City of Newton
Climate Vulnerability Assessment and Adaptation and Resiliency Action Plan

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Prepared for
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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, and more frequent days with extreme heat.

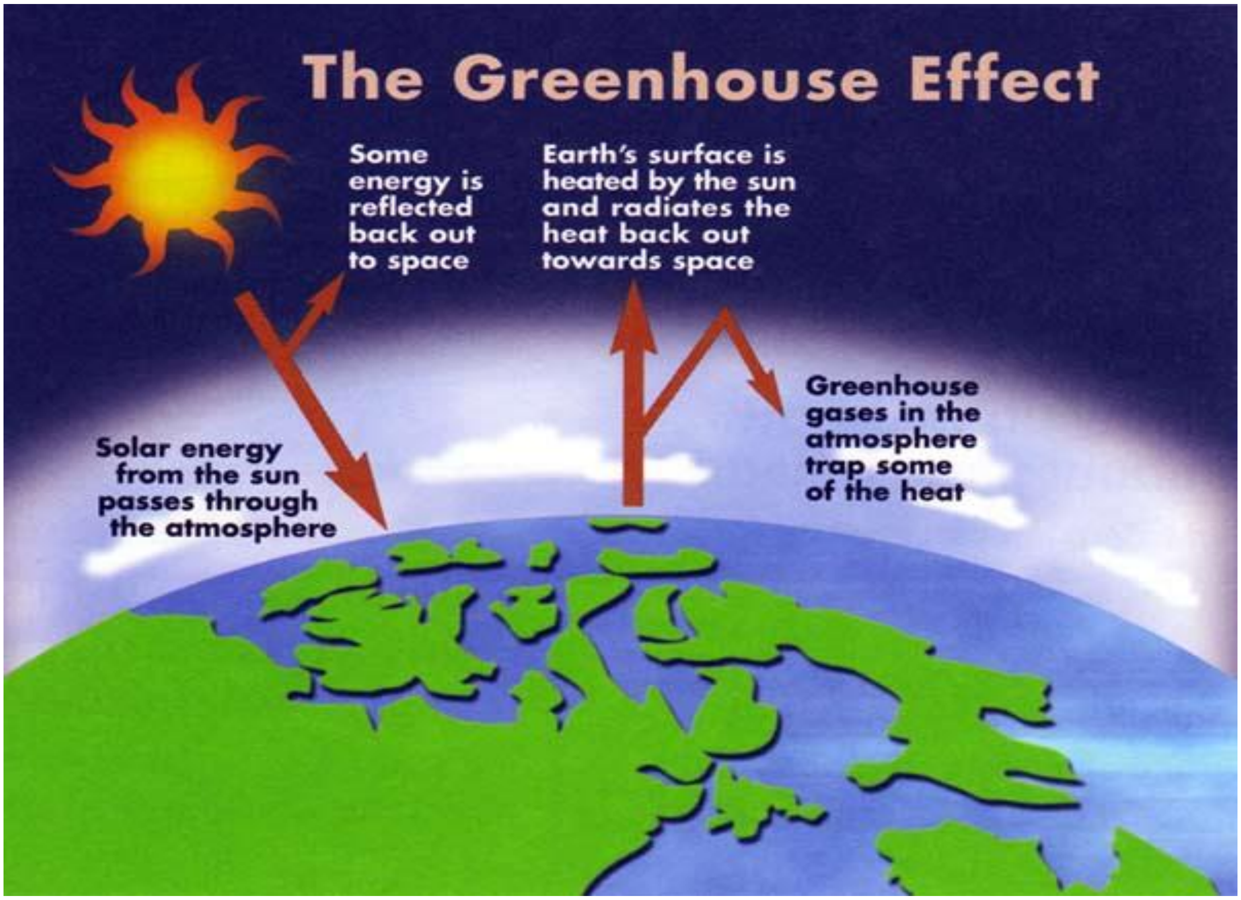
The March 2010 rains caused millions of dollars in damages in Newton and disrupted service on the Green Line. As rainfall amounts increase, rain events similar to 2010 will become more frequent. A one-thousand-year event would nearly double the rainfall experienced over three days in March 2010. As is evident from Hurricane Harvey, 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. Advanced 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 because 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

Climate Change Processes

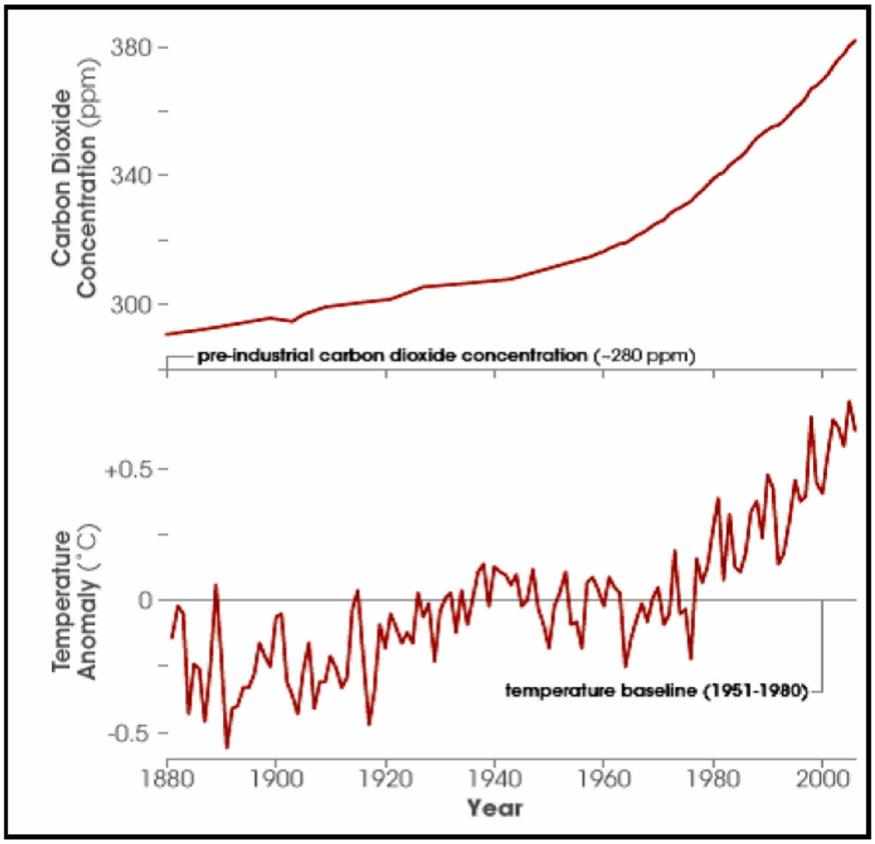
Our climate has always been regulated by gases, including carbon dioxide, methane, and nitrous oxide, that blanket the earth. These gases trap heat that would otherwise be reflected out to space; without them our planet would be too cold to support life. We refer to these gases as "greenhouse gases" (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 Newton. 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 CO_2 Trends



Source: MA Climate Change Adaptation Report 2011

Climate Change: Observations, Projections, Impacts

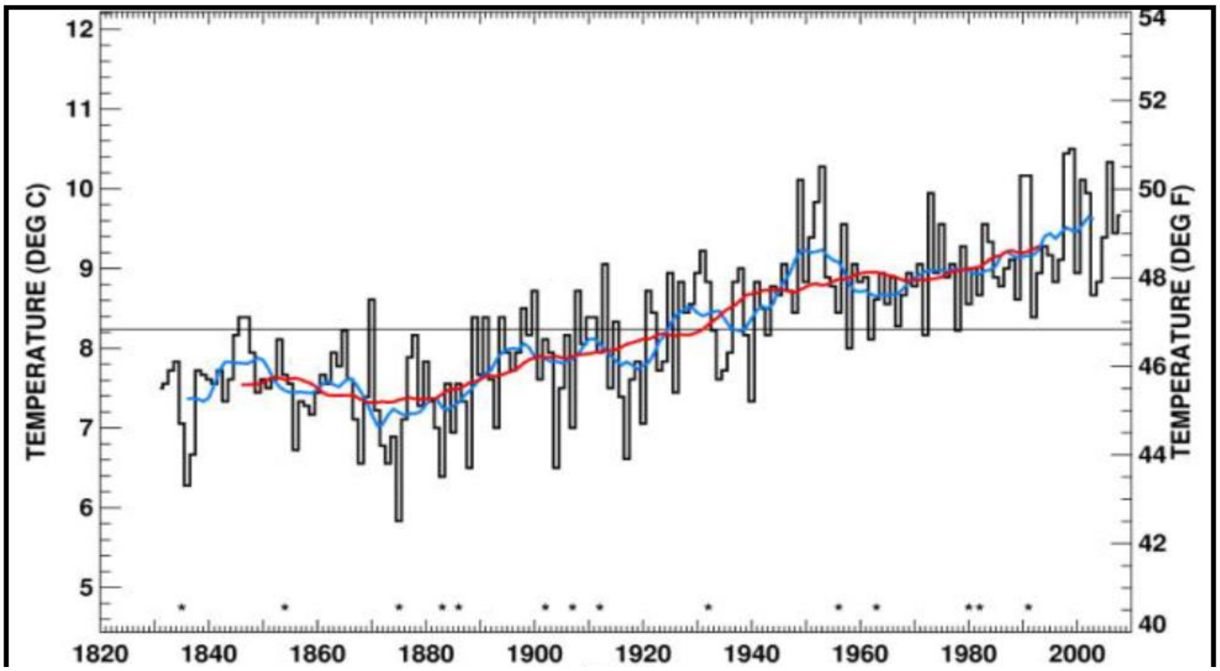
Climate change observations come from a variety of data sources that have measured and recorded changes in recent decades and centuries. Climate change projections, however, predict future climate impacts and by their nature cannot be observed or measured. As a result of the inherent uncertainty in predicting 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 less than ten miles from Newton, 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 Charles River 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.

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.

Figure 3. Projected Temperature Change for the Charles River Basin.

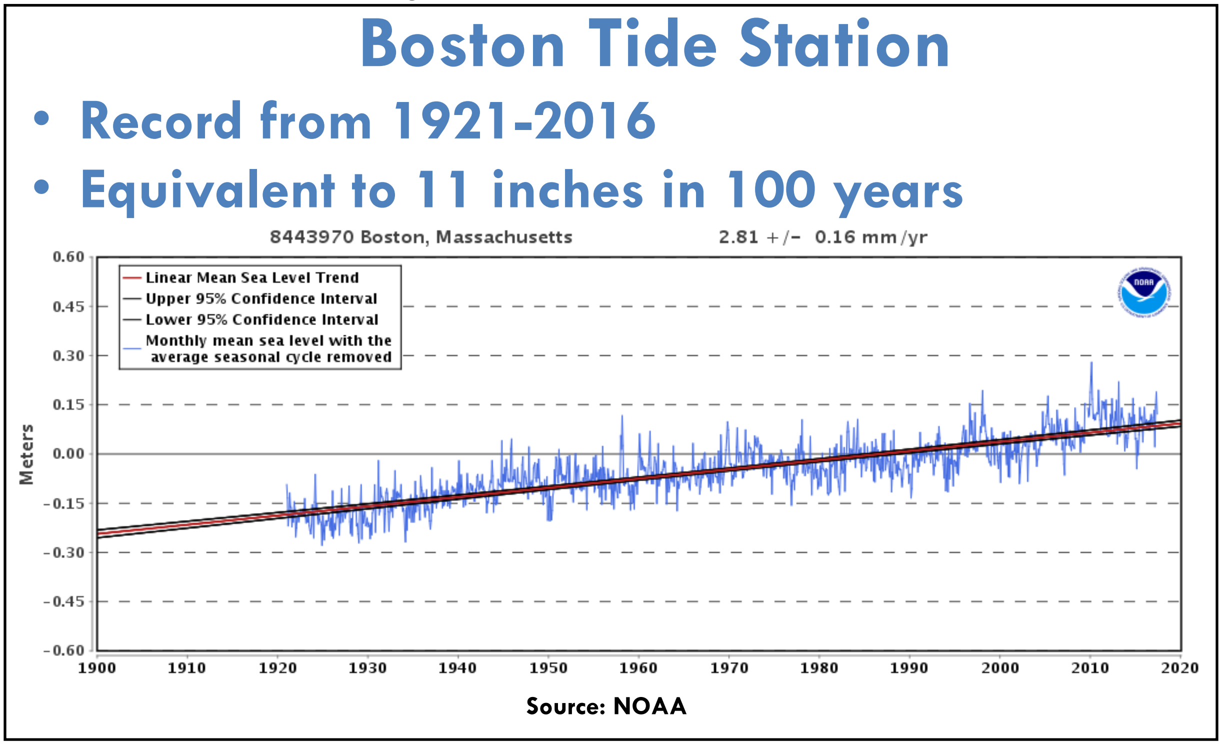
Parameter (Temperature F°)	Observed Baseline (1971-2000)	Predicted 2020-2049	Predicted 2040-2069	Predicted 2060-2089	Predicted 2080-2099
Annual temperature	49°	51-53°	52-55°	52-58°	52-60°
Winter temperature	29°	31-33°	32-35°	32-37°	33-39°
Spring Temperature	47°	48-50°	49-52°	49-55°	50-60°
Summer temperature	70°	72-74°	73-77°	73-80°	74-83°
Fall Temperature	52°	54-57°	56-58°	55-61°	56-64°
Days over 90 (days/year)	9	16-29	19-44	22-66	24-85
Days over 100 (days/year)	0.05	.29-2	.45-5	.58-11	.84-21

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

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 meltwater. 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.

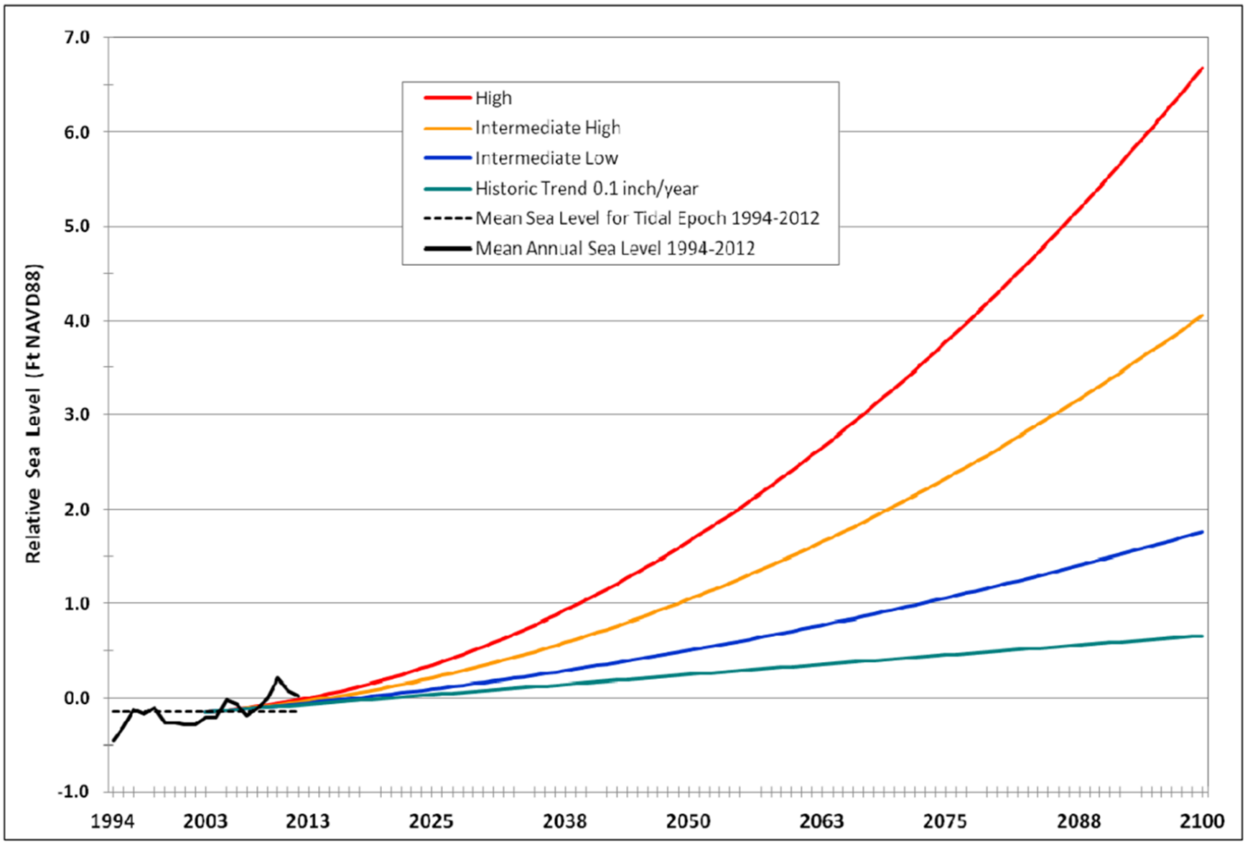
Figure 4. Observed Sea Level Rise



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 Newton has no coastal shoreline, modeling utilized in this study projects that later in the century, storm surge could travel up the Charles River and impact the Newton shoreline.

Figure 5. Projected Sea Level Rise



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

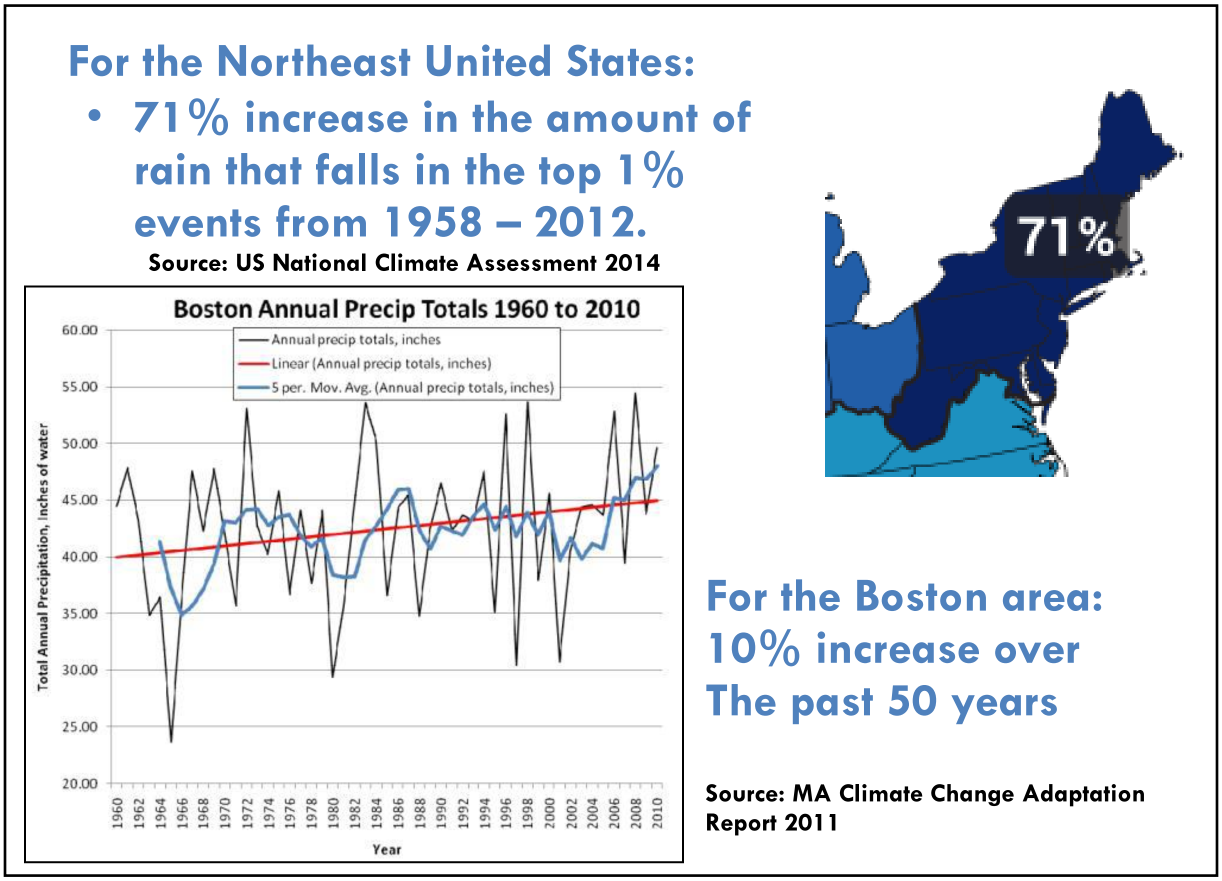
Precipitation

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 US 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 but 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



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 196l 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). TP-40 figures are less precise, reflecting data available at the time. The NOAA 14 and NRCC figures are specific to Newton.

Table 1. Design Storm Estimates

Newton	TP-40	NRCC
10-year, 24-hour storm	4.5"	5.13"
100-year, 24-hour storm	6.5"	8.88"

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 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 (inches)		
		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 UNDERTAKE A CLIMATE VULNERABILITY ASSESSMENT FOR NEWTON?

This climate vulnerability assessment is an effort to determine which Newton 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 shown 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, Newton already has significant experience and expertise to bring to these challenges. Further, many initiatives to address climate impacts provide benefits to the City (tree planting, open space preservation), can help address City obligations (MS4 permit compliance), or combat already 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 City of Newton 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 Newton will be more vulnerable to climate impacts than others, it is also the case that climate change will not affect all residents of Newton equally. In the context of climate change, vulnerable populations include those who may be more susceptible to climate impacts, and those who will have more difficulty adapting to, preparing for, and recovering from extreme weather events. Our demographic analysis indicates that a number of identified vulnerable populations have been growing or are projected to grow over time. These include seniors, individuals living alone, people of color, young children, and people with limited English proficiency. 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.

Socioeconomic vulnerability refers to socioeconomic characteristics, such as income and race/ethnicity that influence vulnerability to 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, people of color, 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.

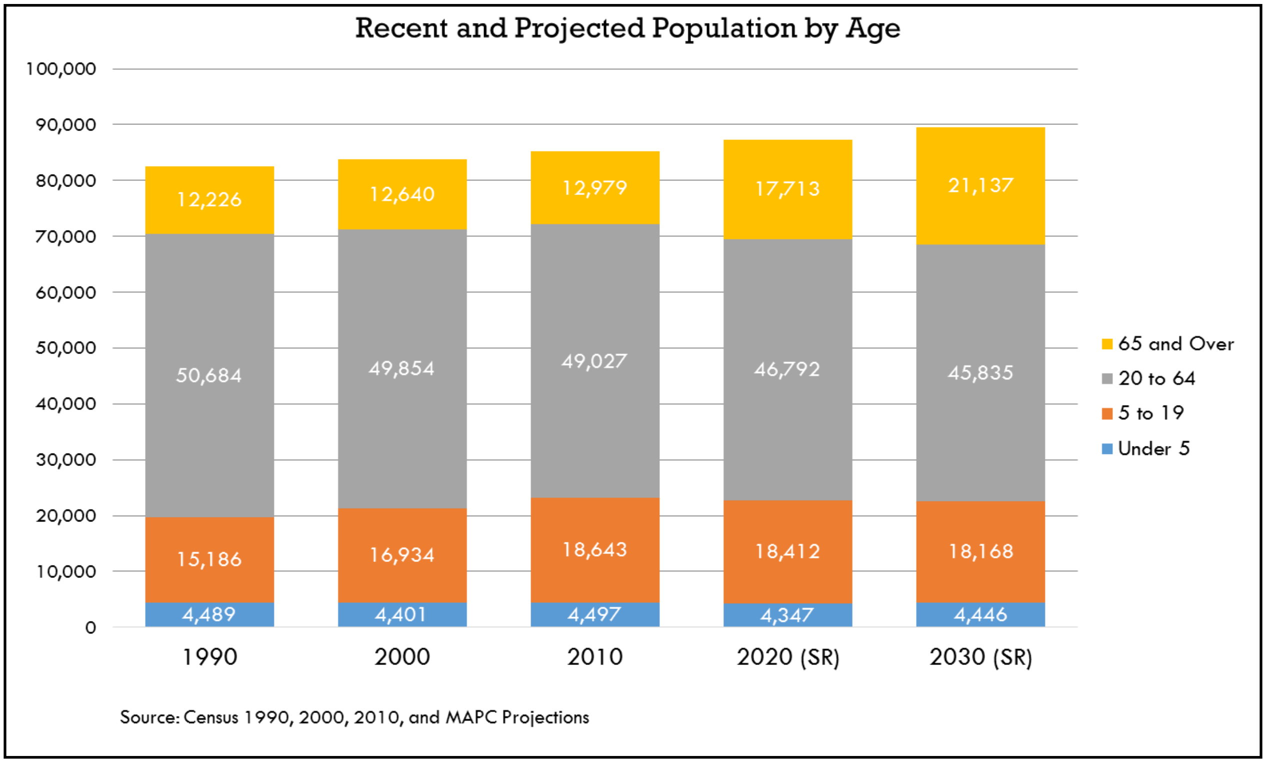
Socioeconomic Conditions in Newton

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 cities' population.

Age

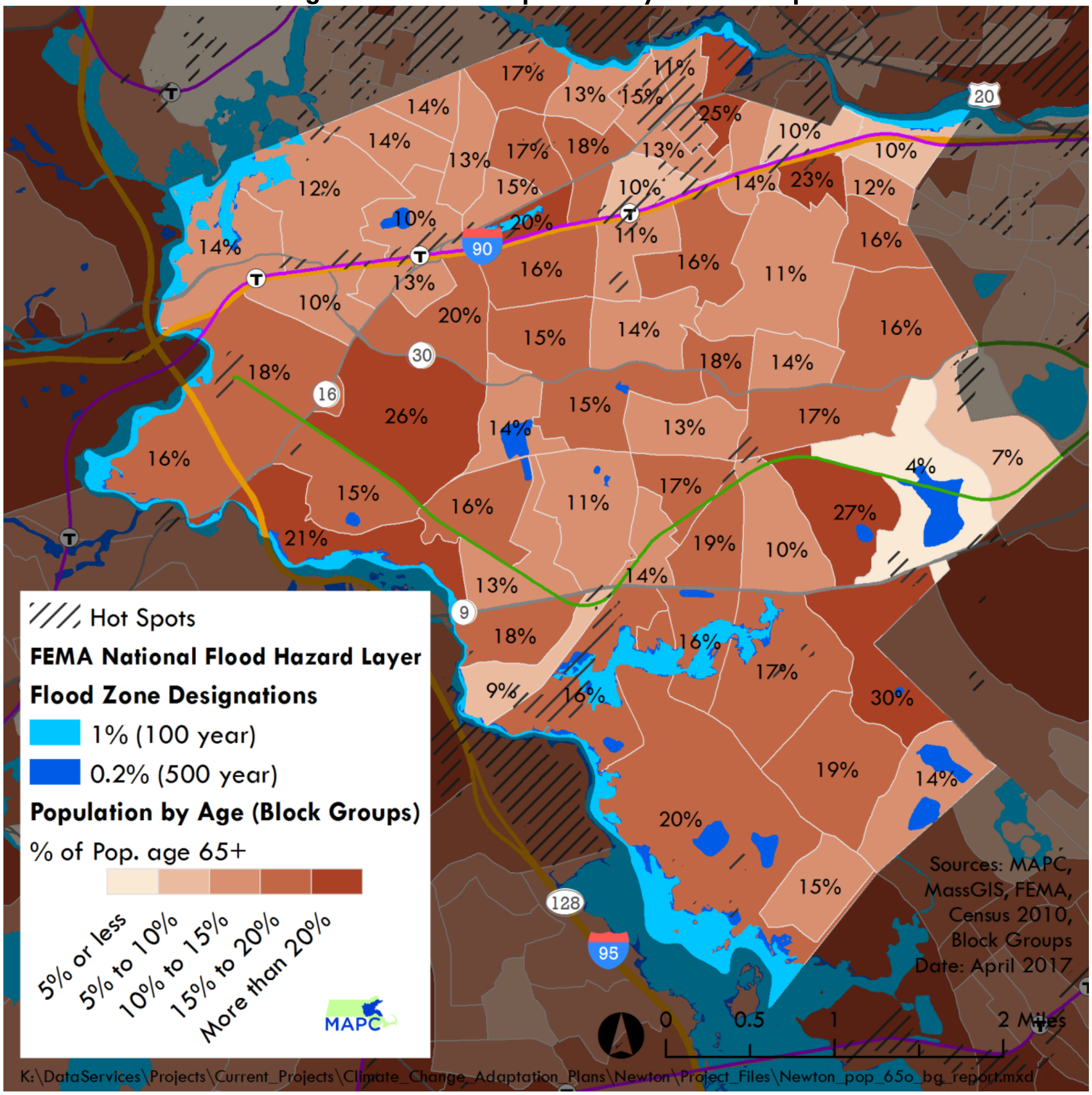
Newton's population has been growing since 1990 and will continue to grow over the coming decades. In 2010, Newton's population was just over 85,000, with approximately 5% children below the age of five, and 15% of residents over 65 years of age (Census 2010). The villages of Thompsonville, Waban, Nonantum, and Newton Corner contain block groups with over 30% seniors. According to the MAPC "Stronger Region" scenario, in which Metro Boston will retain a vibrant economy even as baby boomers retire, MAPC projects that by 2030, Newton's total population will grow modestly by 5% to over 89,000 people. Over the same period, Newton's population will age. MAPC projects that by 2030, the senior population will increase by 63% (Figure 9).

Figure 9. Current Population and Projections



As of 2010, approximately 26% of Newton's households consisted of people living alone (Census 2010). People 65 years of age and older were disproportionately represented in this population, accounting for more than 51% ± 3% of residents living alone (ACS 2011-2015). Currently, several block groups in Newton have more than 25% of their population over the age of 65. These areas are in the Chestnut Hill Village and Waban neighborhoods (Figure 10). Two block groups nearest to Boston College have the lowest percentage of population over the age of 65.

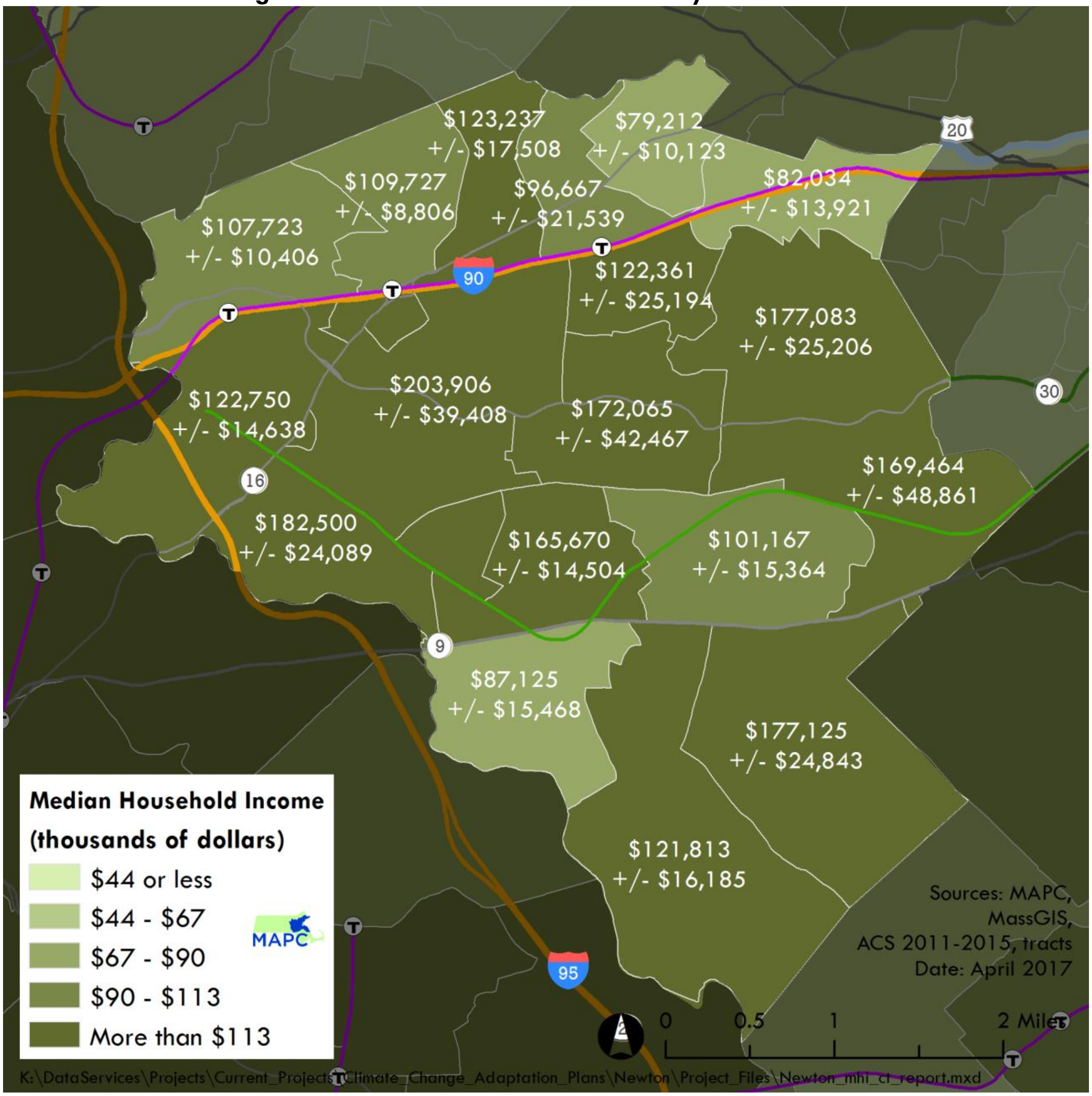
Figure 10. Senior Population by Block Group



Income

The median household income in Newton is $122,080 +/- $4,102 as compared with $75,389 +/- $428 for Metro Boston (ACS 2011-2015). While Newton 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, 6% (±1%) of Newton households are living in poverty. In Newton, Black residents are more likely to live in poverty than White residents (23% ± 14%, and 4% ± 1%, respectively, ACS 2011-2015). Differences in poverty rates between residents of other races are not statistically significant. It is not reliable to map poverty at the census tract or block group level due to high margins of error, but it is possible to identify areas where income is lower than the city average. As shown in Figure 11, relatively lower income areas of the city include Nonantum, Newton Corner, and Newton Upper Falls.

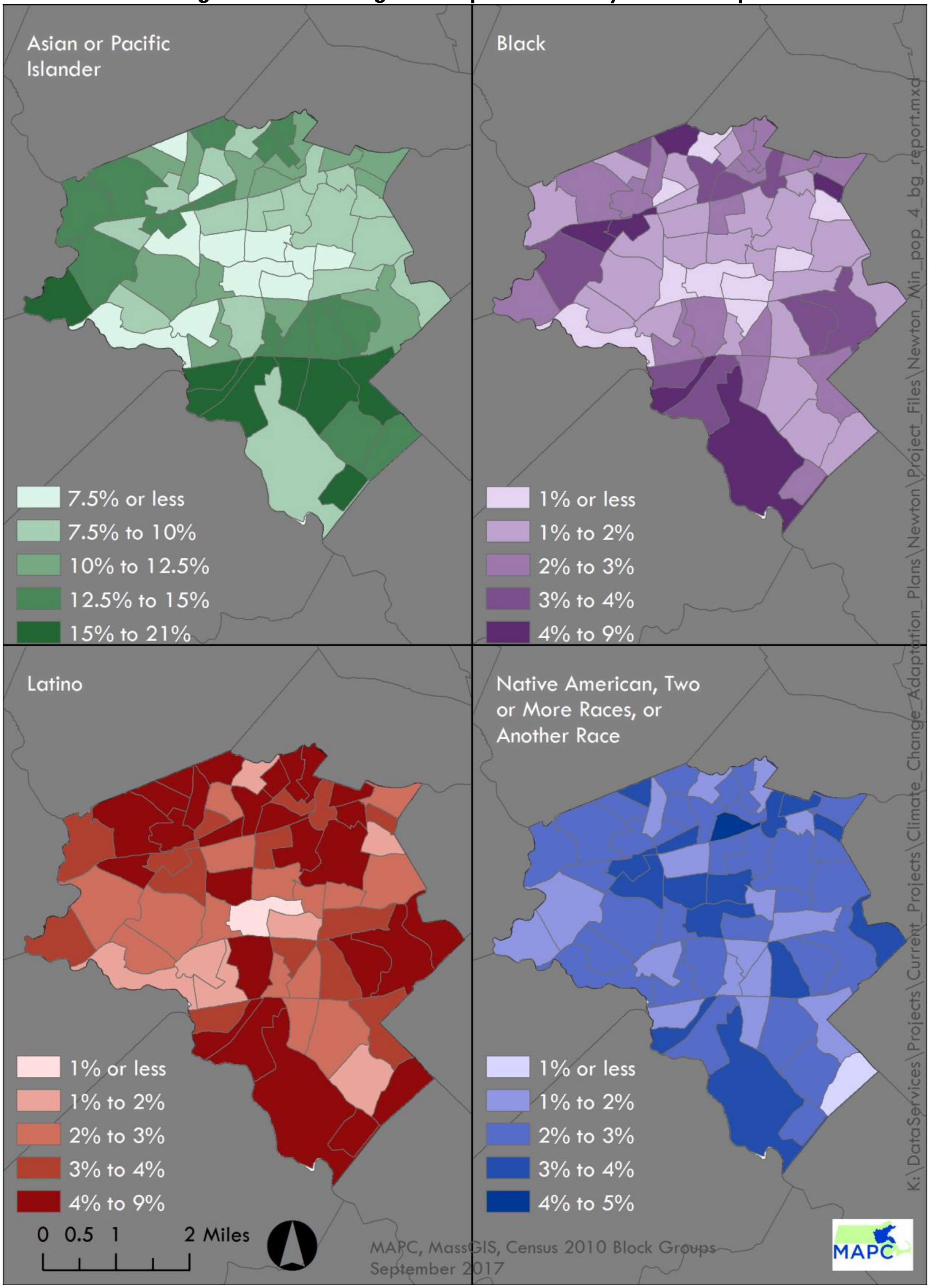
Figure 11. Median Household Income by Census Tract



Race and Ethnicity

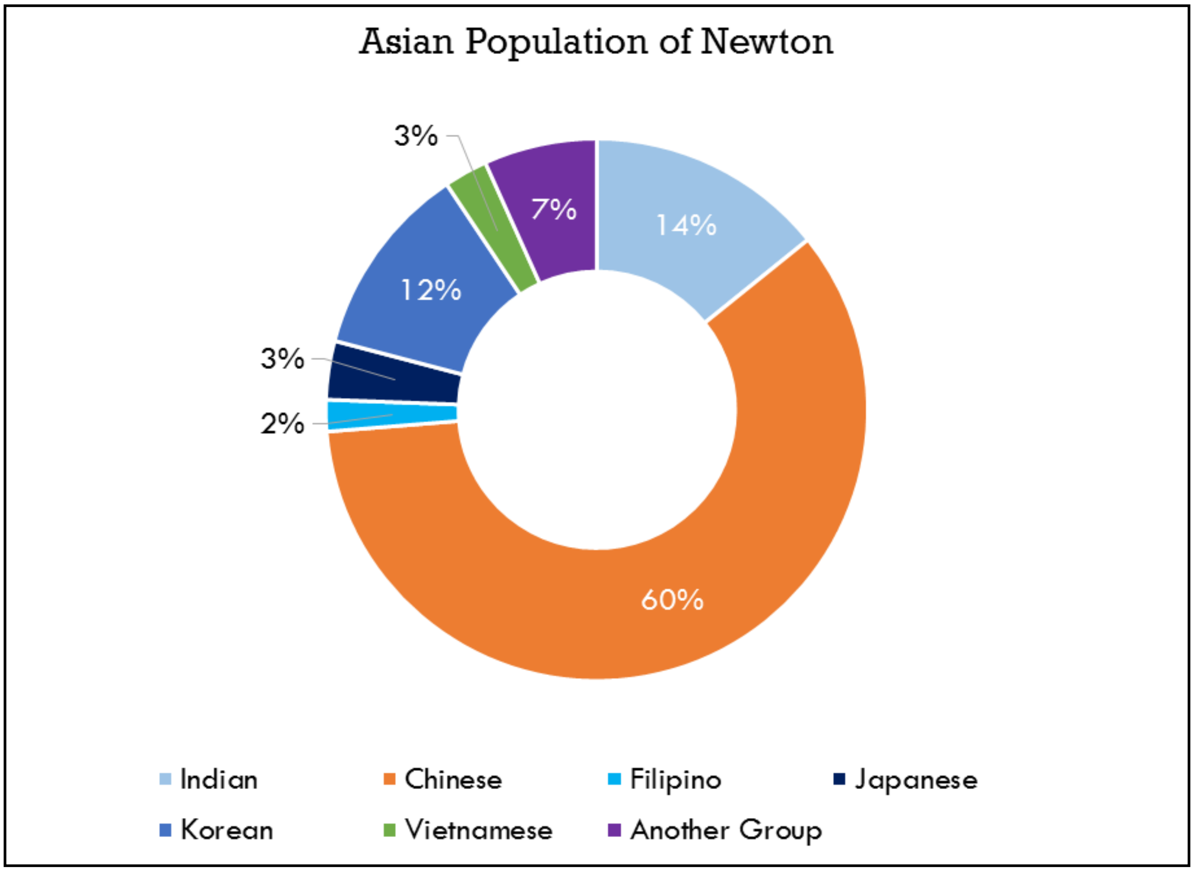
Newton is becoming more diverse. In 2000, people of color were 14% of the total population. By 2010, that number had grown to 20%. The percentage of Asian residents increased the most, going from 8% to 12%. In 2010, 4% of the population was Latino, 2% percent was Black, and the remaining 2% was Native American, multi-racial, or other races. Figure 12 shows the

Figure 12. Percentage of People of Color by Block Group



percentage of people of color by 2010 census block group. Figure 13 displays the country of origin for residents from Asia.

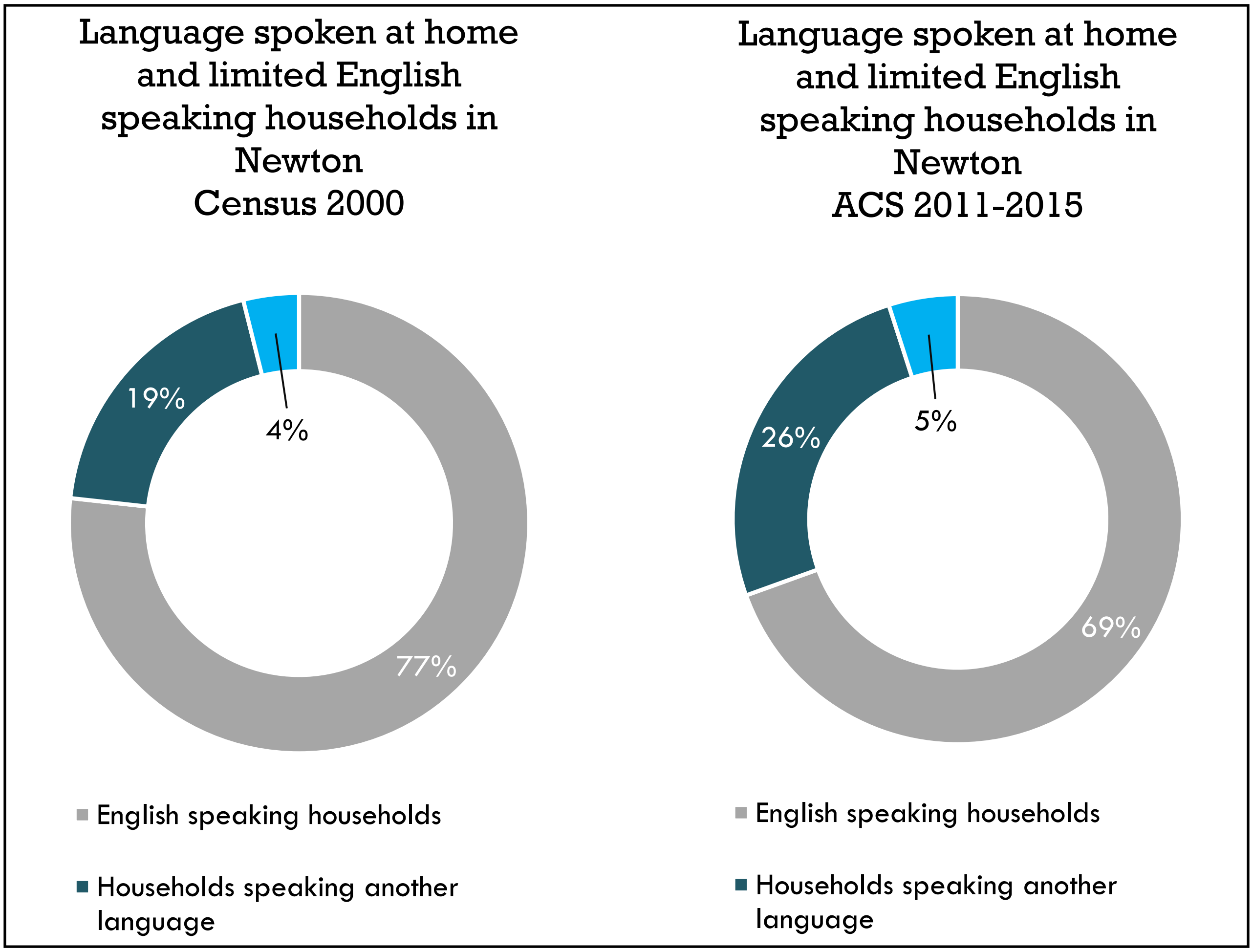
Figure 13. Country of Origin for Asian Residents



Language and Linguistic Isolation

The percentage of Newton households that speak a language other than English in the home has increased over time. According to the 2000 Census, 23% of households spoke a language other than English; by 2011-2015 (ACS) that proportion increased to 31%. 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 (5,470 ± 660), Spanish or Spanish Creole (3,153 ± 245), Russian (2,963 +/- 493), and Korean (1,193 +/-219). In Newton, Asian and Latino residents are much less likely to speak English very well than residents of any other race (29% ± 3% and 14% ± 4% respectively, ACS 2011-2015). City records for households with flood damage in 2010 indicated that 2.5% of respondents of Asian background and 2.5% of respondents of Russian background had difficulty communicating in English. Reliable data regarding geographic distribution of residents based on language and linguistic isolation are not available.

Figure 14. Language and Linguistic Isolation



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 City.

CLIMATE IMPACTS ON PUBLIC HEALTH

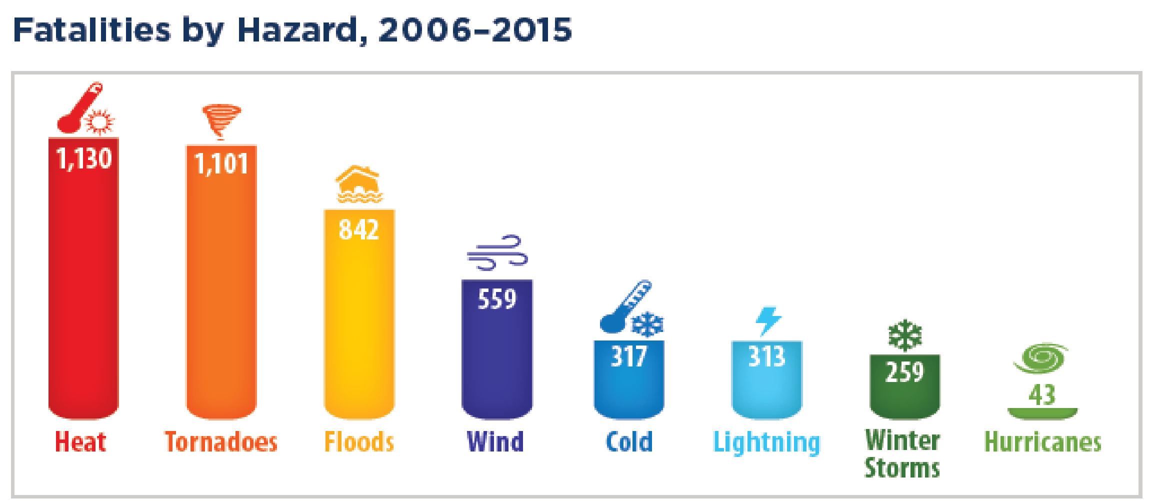
Climate change is expected to have an impact on public health across socioeconomic status and geography. Extreme weather events can increase stress, which can worsen or cause new physical and mental health conditions. An individual's vulnerability to the public health impacts of climate change is influenced 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 Newton, approximately 8% ± 1% of the civilian non-institutionalized population has a disability (ACS 2011-2015). As the population in Newton 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 aged 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 24 to 85 days over 90°F, and .84 to 21 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.

Figure 16. Asthma Hospitalization

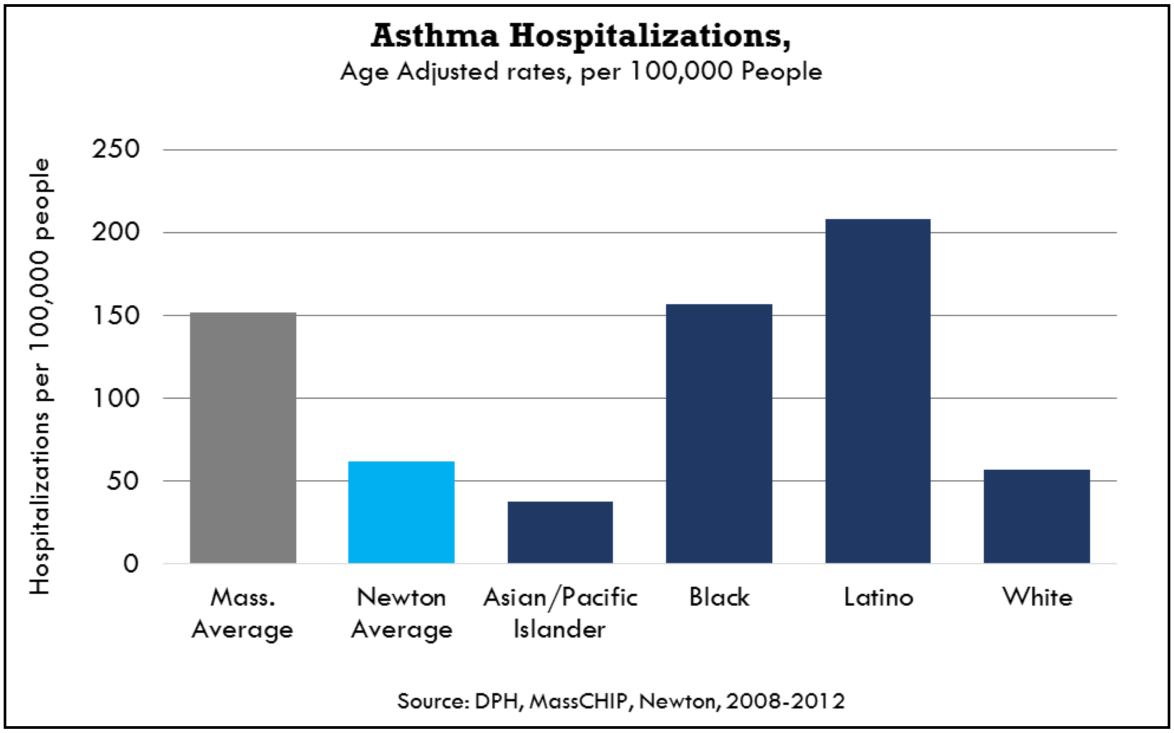
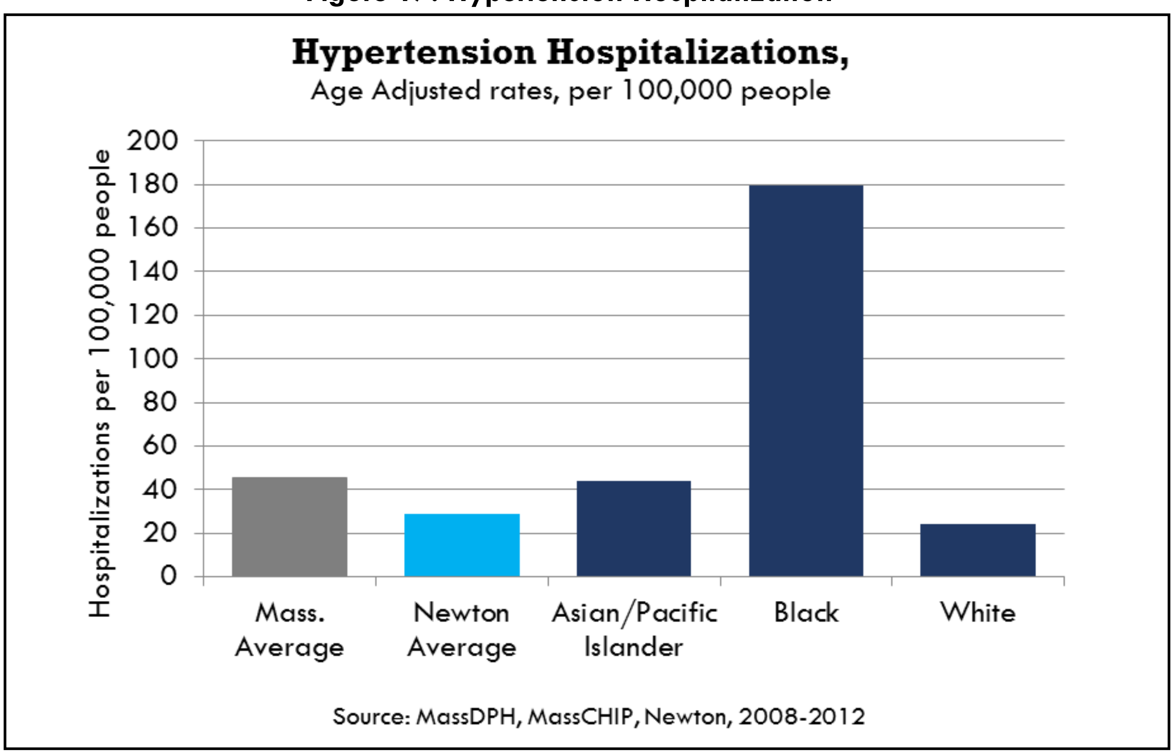


Figure 17. Hypertension Hospitalization

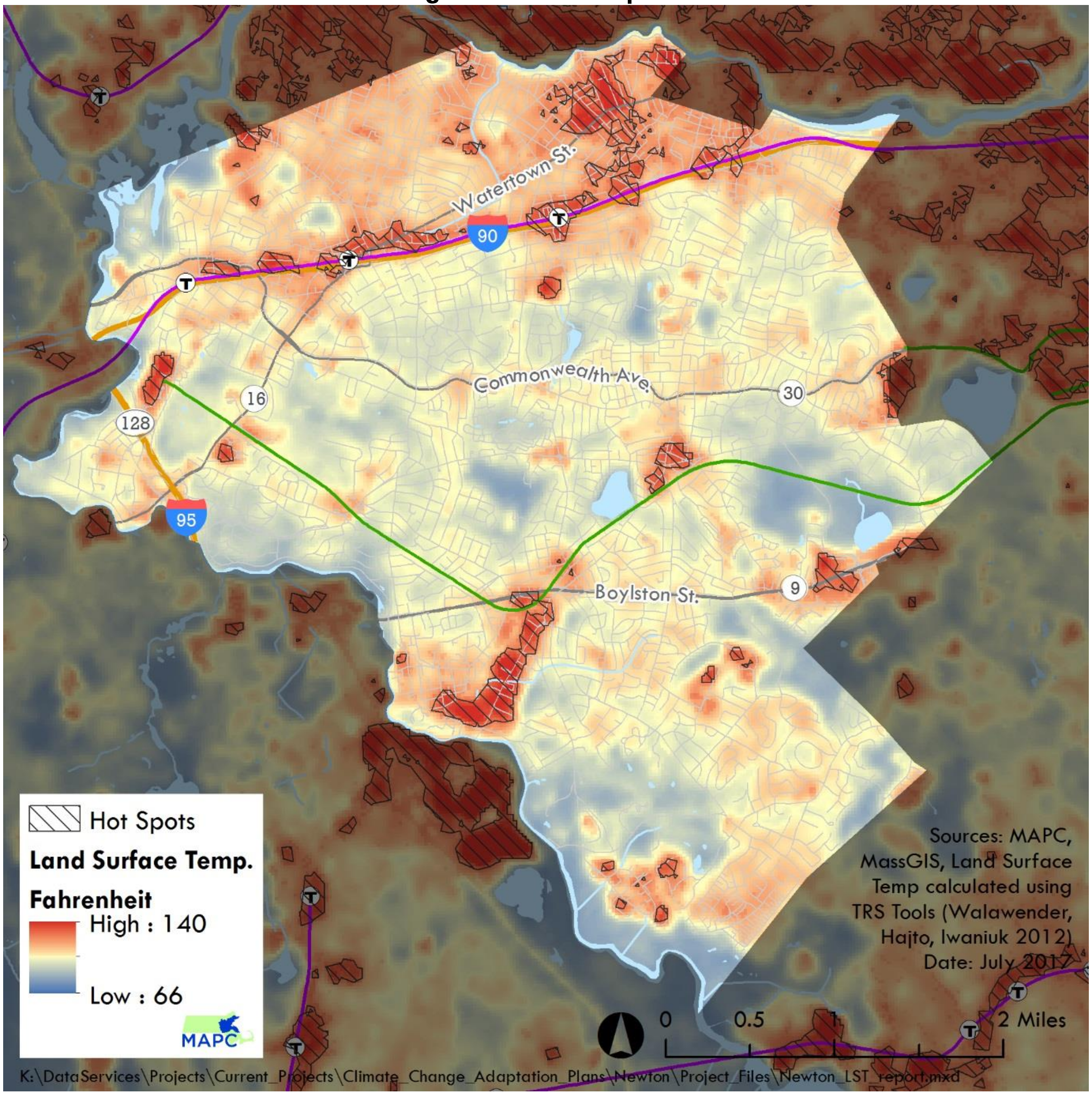


Extreme heat can contribute to greater levels of ground level air pollution and allergens. The poor air quality and high humidity that often accompany heat waves can aggravate asthma and other pre-existing cardiovascular conditions. Anyone who does outdoor physical activity during hot days with poor 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 Newton residents are hospitalized for asthma at a lower rate than are Massachusetts residents as a whole, hospitalizations for Black and Latino residents are higher than for White and Asian/Pacific Islanders in Newton (Figure 16). Data for Native Americans, two or more races, and other races were not available. Similarly, Newton residents have a lower rate of hypertension hospitalization than the Massachusetts average, but residents of color are hospitalized for hypertension at a higher rate than white residents (Figure 17). Data for hypertension hospitalization rates for Latinos, Native Americans, two or more races, or other races were not available.

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

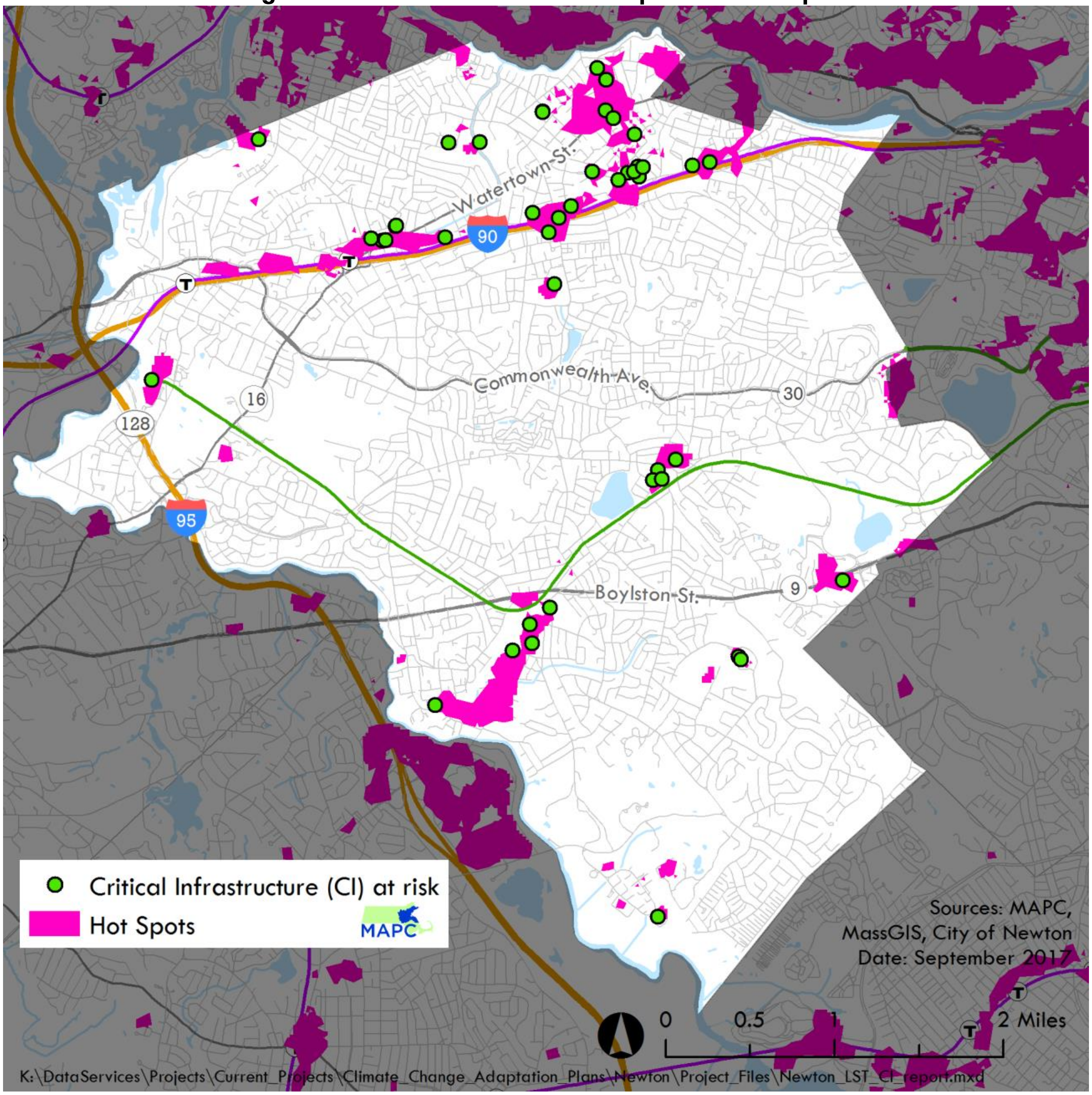
The temperature display reveals that the hottest areas in Newton coincide, for the most part, with locations that are zoned for commercial and industrial use. Given the generally suburban nature of the residential areas in Newton, this is not surprising. There are, however, some residential locations, particularly the multi-residence-zoned areas in Nonantum that are identified as "hot spots": part of the hottest 5% of land area in the MAPC region. Residential locations adjacent to business or industrial areas along the Mass Pike and elsewhere are included in the identified hot spots. Figure 19 and the accompanying Table 3 identify critical facilities in hot spot locations.

Figure 18. Heat Impacts



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

Figure 19. Critical Facilities in Temperature Hot Spots



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

Table 3. Critical Facilities in Temperature Hot Spots

Facility	Location	Type
Avalon at Upper Falls	99 Needham Street	Affordable Housing
Avalon at Chestnut Hill	160 Boylston Street	Affordable Housing
Chestnut Street	1202 Chestnut Street	Affordable Housing
West Street	19 West Street	Affordable Housing
Newton Homebuyer Assistance Program	12 Green Court	Affordable Housing
Scattered Sites	457 Washington Street	Affordable Housing
Genesis House (Genesis II)	295 Adams Street	Affordable Housing
Army National Guard Armory	1137 Washington Street	Armory
Activity Academy Inc./ West Newton School	25 Lenglen Road	Child Care
Close To Home Children's Center, Inc.	144 Bridge Street	Child Care
Little Red Wagon Playschool	56 Winchester Street	Child Care
Newton Community Service Centers	492 Waltham Street	Child Care
Golden Days Children's Center	66 Needham Street	Child Care
The Evan Baptist Church	23 Chapel Street	Church
Italian Pentecostal Christian Church	150 Lowell Avenue	Church
First Baptist Church in Newton	1299 Centre Street	Church
Sacred Heart Church	1321 Centre Street	Church
Lutheran Church of the Newtons	1310 Centre Street	Church
Verizon Telephone Building	787 Washington Street	Communication Tower
NEW TV	23 Needham Street	Communication Tower
Newtonville MBTA stop		Commuter Rail Station
Newton Center Municipal Lot	797 Beacon Street	Distribution Site
Austin Street Municipal Lot	34 Austin Street	Distribution Site
Our Lady Parish Parking Lot	573 Washington Street	Distribution Site
Newton Police Headquarters	1321 Washington Street	Emergency Operations Center
Rumford Avenue Recycling Center	125 Rumford Avenue	Hazardous Material Site
Silent Spring Information Center	29 Crafts Street	Library
Newton History Museum Library	527 Washington Street	Library
Higher Education Center Library	55 Chapel Street	Library
Crafts Street DPW Yard	90 Crafts Street	Municipal
Newton District Court	1309 Washington St	Municipal
Albemarle Field House	250 Albermarle Road	Municipal Facilities
Newton Community Service Center	492 Waltham Street	Municipal Facilities
Carr School	225 Nevada Street	Municipal Facilities
MBTA Riverside Line Electric Station 1	389 Grove Street	Power Substation
Burr School	171 Pine Street	School
EDCO Collaborative - N.E.W. Academy	429 Cherry Street	School
Fessenden School	246 Waltham Street	School
Trinity Catholic High School	575 Washington Street	School
Newton South High School	140 Brandeis Road	School/Shelter
Solomon Schecter Upper School	125 Wells Avenue	School
Jewish Community Day School	25 Lenglen Road	School
Angier Elementary School	225 Nevada Street	School
Newton North High School	457 Walnut Street	School

*Items shown in bold are also listed in Table 6 as potential flooding locations.

Increased Precipitation & 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. Chronic mold is an existing problem in Newton, particularly in public housing, senior housing, and in buildings built before the 1980s. 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. In recent years, Crystal Lake has experienced closures due to high E. coli and cyanobacteria levels. 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

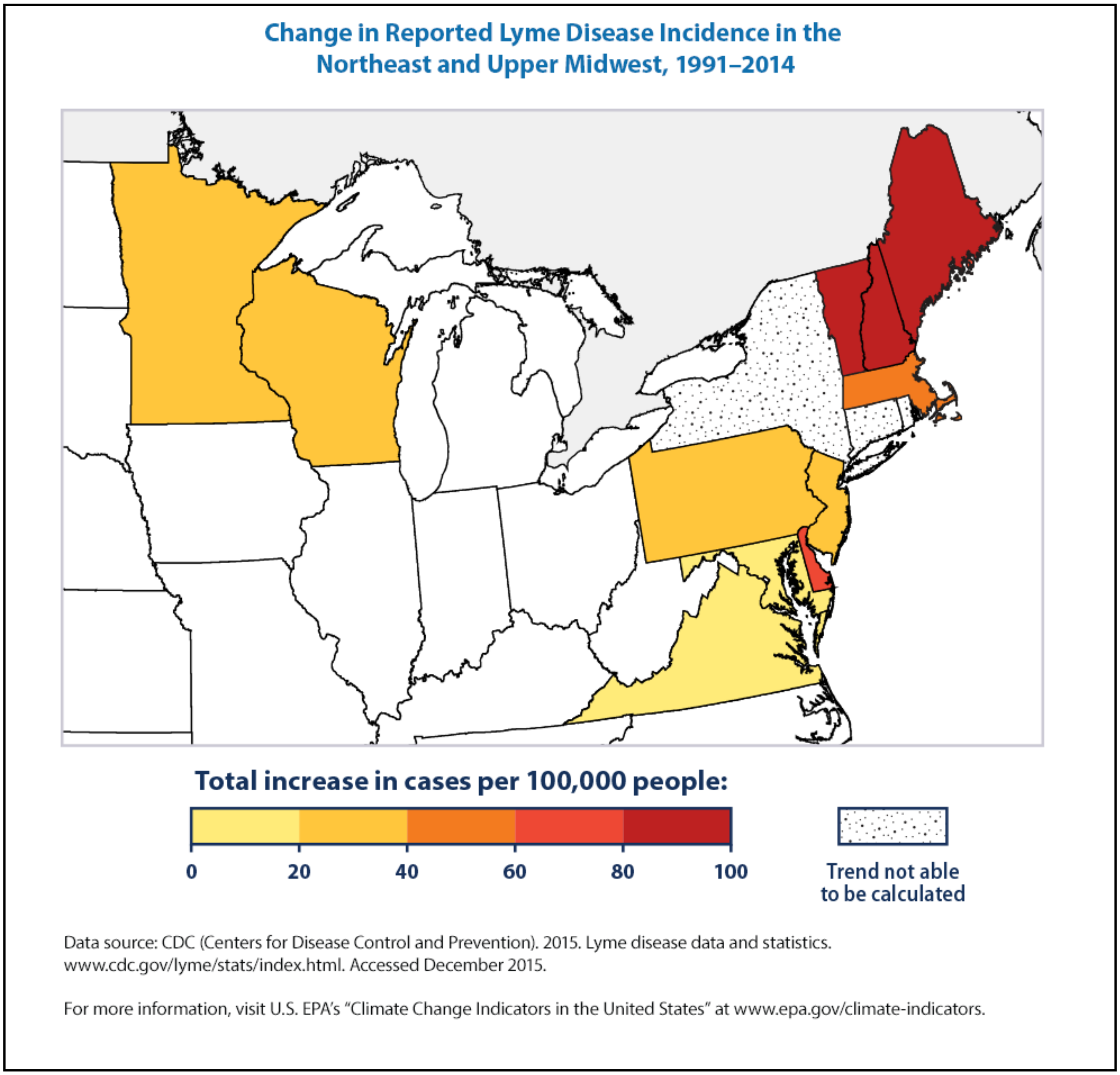
Vector-borne illnesses are those that stem from contact with vectors such as mosquitos and ticks. The spread of vector-borne illnesses is influenced by vector type, weather conditions, built environment conditions, and human behavioral factors. The two most common mosquito-borne illnesses in Massachusetts are eastern equine encephalitis (EEE) and West Nile virus (WNV). Mosquito species present in Newton have been found to carry 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 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 20). Winter frost plays an important role in limiting tick populations; warmer winter 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.

Figure 20. Lyme Disease Incidence



Natural Resources and Climate Resilience

Newton's natural resources lessen climate impacts by absorbing and storing carbon dioxide and by serving vital protective functions. Many natural resources will be challenged by heat, droughts, and storms. Forests, open space, wetlands, 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 City, 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 the emission of GHGs. Newton'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. In 2005, forests throughout Massachusetts were estimated to sequester nearly 85 million metric tons of carbon, or about 13.3% of all carbon emissions in the region. 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, flooding is already a significant issue in Newton, and one that is projected to worsen with climate change. Existing 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.

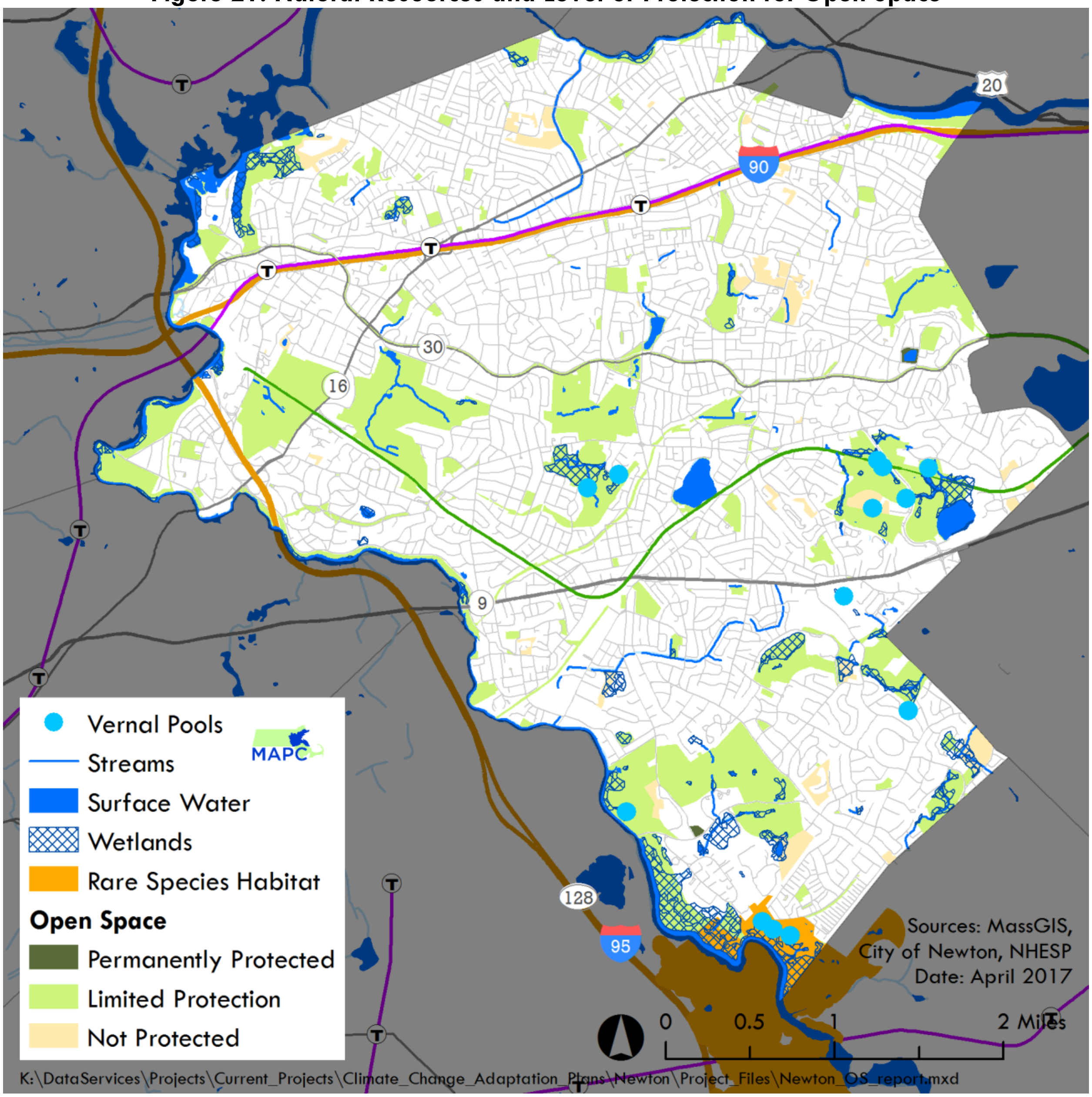
Trees also absorb remarkable quantities of precipitation. Research has shown that a typical medium-sized tree can intercept as much as 2,380 gallons of rain per year (USDA Forest Service). Intercepted rainfall lands on tree leaves and is stored or evaporated back into the atmosphere. This reduces the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

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.

Figure 21. Natural Resources and Level of Protection for Open Space



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. If dry conditions persist, wetlands could shrink in area or lose some of their absorptive capacity and be more prone to runoff and erosion.

According to the Open Space and Recreation plan, Newton's aquatic resources include 14 lakes and ponds, 22 streams and brooks, and the Charles River, amounting to 276 acres or 2.4% of Newton's total area. Wetlands total 258 acres for an additional 2.3% of Newton's land area. These resources have been heavily affected by development. Wetland acreage has been reduced to less than 20% of the approximately 1,470 acres existing in 1897, and water quality has been compromised by stormwater runoff.

As part of compliance with the federal Clean Water Act, Massachusetts must evaluate whether water bodies meet water quality standards. As shown in Table 4, in the 2014 "Final Listing of the Condition of Massachusetts' Waters Pursuant to Sections 305(b), 314 and 303(d) of the Clean Water Act," most of the assessed water bodies in Newton do not meet water quality standards for E. coli, phosphorous, and other impairments. Hammond Pond has not been assessed for all uses, but was identified as attaining uses including: Aesthetic, Fish Aquatic and Wildlife, and Secondary Contact Recreation. Crystal Lake was not assessed. Newton's other streams and ponds are not included in the assessment.

Many of these impairments may be further exacerbated by climate changes. Newton has made significant investments in water quality. In particular, through elimination of illicit and indirect connections, the City estimates it has reduced 4,500 gallons per day of sewage that previously entered storm drains. Wetlands and their buffer areas are protected under the Wetland Protection Act as well as by City ordinance. Approximately 77 acres of wetlands are located in protected open space.

Table 4. Water Quality Impairments

Waterbody	Impairment
Cheese Cake Brook	dissolved oxygen saturation, E. coli, phosphorous, excess algal growth
South Meadow Brook	dissolved oxygen, E. coli, phosphorous, turbidity
Bullough's Pond	excess algal growth, nutrient/eutrophication
Sawmill Brook	dissolved oxygen, E. coli, organic enrichment (sewage), phosphorous, chloride, turbidity
Charles River	E. coli, nutrient/eutrophication, phosphorous, DDT, PCB in fish tissue,

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.

The City estimates that approximately 20% of its land is Open Space. This includes protected and unprotected private and public land (Figure 21). The Recreation/Open Space Plan (ROSP) identifies larger wooded areas, including the Webster Conservation, Hammond Woods and Temple Mishkan Tefila land in Chestnut Hill; East and West Kessler Woods, the Saw Mill Brook Conservation Area and Bald Pate Meadows in Oak Hill; Auburndale Park and Flowed Meadow in Auburndale; and Dolan Pond Conservation Area in West Newton. These larger and connected areas are valuable as they provide greater resilience and protection for plant and animal species impacted by climate changes.

The ROSP indicates that there are approximately 1,200 acres of forested land, but notes that this acreage has declined by over 20% in the last 25 years. The ROSP cites an even steeper decline in street trees, down 35% to approximately 26,000 trees from 40,000 in the early 1970's. City officials estimate Newton is currently losing street trees at the rate of 800 per year.

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 Newton (Figure 22). Table 5 provides tree canopy data by land use category.

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 Newton's tree canopy exceeds $22 million, while the estimated value of annual carbon sequestration (tree growth minus loss due to decomposition and mortality) is over $600,000. Estimates of annual air pollution removal include 2,848 pounds of carbon monoxide, 73,467 pounds of nitrogen dioxide, 208,445 pounds of ozone, 15,158 pounds of sulfur dioxide, and 36,881 pounds of particulate matter. For stormwater runoff i-Tree estimates that 90 million gallons per year is avoided due to transpiration and interception of rainfall. The value of the reduced runoff is estimated at over $800,000 annually. Information on the methodology for these estimate is available at https://landscape.itreetools.org/references/.

Figure 22. Tree Canopy

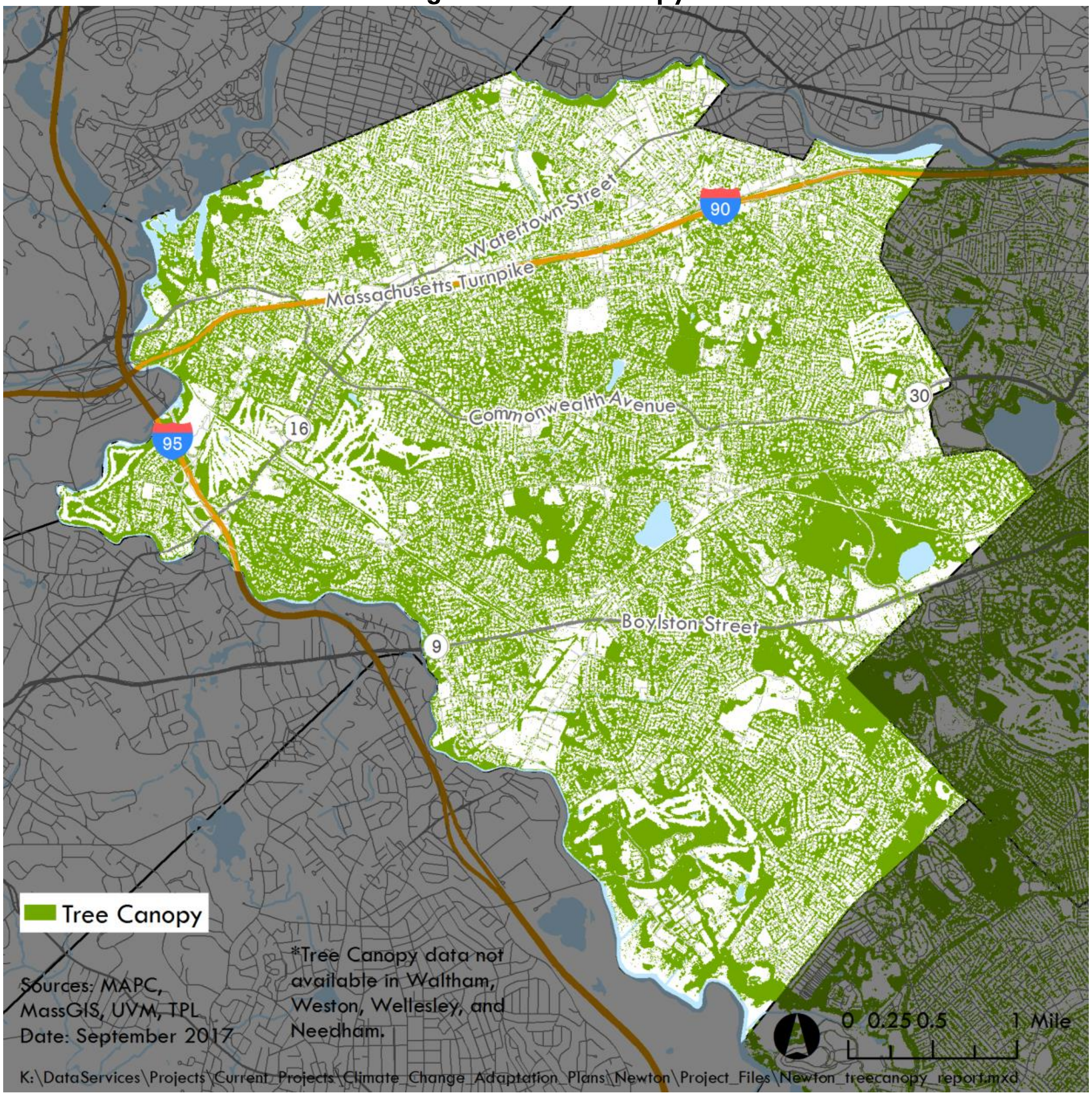


Table 5. Tree Canopy and Land Use

Land Use	Sq. Miles	% of Total Tree Canopy	Land Use %
RESIDENTIAL	4.8	55.5%	51%
OPEN SPACE	1.8	20.6%	17%
RIGHT OF WAY	1.2	14.0%	16%
INSTITUTIONAL	0.3	3.1%	4%
COMMERCIAL	0.2	2.4%	5%
GOVERNMENT	0.2	2.1%	3%
INDUSTRIAL	0.1	0.8%	1%
TOTAL	8.7	100%	100%

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

CLIMATE IMPACTS ON THE BUILT ENVIRONMENT

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. Flooding and stormwater management are already key concerns to which the City devotes considerable resources. The 2013 Newton Hazard Mitigation Plan identifies nine locations of special flooding concern. Newton's Stormwater Infrastructure Improvement Plan 2015 is a comprehensive review of Newton's 320 miles of drainage infrastructure. The Plan identifies seven additional localized flooding areas and prioritizes 32 culvert and 16 stream improvement projects. Many of the locations are along surface waterways, including the Charles River, the Sawmill, Cheesecake, South Meadow, Cold Spring and Hammond Brooks, and Bullough's Pond, but they also include many areas of poor drainage not associated with flood zones or visible waterways.

Rainstorms that occurred in March 2010 provide recent data for considering flood impacts in Newton. Figure 23 shows the United States Geological Survey gage record for March and early April 2010 on the Charles River in Wellesley, just upstream of Route 9 and the Metropolitan Circular Dam. The river peaked at 5.87 feet on April 3, 2010.

Flooding from the 2010 storm was significant: the last time gage heights exceeded the 2010 record was thirty years ago in 1987. This long gap between flooding incidents may give the impression that a storm the magnitude of 2010 is exceedingly rare. Yet gage records from 1960 to the present reveal that peak flow has exceeded the 2010 record four times. That is, Charles River flow the magnitude of 2010 or larger has happened, on average, every 11 years since 1960. This matches fairly closely the FEMA Flood Insurance Study for Norfolk County (2015) calculation that the 10% chance flood will yield a flow of 1,965 cubic feet per second (cfs). The flow recorded at the USGS gage on April 3, 2010 was 2,170 cfs, or slightly higher than FEMA's calculation for the 10% chance flood.

Four additional rain events between 1982 and 2001 did not increase flow in the Charles River as significantly, but did result in the payment of 24 to 52 flood insurance claims in Newton. The Charles River has a large watershed and tends to rise slowly during longer-term flooding events. However, flooding in Newton neighborhoods will also occur during shorter duration high intensity storms. The four rain events ranged

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.

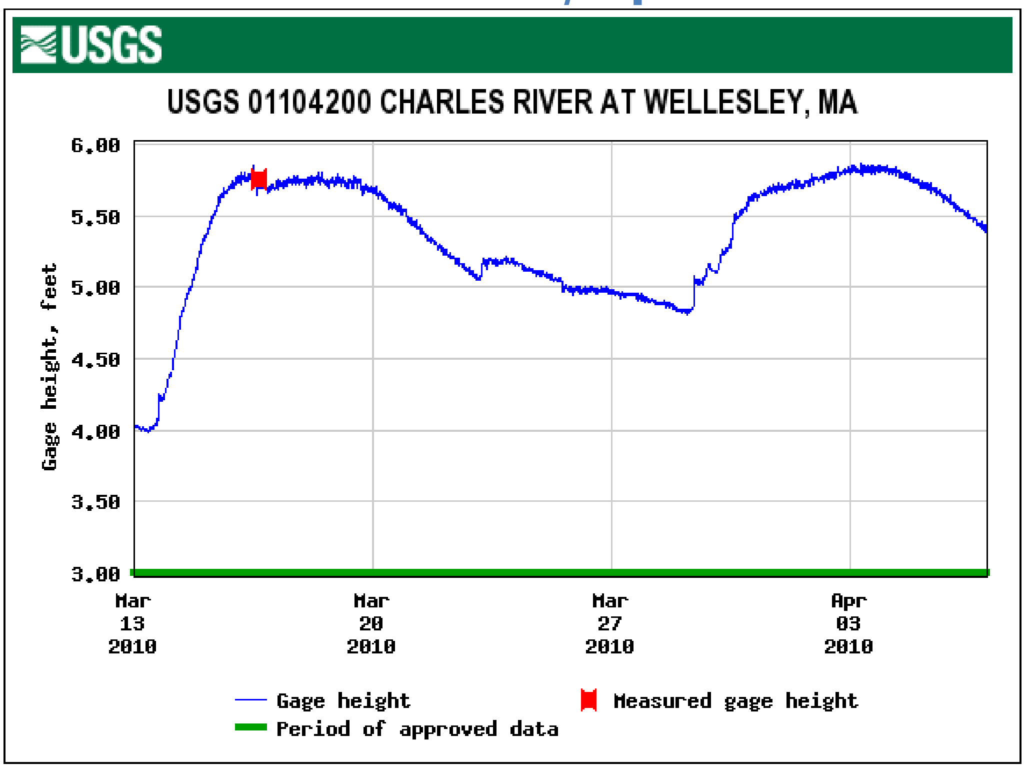
The .2% chance flood = 500 year flood
The 1% chance flood = 100 year flood
The 2% chance flood = 50 year flood
The 10% chance flood = 10 year flood

The 100-year flood 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.

from a little over 4 inches in two days (24 claims in 2001) to almost 8.5 inches in two days (52 claims in 1996). Rainfall records are from the Blue Hill Observatory in Milton.

Figure 23. March 2010 USGS Charles River Gage

Newton: March/April 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**

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 Hill Observatory, totaled 13.76 inches – 9.93 inches of which fell in 24 hours. The Wellesley stream gage did not exist in 1955, but records from the USGS gage on the Charles River in Dover give an indication of the impact of Hurricane Diane relative to the 2010 storm.

At that location, flow was 15% higher (2,790 cfs in 2010 vs. 3,220 cfs in 1955). The flood gage height was more than a foot higher (8.05 feet in 2010 vs. 9.24 feet 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 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 in the past sixty years. This may be less true along the Charles River, where Army Corps of Engineers land purchases in the 1970's and 80's have preserved natural storage.

Figure 24. Selwyn Road, Hurricane Diane 1955

Source: Jackson Homestead and Museum

As shown in Figure 25, the FEMA flood insurance claims from March 2010 account for more than twenty percent of the total number of paid insurance claims, and more than one-third the value of claims paid since 1978. Yet insurance claims represent only a fraction of actual damages. According to storm records in the NOAA Storm Events Database, more than 700 homes and 25 City buildings were damaged by flooding. City officials suggest that the number of homes affected by flooding may have been closer to 2,000. Because the 2010 storm was a federally declared disaster, property owners without flood insurance were eligible for limited reimbursement for damages. Uninsured property owners filed nearly three times the number of claims as those with flood insurance. It should also be noted that FEMA did not fully reimburse the uninsured property owners. City damage estimates, which were available for roughly 85% of the uninsured owners, totaled over $3 million, or nearly ten times the amount reimbursed by FEMA. City officials also estimate that damages to businesses were well over $1million.

City officials also note that short duration high intensity storms have caused flooding in the past. City staff report that this type of storm tends to cause flooding at choke points caused by stormwater drainage facilities that are unable to handle the volume of rain over a short period of time.

Figure 25. Newton Flood Damage Claims

The Cost of Flood Damage

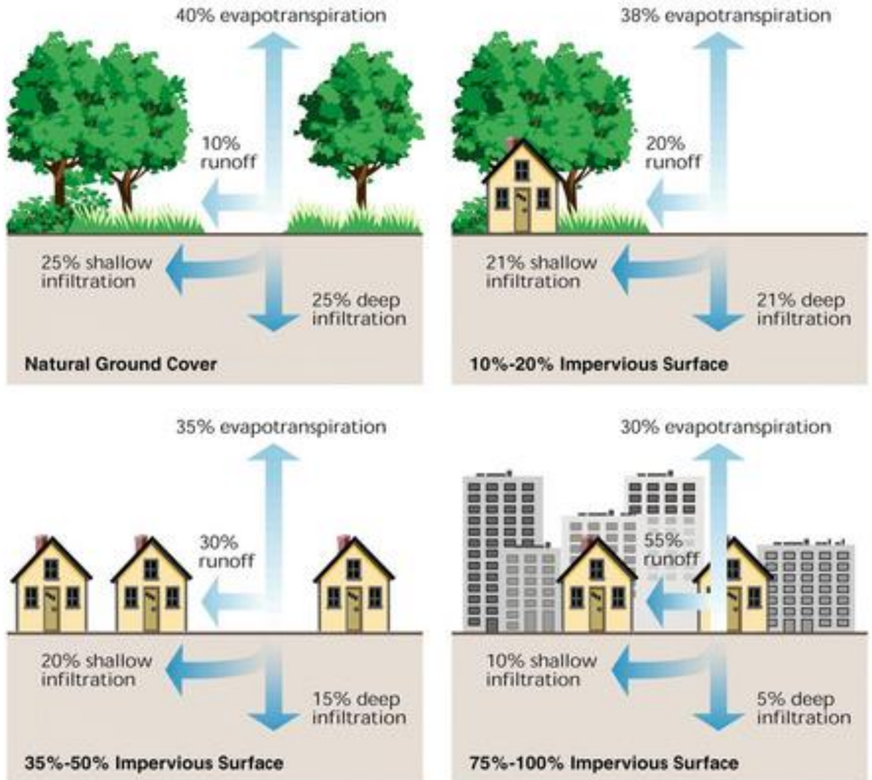
- **Total claims: 1978 through January 2017** FEMA flood insurance paid 275 claims - $1.7 million in damages
- **One stormy month: March 2010** FEMA flood insurance paid 70 claims - $672,843 in damages
- **Plus…** FEMA reimbursed 209 uninsured property owners $338,527 in damages, City of Newton was reimbursed $364,723 for damages (75% of request)

Lyons Field, Auburndale, March 15: Source Gail Spector

Flooding and Development Patterns

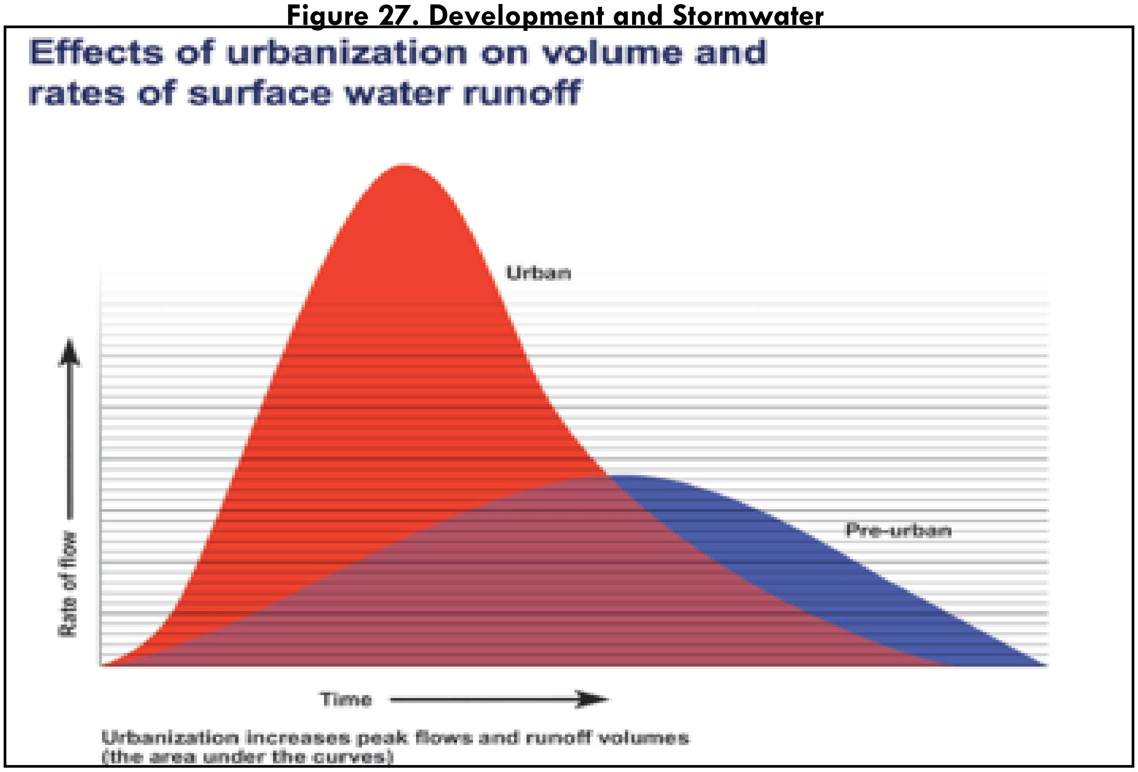
Newton faces significant challenges in addressing flooding. These challenges are commonplace in cities and towns where, over time, development has changed watershed drainage characteristics, re-rerouted or placed brooks and streams in culverts, and filled natural floodplains. As shown in Figure 26, with 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 27.

Figure 26. Development and Rainfall



Source: US EPA

Figure 27. Development and Stormwater

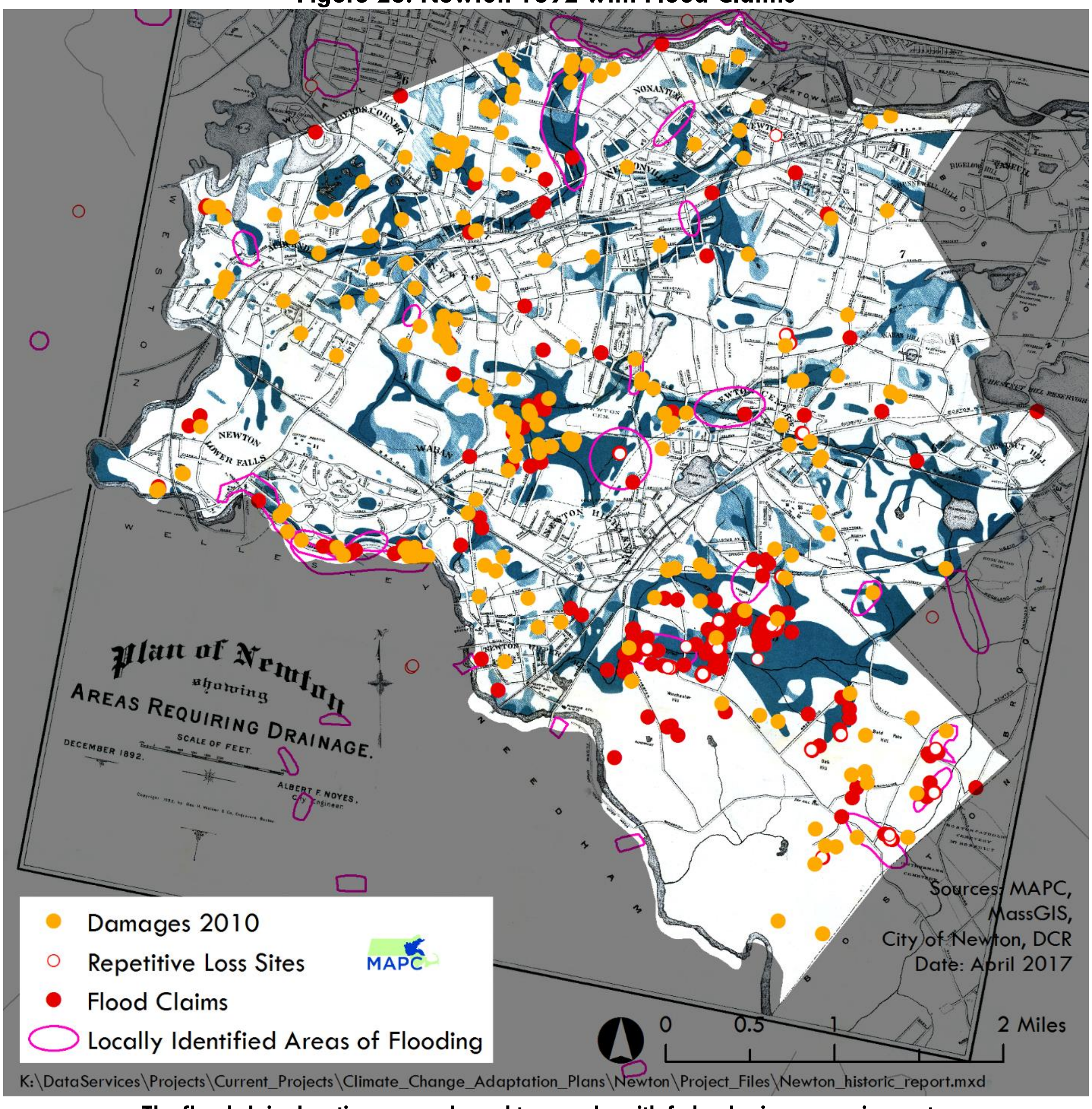


Source: Adapted from Drainage Manual, Roads and Transportation Association of Canada, 1982

Historic Development in Newton

An 1892 map of Newton (Figure 28) identifies "areas requiring drainage," including ponds, streams and wetland areas. In striking contrast, Figure 29 depicts today's surface waters and wetlands; the vast majority of the 1892 wetlands and waterways are no longer visible. As described in the Recreation and Open Space Plan (ROSP), many of Newton's wetlands and ponds have been drained and filled, and streams culverted. All of the 22 brooks and streams have been at least partially culverted or altered. Wetland acreage has been reduced to less than 20% of the approximately 1,470 acres that existed in 1897. As noted in the ROSP, much of the alteration of water resources took place under development pressures or for perceived health reasons. One

Figure 28. Newton 1892 with Flood Claims

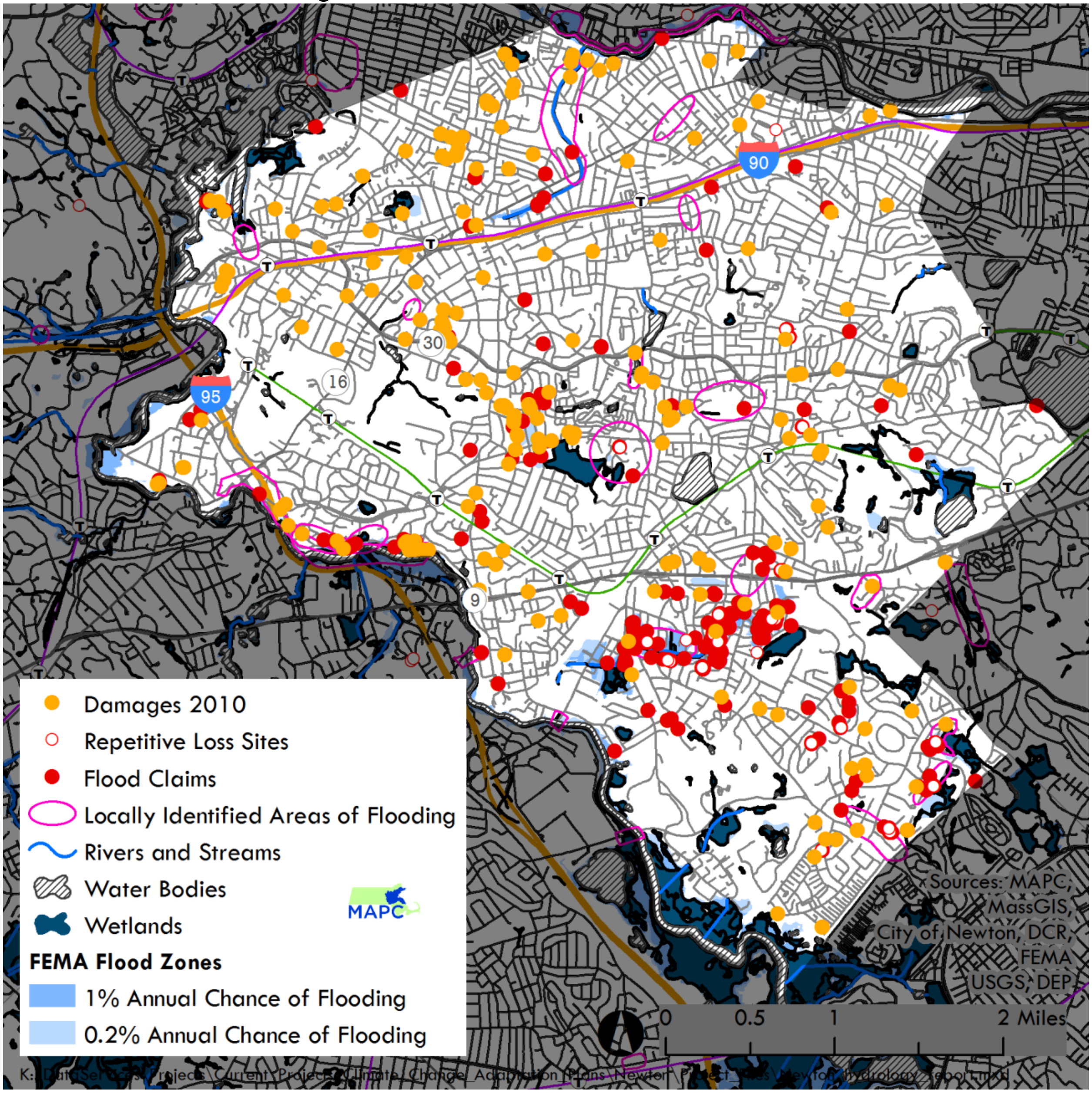


The flood claim locations are enlarged to comply with federal privacy requirements.

measure of these alterations is the 17 miles of underdrains that were constructed to facilitate the installation of sewer lines during the 1800's. The underdrains were installed in low-lying areas to lower groundwater in order to install the sewer lines on dry soil.

The 1892 map and the current map have been amended to identify locations of 1) FEMA flood insurance claims, 2) FEMA claims paid in 2010, and 3) localized flooding areas identified by the City. Placement of the flooding locations on the 1892 map reveals that nearly all of these locations are close to former wetlands or culverted streams.

Figure 29. Newton 2017 with Flood Claims



The flood claim locations are enlarged to comply with federal privacy requirements.

While flooding does occur in FEMA flood areas, there are many more flood damage locations outside of mapped flood areas. As demonstrated by the 1892 map, many of these locations may be related to flood sources that, although no longer visible, are still revealed by their impact. This has important implications for understanding and addressing flooding. In locations outside of flood zones, residents and officials are not necessarily forewarned of the potential for flooding. Regulations that would protect against flood damage do not apply. As an example, buildings in flood zones must comply with building code requirements that preclude basements.

An additional challenge to identifying potential flooding locations, is the 320 miles of Newton drainage infrastructure, the vast majority of which is buried underground. As noted previously, the City is making a significant investment in evaluating and improving its stormwater infrastructure. 100,000 linear feet of the most critical infrastructure has been prioritized for evaluation to identify potential emergencies and plan improvements. Yet, the condition of most of the drainage network is unknown. As a result, there is the potential for flooding in unexpected locations due to aging, or potentially failing, infrastructure. Flooding along the MBTA Riverside line in 2010, described in the MBTA section, is an example of damage due to unexpected drainage failure.

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 and damages, including varying impacts when rain falls on dry, frozen, or saturated land; and varying impacts between 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 that might result from increases in precipitation. Reviewing extreme events that may become more frequent, such as the 2010 storm, is valuable for identifying where damage occurred and where it might have extended had rainfall amounts been greater. FEMA mapped 500-year flood zones, and relatively flat land adjacent to flood zones can be reviewed for vulnerability. Understanding the condition and location of culverts and storm drains is important, because of their potential for blockages and failure. Further, as discussed above, the location of former wetlands is an important indicator of potential flooding locations.

According to Newton officials, 25 of 78 City facilities flooded in 2010. In a number of the locations flooding was minor, either because protective steps had been taken previously, or because water depths were limited. Nevertheless, Newton calculates damage to its facilities totaled over $650,000. As previously discussed, officials estimate that damages to homes and businesses exceeded $4 million from the 2010 storm alone.

Figure 30 and the accompanying Table 6 identify critical facilities in locations that may be subject to flooding. These include 1) flood zones, 2) City-identified flooding areas, 3) in proximity to previous flood claims, and 4) facilities that coincide with “areas requiring drainage” identified in the 1892 map of Newton. 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. Only 30% of the listed facilities are in current FEMA flood zones. 55% are listed solely because they are in historic wetland areas. Facilities shown in bold are also located in temperature "hot spots" (see Figure 19 and Table 3).

Figure 30. Critical Facilities, Flood Zones, Identified Flooding Areas, and Historic Wetlands

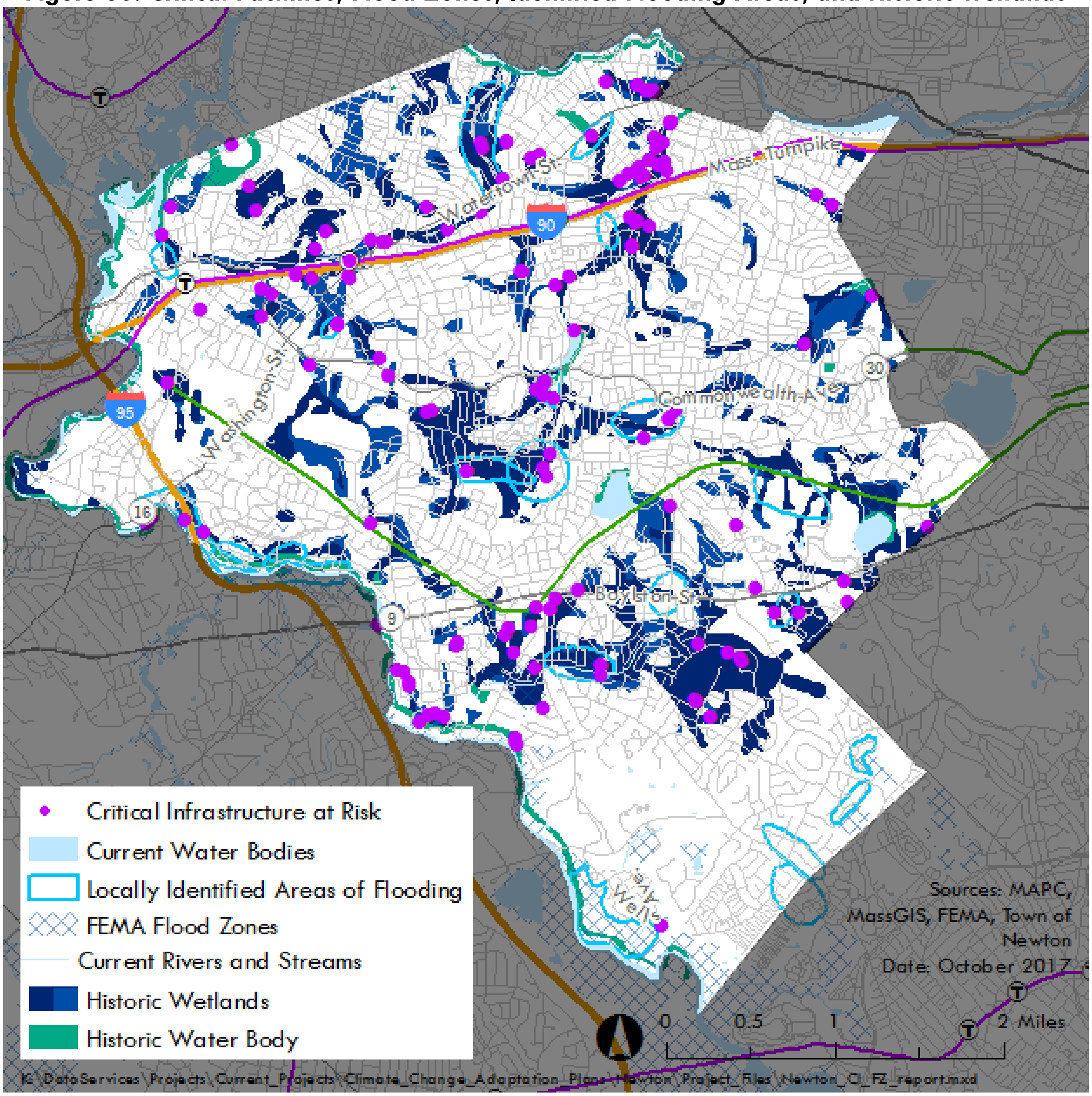


Table 6. Critical Facilities and Potential Flooding Indicators

CRITICAL FACILITY	LOCATION	TYPE	FLOOD ZONE	CITY-IDENTIFIED FLOODING	PROXIMITY TO A FLOOD CLAIM	OVERLAP WITH HISTORIC WETLANDS
	831 Boylston Street	Affordable Housing				X
73 Walnut St #3	73 Walnut St	Affordable Housing				X
Albermarle Road	470 Albermarle Road	Affordable Housing				X
Avalon at Chestnut Hill	160 Boylston Street	Affordable Housing				X
Avalon at Upper Falls	99 Needham Street	Affordable Housing				X
Beacon Street	1115 Beacon Street	Affordable Housing		X		X
Beaconwood Apartments	14 Wilson St	Affordable Housing		X		X
Beaconwood Apartments	36 Hargrave Cir	Affordable Housing		X		
Boylston Street Condos	340 Boylston St.	Affordable Housing		X		
Cabot Park Village	280 Newtonville Ave	Affordable Housing				X
Chatham Park	197 Westwood	Affordable Housing				X
Chestnut Street	1175 Chestnut Street	Affordable Housing				X
Coyne Road Group Home	18 Coyne Road	Affordable Housing				X
Echo Ridge	76 Thurston Road	Affordable Housing				X
Forte House & Townhouses	76 Webster Park	Affordable Housing	X		X	
Grove Street--NWW	87 Grove Street	Affordable Housing			X	
Hampton Place	77 Florence Street	Affordable Housing				X
Highland Glen Condos	92 Christina Street	Affordable Housing				X
Jackson Gardens	111 Kennedy Circle	Affordable Housing				X
Jackson Road	163 Jackson Rd	Affordable Housing				X
Jackson Terrace	15 Jackson Terrace	Affordable Housing				X
Kayla A. Rosenberg House	90 Christina St	Affordable Housing				X
Millhouse Commons	1093 Chestnut St	Affordable Housing				X
Millhouse Commons	1101 Chestnut St	Affordable Housing				X
New Falls Apartments	2281 Washington St.	Affordable Housing		X		
Newton Homebuyer	368 Elliot St	Affordable Housing			X	

CRITICAL FACILITY	LOCATION	TYPE	FLOOD ZONE	CITY-IDENTIFIED FLOODING	PROXIMITY TO A FLOOD CLAIM	OVERLAP WITH HISTORIC WETLANDS
Assist Program						
Nonantum Village	239 Watertown Street	Affordable Housing				X
Nonantum Village Place	241 Watertown	Affordable Housing				X
Orchard Avenue	40 Orchard Avenue	Affordable Housing				X
Parkview Homes	192 Lexington Street	Affordable Housing				X
Riverview Avenue	209 Riverview Avenue	Affordable Housing	X		X	
Tremont Street House	173 Tremont Street	Affordable Housing				X
Wiltshire Road	13 Wiltshire	Affordable Housing				X
Wyman Street	52 Wyman	Affordable Housing				X
Coyne Road Apartments	29 Coyne Rd	Affordable Housing/Assist Living				X
Falls at Cordingly	2300 Washington Street	Assisted Living	X			X
Bowen Cooperative Nursery School	96 OTIS STREET	Child Care				X
Brookline Infant Toddler Center	1900 Commonwealth Ave	Child Care				X
Gan Yeladim Day Care Center	125 WELLS AVENUE	Child Care	X			
Happy Child Preschool/Day Care	1191 CHESTNUT STREET	Child Care				X
Little Red Wagon Playschool	56 WINCHESTER STREET	Child Care				X
Morning Play Program	652 HAMMOND ST	Child Care				X
Newton Creative Start	573B WASHINGTON STREET	Child Care				X
Plowshares At Lincoln Eliot	191 PEARL STREET	Child Care				X
The Preschool Experience, Inc.	1091 CENTRE STREET	Child Care		X		
The Teddy Bear Club, Inc.	1466 Commonwealth Ave	Child Care				X
Ward After School Program	10 Dolphin Road	Child Care				X
Beth Menachem Chabad	229 DEDHAM ST	Church	X	X	X	X

CRITICAL FACILITY	LOCATION	TYPE	FLOOD ZONE	CITY-IDENTIFIED FLOODING	PROXIMITY TO A FLOOD CLAIM	OVERLAP WITH HISTORIC WETLANDS
Church of the Messiah	161 AUBURN ST	Church				X
Congregation Mishkan Tefila	128 OLDE FIELD RD	Church	X			X
Greek Evangelical Church of Boston	1115 CENTRE ST	Church		X		
Myrtle Baptist Church	21 CURVE ST	Church				X
St. John's Church	297 LOWELL AVE	Church				X
Trinity Church	1097 CENTRE ST	Church		X		
United Methodist Church of Newton	430 WALNUT ST	Church				X
Lincoln Park Baptist Church	1450 WASHINGTON ST	Church/Child Care				X
TEMPLE SHALOM	175 TEMPLE ST	Church/Child Care		X		
Lasell College	1844 Commonwealth Av	College or University				X
NEW TV	23 Needham St	Communication Tower				X
WEST NEWTON		Commuter Rail Station				X
Our Ladys Parish Parking Lot	573 Washington Street	Distribution Site				X
The Rashi School	15 Walnut Park	Distribution Site				X
Newton Police Headquarters	1321 Washington Street	Emergency Operations Center				X
Higher Education Center Library	55 Chapel Street	Library			X	
Silent Spring Information Center	29 Crafts Street	Library				X
Newton Free Library	330 Homer Street	Library/Distribution Site		X		
Riverside		MBTA Station				X
Elliot Street DPW Yard	82 Elliot Street	Municipal				X
Newton City Hall	1000 Commonwealth Ave	Municipal				X
Newton District Court	1309 Washington St	Municipal			X	X
Albemarle Field House		Municipal Facilities		X		X
Auburndale Park Shed		Municipal Facilities				X
Cabot Park Field House		Municipal Facilities				X
Clubhouse		Municipal Facilities				X

CRITICAL FACILITY	LOCATION	TYPE	FLOOD ZONE	CITY-IDENTIFIED FLOODING	PROXIMITY TO A FLOOD CLAIM	OVERLAP WITH HISTORIC WETLANDS
Gath Pool		Municipal Facilities		X		X
Jackson Homestead		Municipal Facilities				X
Newton Centre Field House		Municipal Facilities		X		
Newton Highlands Park Bldg.		Municipal Facilities				X
Parks & Rec Admin Bldg.		Municipal Facilities				X
Pellegrini Park Building		Municipal Facilities		X		
Pulsifers Cove Bath House		Municipal Facilities	X			
Stearns Park Building		Municipal Facilities				X
Golden Living Center - West Newton	25 Armory St.	Nursing Home				X
Heathwood Nursing & Rehab Center	188 Florence St.	Nursing Home				X
Waban Health & Rehabilitation	20 Kinmonth St.	Nursing Home				X
MBTA Riverside Line Electric Station	55 Winchester St	Power Substation				X
NSTAR Electric Station 17	334 Homer St	Power Substation				X
Langley Rd Sewer Pump Station	Langley Road	Sewer Pump Station			X	
EDCO Collaborative /N.E.W. Academy	429 Cherry Street	School				X
Integrated Learning Academy	109 Oak Street	School				X
Jackson School	200 Jackson Road	School				X
Newton North High School	457 Walnut Street	School				X
The Education Cooperative (TEC)	675 Watertown Street	School		X		
Trinity Catholic High School	575 Washington Street	School				X
Jewish Community Day School	25 LENGLEN RD	School/Child Care				X
Newton South High School	140 Brandeis Rd	School/Distribution Site/Shelter				X
Burr Elementary		School/Shelter				X

CRITICAL FACILITY	LOCATION	TYPE	FLOOD ZONE	CITY-IDENTIFIED FLOODING	PROXIMITY TO A FLOOD CLAIM	OVERLAP WITH HISTORIC WETLANDS
School						
Cabot School	229 Cabot Street	School/Shelter				X
Countryside School	191 Dedham Street	School/Shelter	X	X		X
Day Middle School	21 Minot Place	School/Shelter				X
Horace Mann School	687 Watertown Street	School/Shelter		X		X
Lincoln-Eliot School	191 Pearl Street	School/Shelter				X
Oak Hill Middle School	130 Wheeler Road	School/Shelter				X
Zervas School	30 Beethoven Avenue	School/Shelter		X		X
Elliot Street Sewer Pump Station	385 Elliot St	Sewer Pump Station			X	
Quinobequin Rd Sewer Pump Station	136 Quinobequin Rd	Sewer Pump Station				X
Brown Middle School	125 MeadowBrook	School/Shelter				X
Echo Ridge Apts - Elder Housing	64 Thurston St.	Special Needs			X	
Newton Education Center	100 Walnut St.	Special Needs				X
Parker House	21 Parker St.	Special Needs				X

*Items shown in bold are also located in hot spots (Table 3).

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 the closed Rumford Avenue landfill. As it is adjacent to mapped wetlands and the Charles River, the City may want to review whether there are any current or future concerns.

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. There are twelve dams with potential impacts on Newton, including two upstream dams in Wellesley and one in Weston. Their ownership, and their condition as of 2009 are shown in Table 7. 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. "Low Hazard Potential" dams are located where failure may cause minimal property damage to others, and loss of life is not expected.

Table 7. Dam Status

DAM	OWNERSHIP	DCR RATING 2009
Waban Hill Reservoir Dam	MA DCR	High hazard/Fair
Newton Lower Falls Dam – Finley	MA DCR	Significant hazard/Satisfactory
Cordingly Dam	MA DCR	Significant hazard/Fair
Silk Mill Dam	MA DCR	Low hazard/Not Rated
Metropolitan Circular Dam (Wellesley)	MA DCR	Significant hazard/Poor
Met Circular Dam, Hemlock Gorge Spillway (Wellesley)	MA DCR	Significant hazard/Poor *the Spillway has been rebuilt since this designation of Poor condition
Brae Burn Dam		Not listed
Nonantum Dam	MA DCR	Not listed
Bullough's Pond Dam	City of Newton	Not listed
Carlisle St. Dam	Private	Not listed
Stoney Brook Reservoir Dam (Weston)	City of Cambridge	High hazard/Fair
Watertown Dam	MA DCR	Significant hazard/Fair

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 and 2070. 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 Mayor communities.

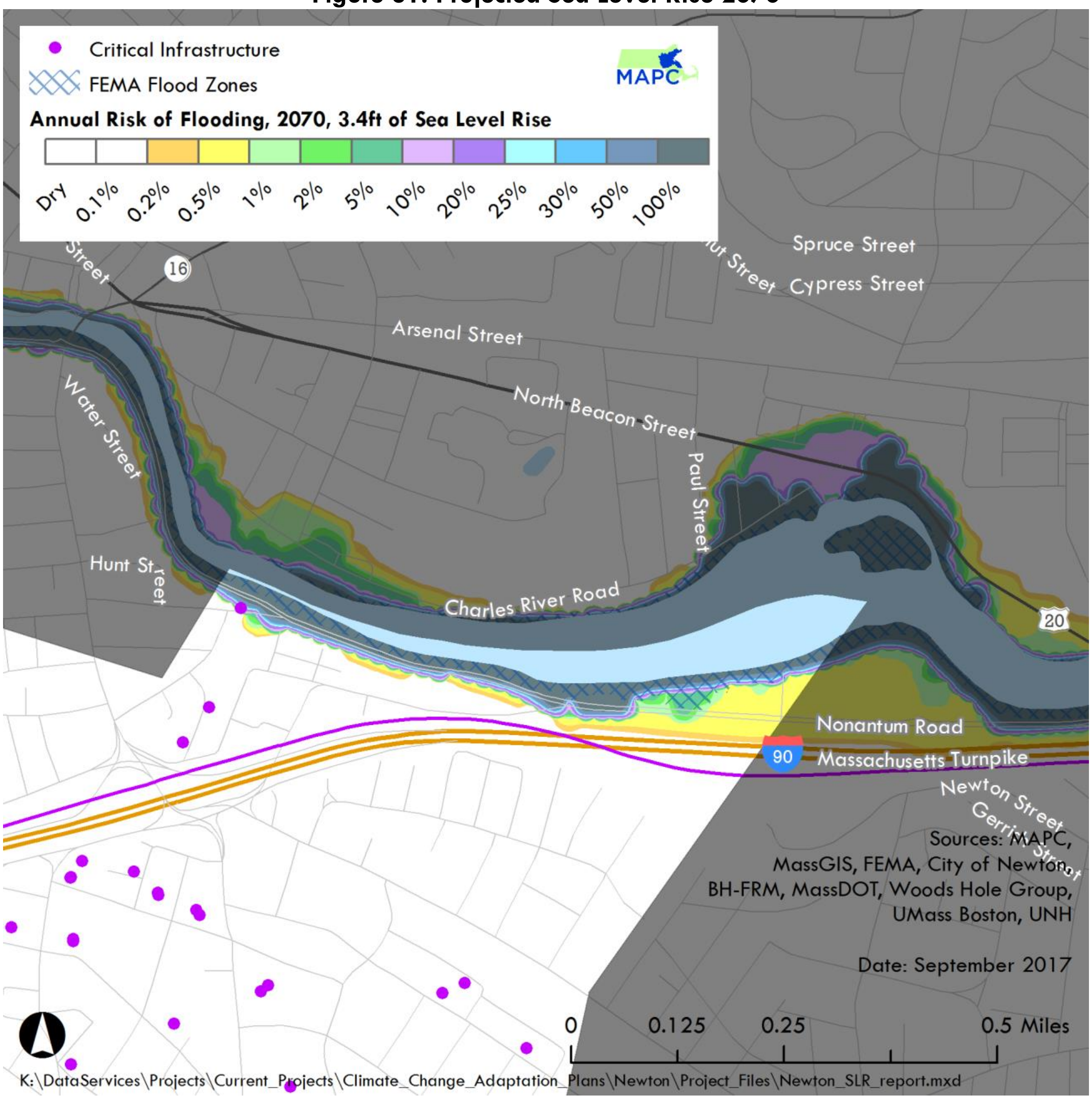
BH-FRM models both risk of flooding and depth of flooding on the basis of sea level rise projections and projected changes in intense storm patterns. Unlike previous models of sea level rise, the BH-FRM takes into account a variety of variables, such as storm surge and wave run up. The model bases projections 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. The maps are not applicable at a fine-grained level to assess individual buildings. Rather the sea level rise map below is 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

can be downloaded at:
https://www.massdot.state.ma.us/Portals/8/docs/environmental/SustainabilityEMS/Pilot_Project_Report_MassDOT_FHWA.pdf

The mapping shows no impact to Newton from sea level rise in 2013 and 2030. In 2070, the model projects that Newton could be affected by flooding along the Charles River (Figure 31). This is based on projections that, in their current configurations, the Charles River and Amelia Earhart Dams in Boston would be overtopped or flanked in low probability storms. As this scenario would have far greater impact on Boston and Cambridge, we consider it likely that steps will be taken to reconfigure the dams to address future sea level rise.

Figure 31. Projected Sea Level Rise 2070



Temperature and the Built Environment

Buildings, roads, 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 impact on public health, communications, transportation, and the economy in general.

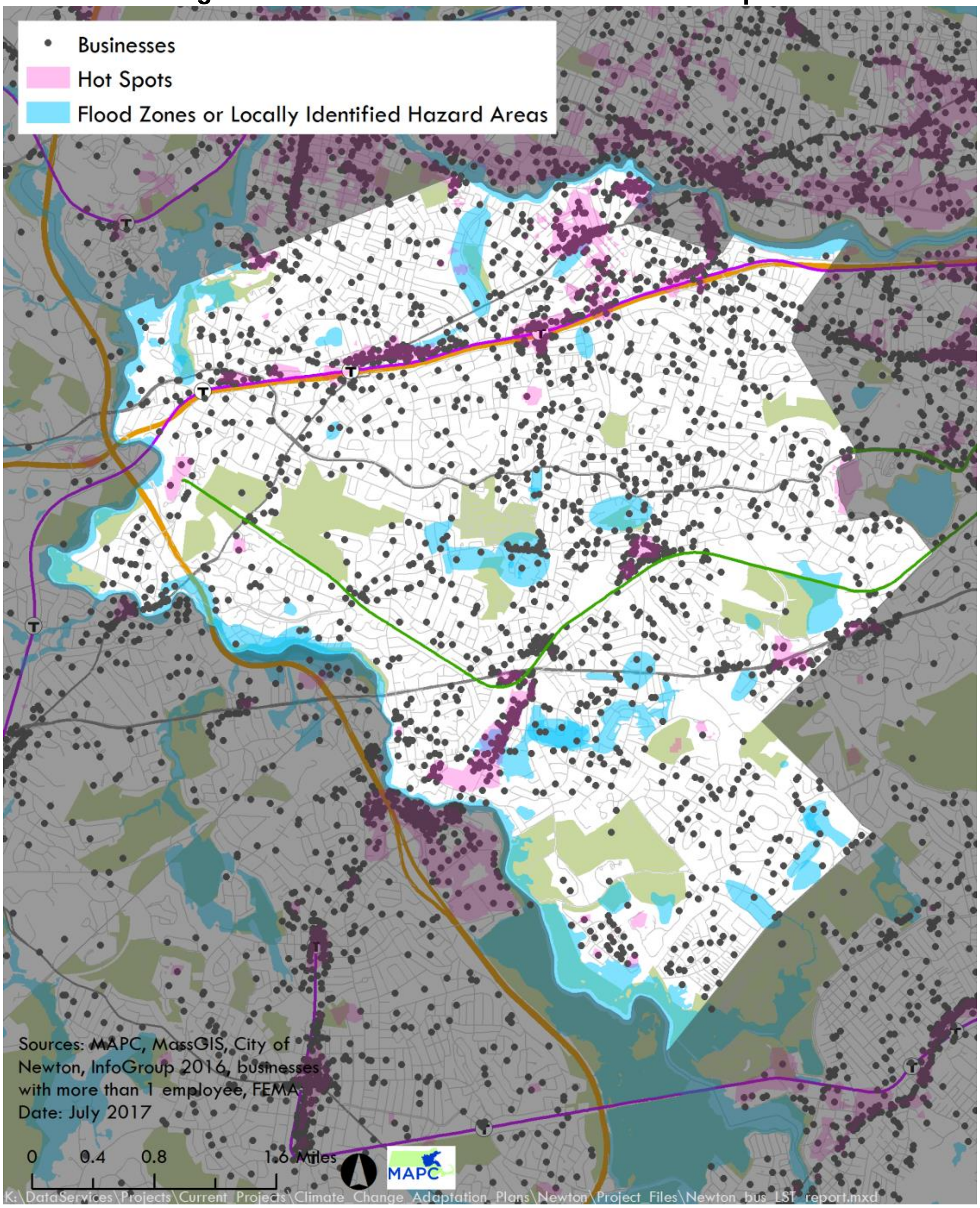
CLIMATE IMPACTS ON THE LOCAL ECONOMY

Businesses, employees, residents, 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.

Approximately 40% of Newton's businesses are in areas with particularly high land surface temperatures (InfoGroup 2016) (Figure 32). Hot days can cause unhealthy work conditions for people who work outside, and Newton has approximately 1,800 workers who are employed in industries that have a large portion of people who work outside (InfoGroup 2016). Excessive heat can cause unsafe and uncomfortable indoor conditions as well, for both employees and patrons. Massachusetts's OSHA regulations do not currently regulate indoor temperatures or air conditioning, but employees can file complaints to the Newton Board of Health or OSHA if workplace conditions are unbearable.

In Newton, a relatively small number of businesses (6%) are located in flood zones and City-identified areas of flooding. This figure may underestimate flooding vulnerability, as it does not include additional locations, identified in this report, where flood claims have been paid. The majority (85%) of employed Newton residents commute outside of the City for work, making a functional transportation system critical for the livelihoods of residents (LEHD, 2014). Because roughly 34% of Newton's residents work in the City of Boston, mostly in Downtown Boston and the Longwood Medical area, they may be affected by flooding on critical transit corridors in Brookline and Boston, such as along the Riverway, Storrow Drive, and the Green line (LEHD, 2014). Flooding along these corridors may result in business disruption and reduced activity if employees and customers experience barriers when trying reach Newton during floods.

Figure 32. Businesses Locations and Climate Impacts



CLIMATE IMPACTS ON STATE-OWNED INFRASTRUCTURE

Massachusetts Bay Transportation Authority

The MBTA provides critical transportation services to Newton residents and businesses. Data from the MBTA Ridership and Services Statistics 2014 Report record over 21,000 daily boardings on MBTA services in Newton. While these figures include passengers from communities other than Newton (particularly the Riverside Station and Bus 57, which together account for over 7,000 boardings), reliance on the MBTA is clear.

MBTA services in Newton include the Riverside Green Line, the Framingham/Worcester commuter rail line, 13 bus lines, and The Ride (ADA compliant service). The MBTA data show that weekday ridership includes nearly 9,500 boardings at Newton Green Line Stations, and 900 at Newton commuter rail stops. An average of 253 trips per day on The Ride originated in Newton in FY 2013. Over 11,000 boardings were recorded on buses that serve Newton. Nine of 13 bus routes provide express service to Boston via the Mass Pike: they primarily provide service to Newton neighborhoods north of the Mass Pike. Daily boardings on those routes totaled nearly 4,500 passengers. The four other bus routes totaled nearly 6,800 daily boardings. They include two that provide north/south service across Newton.

MBTA climate concerns include potential damage and disruption from flooding. 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.

Newton has already experienced a significant instance of MBTA service interruption from flooding. In the March 2010 flood, as described in the NOAA Storm Events Database, a forty foot section of rail bed was washed out after a sinkhole – twelve feet deep and fifty feet in diameter – opened. This took place at Glen Avenue on the Riverside line, requiring bus service between the Newton Highlands and Reservoir stations. According to City officials, this caused over $1 million in damages to the MBTA and had an impact on businesses. In addition to vulnerabilities that may exist for rail lines, surface transportation could be affected if buses travel through flooded streets. Street flooding could also affect trips on The Ride.

Massachusetts Water Resources Authority

The MWRA provides drinking water and sewage treatment to the City of Newton. The MWRA has been analyzing the climate vulnerability of its systems and is working to increase resiliency in identified priority locations. 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. They report no concerns with the Commonwealth Avenue and Dudley Road pumping stations in Newton.

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 1960s 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.

The MWRA has conducted an analysis of its sewer infrastructure, considering potential impacts based on modeling the 1% chance FEMA flood elevation, plus an additional 2.5 feet of elevation. Newton is not affected by the coastal pump stations that are vulnerable to storm surge. City 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, and sewage backflow into streets and basements. According to the MWRA, capacity issues are generally caused by groundwater infiltration and inflow from storm drains, roof leaders, and sump pumps that should not be connected to the sewer treatment system.

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 Newton include Routes 9, 16, 30, and 128 (I-95), as well as the Massachusetts Turnpike.

Department of Conservation and Recreation

The Department of Conservation and Recreation (DCR) owns eight dams discussed earlier. The DCR also owns several roadways, including Hammond Pond Parkway, Quinobequin Road, and Nonantum and Charlesbank Roads.

CLIMATE IMPACTS ON UTILITIES

Electricity

Eversource is the energy utility company that services Newton. Of the five identified Eversource substations, one is located in a potential flooding area, and none are located in temperature "hot spots." Energy infrastructure is vulnerable to extreme weather, in particular winter storms, heat waves, and floods. Ice storms, freeze/thaw cycles, and flooding can cause severe damage to infrastructure. Winter storms and hurricanes can increase loads on utility infrastructure, especially power lines and utility poles, because of 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. Eversource is currently implementing initiatives to bolster the resiliency of their critical assets. These initiatives include emergency preparedness trainings for staff, flood-proofing vulnerable substations, and updating design standards for increased precipitation and flooding.

Natural Gas

Newton's natural gas infrastructure is serviced by National Grid. There are approximately 306 miles of gas distribution lines in the City. 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 this 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. National Grid has verified that Newton is not within any of their high risk distribution clusters.

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 Newton. Cast iron pipes are susceptible to breaks from frost heaves, ground movement, and construction. 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.

Newton has 305.6 miles of gas mains. Just over 80%, or 246 miles, are leak-prone, including 62% cast iron, and 18% non-protected steel. Most recent figures from National Grid show there are eight Grade 2 leaks and 582 Grade 3 leaks in Newton. 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 eight projects in Newton, replacing 3.38 miles of mostly low-pressure cast iron pipe. From 2018 through 2021, National Grid plans 98 projects, replacing 11.7 miles of low-pressure cast iron pipe. If implemented, this would reduce leak-prone mains 6% by 2022, leaving 231.5 miles of leak-prone gas mains. The City of Newton is working aggressively with National Grid to facilitate repair and replacement of leak-prone pipes. Efforts to identify and quickly address large leaks known as "super-emitters" are a high priority.

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 natural resources
- Increasing temperatures, particularly an increase in the number of days over 90°F and 100°F, affecting public health, infrastructure, and natural resources
- Rising sea level, resulting in potential flooding and habitat loss along the Charles River late in the century (if no action is taken to increase the capacity of the downstream Charles River dams)

Socioeconomic Vulnerabilities

Vulnerable populations include those who may be more susceptible to climate impacts, and those who will have more difficulty adapting to, preparing for, and recovering from, extreme weather events. Vulnerable populations that are growing, or projected to grow, include seniors, individuals living alone, people of color, and people with limited English proficiency. In Newton, residents who speak Asian languages are more likely to be linguistically isolated than those who speak other non-English languages at home. Other vulnerable populations include low-income residents, young children, and individuals with a disability or pre-existing health conditions. Social isolation increases vulnerability, as it limits access to critical information, municipal resources, and social support systems valuable in emergencies.

Recent Newton demographics, summarized from the assessment, include:

- Seniors 16%,
- People living alone.. 26% (51% of whom are seniors)
- People of color... 20%
- Limited English speaking households 5%
- Households below the federal poverty level 6%
- Young children (under age 5) 6%
- People with a disability... 8%

Public Health Vulnerabilities

The health impact of increases in 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 and people of color may be at increased risk of such illnesses 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”.

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 Resources Vulnerabilities

Newton’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. Stormwater from rain washes pollutants into waterways and may cause erosion. In large rain 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 earlier spring runoff and more frequent summer droughts. The report details existing water quality impairments identified in relation to the Clean Water Act. While Newton has made significant investments to improve water quality, many of the identified impairments may be exacerbated by climate impacts.

Trees will be affected by warming temperatures. Trees adapted to warmer climates are predicted 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. The Open Space Plan indicates that forested acreage has declined by 20% in the past 25 years, while street trees have decreased by 25% since the early 1970s. Street trees can be damaged by gas leaks.

Built Environment Vulnerabilities

Flooding

Flooding due to rain is already a significant problem in Newton. This report documents the severity and frequency of damaging floods over the past 60 years. An increasing frequency and intensity of storms will exacerbate future flooding. A key finding is that more than 75% of identified flood claims are for properties located outside of FEMA flood zones. This is likely related to overburdened storm drain systems and/or to filled or buried historic wetlands and waterways: a preponderance of the claims outside flood zones align with "areas requiring drainage" shown on an 1892 map of Newton.

Properties outside of FEMA flood zones are not subject to floodplain regulations, and property owners are not formally warned of their flood risk. Future development that increases impervious surfaces or further alters natural drainage will exacerbate flooding problems. This report identifies critical facilities in flood zones, in City-identified flood prone areas, in proximity to previous flood claims, and overlapping historic wetlands identified in the 1892 map of Newton. These categories serve as proxies to identify areas that may be subject to increased flooding in the future.

Sea level rise

The Woods Hole Group model projects that by 2070, flooding along the Charles River due to storm surge will overtop or flank the downstream Charles River dams. As this scenario would have great impact on Boston and Cambridge, it is likely that steps will be taken to reconfigure these dams, thereby protecting Newton from any direct impacts of sea level rise.

Temperature

Heat can cause bridges, roadways, and railways to deteriorate more rapidly. The report identifies 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 Economic Vulnerabilities

Approximately 40% of businesses are located in hot-spots. A relatively small number (6%) are located in flood zones and identified flooding areas. This figure does not, however, include those that are located in former wetlands. Approximately 85% of employed Newton residents work outside of Newton. The largest concentrations work in Downtown Boston, the Longwood Medical area and the Back Bay. Transportation to these areas may be subject to interruption from flooding.

State-Owned Infrastructure Vulnerabilities

MBTA

As of 2014, ridership across all MBTA services in Newton exceeded 21,000 daily boardings. MBTA climate concerns include damage from flooding as well as from heat. Flooding in 2010 caused significant damage on the Riverside "D" line in Newton. Health of passengers and workers is a concern at times of high heat. The MBTA is also concerned that warmer temperatures in the winter could result in more damage from ice storms. The MBTA is proceeding with plans for a system-wide climate vulnerability analysis.

Massachusetts Water Resources Authority

The MWRA provides water and sewer service to Newton. The MWRA has analyzed the vulnerability of its systems. Drinking-water infrastructure is not threatened, even by more intense storms; and the MWRA's analysis is that even if a drought extends for several years, the Authority can supply drinking water to all its communities. Newton's sewage treatment is not vulnerable to coastal storm surges. The capacity of the sewer system has, however, been exceeded during heavy rain. This has resulted in the release of untreated sewage and backflow into streets and basements.

MASS DOT

State roadways in Newton include Routes 9, 16, 30, and 128 and the Massachusetts Turnpike. MassDOT is currently working 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.

Department of Conservation and Recreation

The DCR owns eight dams and inspects an additional one located in, or potentially affecting Newton. Increased precipitation intensity is the primary concern as it could affect dams that were likely designed for historic weather patterns.

Utilities Vulnerabilities

Electricity

Eversource is the energy utility company servicing Newton. Eversource's climate concerns include winter storms, heat waves, and floods. Ice storms, freeze/thaw events, and flooding can cause severe damage to infrastructure. Power outages result from downed lines due to falling trees or ice, and from increased demand and equipment failures during extreme heat. Of the five Eversource substations in Newton, one is located in historic wetlands and one is located in a "hot spot." Eversource's resiliency initiatives include flood-proofing vulnerable substations, updating design standards for future flooding, and emergency preparedness training for staff.

Natural Gas

National Grid is the natural gas provider for Newton. Gas pipes and infrastructure are vulnerable to corrosion and damage from flooding. Freeze/thaw events may cause gas mains to rupture. Gas leaks release methane into the soil and air, contributing to greenhouse gases in the atmosphere and threatening public health and safety. The leaks damage trees by suffocating root systems, and form ground-level ozone, which is an asthma trigger. Due to the damaging impacts and high risk of leaks, the state has required gas companies to accelerate replacement of leak-prone pipes.

In their 2017 plan, National Grid indicated that 80% of Newton's gas mains are leak-prone. Most recent figures reflected nearly 600 gas leaks in Newton. The National Grid plan projects that they will complete replacement of all of their leak-prone pipes by 2035. If successful, climate vulnerability should decline. The City of Newton is working aggressively with National Grid to facilitate repair and replacement of leak-prone pipes. Newton is a leader in efforts to identify and quickly address large leaks known as "super-emitters".

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 above 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.

ADAPTATION AND RESILIENCY ACTION PLAN

On-Going Efforts

The City of Newton has already taken numerous steps to improve its resilience to extreme weather. Flooding, heat waves, and drought are projected to become more frequent and severe over the course of this century, but they are not new concerns. Thus, while planning for climate resilience is a relatively new endeavor, Newton starts with a firm foundation to support its future efforts.

While this plan focuses on adapting to climate change, it is critical to continue efforts to reduce greenhouse gas emissions through *mitigation efforts*. The City of Newton, through its The City, its residents, and its businesses, have already taken many steps to promote energy conservation and the use of renewable energy.

- Participation in the MAPC Metro Mayors Coalition: commitment to creating a climate mitigation plan by 2020 and achieving a Net Zero/Carbon-Free status by 2050.
- Newton's Community Solar Share Initiative.
- Coordinating with National Grid to repair gas leaks
- Starting a Home Energy Savings program
- Starting a Business Energy Savers program
- Creating a transportation strategy that encourages alternatives to car use

- Home weatherization and solar credits for low-income households

In accordance with the plans and processes listed above, Newton has instituted many specific *adaptation strategies*, including:

- Creation of a stormwater utility with incentives for stormwater infiltration
- Opening cooling centers during heat waves
- Investing in stormwater analysis and improvements, including green infrastructure projects
- Establishing strong emergency planning
- Administering public health and wellness programs
- Conducting senior outreach and support activities

The City of Newton currently has the following plans and processes in effect as an effort to take steps towards *both mitigation and adaptation*:

- Capital Improvement Plan (CIP)
- Stormwater Infrastructure Improvement Plan (SWIIP)
- Open Space and Recreation Plan (OSRP)
- Street Tree Planting Plan (STPP)
- Flood Ordinance
- Zoning Ordinance
- Comprehensive Emergency Management Plan (CEMP)
- Hazard Mitigation Plan (HMP)
- Engineering Department Stormwater Infiltration Policy
- Coordinating climate efforts through the Planning Department and Sustainability Office
- Protecting open space that provides flooding buffers and preserves habitat
- Adopting a stretch code for energy conservation and resilience to heat events
- Including green infrastructure in the Complete Streets policy

New Recommendations

MAPC recommends additional strategies that should be considered even in the absence of climate change, as they are likely to generate economic, environmental, and social benefits. The use of green infrastructure and low impact development techniques, for example, reduces stormwater runoff and cooling costs. Beyond resilience concerns, it provides recharge to groundwater aquifers and supports local ecosystems and provides residents with additional green space. MAPC recommends strategies that span planning, policy, design, community outreach, and more. Many require additional analysis and planning and/or financial resources. Recommendations follow the organization of the climate vulnerability assessment. Many recommendations will address multiple vulnerabilities and concerns.

Socio-Economic Recommendations

Newton has many programs that provide services and connect to vulnerable populations. It will be a challenge to catalogue current efforts and identify gaps in services. Outreach to 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.

Public Health Recommendations

Prolonged periods of higher temperatures will occur all over the City and will be magnified by "heat islands", heavily paved and densely built areas, usually in village centers. Those living in those areas, and those without air-conditioners will be disproportionately affected. Exposure to mold and vector-borne illnesses are additional climate-related concerns. Public health strategies overlap significantly with those designed to address social vulnerability (above) and strategies for improved heat and flood protection included in the *Built Environment* section (below).

> **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. GI 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 GI to maintain natural drainage flow paths and reduce impervious surfaces.

Natural Resource Recommendations

Natural resources can be adversely affected by climate change, and changes in natural resources can compound effects of climate change. One key concern in Newton is the continued loss of trees to development and the loss of street trees to disease and gas leaks. Trees play a critical role in mitigating climate change and cooling local areas. Compromised water quality, extremes of water quantity, and resulting impacts on aquatic life are also of concern. The critical role of natural resources in climate change mitigation and climate adaptation cannot be overstated and is addressed throughout the report. This section of the report focuses on the protection and enhancement of green space. Other sections of the report suggest ways in which bolstering natural resources and implementing green infrastructure and low impact development will provide protection from flooding and heat impacts and help address climate change impacts on water quality, water quantity, and heat.

> **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.

Built Environment Recommendations

Flooding

Periodic flooding occurs naturally, but impervious surfaces in developed areas makes it worse. In Newton, as elsewhere, flood damage is more likely to occur when development has encroached on natural floodplains. The City is devoting significant resources to stormwater infrastructure improvements that will reduce flooding. Recommended actions in this section focus on restoring natural drainage to the greatest degree possible and reducing or restricting encroachment in flooding areas.

Heat

Recommended actions focus on improving buildings for the health and comfort of occupants, and on reducing heat and heat island impacts. Many Green Infrastructure/Low Impact Development strategies 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.

Heat and Flood

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

Economic Recommendations

Many actions relevant to the business community are addressed in the *Built Environment* sections above.

State-owned Infrastructure Recommendations

State agencies own, or are responsible for, significant critical infrastructure in Newton. The City has an interest in ensuring that these facilities are prepared for climate change. The City should also make sure that state agency activities (for example vegetation management) do not adversely impact other climate goals. State 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.

Utilities Recommendations

As with state-owned infrastructure, the City has an interest in climate resilience and in limiting adverse impacts of the utilities that serve Newton. The City is already working closely with National Grid to address natural gas leaks. Telecommunications presents challenges, as there are multiple providers and specific information on infrastructure is not publicly available.

Implementation, Outreach, and Planning Recommendations

Climate change modeling has inherent uncertainties and will be affected by unknown levels of future greenhouse gas emissions. Newton will also change over time, as will technologies and other means of climate mitigation and adaptation. This report is the beginning of a dialogue within City government, and between the City, and its residents, businesses and property owners. Expanded and coordinated participation across City departments will strengthen City efforts, while communication with stakeholders will increase public knowledge of climate change impacts and provide community feedback on climate-related actions. Evaluation and implementation of action items will require on-going coordination and leadership from the City.

Climate related issues should be incorporated into City planning including capital planning, operations budgets, zoning, the Complete Streets policy, the Transportation Plan, the master plan, the open space plan, the hazard mitigation plan and all emergency planning. It is especially important that climate change be considered in the capital planning process. Large capital projects present opportunities to make significant improvements in climate resilience that might otherwise be cost-prohibitive. New municipal buildings are already being planned with climate change in mind, and the Building Department and all other departments should be on top of the latest predictions as they emerge from the science. 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.

Newton will need to evaluate and prioritize potential actions and the timing of their implementation. Extreme weather may occur 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 long-term planning.

To help prioritize actions, it may be useful to conduct a risk analysis that examines the probability and the consequences of harm, as illustrated in the graphic below. The flooding of a sewer pump station and open space might be equally likely, for example, but protecting the pump station would have higher priority as the consequence of its flooding is more severe.

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

Priority	Realm	Ref. #	Lead(s)	Action	• Existing Plan/Process	Timing
1	1. Implementation, Outreach, and Planning	1A	Sustainability	Review climate projections and revise and update climate resilience priorities every five years.	• Comprehensive Emergency Management Plan (**CEMP**) • Hazard Mitigation Plan (**HMP**) • Emergency Support Functions (**ESF**) Model	FY23
1	1. Implementation, Outreach, and Planning	1D	Executive Office, Planning	Incorporate climate resilience into all City planning documents and activities. Ensure that all capital planning and projects incorporates climate resilience.	• Comprehensive Emergency Management Plan (**CEMP**) • Hazard Mitigation Plan (**HMP**)	On-going
1	2. Socio-Economic	2D	Emergency Management*	Support facilities that serve vulnerable populations. Assess retrofit needs and emergency readiness, including evacuation plans. Assess air conditioning and back-up generators. Encourage sign-up for the emergency notification system.	• Hazard Mitigation Plan (**HMP**)	On-going
1	2. Socio-Economic	2F	Emergency Management*	Explore options to communicate emergency preparedness information to linguistically isolated households.	• Comprehensive Emergency Management Plan (**CEMP**) • Hazard Mitigation Plan (**HMP**)	On-going
1	2. Socio-Economic	2G	Health and Human Services (HHS)	Work with local health providers to provide emergency response information to clients with physical and mental disabilities.	• Hazard Mitigation Plan (**HMP**)	On-going
1	2. Socio-Economic	2H	Emergency Management*	Develop advance shelter-in-place and communication strategies for residents who may not be able to evacuate during emergencies	• Comprehensive Emergency Management Plan (**CEMP**)	On-going
1	3. Public Health	3C	Parks and Rec/Forestry	Request an increase in funding available to the planting plan for increased street-tree planting and landscaping at public facilities in "hot spot" areas.	• Street Tree Planting Plan (**STPP**)	On-going
1	3. Public Health	3D	Parks and Rec, Planning, HHS	Place signage at popular park and recreation areas to inform residents about tick/mosquito risk and to provide information about how to protect themselves.	• Capital Improvement Plan (**CIP**)	FY19
1	3. Public Health	3E	Emergency Management*	Update the Comprehensive Emergency Management Plan to incorporate changes in emergency situations and response activities that may result from climate impacts.	• Comprehensive Emergency Management Plan (**CEMP**)	At next cycle

* "Emergency Management" refers to the Mayor/Executive Office, Police Chief, Fire Chief, and the Health and Human Services Department.

Priority	Realm	Ref. #	Lead(s)	Action	• Existing Plan/Process	Timing
1	4. Natural Resource	4A	Planning	Incorporate climate resilience into open space planning. Strategic considerations include: 1) protecting large and/or connected green spaces to foster ecological resilience and biodiversity; 2) removing asphalt, planting trees, and installing green or white roofs to cool "hot spots"; 3) maintaining and creating open space buffers to protect water quality and provide flood protection; 4) identifying locations where soil will support stormwater infiltration to replenish groundwater and support stream flow.[i]	• Open Space and Recreation Plan (**OSRP**) • Conservation Restrictions	FY18-19 (plan due in 2020)
1	4. Natural Resource	4B	Parks and Rec	Increase tree planting efforts to address net losses and increase tree canopy. Continue to increase tree diversity and consider trees well-adapted to warming temperatures to boost climate resilience.[ii]	• Street Tree Planting Plan (**STPP**)	FY15 and on
1	4. Natural Resource	4D	DPW	Ensure that bridge and culvert repairs take into account future precipitation projections.[iii]	• DPW adopted the Cornell University Northeast Regional Climate Center's 100-year design storm. DPW also refers to the National Oceanic and Atmospheric Administration Atlas 14. • Evaluate on a Project-specific basis.	As needed
1	5. Built Environment	5A	Planning	Ensure that the zoning/ordinance review requires Green Infrastructure/Low Impact Development/Renewable Energy through creative approaches to parking, driveways, street width, stormwater, and site plan review in all development and redevelopment work. Incorporate stormwater management into street design for construction and reconstruction using green infrastructure principles. Integrate design guidelines for Green Infrastructure and Low Impact Development.[iv]	• Zoning Redesign	FY18-19
1	5. Built Environment	5B	Planning, DPW	Provide funding for training, as needed, to empower City staff on implementing cutting edge techniques for green practices and reviewing, design, and construction of new green infrastructure strategies.[v]	• Training line item in individual departments Annual Budget.	FY18-19 on
1	5. Built Environment	5C	Planning	Consider expanding the floodplain ordinance to documented areas of flooding.[vi]	• Floodplain Ordinance	FY21
1	5. Built Environment	5G	Public Facilities, Planning	Assess municipal properties for opportunities for LID/GI retrofits.[vii]	• Capital Improvement Plan (**CIP**)	On-going

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Priority	Realm	Ref. #	Lead(s)	Action	• Existing Plan/Process	Timing
1	5. Built Environment	5I	DPW	Utilize flood claim (losses) mapping to target stormwater improvements.	• DPW has consulting engineers prepare our stormwater capital improvement program, prioritized based on many factors, including flood mapping.	On-going
1	5. Built Environment	5J	Sustainability Dept., DPW, Executive Office	Continue to prioritize energy efficiency and stormwater management in capital planning.	• Stormwater management and energy efficiency is included in the current 5-year Capital Improvement Plan. • Crystal Lake Watershed projects.	FY18-19 on
1	5. Built Environment	5K	Planning, ISD	Establish green building requirements.[viii]	• Zoning Redesign	FY19-20
1	5. Built Environment	5L	Planning	Ensure the zoning/ordinance review includes incentives to increase green landscaping, reflective pavements, and cool or green roofs to lessen heat island impacts.[ix]	• Zoning Redesign	FY19-20
1	5. Built Environment	5M	DPW, Planning	Encourage depaving and use of permeable concrete and asphalt. Use GIS to prioritize areas where depaving will address flooding. Note: Permeable asphalt and concrete are an example of stormwater management, but these techniques are not always applicable to certain developments, particularly in a suburban environment.	• DPW reviews all special permits, administrative site plans, and proposed subdivisions. DPW recommends minimum roadway widths based on the proposed use of the development. • Consider using Zoning Code or LID Ordinance as a tool.	FY20
1	5. Built Environment	5N	Sustainability	Encourage use of microgrids, district energy, and battery storage to keep critical facilities functioning in the event of power loss.[x]	• NNHS microgrid plan. • NWH microgrid plan.	FY19-20
1	5. Built Environment	5O	Facilities, Emergency Management*	Explore joint procurement opportunities with MAPC to purchase emergency generators and pumps.	• Hazard Mitigation Plan (**HMP**)	As needed
1	5. Built Environment	5R	Public Facilities	Prioritize retrofits and emergency planning for City facilities vulnerable to flooding and heat impacts.	• Capital Improvement Plan (**CIP**)	On-going
1	6. Economic	6A	Sustainability, Planning	Assist local businesses to develop emergency preparedness plans.[xi]	• Comprehensive Emergency Management Plan (**CEMP**)	On-going

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Priority	Realm	Ref. #	Lead(s)	Action	• Existing Plan/Process	Timing
1	8. Utilities	8A	Sustainability, DPW	Work with Eversource to address vulnerabilities and coordinate work, including vegetation management, to ensure protection of Newton assets.	• DPW meets monthly with Eversource (electrical distribution), National Grid (gas distribution), and Verizon (communication distribution), and discusses Capital improvements and repairs with these utility companies.	On-going
1	9. Utilities	9A	Emergency Management*	Review the City's emergency communications infrastructure to ensure redundancy during emergencies.	• Comprehensive Emergency Management Plan (**CEMP**)	On-going
2	2. Socio-Economic	2E	Planning	Target affordable housing sites and low-income residents for flood and heat protection upgrades.	• Capital Improvement Plan (**CIP**)	FY20
2	3. Public Health	3A	HHS	Increase the priority of Public Health education programs that address the illnesses and conditions forecast to be exacerbated by climate change.[xii] Create an outreach campaign focused on the impacts of extreme heat and how to manage it.[xiii]	• Capital Improvement Plan (**CIP**)	FY20
2	3. Public Health	3F	HHS	Explore strategies to identify and support vulnerable households most in need of air conditioning. Encourage use of efficient air conditioning	• Comprehensive Emergency Management Plan (**CEMP**)	FY20
2	4. Natural Resource	4E	DPW, Planning	Look for stream daylighting or naturalizing opportunities to restore natural habitat as part of stormwater or other infrastructure projects.[xiv]	• DPW reviews the possibility of daylighting streams and brooks where applicable. However, this is not always possible in a suburban environment, as many streams and brooks existing in culverts and pipes flow through private property.	As needed
2	5. Built Environment	5H	DPW, Planning	Highlight ways to improve conditions through intensive outreach to property owners and City Green Infrastructure and stormwater projects in a specific catchment area, as a pilot project. Locations could include a chronic flooding area or an important resource area such as the Crystal Lake watershed.	• DPW reviews all special permits, administrative site plans, and proposed subdivisions. DPW requires compliance with DEP and city of Newton stormwater management requirements	FY20
2	5. Built Environment	5Q	Planning, ISD	Publicize hot spot and potential flooding areas to current residents, businesses, and to permit applicants. Direct them to educational materials.	• Capital Improvement Plan (**CIP**)	FY22

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Priority	Realm	Ref. #	Lead(s)	Action	• Existing Plan/Process	Timing
2	5. Built Environment	5R	Planning, ISD	Consider other options to address flooding that takes place outside of FEMA flood zones. Options might include expanding wetlands protection jurisdiction, restricting, or requiring flood proofing for basements/no basements.	• Floodplain Ordinance	FY20
2	7. State-owned Infrastructure	7A	Sustainability, Executive Office	Establish relationships with state agency staff responsible for climate resilience. Communicate City concerns and priorities and stay abreast of agency planning (e.g. DCR and MWRA).	• --	On-going
3	1. Implementation, Outreach, and Planning	1B	All	City departments should review the projections and reevaluate climate vulnerabilities relevant to their assets and mission and identify potential and current activities that bolster resilience.	• Comprehensive Emergency Management Plan (**CEMP**) • Hazard Mitigation Plan (**HMP**)	FY18-19
3	1. Implementation, Outreach, and Planning	1C	Steering Committee	The Steering Committee, or a successor group, should continue to meet to establish priorities, incorporate new information, and monitor progress on climate goals. The City should expand the Steering Committee to include additional relevant departments, such as Senior Services, Inspectional Services, and Urban Forestry.	• Hazard Mitigation Plan (**HMP**) UPDATE	FY18-19 on
3	2. Socio-Economic	2A	Steering Committee, Emergency Management*	Identify gaps in services to vulnerable populations and prioritize: developing strategies to address gaps, coordinating with potential community partners to strengthen relations, and considering staff/Medical Reserve Corps involvement in emergency plans.	• --	On-going
3	5. Built Environment	5F	DPW	If/when the state releases precipitation projections, update design storm requirements so that development projects address rainfall projections for their planned lifespan.	• DPW adopted the Cornell University Northeast Regional Climate Center's 100-year design storm. DPW also refers to the National Oceanic and Atmospheric Administration Atlas 14.	As needed.
3	5. Built Environment	5P	ISD	Develop and distribute education and outreach materials on climate related technologies and practices including, for example, elevating utilities, preventing backflow, protecting basements, and weatherization. Consider targeting flooding areas outside of flood zones, including areas with older housing stock, and properties with chronic mold issues.[xv]	• Capital Improvement Plan	FY20

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[i] 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 provide training on use of the tool.

[ii] 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.

[iii] Massachusetts Stream Crossing Handbook: http://www.mass.gov/eea/docs/dfg/der/pdf/stream-crossings-handbook.pdf and State grant program for replacement of high ecological value culverts.

[iv] MAPC Low Impact Development Toolkit, ex. Town of Littleton Low Impact Development Manual.

[v] The University of New Hampshire Stormwater Center conducts research and offers technical training on innovative stormwater treatments.

[vi] The Town of Braintree floodplain by-law includes documented areas of flooding outside FEMA flood zones.

[vii] Possible project with MAPC.

[viii] The Boston Planning and Development Agency has a climate resiliency checklist that could be modified for use in Newton. LEED resources include climate resilience screening tools. Example: The City of Cambridge has developed sustainable building requirements.

[ix] Examples: Seattle Green Factor establishes green landscaping requirements for projects of a certain size. Sacramento Parking Lot Shading Requirement mitigates urban heat island impacts.

[x] The state's Advancing Commonwealth Energy Storage (ACES) program, and the Mass Clean Energy Center Community Micro grids program. Examples: The City of Northampton is building a microgrid to power its DPW, emergency shelter, and local hospital.

[xi] Example: The City of Cambridge and MAPC partnered in providing workshops to small business owners. The City of Cambridge maintains a Business Emergency Preparedness website: https://www.cambridgema.gov/CDD/econdev/resourcesforbusinesses/smallbusiness/emergencypreparednessforbusinesses

[xii] The Bureau of Environmental Health of the Massachusetts Department of Public Health has online 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.

[xiii] Center for Disease Control Extreme heat guidebook: https://www.cdc.gov/climateandhealth/pubs/extreme-heat-guidebook.pdf MAPC's Keep Cool App. MAPC's Keep Cool App.

[xiv] Example: The Muddy River project in Brookline and Boston has restored natural habitat and reduced flooding risk.

[xv] Example: Basement protection materials from Kingston, Ontario, Canada (https://utilitieskingston.com/Wastewater/BasementFlooding/Protect).

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