm infrastructure, leading to sewage back-ups and overflows. Often people come into contact with contaminated water when it floods onto their property, but contact with contaminated water through recreation can be dangerous, too. If water damage results in a loss of power, residents could be disconnected from telecommunications during a medical emergency, putting at risk residents reliant on electric medical equipment.

Vector Borne-Illnesses

Vector-borne illnesses are those that stem from contact with vectors such as mosquitos and ticks. The spread of vector-borne illnesses is influenced by vector type, weather conditions, built environment conditions, and human behavioral factors. The two most common mosquito-borne illnesses in Massachusetts are eastern equine encephalitis (EEE) and West Nile virus (WNV). As climate change is expected to bring heavy precipitation events (which increase areas of standing water) and warmer temperatures, it is expected that mosquito populations will grow and that the

Figure 19. Lyme Disease Incidence



transmission season will extend beyond its traditional late spring through early fall. Warmer temperatures also accelerate a mosquito's lifecycle and increase their biting rates.

Tick-borne illnesses, particularly Lyme disease, babesiosis, and anaplasmosis have been on the rise in Massachusetts. From 1991-2014, there has been an average increase of 59 cases of Lyme disease per 100,000 people (Figure 19). Winter frost plays an important role in limiting tick populations; warmer winters may lead to more nymphs surviving into the spring months. As with mosquitos, warmer temperatures can lead to longer transmission seasons as ticks begin to seek hosts earlier in the season. Tick populations thrive with increased precipitation and humidity, and may be more susceptible to annual fluctuations in precipitation than mosquitos.

Forecasting the spread of vector-borne illnesses and estimating risk due to climate change is very challenging, due to multiple factors at play. For example, research suggests that heavy precipitation in urbanized areas could actually reduce mosquito populations by flushing underground breeding habitat. Further, vector populations' size and range is dependent on the size and range of their host species (i.e., migratory birds, mice, and deer), which may shift as the climate changes. As the climate gets warmer, tropical vector species may expand their ranges north, which could bring with them vector-borne illnesses not typically found in the Northeast (i.e., dengue fever or chikungunya). As vector-borne disease outbreaks occur globally, residents may import vector-borne illnesses acquired during trips to other countries.

People who spend a lot of time outdoors, or live close to vector habitats, are at greatest risk of exposure to vector-borne illnesses. The ability to protect oneself from mosquito-borne illnesses has been associated with socioeconomic status via housing conditions. Households that can afford air-conditioning and maintenance of windows/screens are less likely to come into contact with mosquitos in their home. Those most likely to experience severe vector-borne illnesses are children, people over the age of 50, and people with compromised immune systems.

NATURAL RESOURCES AND CLIMATE RESILIENCE

Braintree's natural resources can lessen climate impacts by absorbing and storing carbon dioxide and by serving vital protective functions. Many natural resources will be challenged by heat, drought, and storms. Forests, open space, wetlands, salt marsh, rivers and streams serve important functions, from providing clean drinking water, to flood control, to giving relief from extreme heat. Healthy ecosystems will be more resistant to stresses a changing climate may bring, including disease, invasive plants, and storm damage. Healthy ecosystems will also be better able to protect against heat and flooding. Natural resource conservation and preservation can provide economic benefits, for individuals and the town, by reducing the costs associated with addressing damage from climate impacts. As an example, utilizing natural areas to absorb stormwater can reduce the need for costly pollution abatement; and for stormwater infrastructure.

Mitigation

Climate mitigation refers to efforts to reduce or prevent emission of GHGs. Braintree's forested areas and trees provide significant mitigation. Trees help reduce the amount of carbon dioxide in the atmosphere because they absorb carbon dioxide from the air and convert it into carbon that is stored in their trunks, roots and foliage. Trees also reduce energy demand from air conditioners when they directly shade buildings.

Protection

Heat

Our natural resources provide protection from climate threats in a wide variety of ways. Trees are important in mitigating the impact of heat waves. According to the EPA, suburban areas with mature trees are 4-6 degrees cooler than new suburbs without trees. Shaded surfaces can be 25-40 degrees cooler than the peak temperatures of unshaded surfaces. Vegetated surfaces of all types are cooler than pavement and rooftops.

Flooding

As will be detailed in following sections, inland flooding is already a significant issue in Braintree, and one that is projected to worsen with climate change. Existing inland wetlands, as well as forests and other open lands, soak up and store rain waters, reducing flooding to streets and homes. Maintaining open space in floodplains allows the land to absorb the brunt of flooding without impact to homes and infrastructure.

Trees also absorb remarkable quantities of precipitation. Research has shown that a typical medium-sized tree can intercept as much as 2,380 gallons of rain per year (USDA Forest Service). Intercepted rainfall lands on tree leaves and is stored or evaporated back into the atmosphere. This reduces stormwater runoff and flooding.

Along the coastal shoreline, salt marshes, beaches, and coastal banks take the first brunt of storms and reduce wave energy, protecting homes and infrastructure from damage. Braintree has areas of salt marsh, beach, coastal bank, and tidal flats along the Fore River shoreline and the tidal portion of the Monatiquot River. In addition to providing flood protection, salt marshes store carbon dioxide, providing climate mitigation.

Climate Impacts on Natural Resources

Aquatic and Wetland Resources

Aquatic resources will be affected by warmer temperatures and by changes in the timing and amount of precipitation. Rain has a negative effect on water quality, because it flushes ground pollutants – everything from dog waste, to oils on the road, to sand – into rivers, streams, and ponds. Large rain events can also cause sewage overflow into waterways when sewer systems become inundated with rainwater and unable to handle the flow. Finally, large rain events can increase erosion and scour stream beds.

The combined effects of washing nutrients into lakes and ponds and warmer summer temperatures may lead to an increase in the growth of aquatic vegetation. Such growth can deplete dissolved oxygen and lead to die-offs of aquatic animals. Additionally, excessive aquatic vegetation can make water bodies unpleasant for recreational use. Algae blooms can also lead to growth in toxic bacteria that makes water bodies unsafe for use by humans and pets.

An increase in summer heat and drought, combined with earlier spring run-off due to warmer temperatures and a shift from snow to rain, can lead to warmer waters and seasonal low-flow or no-flow events in rivers and streams. Shallower waters and warmer temperatures also lead to low levels of dissolved oxygen with negative effects on fish species. The Monatiquot River is host to river herring and rainbow smelt; both are anadromous species, meaning they live their adult lives in the ocean, but return to fresh waters to spawn. Low-flow events have the potential to be disruptive to these species. As the Town is working with the MA Department of Marine Fisheries and the Fore River Watershed Association toward restoration of the historic fish runs, this concern is particularly relevant.

Braintree has extensive wetlands, mostly, but not entirely, within mapped flood zones. These include Broad Meadow along the Cochato River, White Cedar Swamp off Plain Street, Arnold Meadow along Route 3 near the rotary, along West Street partly in the Blue Hills Reservation, and the bogs and fens of Cranberry Brook watershed that are part of the state designated Area of Critical Environmental Concern. Braintree's ponds and reservoirs, and its rivers and streams accept floodwaters from overland flow and from storm drains.

As part of compliance with the federal Clean Water Act, Massachusetts must evaluate whether water bodies meet water quality standards. Farm River has not been assessed; as shown in Table 4, the 2014 "Final Listing of the Condition of Massachusetts' Waters Pursuant to Sections 305(b), 314 and 303(d) of the Clean Water Act"; the assessed rivers in Braintree do not meet water quality standards for fecal coliform and other impairments. Sunset Lake is affected by aquatic weeds. Many of these impairments may be further exacerbated by the above described climate changes. If dry conditions persist, wetlands could shrink in area or lose some of their absorptive capacity and be more prone to runoff and erosion.

Figure 20. Natural Resources and Level of Protection for Open Space

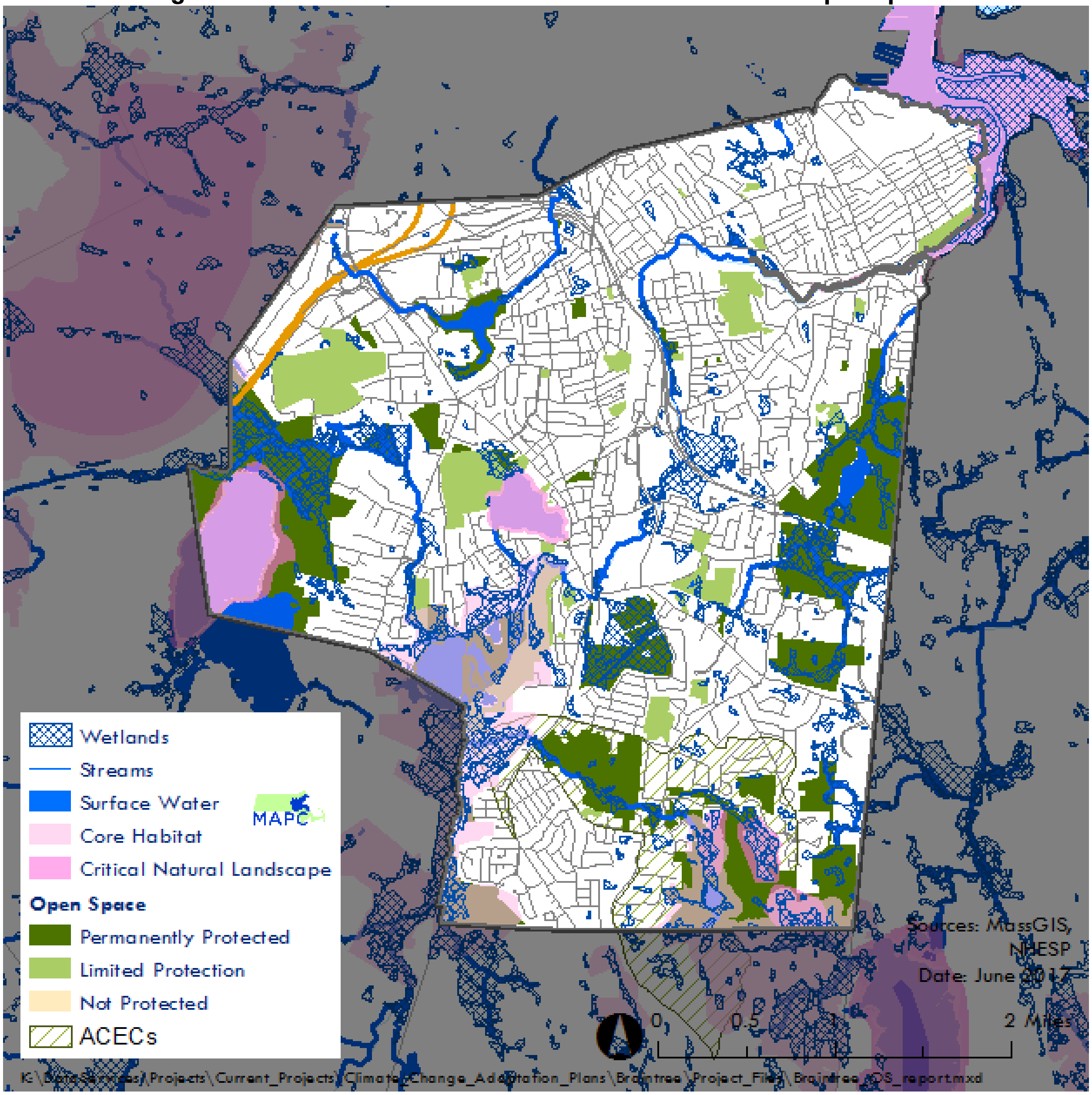


Table 4. Water Quality Impairments

Waterbody	Impairment
Sunset Lake	Aquatic weeds
Cochato River	Fecal Coliform, Dissolved Oxygen, Chlordane, DDT
Monatiquot River	Fecal Coliform, Dissolved Oxygen, Aquatic Macroinvertebrate Bioassessments
Town Brook	Fecal Coliform, , Aquatic Macroinvertebrate Bioassessments
Fore River	Fecal Coliform, PCB in fish tissue

The Great Pond, Upper Reservoir and Richardi Reservoirs are critical resources as they provide Braintree, Randolph, and Holbrook, their water supply. Degraded water quality, in particular due to heavy stormwater runoff containing pollutants, may increase the treatment needs for water supply. Climate projection indicate the potential for more frequent and/or severe drought. The drought of 2016 reduced the reservoir levels to 54%. This resulted in Phase Four (of Five) water use restrictions, banning all outside use of water. Phase Five restrictions are instituted when the reservoirs fall between 50% and 40% full. In Phase Five, all non-essential water use is prohibited.

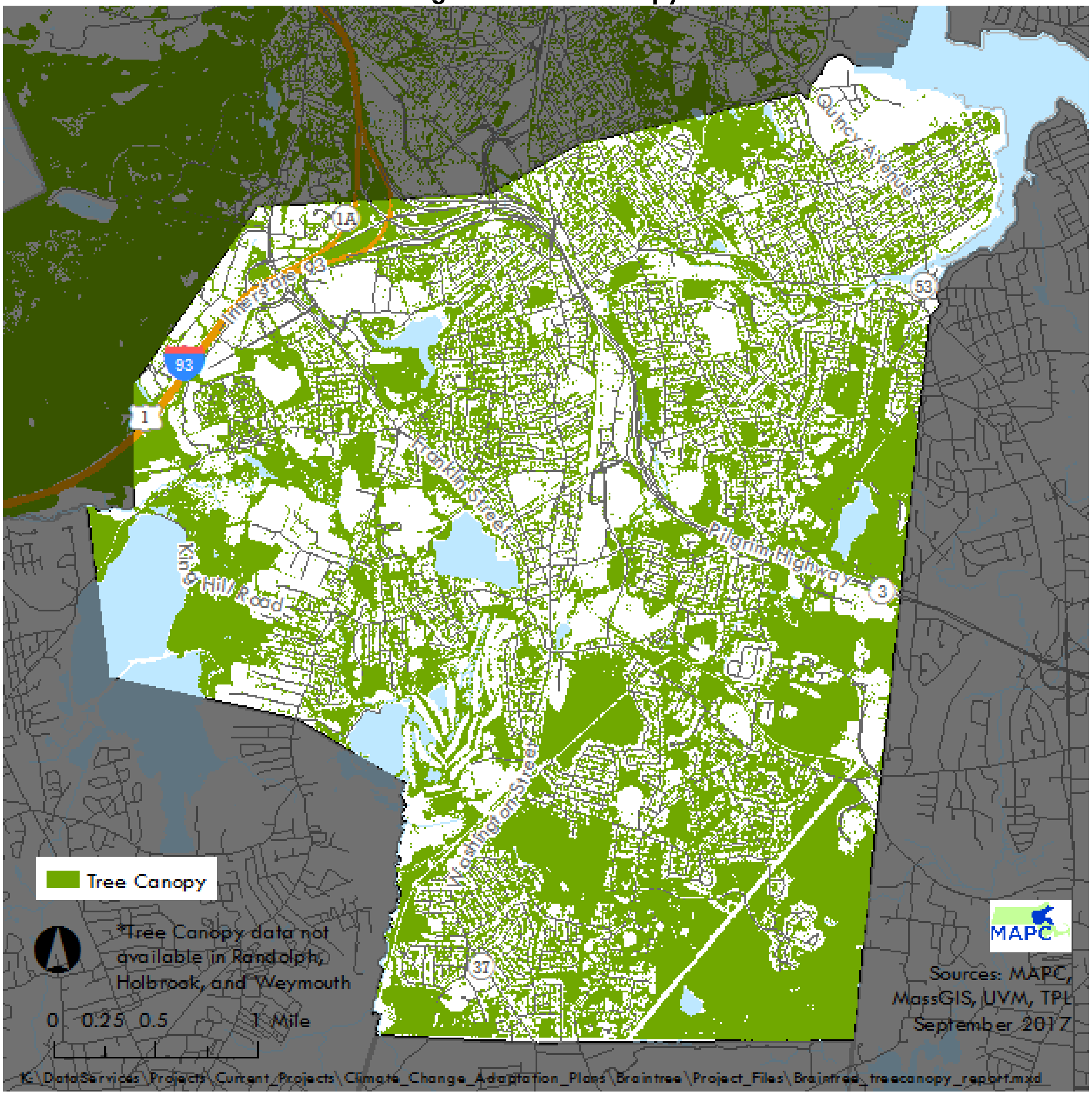
Forests and Trees

Warming temperatures are expected to change the composition of forests as trees adapted to more northern climates decline and those adapted to warmer climates increase in abundance. As an example, maples are expected to decline, while oaks become more abundant. Increasing intensity and frequency of weather events, including ice storms, drought and wildfire, can weaken and damage trees. Forests may also be subject to new pests and diseases brought by warmer climates.

Braintree has a number of large forested areas that are permanently protected. These include Town Forest, Cranberry Pond, Eaton's Pond, South Street conservation land, Pond Meadow Park, and water supply land surrounding the reservoirs. These larger and connected areas are valuable as they provide protection and greater resilience for plant and animal species negatively impacted by climate changes.

According to the Braintree Open Space Plan, the town planted over 500 trees from 2008 to 2012. The Braintree Electric Light Department (BELD) also has an ongoing program to plant two trees for any property owner that requests it. Using tree canopy data create by the University of Vermont, based on remote sensing data, we estimate that tree canopy covers 48% of total land in Braintree (Figure 21). Table 5 provides tree canopy data by land use category.

Figure 21. Tree Canopy



The USDA Forest Service has created a peer-reviewed web-based software tool called i-Tree that quantifies the value of ecological services trees provide. The i-Tree software estimates the value of carbon storage, air pollution removal, and stormwater runoff reduction provided by trees. Their estimates underscore the value and importance of forests and street trees in providing climate mitigation and resilience. The estimated value of carbon storage in Braintree's tree canopy exceeds $18 million, while the estimated value of annual carbon sequestration (tree growth minus loss due to decomposition and mortality) is over $400,000. Estimates of annual air pollution removal include 2,691 pounds of carbon monoxide, 12,899 pounds of nitrogen dioxide, 204,618 pounds of ozone, 8,812 pounds of sulfur dioxide, and 40,942 pounds of particulate matter. For stormwater runoff, i-Tree estimates that 53.3 million gallons per year is avoided due to transpiration and interception of rainfall. The value of reduced runoff is estimated at over $476,000 annually. Information on the methodology for these estimate is available at https://landscape.itreetools.org/references/

Table 5. Tree Canopy and Land Use

Land Use	Sq. Miles	% of Total Tree Canopy	Land Use %
RESIDENTIAL	2.7	40%	39%
OPEN SPACE	2.4	35%	20%
RIGHT OF WAY	0.5	8%	13%
GOVERNMENT	0.5	7%	11%
COMMERCIAL	0.3	4%	8%
INDUSTRIAL	0.2	3%	5%
INSTITUTIONAL	0.1	2%	3%
OTHER	0.0	1%	1%
TOTAL	6.8	100%	100%

Source: MAPC and Trust for Public Land with the U. Vermont Spatial Analysis Laboratory

Coastal Resources

Coastal resources in the tidal portion of the Monatiquot River and the length of the Fore River include salt marsh, mud flats, beaches, and coastal banks. Salt marsh along the banks of the Monatiquot extend up to Watson Park. Salt marsh and mud flats provide critical habitat for fish, shellfish, and invertebrates. All of the shoreline resources provide protection against waves and storm surge.

The shoreline resources may be eroded and damaged to the extent they are subject to wave action during coastal storms. These resources may be endangered if they cannot migrate landward as seas rise. Where they are hemmed in by development or other obstacles, rising seas will, over time, result in mudflats, salt marsh and beaches being replaced by open water.

Climate Impacts on the Built Environment

Inland Flooding and the Built Environment

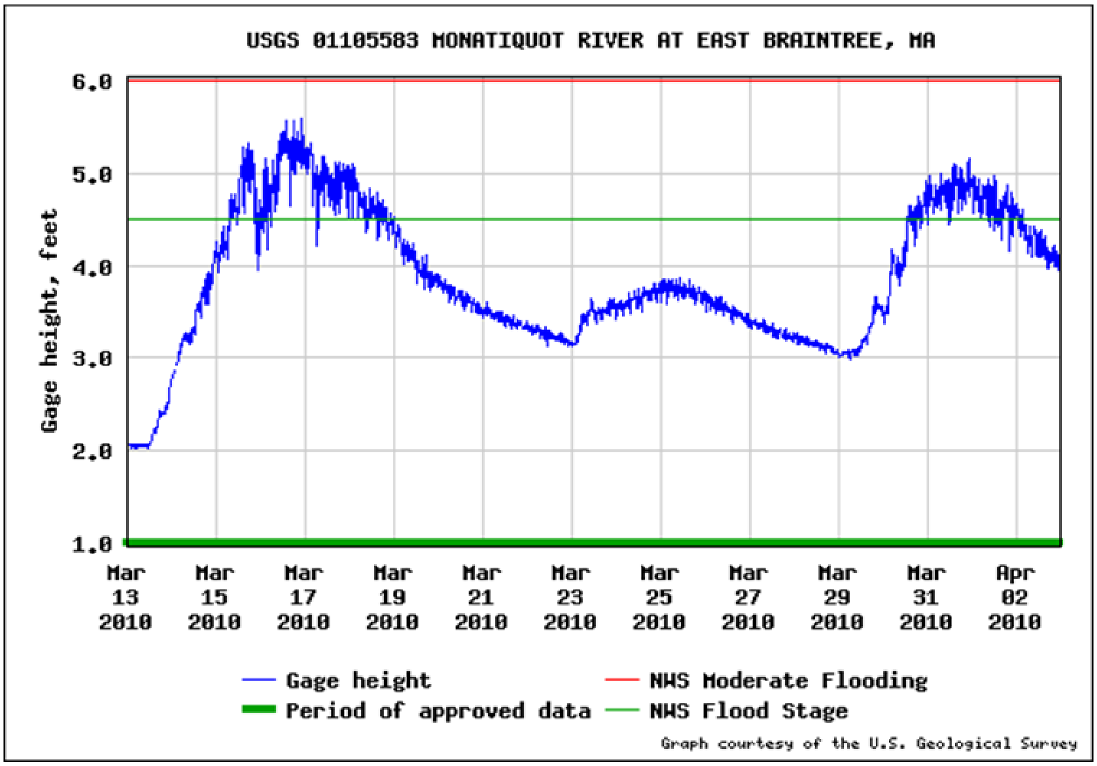
In many instances, potential impacts of a warming climate do not prompt entirely new challenges, but rather, exacerbate existing concerns. This is certainly the case regarding the projection that significant rain events will increase in intensity and frequency over the next century. The 2012 Braintree Hazard Mitigation Plan identifies 28 locations of special flooding concern. Most of the locations are along the Farm, Cochato, and Monatiquot Rivers, but they also include locations on smaller unnamed tributaries and areas outside of identified flood zones.

As shown in Figure 22, the Monatiquot River near Commercial Street in East Braintree, exceeded flood stage during two different rain events in March and April 2010. Town officials noted that flooding resulting from the March 13-15 storm generally mirrored the extent of the FEMA 100-

year (1% chance per year) floodplain. However, while the river reached 5.6 feet March 16, exceeding flood stage, it did not reach the USGS standard for Moderate (6 feet) or Major (8 feet) flooding.

Figure 22. March 2010 USGS Monatiquot River Gage

Braintree: March 2010



Blue Hill Observatory precipitation records March 2010:

March 13: 1.60 inches	March 23: 2.52 inches	March 29: 2.65 inches
March 14: 4.95 inches		March 30: 2.92 inches
March 15: 2.86 inches		
Total: 9.41 inches	**Total: 2.52 inches**	**Total: 5.57 inches**

Gage records show that the highest flow on March 16 was 1,600 cubic feet per second (cfs). According to the 2015 FEMA Flood Insurance Study for Norfolk County, 1,600 cfs is roughly equivalent to the 2% annual chance flood. FEMA calculates that the 100-year flood would yield discharges of 2,000 to 2,200 cfs. That is an additional 25% to 37% flow compared to the peak flow in 2010. This suggests that flooding from a100-year storm would exceed the 100-year FEMA mapped floodplain.

As shown in Figure 23, FEMA flood insurance claims from March 2010 account for one-third of all paid insurance claims, and two-thirds of damage paid out since 1978. Yet insurance claims represent only a small fraction of actual damages. Because the 2010 storm was a federally declared disaster, property owners without flood insurance were eligible for a limited amount of reimbursement for damages. FEMA paid ten times the number of claims to uninsured homeowners, and provided some reimbursement to the Town of Braintree for expenses related to the storm. As related by town officials, the storm closed roadways, caused sewer overflows and back-ups, and required power shut-offs, neighborhood evacuations, temporary home condemnation, and evacuation for many residents whose homes were flooded.

What is a "100-year" flood?

The term "100-year flood" is shorthand for a flood that has a 1% chance of happening in a given year. In reality, a 100-year flood could occur two years in a row, or not at all for 100 years. But each year, there is a 1% chance it will occur.

The .2% chance flood = 500 year flood
The 1% chance flood = 100 year flood
The 2% chance flood = 50 year flood
The 10% chance flood = 10 year flood

The 100-year food zone is the location where there is a 1% chance of flooding each year. In the 500-year flood zone there is a .2% chance of flooding each year.

While the 2010 rains were significant, they did not approach the magnitude of rainfall produced by Hurricane Diane in August 1955. Rainfall from Diane, recorded at the Blue Hills Observatory, totaled 13.76 inches, including 9.93 inches in 24 hours. While the Monatiquot River stream gage did not exist in 1955, flooding records from a nearby gage give an indication of the impact of Hurricane Diane relative to the 2010 storm.

FEMA uses a gage on the East Branch of the Neponset River in Canton as a reference for its study of flooding on the Monatiquot. At that location, the flood gage height was 6 feet in March 2010 and 8.18 feet in August 1955. Flow was nearly 50% higher (1,200 cfs in 2010 vs. 1,790 cfs in 1955). Clearly a storm the size of Hurricane Diane would cause damage far exceeding that experienced in 2010. As will be discussed in following sections, a storm of the magnitude of Hurricane Diane would also likely produce greater flooding and damage today than it did in 1955, due to the amount of development that has taken place over the past sixty years.

Town officials also note that short duration high intensity storms have caused significant flooding in the past. As recorded at the Blue Hill Observatory, over 2 inches of rain fell in forty minutes in a torrential downpour in August 2005. In Hingham, during the same storm, 5.35 inches of rain fell in three hours. Town staff report that in addition to river flooding, the storm caused flooding in other locations due to stormwater drainage facilities that were unable to handle the volume of rain in such a short period of time.

Figure 23. Braintree Flood Claims

The Cost of Flood Damage

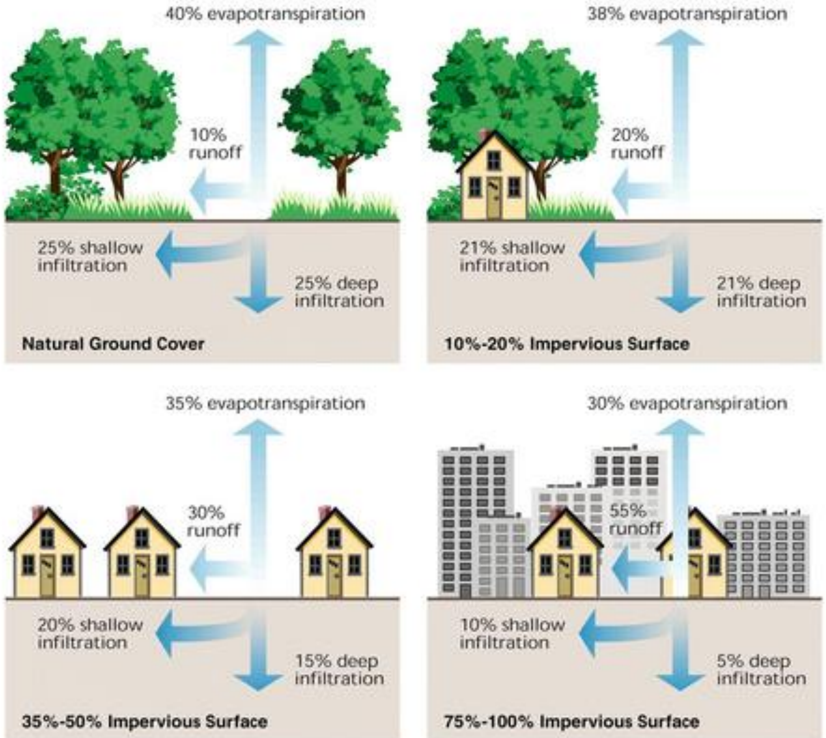
- **Total claims: 1978 through July 2016** FEMA flood insurance paid 133 claims - $1.9 million in damages
- **One stormy month: March 2010** FEMA flood insurance paid 46 claims - $1.2 million in damages
- **Plus…** FEMA reimbursed 475 uninsured households $1.1 million in damages, Town of Braintree was reimbursed $319,000 for damages

March 2010 Hancock/Washington Streets

Inland Flooding and Development Patterns

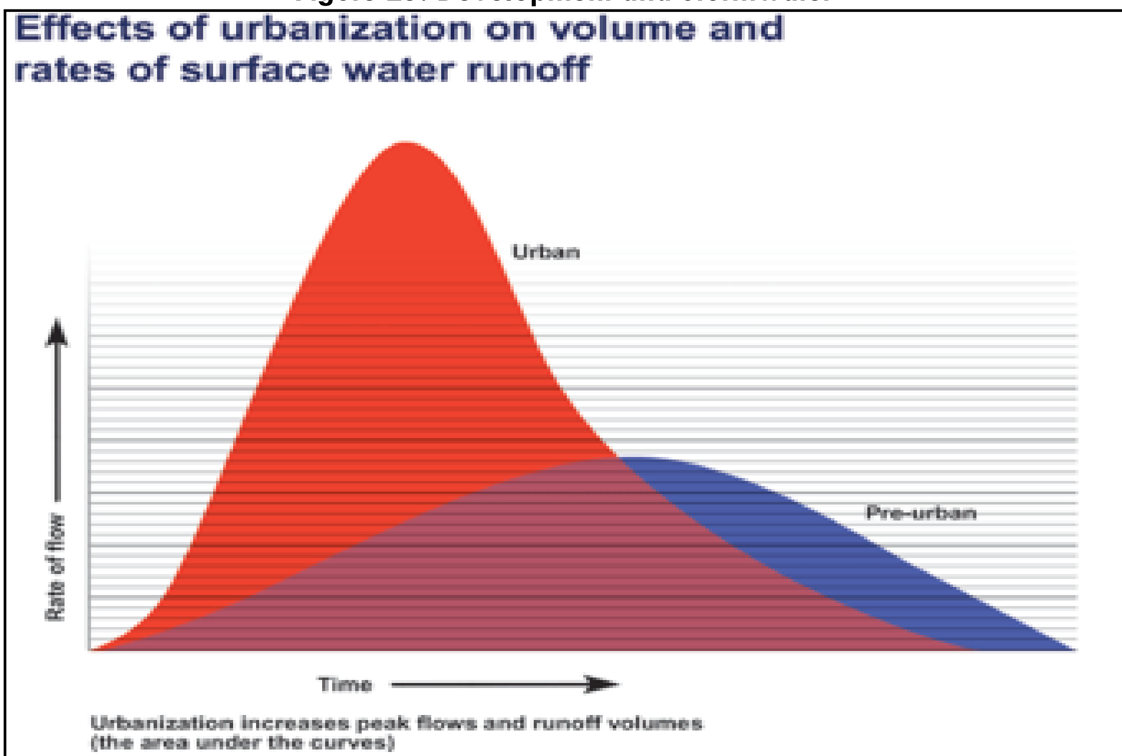
Flooding challenges are commonplace in all cities and towns where, over time, development has changed watershed drainage characteristics, re-rerouted or placed rivers in culverts, and encroached upon natural floodplains. As shown in Figure 24, with development comes an increase in impervious surfaces. As a result, the watershed hydrology is changed. Less rainfall reaches streams and rivers through groundwater infiltration, but instead reaches waterways through overland runoff. Runoff is directed to storm drains and reaches waterways much more quickly, causing an increase in flooding as shown in Figure 25.

Figure 24. Development and Rainfall



Source: US EPA

Figure 25. Development and Stormwater



Source: Adapted from Drainage Manual, Roads and Transportation Association of Canada, 1982

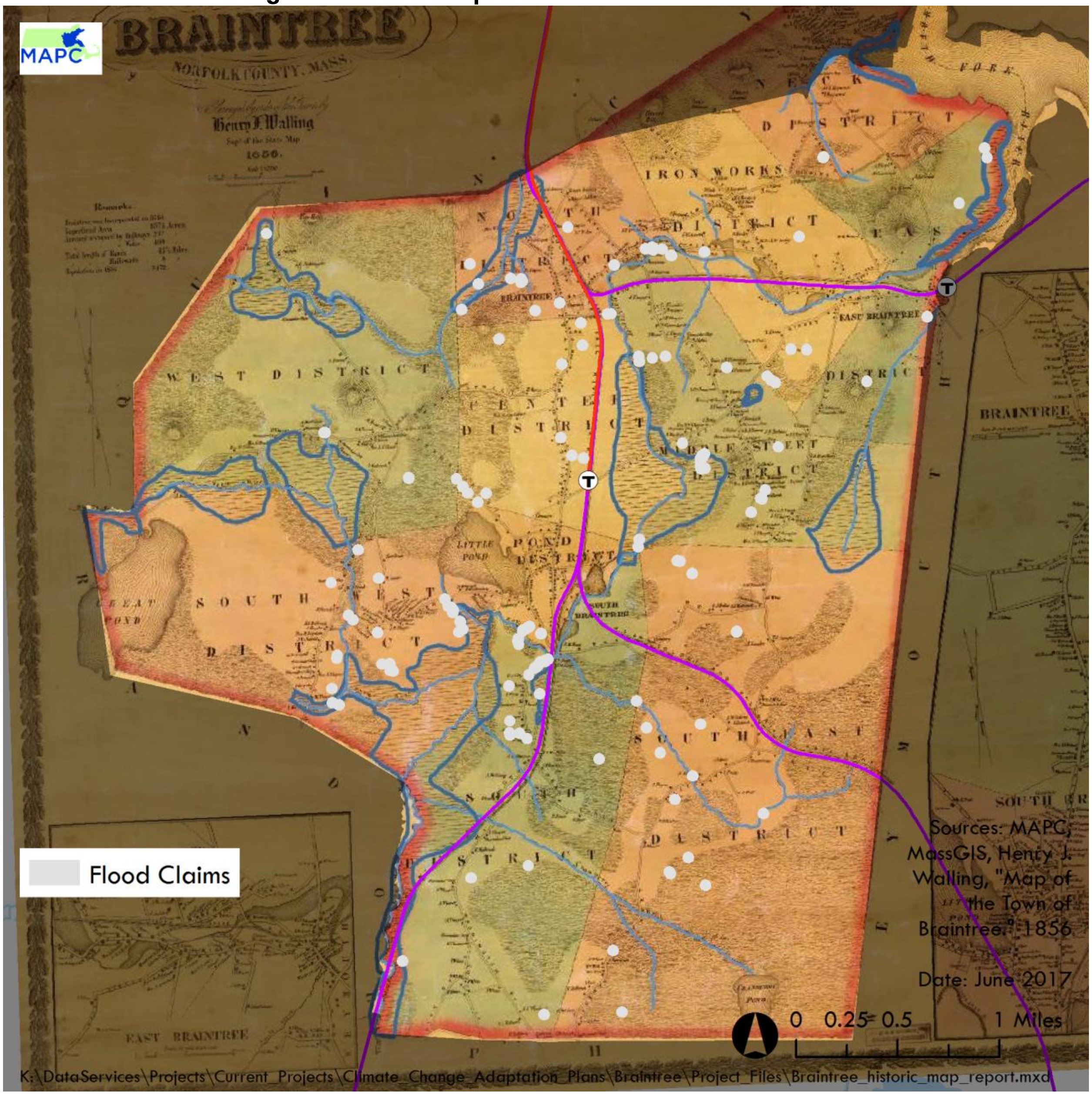
Historic Development in Braintree

An 1856 map of Braintree (Figure 26) identifies wetland areas (circled in blue) that existed at that time. Included among them are the industrial areas on Lundquist, Campanelli, and Bay State Drives, and along the Southeast Expressway and Union Street, as well as the Braintree Golf Course. The industrial park areas and the Southeast Expressway corridor are examples of encroachment and filling of floodplains resulting in a loss of flood storage, and increase in pavement resulting in additional runoff to the rivers. Both have been identified as areas subject to flooding.

In his history of the Monatiquot River, W.E. Albert describes the town landfill filling three to four acres of the river's floodplain, "swamp reclamation" via the dumping of trash from the New Haven and Hartford Railroad, and the removal of "Long Pool" for the construction of the southeast expressway as examples of alterations to the river and adjacent floodplains that took place along a short segment of the Monatiquot River. The former Long Pool is described as a three-quarter mile, fifty foot wide, slow flowing section of the river created by a natural dike at the foot of Hunt Avenue. According to the account, the pool was removed and a straight channel dug parallel to the expressway as a replacement for the path of the river.

Albert also notes the mill dams and other construction along the Monatiquot that changed the river's flow, shape and banks. Town staff noted changes to the Monatiquot from the construction of Route 3, and also from Shaw's Supermarket. Beyond these notable areas of impact, the 1856 map highlights that an entire community has grown up over the past 150 years. Each road, home, and business has an incremental effect on drainage and flood patterns. Figure 26 has been amended to show flood claims and their relationship to historic wetlands and waterways.

Figure 26. 1856 Map of Braintree with Flood Claims



Flood claim locations are enlarged to comply with federal privacy requirements.

An additional challenge is that while almost all of Braintree lies within the Monatiquot River watershed, more than half of the upper watershed is located in Randolph, Holbrook, and other towns, as shown in Figure 27. This means that flooding in Braintree is impacted by development patterns and actions beyond the control of the Town of Braintree.

Figure 27. Monatiquot River Watershed

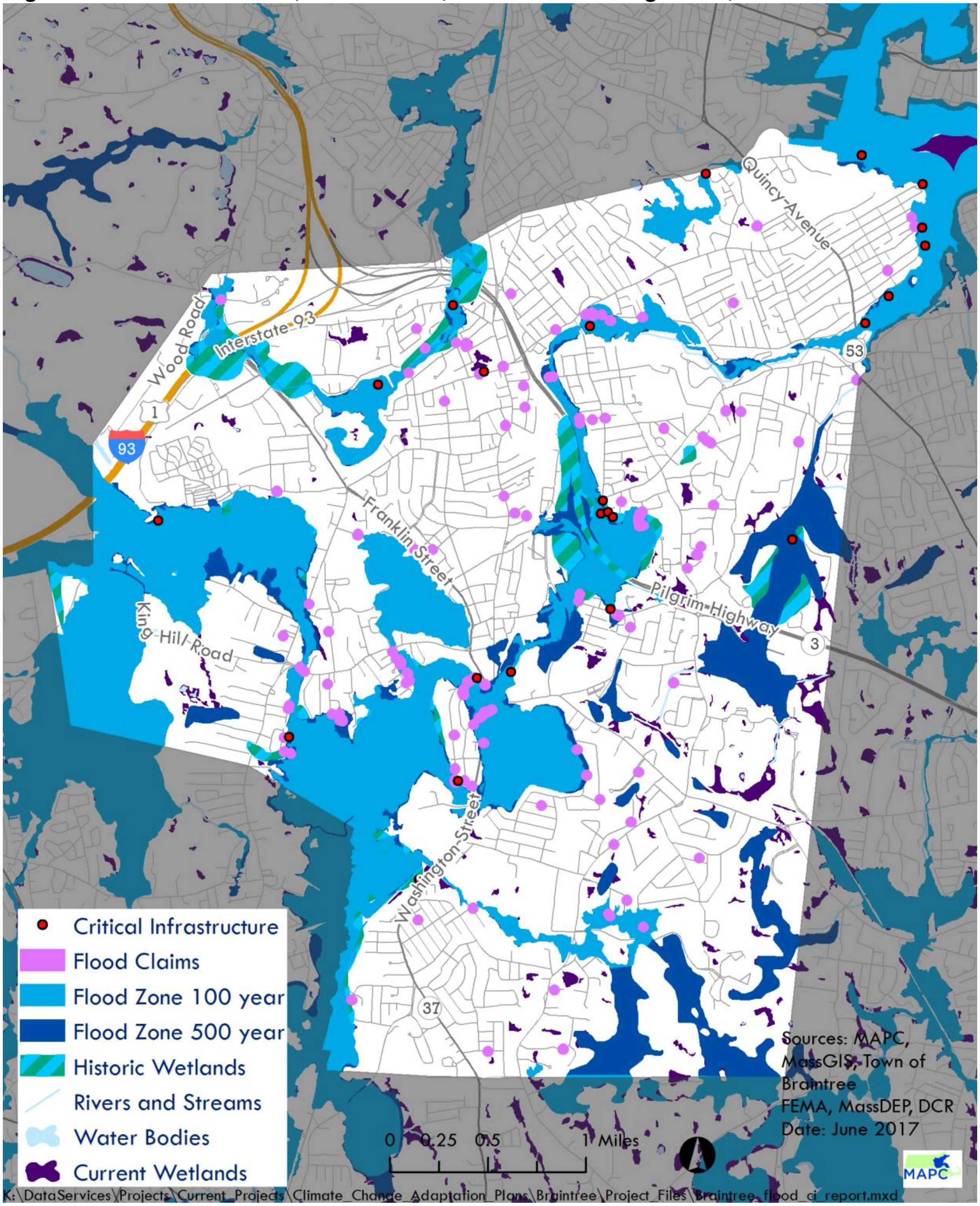
Source: Town of Braintree Monatiquot River Watershed Study

Flooding and Critical Facilities

In this report we utilize models to project where future sea level rise may change flood locations and depths. To date, however, no similar mapping of potential future inland flood zones is available. There are particular challenges to projecting future inland flooding including, varying impacts when rain falls on dry, frozen, or saturated land; and differential impacts of long and short-duration rain events. Flooding associated with storm drainage infrastructure is also particularly difficult to predict.

Yet there are ways to assess and consider future vulnerabilities resulting from increases in precipitation. Reviewing extreme events that may become more frequent, such as the 2010 and 2005 storms, is valuable for identifying where damage occurred and where it may have extended if rainfall amounts were greater. FEMA mapped 500-year flood zones, and relatively flat land adjacent to flood zones can be reviewed for vulnerability. In addition, infrastructure such as bridges, culverts, and storm drains can be analyzed for their potential to create blockages and flooding. Further, as discussed above, the location of former wetlands may be an important indicator of potential flooding locations.

Figure 28. Critical Facilities, Flood Zones, Identified Flooding Areas, and Historic Wetlands



Flood claim locations are enlarged to comply with federal privacy requirements.

Figure 28 identifies critical facilities in locations that may be subject to flooding. These include1) flood zones, 2) town-identified flooding areas, 3) in proximity to previous flood claims, and 4) historic brooks and wetland areas from the 1856 map of Braintree. These categories serve as proxies for identifying locations that may be subject to flooding now, or in the future as a result of larger storms. We do not have the capacity to predict more precisely where future flooding may occur. Table 6 summarizes the critical facilities and their relationship to potential flooding indicators.

Table 6. Critical Facilities and Potential Flooding Indicators

Critical Facility	Location	Flood Zone	Town identified flooding area	Proximity to a flood claim	Overlap with historic wetlands
Temple B'nai Shalom	41 Storrs Ave.			X	
Fire Station #2	1652 Washington St				X
Braintree Yacht Club	9 Gordon Road	X			
Marge Crispin Center	90 Pond Street		X	X	
Braintree Highway Dept	245 Union Street	X	X		X
Braintree Sewer Dept and Garage	245 Union Street	X			X
Braintree Park Dept	243 Union Street	X			X
Metropolitan Yacht Club	39 Vinedale Road	X			
Citgo Pier		X			
Sewer Pump Station	Common Street				X
Sewer Pump Station	308 Pearl Street	X	X		
Sewer Pump Station	249 Union Street		X		X
Sewer Pump Station	720 West Street	X	X		
Sewer Pump Station	10 Hingston Circle	X	X	X	
Sewer Pump Station	275 Jefferson Street	X	X	X	
BELD Station 10	Adams Street	X			
Pilgrim Center	140 Adams		X		
Elihu White Nursing Home	95 Commercial St.		X		
Morrison Elementary School	15 Mayflower Rd.		X		
Braintree Police Dept HQ	282 Union St		X		
T Station	300 Ivory St.		X		
Braintree Manor	1102 Washington St.		X		
Totland College	74 Commercial St		X		
B.A.S.E.	426 Pond Street		X		
National Guard Armory	275 Union Street		X		
Archie T Morrison School	260 Liberty Street		X		
University Of Phoenix-Boston	100 Grossman Drive		X		
Fuel Cell		X			

The Town of Braintree has been active in analyzing and addressing flooding. The 2008 Flood Hazard Mitigation Plan and the 2012 Hazard Mitigation Plan both include a thorough review of flooding areas and strategies to address them. Sewage and power are critical systems that must be protected and made resilient. Loss of sewage pumping ability can lead to back-ups into homes and businesses. Failure of electrical systems can lead to cascading problems, including failure of pumps, requiring home evacuations. The 2008 report notes that BELD has the ability to reroute power away from any station that may be flooded to continue to provide power to the town. The 2010 rainstorm did, however, require power shut-off to the Kensington Street neighborhood where utilities are located underground.

Town staff report that all of the sewage pumping stations listed in Table 6 have been elevated above the 100-year floodplain. The Brookside and Howard Street pump stations have not yet been elevated. While not in today's floodplain, the Brookside pump station may be susceptible to flooding due to its proximity to Smelt Brook. The Howard Street station is at the edge of the flood zone; town staff indicate the Pearl Street station has required sandbagging for protection from flooding from the Monatiquot. BELD Station 10, is located on the bank of the Monatiquot but did not have flooding or access issues in 2010.

The Braintree Highway Department is located on the banks of the Monatiquot River and has been flooded four times. The salt shed and tanks have been relocated to higher ground, but the barn remains vulnerable. Town staff reports that in 2010 the reservoir rose to within three feet of the Water Treatment Plant at Great Pond.

The 2008 report also highlighted the Union and Ivory Street intersection as a critical flooding area because of its status as an evacuation route. Street flooding is common in numerous other areas of town including: Hancock, Washington, Adams, Jefferson, West, and Union Streets, and Rex Drive.

The Massachusetts Climate Adaptation Report suggests that existing and capped landfills could be vulnerable, saying: "More rainstorms and associated runoff could cause structural damage, increased release of leachate, or even exposure of waste at landfills located in historic wetlands and other sensitive locations. " MAPC did not investigate the status of Braintree's former landfill. As it is adjacent to the Monatiquot River, the Town may want to review whether there are any current or future concerns.

Private property

Many homes and businesses are also vulnerable to flooding. FEMA claims statistics show that since 1978, property owners have filed 160 flood insurance claims. Flood insurance payments from 1978 through October 2016, total nearly $2 million. These figures do not, however, reflect the amount of flood damage that has occurred. Many property owners do not have flood insurance and many don't file claims for all damages. Property owners without flood insurance were eligible to receive FEMA reimbursement for damages for the 2010 storm. In that storm alone, 627

Braintree property owners filed flood damage claims, and 475 were reimbursed a total of $1.1 million in damages.

Figure 26 identifies the location of all FEMA flood claims since 1978 and the (partial) available data on the 2010 flood locations. Notably, a majority of the claims are outside of FEMA flood zones. This has important implications for understanding and addressing flooding. In locations outside of flood zones, residents and town officials are not necessarily forewarned of the potential for flooding. Regulations that would protect against flood damage do not apply. Claims outside of FEMA flood zones may be caused by high groundwater, filled or buried wetlands, stormwater drainage issues or other unknown sources.

Dams

The Massachusetts Climate Adaptation Report notes that increased intensity of precipitation is the primary concern for dams, as they were most likely designed based on historic weather patterns. The Department of Conservation and Recreation (DCR) Office of Dam Safety monitors the condition of the state's dams. A potential effect of increased significant rain events is the failure and/or overtopping of existing dams. Braintree's eight dams, their ownership, and condition as of 2009 are shown in Table 7.

Table 7. Department of Conservation and Recreation Dam Status

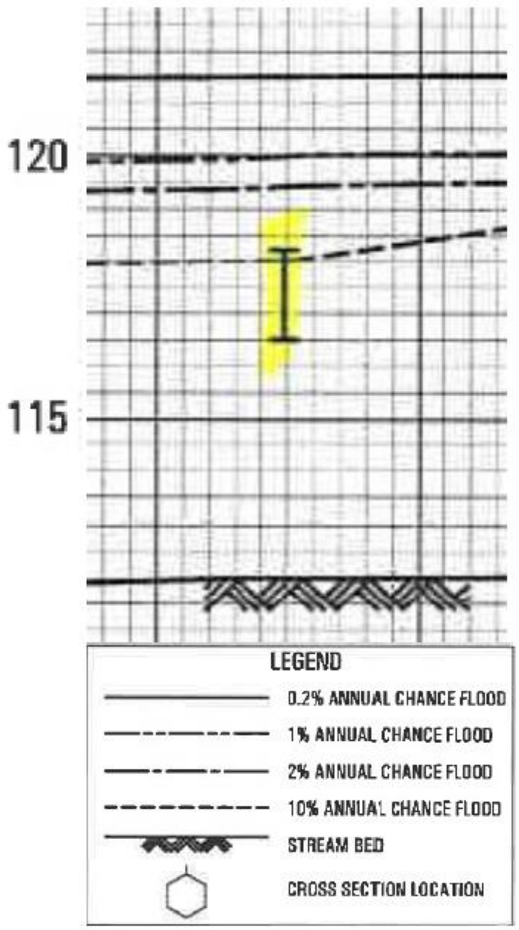
DAM	OWNERSHIP	DCR RATING 2009
Great Pond Upper Reservoir	Tri-Town Water Board	High hazard/Satisfactory
Great Pond	Tri-Town Water Board	High hazard/Poor
Smelt Brook (Pond Meadow Park)	Weymouth/Braintree Recreation Department	High Hazard/Satisfactory
Sunset Lake	Town of Braintree	Significant Hazard/Fair
Eaton's Pond	Conservation Commission/Private	Not listed
Braintree Dam (Quincy Reservoir)	DCR	High Hazard/Good
Armstrong Dam	Private	High Hazard/Fair
Cranberry Brook Dam	Town of Braintree	Not listed

DCR potential hazard ratings are high, significant, and low; conditions were rated good, satisfactory, fair, poor, or unsafe. The State Hazard Mitigation Plan uses the term "High Hazard Potential" for dams located where failure will likely cause loss of life and serious damage to homes, industrial or commercial facilities, important public utilities, main highways, or railroads. A "Significant Hazard Potential" dam is one located where failure may cause loss of life and damage homes, industrial or commercial facilities, secondary highways, or railroads; or cause interruption of use or service of relatively important facilities.

Great Pond Reservoir is slated for repairs in 2017. The Braintree Dam has been repaired by the DCR; as a consequence, FEMA is re-evaluating the flood maps along Town River downstream of the dam. Braintree's most recent Hazard Mitigation Plan indicates that Great Pond, Braintree, Eaton's Pond, Armstrong and Pond Meadow Park Dams all drain into streams that have the capacity to handle waters in the event of a dam failure. In addition, the plan notes that the town has developed plans for lowering water levels behind publically owned dams in advance of severe storms. The Braintree Dam was identified as a location where failure would likely result in property damage.

Bridges

Figure 29. West St. Bridge Profile



West Street Bridge over the Farm River.

FEMA analyzed the 28 bridges that cross the Monatiquot, Farm, and Cochato Rivers. The Flood Insurance Study for Norfolk County (2015) includes FEMA flood profiles for major rivers and streams. As part of that work FEMA profiles each bridge and its relationship to the projected .2%, 1%, 2% and 10% chance floods. Figure 29, depicts the West Street bridge over the Farm River. As analyzed by FEMA, the top of the bridge is 1.5 feet below the projected height of the current 2% annual chance flood, and just three inches above the projected height of the 10% annual chance flood. The West Street Bridge is the lowest in Braintree, relative to the flood zones, however, all of the bridges over the Farm and Cochato, and two of those over the Monatiquot are below the projected flood height of the 1% chance flood (Table 8).

In addition to the concern that bridges such as the one at West Street could be overtopped even in relatively minor storms, the bridge structures themselves may obstruct water flow and cause upstream flooding. The base of all of the bridges on the Farm and Cochato Rivers are at, or below, the 10% flood height. The base of four of the twenty-one bridges over the Monatiquot River (Adams – both bridges, Plain and Shaw) are below the height of the10% chance flood.

Gomez and Sullivan Engineers, released a draft report of the Armstrong Dam Removal Feasibility Study in October 2016. The purpose of the study is to evaluate the feasibility of restoring river herring access to the Great Pond Reservoir. Their evaluation included analysis of flooding impacts of the dam, and of dam removal. Modeling the 100-year flood, they conclude that the dam impoundment impacts stream flow upstream to the face of the Jefferson Street Bridge.

The report states: “the 100-year profile shows that for at least the Plain Street Bridge it is undersized to pass the 100-yr and 50-yr flood flows (under both dam-in and dam-out conditions) as it becomes overtopped. Because of undersized hydraulic capacity at the Plain Street Bridge it creates a backwater that also overtops the Washington and Jefferson Street Bridges. If the Plain

Street Bridge was not hydraulically undersized it is unclear if the Washington and Jefferson Street Bridges would be overtopped. All three bridges are overtopped under the 50-year and 100-year flood".

Table 8. Braintree Bridges

RELATIONSHIP OF TOP OF BRIDGE TO THE FEMA CALCULATED FLOOD HEIGHT PROBABILITY FOR THE .2% CHANCE (500 year), 1% CHANCE (100 year) AND 2% CHANCE (50 year) STORMS						
River (upstream to downstream)	**Bridge**	**Feet above .2% chance storm**	**Feet above 1% chance storm**	**Feet below 1% chance storm**	**Feet below 2% chance storm**	**Overtopped in 2010**
Monatiquot	Jefferson Street	+ .5 *				Yes
	Washington Street		+ 1.5			Yes
	MBTA Railroad Bridge		+ 1.5			
	Plain Street		+2			
	Hancock Street		+ 1.5			Yes
	MBTA Railroad Bridge	+ 4				
	Mahar Highway		+ 1.5			
	Pearl Street		+ 3			
	Route 3	+ 4.5				
	Union Street	+ 2				
	Union Street	+2.5				
	River Street			-1		
	Railroad	+ 7				
	Middle Street	+ 11.5				
	Adams Street			-1		Yes
	Adams Street		0	0		Yes
	Railroad	+ 9				
	McCusker Drive	+ 6.5				
	Foot Bridge	+ 7.5				
	Commercial Street	0				
	Railroad	+ 15				
	Shaw Street	+ 3.5				
Cochato	Railroad Bridge				-.5	
	Bridge near Richardi Dam				-1.5	
Farm	West Street				-1	Yes
	Lundquist Drive				-.5	
	Lundquist Drive				-.5	
	Granite Street				-1	
	Pond Street				-.25	

This analysis suggests that removal of the Armstrong Dam could relieve upstream flooding, at least to the Plain Street Bridge; it also suggests that the FEMA calculations, shown in Table 8, overestimate the height of the Plain, Washington, and Jefferson Street Bridges relative to flooding levels. More study would need to be done to determine to what extent the bridges are at risk for flooding, or for causing flooding. Town staff report that six bridges were flooded in 2010 as shown in Table 8.

The work of Gomez and Sullivan was more detailed than the FEMA evaluation, and took in to account any changes that have taken place since the analysis was done by FEMA in the1980's. As a result, the FEMA analysis of all of the bridges should be viewed with some caution. It does, however, provide a starting point for considering the impact of the bridges on flooding, and the impact of flooding on the bridges.

Sea Level Rise and the Built Environment

MAPC used Version 3 of the Boston Harbor Flood Risk Model (BH-FRM) developed by the Woods Hole Group (WHG) to provide projections for flooding probabilities and depths in 2030 (Figure 31) and 2070 (Figure 32). The BH-FRM was originally developed for Mass DOT and the Federal Highway Administration to evaluate the vulnerability of the central artery tunnel system. WHG has provided data for MAPC Metro Mayors communities.

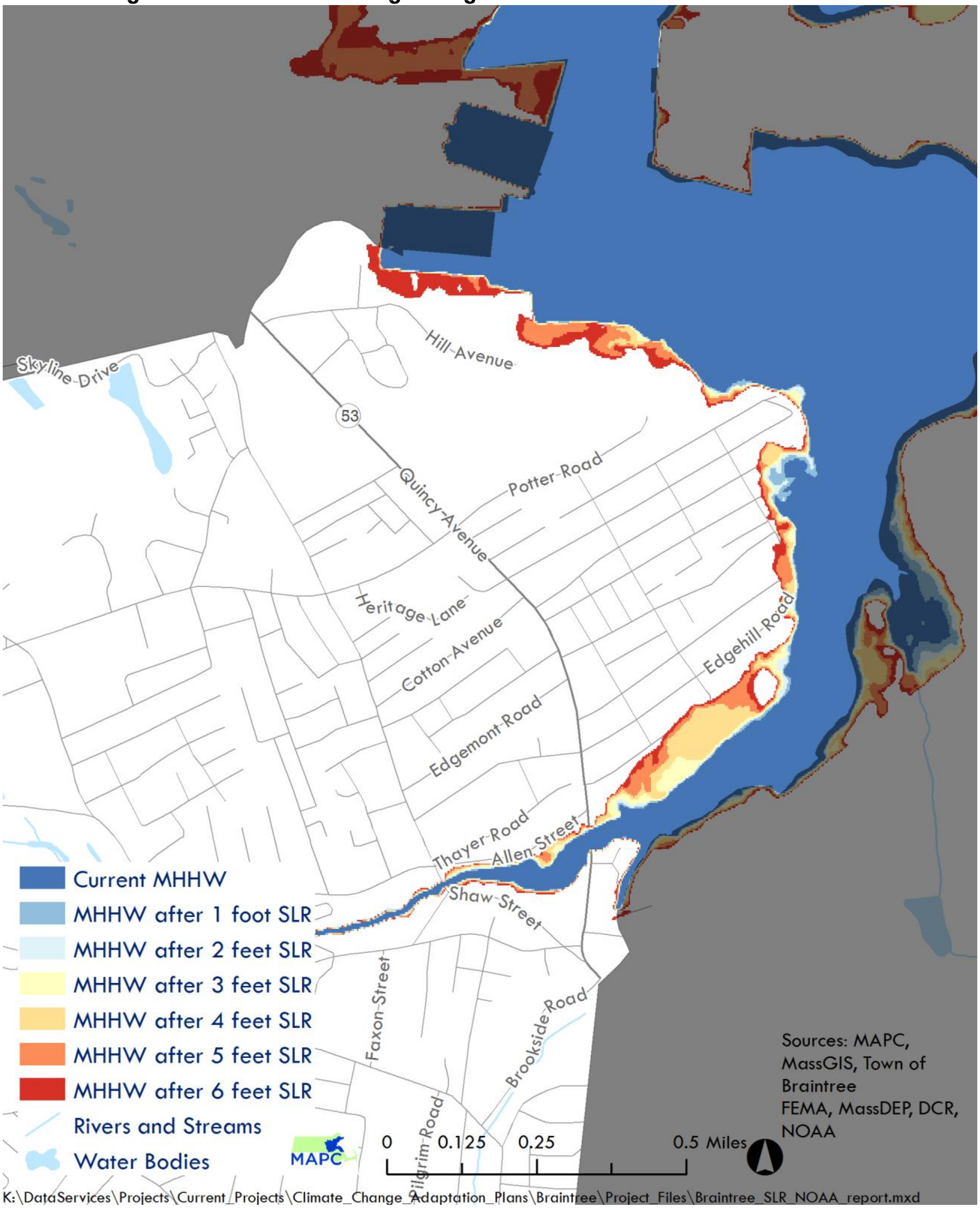
BH-FRM models both risk of flooding and depth of flooding on the basis of sea level rise projections and projected changes in intense storm patterns. Unlike previous models of sea level rise, the BH-FRM takes into account a variety of variables such as storm surge and wave run up. The model bases projections on .68 feet of sea level rise by 2030 and 3.4 feet of sea level rise by 2070, relative to sea level in 2013. These figures are comparable to the "high" scenario for sea level rise shown in Figure 5. While this is a conservative scenario, observed rates of sea level rise have been trending toward the high scenario in recent years.

Caution should be used in interpreting the projections. There are inherent mapping inaccuracies due to the need to interpolate between calculation nodes. In the furthest inland location on the Monatiquot River near Shaw Street, the WHG has confirmed that a display error indicates a 100% chance of flooding in 2013, where in fact none is predicted by the BH-FRM. As a result, the flood risk shown in Figures 31 and 32 along the shore line above Quincy Avenue exaggerates projected impacts. This example illustrates that the maps are not applicable at a fine-grained level to assess individual buildings. Rather the sea level rise maps are provided as general guidance for future flooding analysis. The projections are not related to FEMA flood insurance maps and cannot be used for boundary resolution or location. Details on the BH-FRM methodology are available at:
https://www.massdot.state.ma.us/Portals/8/docs/environmental/SustainabilityEMS/Pilot_Project_Report_MassDOT_FHWA.pdf

Given the technical challenges in modeling and the possibility of error, we have also included modeling provided by the National Oceanic and Atmospheric Administration (NOAA) (Figure 30). The NOAA maps are what is termed a "bathtub" model. That is, unlike the BH-FRM, they do not account for storm surge and other dynamic factors. The NOAA mapping locates mean higher high water (MHHW, the average height of daily highest tides) and adds one-foot increments of sea level rise using LIDAR elevation data. The NOAA maps are not alternate models of the same information provided by the BH-FRM. The NOAA model predicts the location of (MHHW) under various sea level rise scenarios, while the BH-FRM predicts the extent of flooding for a variety of storm scenarios in 2030 and 2070. Given the error identified for the shoreline upstream of Quincy Avenue, the NOAA model is preferred in that location. The NOAA model can be viewed, and details on the methodology accessed at: https://mass-eoeea.maps.arcgis.com/apps/MapSeries/index.html?appid=6f2797652f8f48eaa09759ea6b2c4a95

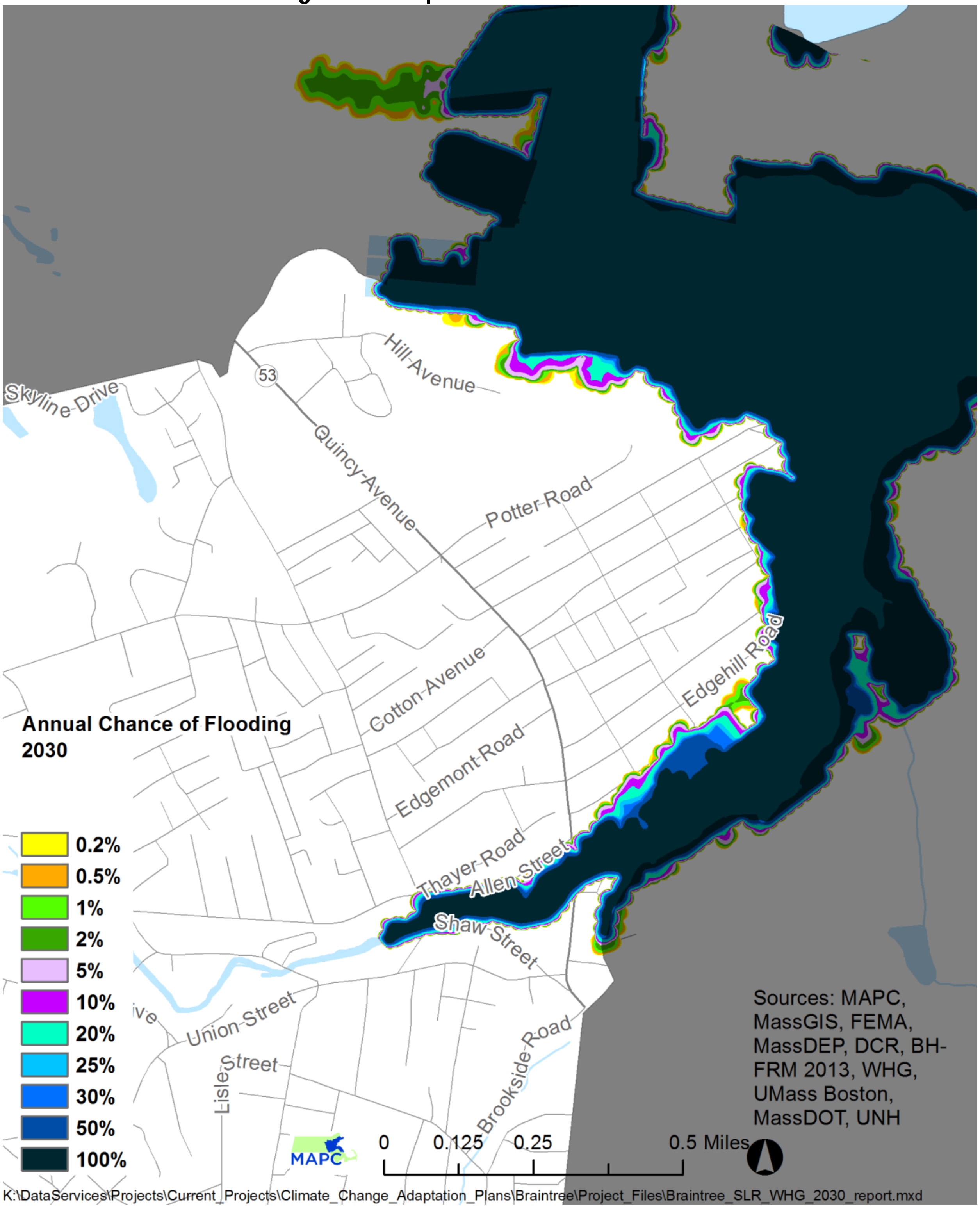
While there are differences in detail, the two models, and the current FEMA maps show strong agreement in terms of identifying locations that are vulnerable to flooding. The future projections show potential impacts to the BELD facility on Potter Road later in the century. However, future flooding was taken into account when the new facility was built; it is elevated above the current flood zone. Other public facilities that may be affected by surge from severe storms as sea level rises include the electric substation on Edgehill Road, and the heliport at Watson Park; Watson Park and Smith Beach are also within sea level rise projections. Projections show sea level rise impacts extend along the shoreline of the Fore River and the Monatiquot River to slightly upstream of Shaw Street. Businesses and homes at the lowest elevations along Vinedale and Edgehill Roads and Allen Street may start experiencing impacts from coastal storm surge by mid-century. For any building, a site-specific analysis, including consideration of ground and building elevation, flood proofing, and the elevation of utilities, is necessary to evaluate vulnerability.

Figure 30. Current Mean Higher High Water and 1-6 feet of Sea Level Rise



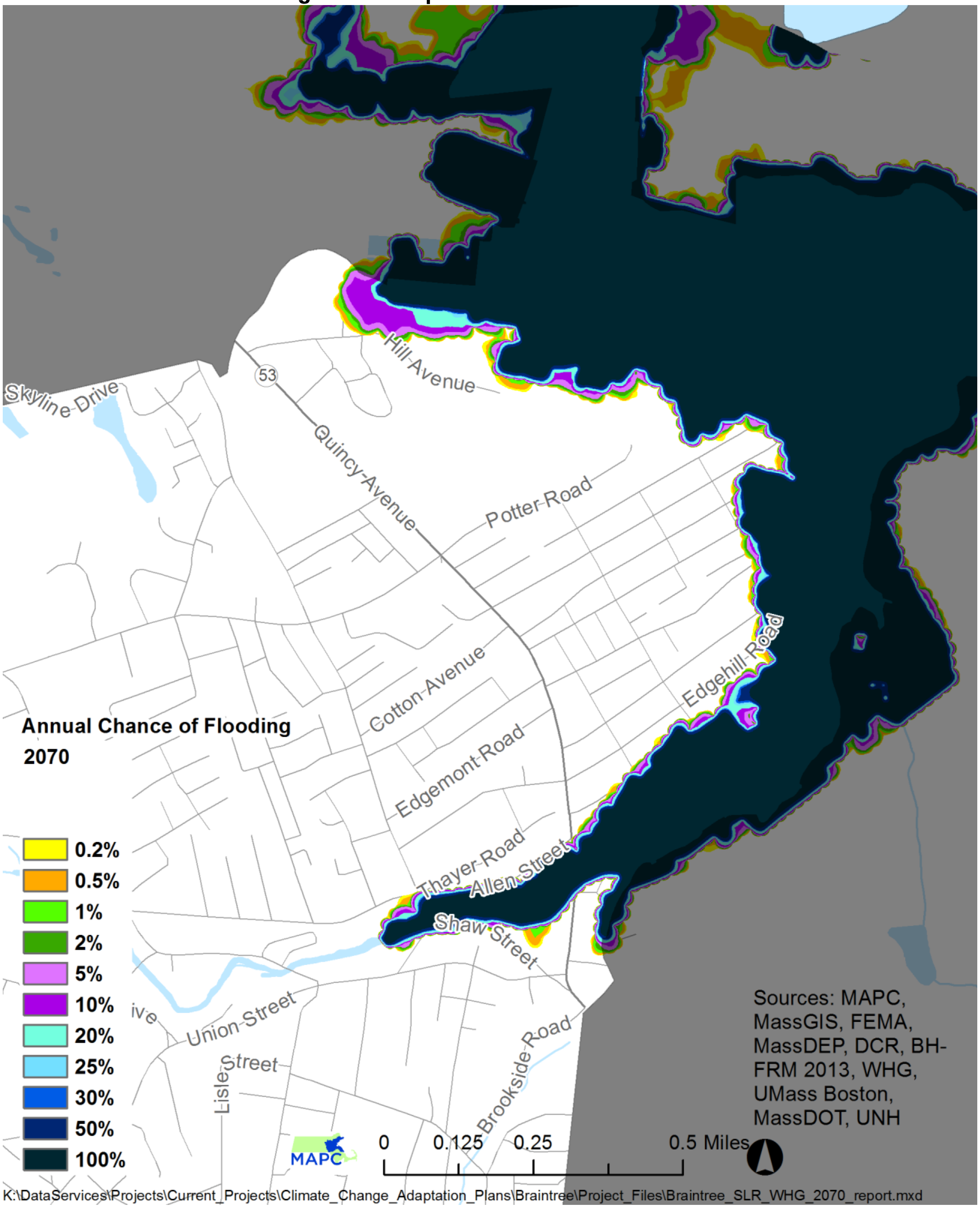
Source: NOAA

Figure 31. Projected Sea Level Rise 2030



Source: WHG

Figure 32. Projected Sea Level Rise 2070



Source: WHG

In 2009, MA CZM published an assessment of coastal infrastructure presumed to be publically owned. The Braintree structures were assessed in June, 2007. The assessments were based on visual observation; the repair estimate was based on presumed cost to bring the structure back to original design. A grade of "B" signifies only minor repairs needed, and the structure should be adequate to survive a major storm without damage. A "C" grade signifies minor deterioration; the structure should be adequate to withstand a major storm with little to moderate damage. A grade of "D" indicates advanced deterioration and the possibility of failure during a major storm. Priority levels were assigned based on the potential for damage to inland infrastructure and/or homes if failure occurred. None of the Braintree structures were in the highest or lowest level of priority. The results are summarized in Table 9 below.

Table 9. Coastal Infrastructure

Location	Type Structure	Length (ft)	Condition	Repair Cost	Priority
Braintree Yacht Club	Steel Seawall	330	B	$17,860	high
Braintree Yacht Club	Concrete Seawall	85	B	$7,181	moderate
Braintree Yacht Club	Stone seawall	300	B	$25,344	moderate
Quincy Ave. DOT Bridge	Mortared seawall	130	B	$43,586	moderate
Watson Park	Stone seawall	530	B	$44,774	low
Watson Park	Stone seawall	30	C	$12,751	low
Smith Beach (south end)	Stone jetty	60	B	$7,920	moderate
Smith Beach	Sand beach	560	B	$14,784	moderate
Smith Beach (north end)	Stone jetty	105	B	$13,860	moderate
Harbor Villa Ave.	Stone revetment	300	D	$199,188	moderate

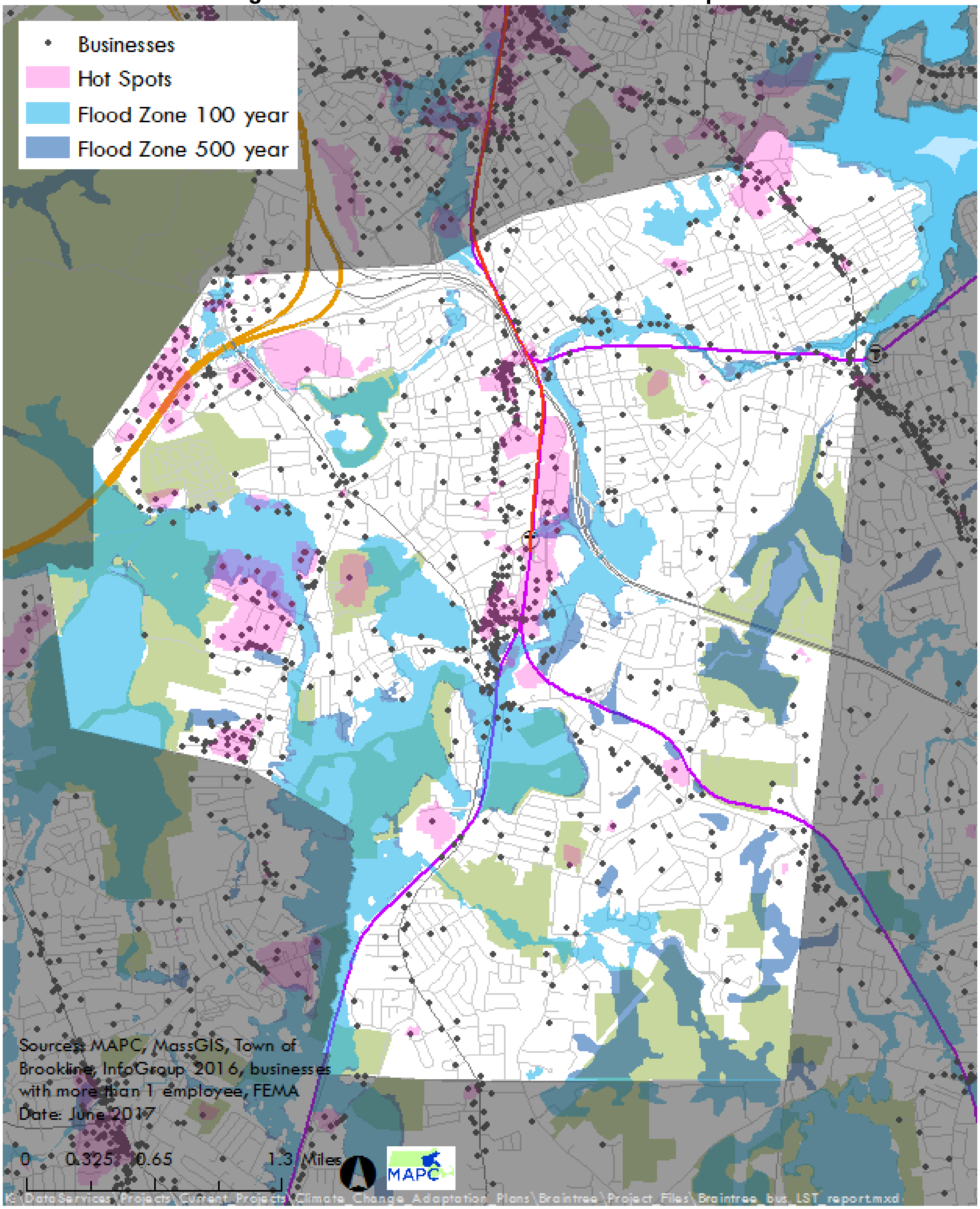
Temperature and the Built Environment

Buildings, roadways, and railways can be stressed by extreme temperatures. Heat can cause damage to expansion joints on bridges and highways, and may cause roadways to deteriorate more rapidly. Extreme heat will increase demand for cooling. According to the Massachusetts Climate Adaptation Report, 2011, there is a potential for significantly increased household energy consumption as the climate warms. The report notes that because higher temperatures reduce the efficiency of electric generation, it could be difficult to meet peak electricity demands. Power outages have significant impacts on public health, communications, transportation and the economy in general.

Climate Impacts on the Local Economy

Businesses, employees, homeowners, and the municipality could experience financial shocks from business disruption, property damage, and property loss caused by extreme weather. Severe climate effects that result in property damage and financial stress can cause commercial and residential displacement, if the cost of repair, hardening infrastructure, and increased utility or insurance costs become too great for property owners. Job disruption during an extreme weather, such as a Nor'easter or heatwave could result in delayed projects, forced business closures, job loss, and reduced spending.

Figure 33. Business Locations and Climate Impacts



Nearly 40% of Braintree's businesses are in areas with particularly high land surface temperatures (hot spots) (InfoGroup 2016) (Figure 33). Hot days can cause unhealthy work conditions for people who work outside. Excessive heat can cause unsafe and uncomfortable indoor conditions as well, for both employees and patrons. Massachusetts's OSHA regulations do not currently regulate warm-weather indoor temperatures or air conditioning, but employees can file complaints to the Braintree Board of Health or OSHA if workplace conditions are unbearable.

Roughly 9% of Braintree businesses are located in flood zones. Businesses along Adams Street and in other locations were impacted by flooding in 2010. Flooding from sea level rise may impact businesses adjacent to the Monatiquot and Fore Rivers. Approximately 87% of employed Braintree residents work outside of Braintree. Roughly 30% commute to Boston and 9% commute to Quincy. Significant employment destinations include Downtown Boston and the Longwood Medical area. Heat or flooding impacts to the MBTA could impact commuters. Flooding of roadways (such as the Union Street rotary) would impact far more Braintree residents, as 82% +/-2% commute by car (ACS 2011-2015).

CLIMATE IMPACTS ON STATE-OWNED INFRASTRUCTURE

Massachusetts Bay Transportation Authority

The MBTA provides critical transportation services to Braintree residents and businesses. Braintree is serviced by the Red Line, the Middleborough/Lakeville, Plymouth/Kingston, and Greenbush commuter rail lines, three bus routes, and by The Ride (ADA compliant service). Data from the MBTA Ridership and Services Statistics 2014 report show that weekday ridership includes over 5,000 boardings at the Braintree Red Line stop, nearly 450 on the commuter rail lines, and over 4,500 on the three bus routes. Nearly 28,000 (average 76 per day) trips on The Ride originated in Braintree in FY 2103.

MBTA climate concerns include potential damage and disruption from rain and coastal flooding. The damaging effect of corrosive salt water is a key concern. Extreme heat can cause buckled rails, overheated equipment, regional power failures, wear and tear on paved surfaces, and health and safety issues for workers and passengers when temperatures exceed 85 degrees. Warmer temperatures could lead to more damage from ice storms if temperatures hover around freezing.

The MBTA is taking steps to address climate resiliency. Requests for Proposals (RFPs) for architectural and engineering plans must now address historic and future vulnerabilities by the 30% design stage. Capital plan requests need to indicate whether projects will improve resiliency; they receive greater priority if they address resilience. A pilot resiliency evaluation has been conducted for the Blue Line, and an RFP is being developed for a system-wide analysis. Specific climate resiliency projects in Charlestown and Kenmore Square are already planned or underway.

Braintree has already experienced MBTA service delays from flooding. In the March 2010 flood, service on the commuter rail tracks upstream of the Armstrong Dam was delayed due to water on the tracks. When water exceeds three inches in depth, standard operating procedure requires trains to slow to walking speed; this resulted in roughly twenty minute delays for eleven trains that day.

In addition to vulnerabilities that may exist on the rail lines, surface transportation could also be affected by flooding events. The #230 bus (Brockton to Quincy) travels along Hancock Street which has experienced flooding. The #236 bus (South Shore Plaza to Quincy Center) travels through the Union St. rotary, which is another chronic flooding spot. Street flooding could also affect trips on The Ride.

Massachusetts Water Resource Authority

The Massachusetts Water Resource Authority (MWRA) provides sewage treatment for the Town of Braintree. The MWRA has conducted an analysis of its sewer infrastructure, considering potential impacts based on modeling the 1% chance FEMA flood, plus an additional 2.5 feet of elevation. Sewage from Braintree is pumped through the Intermediate Pump Station in Weymouth. The facility is considered at minimal risk, their lowest risk category, as it is elevated more than 5 feet above the modeled elevation for sea level rise. The Nut Island Headworks and the Deer Island Treatment Plant are also at an elevation that puts them in the minimal risk category.

While the MWRA analysis suggests good protection from sea level rise for Braintree, there is the potential for impacts from increased precipitation. Both MWRA and town officials note that the capacity of the sewage system has been exceeded during heavy rain events. This has resulted in the release of untreated sewage in the Monatiquot River and sewage backflow into streets and basements. According to the MWRA, the capacity issues are caused by groundwater infiltration and inflow from storm drains, roof leaders, and sump pumps that should not be connected to the sewer treatment system.

The MWRA has the potential to provide emergency potable water supplies through a connection to Braintree's drinking water system. The MWRA is confident that its drinking water infrastructure is not threatened by more intense storms. Pump stations and storage tanks are above flooding elevations; spillways have been improved to handle the .01% storm (1 in 1,000 years). They have reviewed the status of their dams and report no current issues. The MWRA does not anticipate issues with water supply. The Authority's safe yield of 300 million gallons per day (gpd) took into account the 1960's drought, which was characterized as a 400-year event. Current usage is 200 million gpd. The MWRA has very large reservoirs relative to the size of the watershed. Because of this capacity, and because of significant success in water conservation efforts over the past 35 years, even if a drought extends several years, the MWRA can supply all existing communities and provide assistance to neighboring communities as needed.

MASS Department of Transportation

Mass DOT is currently working with a consultant to develop a model to project the future 100-year floodplain for the 24-hour storm, using future precipitation projections. It is not yet known when the model, now in a test phase, will be available statewide, but MassDOT hopes to be able to use it to identify priority flooding locations. State roadways in Braintree include Route 3, Route 37 and Route 53. The Union Street interchange with Route 3 and Route 37 (at Plain and Washington Streets) are significant flooding locations.

Department of Conservation and Recreation

The Department of Conservation and Recreation owns the Quincy Reservoir (Braintree) Dam. This facility was discussed in the section on dams.

CLIMATE IMPACTS ON UTILITIES

Electricity

The Braintree Electric Light Department (BELD) provides electric service to Braintree. Energy infrastructure in general is vulnerable to extreme weather events, in particular winter storms, heat waves, and flood events. Ice storms, freeze/thaw events, and flooding can cause severe damage to infrastructure. Winter storms and hurricanes can increase load on utility infrastructure, especially power lines and utility poles, due to increased weight from precipitation and wind. Additionally, over 90% of power outages are caused by fallen trees and limbs during storms. Heat waves are also damaging to infrastructure because of disruptions to core components within transformers, which are already overburdened during times of increased demand on the electric grid. Flooding can corrode critical infrastructure and prevent electronic components from functioning.

BELD officials indicate that they are most concerned about impacts from heat waves. They have taken many steps to reduce stress on their system. They have instituted advanced metering which identifies circuit weaknesses; upgrades are made where indicated. Conservation, including such efforts as LED lighting, home energy assessments, and tree planting have reduced demand from 93.5 MW in 2006 to 83 MW in 2016. Incentives encourage off peak usage. BELD officials note that during the northeast blackout in 1965, Braintree was a rare community that was able to maintain power. BELD is connected to two Eversource lines and is able to generate power from the plant to the grid. BELD can also isolate from the grid and power Braintree only - if needed. Critical equipment has been elevated above flood levels; substations have 24-hour monitoring, and redundant systems have been incorporated.

Natural Gas

Braintree's natural gas infrastructure is serviced by National Grid. There are approximately 119 miles of gas distribution lines in the town. Critical gas infrastructure includes pipelines, compressor stations, storage facilities, and control stations. This infrastructure is necessary to transport, store, and distribute natural gas.

Flooding from heavy precipitation poses a threat to underground gas infrastructure. Gas pipes rely on internal pressure to keep natural gas flowing. Water intrusion can disturb internal pressure and result in service disruption. Gas pipes within low pressure distribution systems are the most vulnerable to flooding because they do not have the hydrostatic pressure necessary to keep water out. Above ground infrastructure, such as compressor stations, metering stations, and control stations are also vulnerable to flooding. Freeze/thaw events can cause gas mains to break. Older cast iron pipes are the most vulnerable to freeze/thaw events. Extreme heat does not pose significant threats to gas infrastructure.

National Grid has initiated a Yearly Improvement Program; targeted at enhancing resiliency in areas that have suffered repeat flood outages. The utility company has also undergone an in-depth climate vulnerability assessment of their assets to identify high risk areas. Within these areas, they will be upgrading low pressure distribution systems to high pressure distribution systems and flood-proofing aboveground infrastructure that may be affected by flooding.

Massachusetts has a gas leaks problem that adds complexity to addressing future climate impacts. The natural gas system is one of the oldest in the country. Non-protected steel, and cast iron pipes are particularly leak prone; they constitute 3,172 miles, or 44% of the 7,215 miles of pipe main in National Grid's Boston Gas distribution system which includes Braintree. Braintree does not have any cast iron mains. Unprotected steel pipes are subject to corrosion.

Gas leaks release methane, the most powerful greenhouse gas, into the soil and the air. Gas leaks carry serious environmental and health risks including suffocating the root systems of trees and forming ground-level ozone (an asthma trigger). In 2014 the Massachusetts legislature passed a law that requires gas companies to accelerate the replacement of leak-prone pipes. Gas companies are required to submit annual Gas Safety Enhancement Plans (GSEP). In their 2017 plan, submitted in October 2016, National Grid indicated that they intend to replace 105 miles of leak-prone pipes in 2017 and complete replacement of all leak-prone pipes by 2035.

Braintree has 118.9 miles of gas mains; 24% of the gas mains are non-protected steel. Most recent figures from National Grid show there are two Grade 2 leaks, and 168 Grade 3 leaks in Braintree. National Grid defines Grade 2 leaks as non-hazardous to persons or property, but justifying repair based on probable future hazard. Grade 3 leaks are characterized as non-hazardous and expected to remain non-hazardous. A Grade 1 leak is an existing or probable hazard that requires immediate attention.

The 2017 National Grid GSEP includes plans for three projects in Braintree, replacing .71 miles of non-protected steel pipe. From 2018 through 2021, National Grid plans 21 projects, replacing 3 miles of non-protected steel pipe. If implemented, this would reduce leak-prone mains in Braintree 13% by 2022, leaving nearly 25 miles of leak-prone mains.

Telecommunications

Telecommunications infrastructure is the technology that transmits information electronically. Telecommunications systems include phone and computer networks, and the internet. This infrastructure plays a critical role in emergency response and recovery. Telecommunications infrastructure is vulnerable to extreme heat, precipitation, and storms. Most heat-related service disruptions are caused by power outages resulting from increased demand on the electric grid. Extreme heat can also cause critical infrastructure to overheat or malfunction, leading to equipment failure and reduced lifespan. Corrosion and erosion that can be caused by flooding from heavy precipitation, sea level rise, and storm surges are primary concerns for underground infrastructure and critical facilities. Heavy ice formation and snow accumulation can increase the load on telecommunication lines and infrastructure, resulting in damage. Heavy precipitation and increased humidity can interfere with the signal transmission that wireless systems rely on.

Aboveground infrastructure is vulnerable to strong winds and lightning. Wired infrastructure and utility poles are particularly vulnerable to damage from falling trees and limbs. Many providers utilize shared fiber networks that reduce redundancy and increase vulnerability to systems disruption during extreme weather.

Some service providers, such as Verizon, are taking steps to protect their infrastructure from the impact of climate change. They are creating backup power capability on critical sites, implementing emergency fuel plans for generators, hardening buildings and structures to withstand flooding and precipitation, deploying mobile communications units to heavily affected communities, and training staff to respond to emergencies. Specific data on the location of telecommunications infrastructure and networks is not publically available. MAPC Metro Mayors communities have the option to purchase proprietary information about telecommunications infrastructure for their communities.

VULNERABILITY ASSESSMENT SUMMARY

The key projected impacts from a warming climate include:

- Increased winter/spring precipitation, and large rainfall events, resulting in flooding damage to built infrastructure, and negative water quality impacts
- Increased summer drought, compromising water quality and quantity and putting stress on other natural resources
- Rising sea level, resulting in flooding and habitat loss along the Fore River and the tidal portion of the Monatiquot River
- Increasing temperatures, particularly an increase in the number of days over 90°F and 100°F, affecting public health, infrastructure, and natural resources

Socioeconomic Vulnerabilities

Vulnerable populations are likely to include a higher proportion of individuals who may be more susceptible to climate impacts, and individuals who may have more difficulty adapting to, preparing for, and recovering from extreme weather events. Social isolation increases vulnerability as it limits access to critical information, municipal resources, and social support systems valuable in emergencies.

Vulnerable populations that are growing, or projected to grow, include seniors, individuals living alone, people of color and people with limited English proficiency. In Braintree, residents who speak Asian languages are more likely to be linguistically isolated than others who speak a language other than English at home. Other vulnerable populations include low income residents, the very young, and individuals with a disability or pre-existing health conditions. East Braintree census tracts have a much higher proportion of residents living in poverty than the rest of Braintree.

Public Health Vulnerabilities

The health impacts of extreme heat and heat waves are a primary concern. Heat is the leading cause of weather fatalities, and exposure to high temperatures can cause a variety of heat-related illnesses. Young children and seniors are more physically vulnerable to heat than other age groups. Those who work outdoors, or participate in outdoor physical activity increase their susceptibility to heat-related illness, as do those in older housing stock, or those without access to air conditioning. People who require electric medical equipment may be at increased risk during loss of power. Extreme heat is often accompanied by high humidity and poor air quality. These conditions can aggravate or trigger cardiovascular and respiratory illnesses. Low-income individuals, people of color, and seniors may be at increased risk due to a higher prevalence of these chronic diseases.

Areas with less shade and a higher percentage of dark surfaces will experience the highest temperatures, known as the "heat island effect". The report identifies critical facilities in the hottest 5% of land area in the MAPC region. Public facilities in these hot spots include most of the Braintree Public Schools as well as the Thayer Academy Athletic Campus and the Archbishop Williams stadium.

Health-related problems from flooding can include diseases from mold in flooded homes and from contact with contaminated water. Such contact can happen in the home because of sewage back-ups and overflows, or in polluted recreational waters. A changing climate may cause an increase in mosquitos and ticks, as well as the illnesses they spread, such as eastern equine encephalitis, West Nile virus, and Lyme disease. Forecasting change in vector-borne illnesses, however, is complicated by a variety of climate and non-climate factors that may have conflicting effects. Those who spend significant time outdoors and/or live close to vector habitats are most vulnerable to vector-borne diseases. Substandard housing may increase contact with mosquitoes in the home.

Natural Resource Vulnerabilities

Braintree's existing natural resources lessen climate impacts. Trees confer many benefits, including carbon absorption and storage, air pollution removal, and stormwater interception. Tree-shade provides relief from heat and reduces energy demand from air conditioners. Wetlands, forests, and other open lands soak up and store rainwater, reducing flooding and protecting water quality. Maintaining open space in floodplains allows the land to absorb the brunt of flooding without impact to homes and infrastructure.

Aquatic resources will be affected by warmer temperatures and by changes in the timing and amount of precipitation events. Stormwater from rain washes pollutants into waterways and may cause erosion. In large events waterways may be affected by sewage overflows. Warmer summer temperatures may lead to an increase in aquatic vegetation, which can deplete dissolved oxygen and may have negative effects on aquatic animals and recreational use of waterbodies. Warmer waters, seasonal low-flow or no-flow events, and low levels of dissolved oxygen in the water, may result from a shift in precipitation patterns toward early spring runoff and more frequent summer droughts. Drought will have an impact on drinking water supply. The report details existing water quality impairments identified in compliance with the Clean Water Act. Many of the identified impairments may be exacerbated by climate impacts. Loss of salt marsh, beach and tidal flat habitats may result if these areas are not able to migrate landward as sea level rises. Watson Park is projected to be affected by flooding from storm tides as sea level rises.

Trees will be affected by warming temperatures. Trees adapted to warmer climates are predicted to become more abundant, while those that grow well in more northern climates will decline. Trees may also be subject to new pests and diseases that can thrive in a warming climate. Drought and wildfire, as well as ice storms, can weaken and damage trees. Street trees are subject to damage from gas leaks.

Built Environment Vulnerabilities

Inland flooding

Flooding due to rain has already had significant impacts in Braintree. The report documents flooding over the past 60 years. An increasing frequency and intensity of storms will exacerbate future flooding. Although the 2010 rainfall and river flow match most closely to 50-year flooding levels, town officials indicate that the flooding generally matched the 100-year flood zone. A key finding is that while significant flooding occurs adjacent to existing waterways, a majority of identified flood claims are for properties located outside of FEMA flood zones. As a result, many properties that experience flooding are not subject to floodplain regulations and affected property owners are not formally warned of their flood risk.

Much of today's flooding that occurs outside of FEMA flood zones is likely related to filled or buried historic wetlands and waterways, to high groundwater, to overburdened storm drain systems, or for other unidentified reasons. Future development that increases impervious surfaces or further alters natural drainage will exacerbate flooding. The report identifies critical facilities in flood zones, in town-identified flood prone areas, in close proximity to previous flood claims, and overlapping historic wetlands identified in the 1856 map of Braintree. These categories serve as proxies to identify facilities that may be subject to increased flooding in the future.

Areas and facilities of current (as well as future) flooding concern include the Braintree Highway Department, and street flooding at Hancock, Washington, Adams, Jefferson, West, and Union Streets, and Rex Drive. Bridges across Jefferson, Washington, Hancock, Adams (2) and West Streets were overtopped in 2010.

Sea level rise

The report reviews two different models of future sea level rise. Rising seas will affect the Fore River shoreline, as well as the Monatiquot River to just upstream of Shaw Street. Businesses and residences at the lowest elevations along the river will be impacted by surge from large storms as sea level rise progresses. Town properties that may be impacted include Watson Park and Smith Beach, as well as 44 Allen Street and the electric substation on Edgehill Road. The projections show potential impacts to BELD later in the century. However, future flooding was taken into account when the new BELD facility was built; it is elevated above the current flood zone.

Temperature

Heat can cause bridges, roadways and railways to deteriorate more rapidly. The report maps land projected to be in the hottest 5% in the MAPC region. As the climate warms, increased demand for cooling combined with the decreased efficiency of electric generation at high temperatures may make it difficult to meet peak energy demands. Power outages have significant effects on public health, communications, transportation and the economy in general.

Local Economy Vulnerabilities

Nearly 40% Braintree's businesses are located in hot spots, while roughly 9% are located in identified flooding areas. Some businesses and town properties along the Monatiquot and Fore Rivers will be impacted by sea level rise in the future. Nearly 90% of Braintree residents work outside of Braintree. Common destinations are Downtown Boston and the Longwood Medical area. Flooding and heat could disrupt public and private transportation.

State-Owned Infrastructure Vulnerabilities

MBTA

As of 2014, ridership across all MBTA services in Braintree was approximately 10,000 boardings daily. MBTA climate concerns include damage from flooding as well as from heat. Corrosion from coastal flooding is of particular concern. The MBTA is also concerned that warmer temperatures in the winter could result in more damage from ice storms. Health of passengers and workers is a concern at times of high heat. Flooding in 2010 caused delays on the commuter rail. The MBTA is proceeding with plans for a system-wide climate vulnerability analysis.

Massachusetts Water Resources Authority

The MWRA provides sewer service to Braintree. Braintree is not serviced by the coastal sewage pump stations that are vulnerable to storm surge. Sewage back-ups and releases have occurred due to stormwater inundation during heavy rainstorms.

MASS DOT

State roadways include Routes 3, 37, and 53. Mass DOT is currently working with a consultant to develop a model to project the future 100-year floodplain for the 24 hour storm, based on future precipitation projections. The model is in a test phase; it is not known when it will be available statewide. Flooding has occurred on Rt. 37 at Plain St. and at Rt. 3 at the Union Street rotary.

Department of Conservation and Recreation

The DCR inspects six of the dams in Braintree and owns the Braintree Dam. Increased precipitation intensity is the primary climate concern as it could affect dams that were likely designed for historic precipitation patterns.

Utilities

Electricity

BELD is Braintree's electricity provider. The primary concern is impacts to the system from heat waves. BELD has been proactive in instituting advanced metering to identify and correct circuit weaknesses, and in promoting conservation strategies which have reduced energy usage significantly in the past decade.

Natural Gas

National Grid is the natural gas provider for Braintree. Gas pipes in Braintree are vulnerable to corrosion from flooding, but not extreme heat. Gas leaks release methane into the soil and air, contributing to greenhouse gases in the atmosphere. The leaks damage trees by suffocating root systems, and form ground-level ozone, which is an asthma trigger. Due to the damaging impacts of leaks, the state has required gas companies to accelerate replacement of leak-prone pipes.

In their 2017 plan, National Grid indicated that 24% of Braintree's gas mains are leak-prone. Most recent figures show approximately 170 gas leaks in Braintree. National Grid projects that they will complete replacement of all of their leak-prone pipes by 2035. If successful, GHG releases and damage to street trees should decline.

Telecommunications

Telecommunications systems include phone and computer networks, and the internet. This infrastructure plays a critical role in emergency response and recovery. Vulnerabilities essentially mirror those described in the *Electricity* section. Specific data on the location of telecommunications infrastructure and networks is not publically available. A key concern is that many providers utilize shared fiber networks. This reduces redundancy and increases vulnerability to disruption during extreme weather.

ACTION PLAN

Introduction

Braintree, across its departments, has already taken numerous steps to improve its resilience to weather events. Many of its programs support climate resilience, either directly or, more typically, as a result of initiatives with other primary aims. As a result, while planning for climate resilience is a relatively new endeavor, Braintree starts with a firm foundation to support its future efforts.

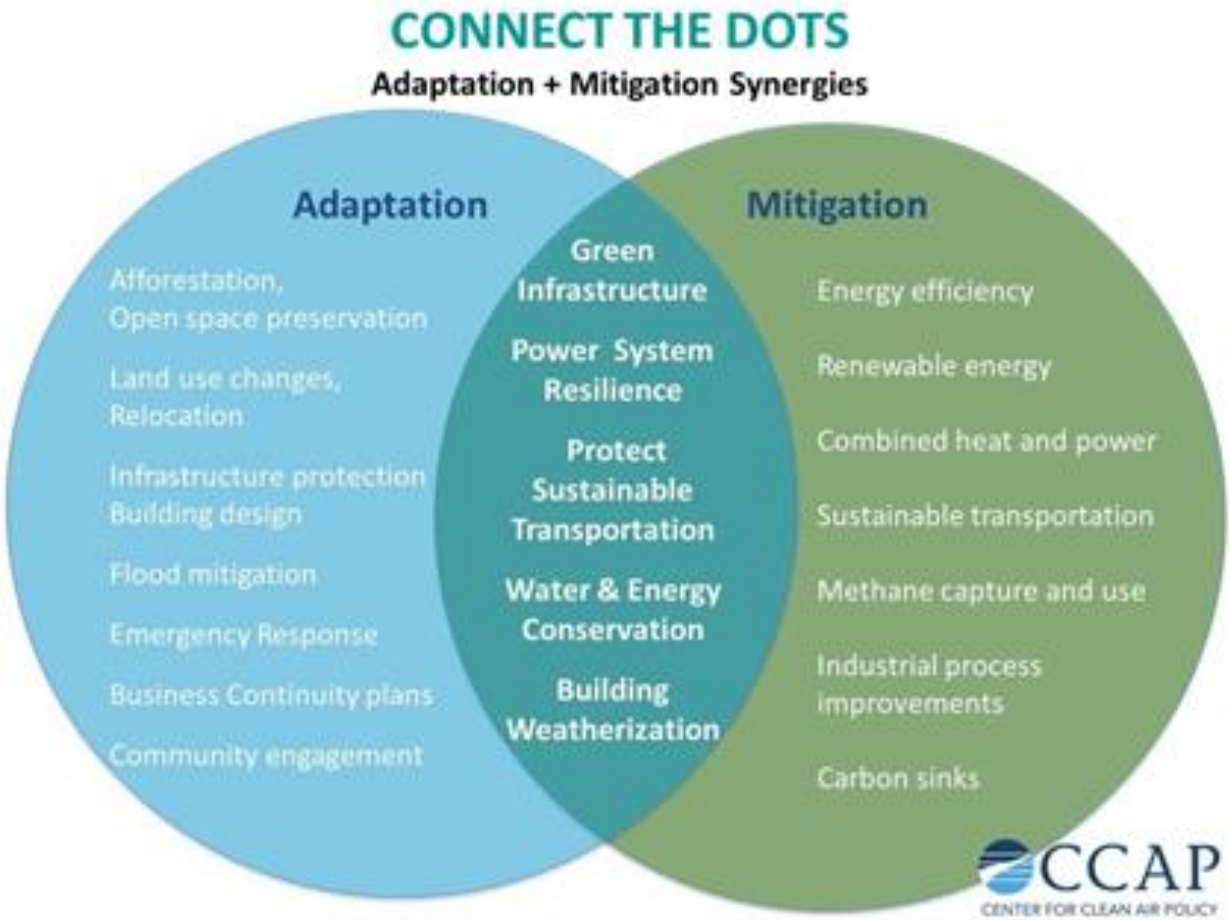
As an example, Braintree's Watershed Protection District is designed to protect drinking water. One of its protective mechanisms is to limit impervious surfaces. Limits on impervious surfaces are an important strategy to reduce stormwater flooding. Another example is the ongoing effort to remove the Armstrong Dam. The primary focus of the project is to restore the historic diadromous fish passage. The feasibility study found that removal of the dam would lessen upstream flooding without increasing downstream flooding. Removal of the dam could also provide an opportunity to protect the new riverbank area as flood buffer, habitat corridor, and public access along the Monatiquot River.

The following sampling illustrates the breadth of Braintree's current strategies:

- Wetlands and Floodplain by-law protects against flood damage
- 43% of the floodplain is protected open space
- BELD smart metering helps prevent outages
- Open space purchases provide flooding buffers and preserve habitat
- Cooling centers protect vulnerable residents
- Renewable energy and conservation initiatives reduce peak loads
- Town and BELD sponsored tree planting programs provide heat relief and absorb stormwater
- Targeted outreach to elderly and disabled residents identifies services needed in emergencies
- Projects identified in hazard mitigation planning have reduced flood hazards
- Water use restrictions preserve drinking water supply during droughts
- Maintenance of stormwater infrastructure reduces flooding

The additional strategies MAPC recommends embrace a "no-regrets" approach. That is, they should be considered even in the absence of climate change, as they are likely to generate economic, environmental, and social benefits. For example, the use of green infrastructure and low impact development (LID) techniques reduces stormwater runoff and cooling costs, and provides recharge to groundwater aquifers. Beyond resilience concerns, it also provides residents with additional green space and supports local ecosystems. Many strategies will help meet federal stormwater "MS4" permit requirements and may also be credited towards Braintree's participation in the Community Rating System that provides flood insurance discounts for residents.

This plan focuses on adapting to climate change, but it remains critical to pursue strategies to reduce greenhouse gas emissions, and thereby mitigate future climate impacts. Through its participation in the MAPC Metro Mayors Coalition Braintree has committed to developing a climate mitigation plan by 2020 and achieving a NET ZERO/Carbon-Free status by 2050. The Town, and its residents, have already taken many steps to promote energy conservation and the use of renewable energy. Braintree's solar projects and investment in electric municipal vehicles and charging stations are examples of the town's leadership in this area. As shown in the figure below, many strategies will address both adaptation to, and mitigation of, future climate impacts.



The strategies MAPC recommends span planning, policy, design, community outreach, and more. Many require additional analysis and planning and/or financial resources. Naturally, Braintree will need to evaluate and prioritize potential actions, and the timing of their implementation. Extreme events may happen at any time, but climate change is projected to occur slowly over the course of many decades. Effective implementation must reflect these realities and include both near-term action and longer-term planning.

The first set of MAPC's recommendations address overall implementation, outreach, and planning. Subsequent recommendations follow the organization of the climate vulnerability assessment. Many recommendations address multiple vulnerabilities and concerns.

To help prioritize actions, Town officials may find it useful to engage in a risk analysis exercise, considering the probability and the consequences of harm, as shown in the graphic below. As an example, the flooding of a sewer pump station and open space might be equally likely, but the protection of the pump station from flooding may have higher priority as the consequence of its flooding is more severe.

		Probability		
Consequence		Low	Medium	High
	Low	Least Risk	M-L	M
	Medium	M-L	Medium Risk	M-H
	High	M	M-H	Greatest Risk

Implementation and Planning Recommendations

The modeling of future impacts of climate change has inherent uncertainties and will be affected by unknown levels of future greenhouse gas emissions. Braintree will also change over time. This report should be seen as the beginning of a dialogue within town government, and between the town and its residents. Communication with various constituencies will increase public awareness of climate change and provide community feedback on proposed climate actions. Evaluation and implementation of action items will require on-going coordination and stewardship.

Climate concerns should be incorporated into town planning efforts including, for example, the master plan, the open space plan, and the hazard mitigation plan. It is also critical that climate goals be included in the capital planning process. Large capital projects present opportunities to make significant improvements in climate resilience that might otherwise be cost-prohibitive. The vulnerability assessment identified several bridges that have been flooded in rain events. While replacement of the bridges in the near-term is not realistic, the eventual need for replacement will present an opportunity to elevate the bridges so that they are not overtopped and so that they don't obstruct the waterways.

New municipal buildings should meet high standards for climate resilience and mitigation. Major rehabilitation projects should also incorporate climate resilience and mitigation features. Climate considerations are also appropriate for smaller capital projects. As an example, road reconstruction provides an opportunity to reduce road width and incorporate green infrastructure.

ACTION: Review climate projections and revise and update climate resilience priorities every five years.

ACTION: Have each town department review climate vulnerabilities relevant to its assets and mission, and identify current and potential activities that bolster resilience.

ACTION: Have the Steering Committee, or a successor group, continue to meet to establish priorities, incorporate new information, and monitor progress on climate goals. The Town may wish to expand the Steering Committee to include additional departments such as the Library and the School Department.

ACTION: Incorporate climate resilience into all Town planning documents. Ensure that all capital projects incorporate climate resilience.

Socio-Economic Recommendations

Braintree has many programs across public health, emergency planning, elder affairs, community development, and others, that provide services and connect to vulnerable populations. A challenge will be cataloguing current efforts and identifying gaps in services. Outreach to communities will provide valuable feedback regarding concerns and needs. Social connectedness helps communities prepare for, respond to, and recover from natural disasters. Communities with stronger ties and networks have reacted faster to meet needs and begin recovery efforts. A growing body of evidence indicates that social cohesion is a protective health factor as those with stronger connections typically experience healthier outcomes.

ACTION: Identify gaps in services and prioritize strategies to address gaps.

ACTION: Identify community partners that can strengthen relationships where needed.

ACTION: Reach out to facilities that serve vulnerable populations. Assess retrofit needs and emergency readiness, including evacuation plans. Review needs for air conditioning and back-up generators. Encourage sign-up for the emergency notification system.

ACTION: Develop shelter-in-place and communication strategies for residents who may not be able to evacuate during emergencies.

Public Health Recommendations

Heat impacts will be felt town-wide, more so in hot spot areas and among those without air conditioning. Exposure to mold as a result of flooding and exposure to vector-borne illnesses are additional climate-related concerns. Strategies to address public health overlap significantly with strategies to address social vulnerability (above) and strategies for improved heat and flood protection included in the *Built Environment* section.

ACTION: Prioritize wellness programs that address the illnesses and conditions forecast to be exacerbated by climate changes and the populations forecast to be disproportionately affected. **Resource:** The Bureau of Environmental Health of the Massachusetts

Department of Public Health has on-line resources including a conceptual pathways matrix that identifies hazards, exposures, vulnerable groups, and health risks. (https://matracking.ehs.state.ma.us/Climate-Change/conceptual-pathways.html).

ACTION: Create an outreach campaign focused on the impacts of extreme heat and how to manage it. **Resources:** Center for Disease Control Extreme heat guidebook: https://www.cdc.gov/climateandhealth/pubs/extreme-heat-guidebook.pdf, MAPC's Keep Cool App.

ACTION: Utilize tree canopy and hot spot mapping to strategically increase tree planting and landscaping for heat relief.

ACTION: Ensure adequacy of cooling centers and access for vulnerable populations. Consider developing relationships with large businesses and institutions to explore opportunities to add cooling areas throughout the town.

ACTION: Place signage at popular park and recreation areas to let residents know about tick/mosquito risk and provide information about how to protect themselves.

ACTION: Review and update the Comprehensive Emergency Management Plan to incorporate changes in emergency situations and response activities that may result from climate impacts.

Natural Resource Recommendations

The critical role of natural resources in climate change mitigation and adaptation cannot be overstated: natural resources can be adversely affected by climate change, and changes in natural resources can compound the effects of climate change. As Braintree is reliant on surface water for drinking water supply, drought will have affects beyond natural resource concerns. This section of the report focuses on the protection and enhancement of natural resources. Other sections suggest additional ways in which bolstering natural resources and implementing green infrastructure and low impact development will provide protection from flooding and heat and help address climate change impacts on water quality and quantity.

> **Green Infrastructure (GI)** is an approach to infrastructure and natural resource management that incorporates natural features, such as forests and wetlands, as well as engineered landscapes that mimic natural processes. Green infrastructure practices include preservation and restoration of natural landscapes, along with the use of rain gardens, porous pavements, green roofs, infiltration planters, trees and tree boxes, and rainwater harvesting systems. GI is a cost-effective, resilient approach to managing wet weather impacts.
>
> **Low Impact Development (LID)** is a development process that begins with smart growth-based best site planning practices to identify critical natural resource areas for preservation and uses Green Infrastructure to maintain natural drainage flow paths and reduce impervious surfaces.

ACTION: Incorporate climate resilience into open space planning. Strategic considerations include: 1) protecting large and/or connected green spaces to foster resilience and biodiversity; 2) creating green space to cool "hot spots"; 3) maintaining or creating open space buffers to flood areas to protect water quality and provide flood protection; 4) identifying locations where soils will support stormwater infiltration to replenish groundwater and support stream flow; 5) protecting areas adjacent to the shoreline that may be affected by future sea level rise. **Resource:** The Metro Mayors Climate-Smart Region (CSR) Decision Support Tool is a new GIS-based program developed to prioritize locations for green infrastructure. The CSR program analyzes spatial data in four climate strategies: Connect (carbon-free transportation links), Cool (shade areas to reduce heat), Absorb (innovative stormwater management), and Protect (natural land buffers for sea level rise). MAPC can arrange training on use of the tool.

ACTION: Use tree canopy GIS to identify tree planting opportunities on private land.

ACTION: Boost climate resilience by increasing tree diversity and considering trees well-adapted to warming temperatures. To address public health concerns, consider trees that produce fewer allergens. **Resource**: The U.S. Forest Service has developed a comprehensive manual: "Forest Adaptation Resources: Climate Tools and Approaches for Land Managers" available at https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs87-2.pdf.

ACTION: Ensure that stream crossing standards for fish and wildlife passage and stream continuity are applied to bridge and culvert repairs. **Resources:** Massachusetts Stream Crossing Handbook: http://www.mass.gov/eea/docs/dfg/der/pdf/stream-crossings-handbook.pdf. State Division of Ecological Restoration grant program for replacement of high ecological value culverts.

ACTION: Develop strategies to reduce peak water demand as it coincides with the potential for summer drought. **Resource:** "Summer Smart Water Use, A Guide to Peak Season Water Demand Management" (MAPC).

ACTION: Encourage residents to reduce water use through drought resistant landscaping, rain barrels, low-flow toilets, aerator faucets, and the like.

ACTION: Evaluate coastal shoreline resources (beach, saltmarsh, mud flat) for their capacity to adapt to rising seas. Consider projects to bolster resilience and allow salt marsh and other coastal resources to migrate upland as needed in the future.

ACTION: Continue efforts to restore the Monatiquot River through removing the Armstrong Dam. Consider projects to restore the natural shoreline.

ACTION: Monitor for new invasive plant and animal species that may be introduced by a warming climate. Develop management strategies as needed.

Built Environment Recommendations

Flooding – Inland

Flooding is a natural periodic occurrence, but it is exacerbated in developed areas with impervious surfaces. In Braintree, as is typical of urban areas, most flood damage to structures occurs where development has encroached on natural floodplains. Flooding from rain events is already a significant concern; flooding along the tidal shoreline will increase as sea level rises.

ACTION: Conduct a by-law/zoning review to ensure GI/LID and climate resiliency are promoted, and not restricted. Examine requirements for parking, driveways, street width, open space residential design, stormwater, and site plan review. Develop recommendations for requirements and incentives that will integrate GI/LID into all development and redevelopment work.

Green Infrastructure as Standard Operating Procedure

Since 2008, the Town of Franklin DPW has installed dozens of rain gardens, tree filter boxes, infiltration basins and, reduced pavement. In a single roadway project the town saved $195,000 in asphalt costs by reducing the road width by six feet. Rather than purchasing proprietary tree filter boxes, the DPW developed their own design, dramatically reducing the cost of their installation. These projects help Franklin manage stormwater, comply with MS4 water quality requirements, and maintain the health of the groundwater aquifer, which supplies the town's drinking water.

ACTION: Develop design guidelines for Green Infrastructure and Low Impact Development. **Resource:** MAPC Low Impact Development Toolkit. **Example:** Town of Littleton Low Impact Development Manual.

ACTION: Assess municipal properties for opportunities for LID/GI retrofits. **Resource:** Possible project with MAPC.

ACTION: As a demonstration project, highlight ways to improve conditions through intensive outreach to property owners, and Town GI and stormwater projects, in a specific catchment area. Locations could include a chronic flooding area or an important resource area such as the Sunset Lake watershed.

ACTION: Provide training, as needed, for town staff implementing new green infrastructure strategies. **Resource:** The University of New Hampshire Stormwater Center conducts research and offers technical training on innovative stormwater treatments.

ACTION: Educate property owners regarding flood risks outside the 100-year floodplain (500-year, known flooding areas, projected sea level rise).

ACTION: Consider strategies such as the Watershed Protection District infiltration requirements to encourage infiltration and reduce stormwater flooding.

ACTION: Adopt a stormwater by-law.

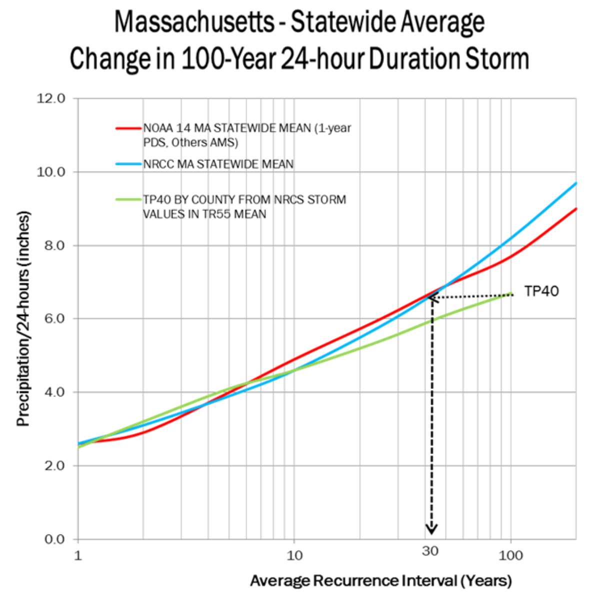
ACTION: Consider establishing Stormwater Utility to provide resources for stormwater management and MS4 requirements. Include incentives for property owners to infiltrate stormwater. **Resource:** MAPC Stormwater Utility Kit. **Examples**: City of Newton, Town of Milton.

ACTION: Use mapping of sewer back-up locations to focus prevention efforts.

ACTION: Reach out to the Towns of Holbrook and Randolph to communicate how development in their communities affects downstream flooding in Braintree. Look for opportunities to cooperate regarding mutual concerns.

ACTION: Continue efforts to ensure that critical town facilities are resilient to flooding. Moving the DPW should be a high priority and can restore floodplain and provide public access to the Monatiquot River. Plans for the new water treatment facility provide an opportunity to ensure additional protection for the intake pump. Evaluate bridge impacts when projects are planned. Continue to monitor sewer pump stations and electric facilities to determine whether additional protective steps are required for the facilities themselves or for access to the facilities.

ACTION: Consider updating the stormwater requirements and the Wetlands By-law requirements to reflect NOAA 14 or Northeast Regional Climate Center design storms. If the state releases precipitation projections, update design storm requirements so that development projects address rainfall projections for their planned lifespan.



The TP-40 100-year storm is now approximately a 30-year storm.

Source: MWRA

Sea Level Rise

ACTION: In order to minimize future impacts, start planning now for future sea level rise. Review maps to identify areas and facilities of concern.

ACTION: Under the Floodplain by-law, identify the areas of coastal impact. Consider strategies to ensure future development is resilient and encourage protection of existing assets. Consider increasing the freeboard requirement.

Heat

Recommended actions focus on strategies to improve the status of buildings for the health and comfort of occupants, and to reduce heat and heat island impacts. Many GI/LID strategies referenced in the flooding section will also reduce heat impacts by reducing paving and expanding green space. Encouraging "green" building is also an important climate mitigation action.

ACTION: Establish green building recommendations or requirements. **Example:** The City of Cambridge has developed sustainable building requirements. **Resource:** The Boston Planning and Development Agency has a climate resiliency checklist that could be modified for use in Braintree. **Resource:** LEED resources include climate resilience screening tools.

ACTION: Explore zoning code and/or incentives to increase green landscaping, reflective pavements, and cool or green roofs to lessen heat island impacts. **Examples:** Seattle

Green Factor establishes green landscaping requirements for projects of a certain size. Sacramento Parking Lot Shading Requirement mitigates urban heat island impacts.

Heat and Flood

Recommended strategies address the need for resilience in the event of power outages caused by heat, flood, and other extreme weather events, as well as outreach and retrofits for properties affected by heat and flood.

ACTION: Encourage use of microgrids, district energy, and battery storage to keep critical facilities functioning in the event of power loss. **Examples:** The City of Northampton is building a microgrid to power its DPW, emergency shelter, and local hospital. The Town of Sterling Municipal Light Plant has installed battery storage that can operate its police station and dispatch center for two weeks in the event of an outage. The town also saves money by using battery storage when energy costs are high. **Resources:** The state's Advancing Commonwealth Energy Storage (ACES) program, and the Mass Clean Energy Center Community Micro grids program.

ACTION: Explore joint procurement opportunities with MAPC to purchase emergency generators and pumps.

ACTION: Continue Community Rating System efforts to develop and distribute education and outreach materials on flood related technologies and practices including, for example, elevating utilities, preventing backflow, protecting basements, and weatherization. Consider developing a contractor/homeowner resilience checklist to address flood and heat strategies. **Example**: Basement protection materials from Kingston, Ontario, Canada: https://utilitieskingston.com/Wastewater/BasementFlooding/Protect.

ACTION: Publicize hot spot and potential flooding areas to current residents and to permit applicants. Direct them to educational materials.

ACTION: Alert homeowners to flood insurance savings available for those who elevate above base flood elevation, as well as reduced rates for those not in a flood zone. **Resource:** MA Coastal Zone Management freeboard handout.

ACTION: Prioritize retrofits and emergency planning for Town facilities vulnerable to flooding and heat impacts.

State-owned Infrastructure Recommendations

State agencies own, or are responsible for, significant critical infrastructure in Braintree. The Town has an interest not only in ensuring that these critical facilities are prepared for climate change, but also that agency actions (for example vegetation management) do not adversely impact other climate goals. The agencies are in various stages of developing climate resilience analysis and plans. As a result of Governor Baker's Executive Order 569, all will be required to identify adaptation options for their assets.

ACTION: Establish relationships with state agency staff responsible for climate resilience. Communicate Town concerns and priorities, and stay abreast of agency planning.

Current examples of areas of common concern include the Armstrong Dam removal project that may reduce flooding on the commuter rail and may affect the MBTA railroad bridge; and two street flooding locations (Union St. and Washington St.) involve MassDOT roadways.

Utilities Recommendations

As with state-owned infrastructure, the Town has an interest in climate resilience and in limiting adverse impacts from the utilities that serve Braintree. Gas leaks are a key concern. Telecommunications presents challenges as there are multiple providers and specific information on infrastructure is not publicly available.

ACTION: Work with National Grid to ensure efficient and speedy leak-prone pipe replacement. Identify "super-emitter" leaks for priority attention. **Resource:** MAPC and the Home Energy Efficiency Team collaborated on a report which identifies low-cost best practices that municipalities and gas companies can implement to accelerate replacement of leak-prone pipes, better protect the quality of local roads, and avoid unnecessary costs: http://fixourpipes.org/

ACTION: Continue to review the Town's emergency communications infrastructure to ensure redundancy during emergencies.

ACTION	LEAD DEPARTMENT
Implementation, Outreach, and Planning Recommendations	
Review climate projections and revise and update climate resilience priorities every five years.	Steering Committee
Have each town department review climate vulnerabilities relevant to its assets and mission, and identify current and potential activities that bolster resilience.	Town Departments
Have the Steering Committee, or a successor group, continue to meet to establish priorities, incorporate new information, and monitor progress on climate goals. The Town may wish to expand the Steering Committee to include additional departments such as the Library and the School Department.	Steering Committee
Incorporate climate resilience into all Town planning documents (including capital plan) and ensure that all capital projects incorporate climate resilience.	Town Department initiating project
Socio-Economic Recommendations	
Identify gaps in services and prioritize strategies to address gaps.	Inspectional Services – Health Division
Identify community partners that can strengthen relationships where needed.	Inspectional Services – Health Division
Reach out to facilities that serve vulnerable populations. Assess retrofit needs	Inspectional

and emergency readiness, including evacuation plans. Review needs for air conditioning and back-up generators. Encourage sign-up for the emergency notification system.	Services – Health Division
Develop shelter-in-place and communication strategies for residents who may not be able to evacuate during emergencies.	Inspectional Services – Health Division
Public Health Recommendations	
Prioritize wellness programs that address the illnesses and conditions Forecast to be exacerbated by climate changes and the populations forecast to be disproportionately affected. **Resource:** The Bureau of Environmental Health of the Massachusetts Department of Public Health has on-line resources including a conceptual pathways matrix that identifies hazards, exposures, vulnerable groups, and health risks. (https://matracking.ehs.state.ma.us/Climate-Change/conceptual-pathways.html).	Inspectional Services – Health Division
Create an outreach campaign focused on the impacts of extreme heat and how to manage it. Partner with local hospitals and social assistance organizations on awareness campaigns for heat-related illnesses. **Resources:** Center for Disease Control Extreme heat guidebook: https://www.cdc.gov/climateandhealth/pubs/extreme-heat-guidebook.pdf, MAPC's Keep Cool App.	Inspectional Services – Health Division & Council on Aging
Utilize tree canopy and hot spot mapping to strategically increase tree planting and landscaping for heat relief.	Planning & Community Development
Ensure adequacy of cooling centers and access for vulnerable populations. Consider developing relationships with large businesses and institutions to explore opportunities to add cooling areas throughout the Town.	Inspectional Services – Health Division
Place signage at popular park and recreation areas to let residents know about tick/mosquito risk and provide information about how to protect themselves.	Planning & Community Development
Review and update the Comprehensive Emergency Management Plan to incorporate changes in emergency situations and response activities that may result from climate impacts.	Local Emergency Planning Committee
Natural Resource Recommendations	
Incorporate climate resilience into open space planning. Strategic considerations include: 1) protecting large and/or connected green spaces to foster resilience and biodiversity; 2) creating green space to cool "hot spots"; 3) maintaining or creating open space buffers to flood areas to protect water quality and provide flood protection; 4) identifying locations where soils will support stormwater infiltration to replenish groundwater and support stream flow; 5) protecting areas adjacent to the shoreline that may be affected by future sea level rise. **Resource:** The Metro Mayors Climate-Smart Region (CSR) Decision Support Tool is a new GIS-based program developed to prioritize locations for green infrastructure. **Resource:** MAPC can arrange training on use of the tool.	Planning & Community Development
Use tree canopy GIS to identify tree planting opportunities on private land.	Planning & Community

	Development Braintree Electric Light Department
Boost climate resilience by increasing tree diversity and considering trees well-adapted to warming temperatures. To address public health concerns, consider trees that produce fewer allergens. **Resource**: The U.S. Forest Service has developed a comprehensive manual: "Forest Adaptation Resources: Climate Tools and Approaches for Land Managers" available at https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs87-2.pdf.	Planning & Community Development
Ensure that stream crossing standards for fish and wildlife passage and stream continuity are applied to bridge and culvert repairs. **Resources:** Massachusetts Stream Crossing Handbook: http://www.mass.gov/eea/docs/dfg/der/pdf/stream-crossings handbook.pdf State Division of Ecological Restoration grant program for replacement of high ecological value culverts.	Planning & Community Development (as part of permitting process)
Develop strategies to reduce peak water demand as it coincides with the potential for summer drought. **Resource:** "Summer Smart Water Use, A Guide to Peak Season Water Demand Management" (MAPC).	Department of Public Works – Water and Sewer Division
Encourage residents to reduce water use through drought resistant landscaping, rain barrels, low-flow toilets, aerator faucets, and the like.	Department of Public Works – Water and Sewer Division
Evaluate coastal shoreline resources (beach, saltmarsh, mud flat) for their capacity to adapt to rising seas. Consider projects to bolster resilience and allow salt marsh and other coastal resources to migrate upland as needed in the future.	Planning & Community Development
Continue efforts to restore the Monatiquot River through removing the Armstrong Dam. Consider projects to restore the natural shoreline.	Planning & Community Development
Built Environment Recommendations	
Flooding Inland	
Conduct a by-law/zoning review to ensure GI/LID and climate resiliency Are promoted, and not restricted. Examine requirements for parking, driveways, street width, open space residential design, stormwater, and site plan review. Develop recommendations for requirements and incentives that will integrate GI/LID into all development and redevelopment work.	Planning & Community Development
Develop design guidelines for Green Infrastructure and Low Impact Development. **Resource:** MAPC Low Impact Development Toolkit. **Example:** Town of Littleton Low Impact Development Manual.	Planning & Community Development
Assess municipal properties for opportunities for LID/GI retrofits. **Resource:** Possible project with MAPC.	Planning & Community Development
As a demonstration project, highlight ways to improve conditions through intensive outreach to property owners, and Town GI and stormwater projects, in a specific catchment area. Locations could include a chronic flooding area or an important resource area such as the Sunset Lake	Planning & Community Development

watershed.	
Provide training, as needed, for town staff implementing new green infrastructure strategies. **Resource:** The University of New Hampshire Stormwater Center conducts research and offers technical training on innovative stormwater treatments.	Department of Public Works
Educate property owners regarding flood risks outside the 100-year floodplain (500-year, known flooding areas, projected sea level rise).	Planning & Community Development
Consider strategies such as the Watershed Protection District infiltration requirements to encourage infiltration and reduce stormwater flooding.	Planning & Community Development
Consider updating the stormwater requirements and the Wetlands By-law requirements to reflect NOAA 14 or Northeast Regional Climate Center design storms. If the state releases precipitation projections, update design storm requirements so that development projects address rainfall projections for their planned lifespan.	Planning & Community Development
Adopt a stormwater by-law.	Department of Public Works
Consider establishing Stormwater Utility to provide resources for stormwater management and MS4 requirements. Include incentives for property owners to infiltrate stormwater. **Resource:** MAPC Stormwater Utility Kit. **Examples:** City of Newton, Town of Milton.	Department of Public Works
Use mapping of sewer back-up locations to focus prevention efforts.	Department of Public Works – Water and Sewer Division
Reach out to the Towns of Holbrook and Randolph to communicate how development in their communities affects downstream flooding in Braintree. Look for opportunities to cooperate regarding mutual concerns.	Tri-Town Water Board
Continue efforts to ensure that critical town facilities are resilient to flooding. Moving the DPW should be a high priority and can restore floodplain and provide public access to the Monatiquot River. Plans for the new water treatment facility provide an opportunity to ensure additional protection for the intake pump. Evaluate bridge impacts when projects are planned. Continue to monitor sewer pump stations and electric facilities to determine whether additional protective steps are required for the facilities themselves or for access to the facilities.	Department of Public Works Braintree Electric Light Department
Sea Level Rise	
In order to minimize future impacts, start planning now for future sea level rise. Review maps to identify areas and facilities of concern.	Department of Public Works Planning & Community Development
Under the Floodplain by-law, identify the areas of coastal impact. Consider strategies to ensure future development is resilient and encourage protection of existing assets. Consider increasing the freeboard requirement.	Planning & Community Development
Heat	
Establish green building recommendations or requirements. **Example:** The City	Planning &

of Cambridge has developed sustainable building requirements. **Resource:** The Boston Planning and Development Agency has a climate resiliency checklist that could be modified for use in Braintree. **Resource:** LEED resources include climate resilience screening tools.	Community Development
Explore zoning code and/or incentives to increase green landscaping, reflective pavements and cool or green roofs to lessen heat island impacts. **Examples:** Seattle Green Factor establishes green landscaping requirements for projects of a certain size. Sacramento Parking Lot Shading Requirement mitigates urban heat island impacts.	Planning & Community Development
Encourage use of microgrids, district energy, and battery storage to keep critical facilities functioning in the event of power loss. **Examples:** The City of Northampton is building a microgrid to power its DPW, emergency shelter, and local hospital. The Town of Sterling Municipal Light Plant has installed battery storage that can operate its police station and dispatch center for two week in the event of an outage. It also saves money, by allowing the town to use battery storage when energy costs are high. **Resources:** The state's Advancing Commonwealth Energy Storage (ACES) program, and the Mass Clean Energy Center Community Micro grids program.	Braintree Electric Light Department
Explore joint procurement opportunities with MAPC to purchase emergency generators and pumps.	Department of Public Works
Continue Community Rating System efforts to develop and distribute education and outreach materials on flood related technologies and practices including, for example, elevating utilities, preventing backflow, protecting basements, and weatherization. Consider developing a contractor/homeowner resilience checklist to address flood and heat strategies. **Example:** Basement protection materials from Kingston, Ontario, Canadahttps://utilitieskingston.com/Wastewater/BasementFlooding/Protect.	Planning & Community Development
Publicize hot spot and potential flooding areas to current residents and to permit applicants. Direct them to educational materials.	Planning & Community Development
Alert homeowners to flood insurance savings available for those who elevate above base flood elevation, as well as reduced rates for those not in a flood zone. **Resource:** MA Coastal Zone Management freeboard handout.	Planning & Community Development
Prioritize retrofits and emergency planning for Town facilities vulnerable to flooding and heat impacts.	Department of Public Works Local Emergency Planning Ctte
State-owned Infrastructure Recommendations	
Establish relationships with state agency staff responsible for climate resilience. Communicate Town concerns and priorities, and stay abreast of agency planning. Current examples of areas of common concern include the Armstrong Dam removal project that may reduce flooding on the commuter rail and may affect the MBTA railroad bridge; and two street flooding locations (Union St. and Washington St.) involve MassDOT roadways.	Department of Public Works Planning & Community Development
Utilities Recommendations	
Work with National Grid to ensure efficient and speedy leak-prone pipe	Department of

replacement. Identify “super-emitter” leaks for priority attention. **Resource:** MAPC and the Home Energy Efficiency Team collaborated on a report which identifies low-cost best practices that municipalities and gas companies can implement to accelerate replacement of leak-prone pipes, better protect the quality of local roads, and avoid unnecessary costs: http://fixourpipes.org/	Public Works
Continue to review the Town’s emergency communications infrastructure to ensure redundancy during emergencies.	Braintree Electric Light Department Braintree Emergency Management Local Emergency Planning Ctte.