Water, Water, Everywhere:

The Increasing Threat of Stormwater Flooding in Greater Boston

MAPC

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Executive Summary

....How high's the water, mama?
Three feet high and risin'.
How high's the water, papa?
She said it's three feet and risin'...

— Johnny Cash, Five Feet High and Rising

In March 2010, Eastern Massachusetts was deluged with several historic rainfall events. A series of three storms dropped a foot and a half of rain over a 19-day period, representing more than a third of the normal annual rainfall. The resulting flooding affecting thousands of homes, shutting down roads, parts of the MBTA, and entire downtowns, while also causing raw sewage to be released into our waterways. In the storms' aftermath, President Obama granted a major disaster declaration for seven counties in Eastern and Central Massachusetts. More than 27,000 flood claims were ultimately paid out, running to $59 million in disaster assistance.

While sea level rise rightfully has garnered the attention of researchers, property owners, and municipal and state officials, stormwater flooding (sometimes referred to as inland or urban flooding) occurs when the volume of water on land exceeds the capacity of natural and built drainage systems and is devastating in its own right. Progress continues on developing models to assess the likely impacts of sea level rise, but no similar predictive tools exist for the widespread, and poorly understood, phenomenon of stormwater flooding. Unlike their coastal counterparts, inland property owners do not have access to a predictive flooding model, nor do the Federal Emergency Management Agency's (FEMA) flood maps capture much of the risk of stormwater flooding. With climate change increasing the frequency, intensity, and impacts of precipitation events in New England, greater understanding and more effective responses to stormwater flooding are imperative. For example, the number of intense two-day storms increased by 74% from 1901 to 2016, and the heaviest rain events of the year now drop 55% more precipitation than the rainiest days of the midcentury. An additional 40% increase is projected by the end of the century.

As part of the Metropolitan Area Planning Council's (MAPC) hazard mitigation planning efforts, we entered into an unprecedented data sharing agreement with FEMA and the Massachusetts Emergency Management Agency (MEMA) to access disaster claims records from the March 2010 storm. Due to federal privacy rules, the locational data of where the claims originated must remain confidential. These data, however, allowed a first-of-its kind analysis of stormwater flooding in Eastern Massachusetts.

Major Takeaways

The flooding caused by the March 2010 storms was widespread and distributed throughout the region. Unsurprisingly, areas that received higher rainfall totals tended to experience greater impacts.

However, we also learned that FEMA Flood Maps are poorly predictive of where stormwater flooding is most likely to occur. Ninety-six (96) percent of the disaster claims arose in areas outside of the FEMA Special Flood Hazard Areas (SFHAs), also known as the 1% chance flood zones. As the vast majority of claims were outside the SFHA, most residents were unaware of their risk. As a result, damages were much greater than they otherwise might have been. Of the flood claims granted, 87% were for flooding levels of less than one foot and 71% were for flood heights of less than six inches, indicating that even moderate levels of flooding can cause significant, widespread damage to properties.

A major part of our analysis looked at flooding indicators in relation to the location of flood claims. Indicators included presence within the FEMA SFHA, proximity to water and wetlands, slopes, soils, and the year a home was built. We found there is no factor that can easily predict susceptibility to stormwater flooding, though a number of indicators were "over-represented" in the flood claims. These included homes in the 1% (100-year) and .2% (500-year) chance flood zones, homes built between 1940 and 1980, those sited on relatively flat elevations or on sandy soils, and proximity to water and wetlands. Another potential factor is homes built on filled wetlands. Homes that were less likely to file claims were those built before 1940 and those on steeper slopes.

MAPC also explored the relationship between flood claims, flood zones, and equity factors like race, income, language, and places with high concentrations of renters. Our analysis did not find a relationship (e.g., flood claims were not any more likely to be found in low-income areas). There are a number of possible explanations for this, such as the widespread affected geography did not overly impact any particular populations, and low-income households may have been less likely to file disaster claims. Despite not finding a conclusive correlation, recovery for low-income households is likely to be more difficult. More research is needed to explore flooding risk for environmental justice (EJ) populations.

To better understand the human cost of stormwater flooding, we interviewed home-owners in Woburn who experienced flooding. Woburn was significantly impacted by the March 2010 storms and basements throughout the city flooded as a result. Through the interviews, we documented the financial and emotional toll that too much water in the wrong place exacts on homeowners. A significant portion reported moderate to severe anxiety in responding to their flooded homes. Unlike prospective car buyers who have access to information about a vehicle's accident history, there is no similar disclosure requirement for properties with flood histories. In fact, disaster claims are considered confidential under federal privacy rules, benefiting the existing homeowner when it comes time to sell, but clearly disadvantaging a prospective buyer.

MAPC also investigated the potential relationship between filled wetlands and stormwater flooding using a historical 1892 map of wetlands in Newton and comparing the locations of flood claims. Many of those historical wetlands have been filled or drained for development over the last century, and some clusters of 2010 flood claims seem to be located on sites that were mapped as wetlands 100 years ago but have since been filled. However, this is considered a preliminary finding due to data limitations of the historical wetlands map. MAPC is continuing to conduct research to evaluate the connection between historic wetlands and stormwater flooding in a more robust way.

We recommend the following actionable recommendations for federal, state, and local measures:

- Enable more widespread access to flood claims data. Federal privacy requirements privilege the privacy rights of current property owners over the needs of municipalities to identify and respond to flood risk, and over the rights of the public to be informed of risk.
- Require flood history disclosure. Massachusetts is one of only 15 states that has no disclosure requirements for potential home buyers. Renters also need to be aware of risks to their properties.
- Finance property retrofits and repairs. MEMA should apply to the federal Storm Act that provides funding for hazard mitigation revolving loan funds. The state and municipalities can also set up programs that provide financial and technical assistance to property owners at risk of flooding.
- Provide more funding for stormwater management. Repairs to aging infrastructure and additional green and gray infrastructure is required to meet the increasing flood risks we face. This is especially important in highly urban locations that are home to environmental justice populations.
- Strengthen development and building regulations. Updated flood overlay districts and stormwater regulations, and common-sense building code improvements, like raising utilities by at least six inches, can help limit the disruption and financial impacts caused by stormwater flooding.

- Adopt innovative insurance strategies to assist low-income households. Many insurance programs are not affordable for low-income households and are slow to reimburse costs. Some places have started providing insurance funds up-front, addressing the gap of not having access to cash immediately after a flooding event.
- Continue to investigate the causes and impacts of stormwater flooding. Our analysis points to the need for additional research into groundwater and wetlands dynamics, as well as impacts on Environmental Justice populations. Ongoing study of flooding events, and interviews with affected residents, are needed to improve our capacity to reduce future flooding.

Through our policy and legislative work, MAPC will pursue the adoption of these mitigation measures, which would benefit not only our region, but also the entire state. These are critical actions needed to achieve the vision for an equitable and resilient region as called for in MetroCommon 2050, our long-term regional plan.

Introduction

In March 2010, three rainstorms of historic proportions deluged Eastern Massachusetts in rapid succession. In the seventeen days from March 13 to March 31, 18 inches of rainfall was recorded at the Blue Hill Observatory in Milton, MA. It was the rainiest month ever recorded at the observatory, with almost 40% of Boston's typical annual rainfall occurring in just seven-teen days. Throughout Eastern Massachusetts, this precipitation fell on land primed for flooding — existing impervious surfaces, such as rooftops, parking lots, and roads, as well as saturated soils that were functionally impervious due to recent snow melt — leading to immediate and severe impacts.

Table 1: Recorded precipitation at Blue Hills Observatory

Dates	**Recorded precipitation at Blue Hills Observatory**
March 13 – 15	9.4 inches
March 22 – 24	2.7 inches
March 26	0.3 inches
March 29 – 31	5.6 inches
Total	**18.0 inches**

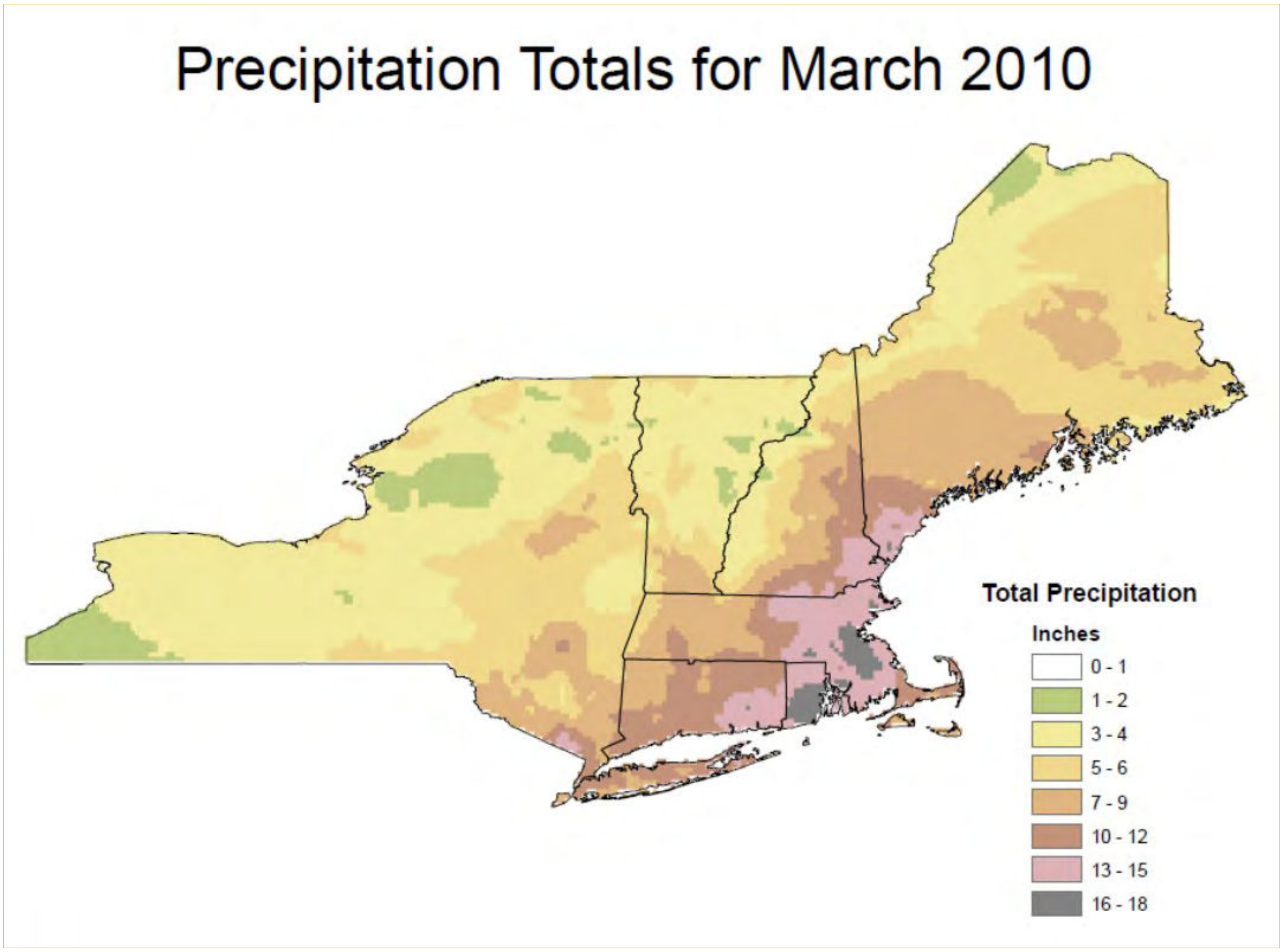

Figure 1: NWS Taunton, Provisional rainfall totals for March 2010[1]

As a result of the heavy rain and substantial runoff, flooding and flood damage was widespread across the region: MBTA train tracks were washed out and service was interrupted in multiple locations; major roadways were flooded and closed; raw sewage was discharged into rivers and Boston Harbor through combined sewer overflows; the Norwood airport was flooded and closed; and neighborhoods such as Downtown Peabody were under as much as seven feet of water. Flooding of homes and basements was "rampant" according to the National Weather Service. In Newton, more than 700 homes and 25 city buildings were damaged. Large apartment buildings were evacuated in Melrose and Quincy, and residents across the region reported destroyed water heaters, boilers, appliances, bedrooms, and entertainment centers.[2] For these reasons and more, on March 29, President Obama issued a major disaster declaration for Bristol, Essex, Middlesex, Norfolk, Plymouth, Suffolk, and Worcester counties.

1 Monthly Report of Hydrologic Conditions, March 2010, National Weather Service, Taunton MA

2 Boston Globe, Tuesday, March 16, "A deluge of misery across the region" Peter Schworm, Noah Bierman

Forest Street, Winchester, Boston.com

Furnace Avenue, Quincy, Boston.com

Chris Bassolino, Watertown

Woburn, Boston.com

Figure 2: Images of flooding from March 2010. Clockwise from upper left: Forest Street in Winchester (Boston.com), Furnace Avenue in Quincy (Boston.com), Basement in Watertown (Chris Bassolino), Basement in Woburn (Boston.com)

In the wake of the storms, property owners that held flood insurance were able to file claims and receive funds for repairs covered by this insurance. In total, 984 residents of the MAPC region received just under $10 million in flood insurance reimbursements.

The March 29 federal disaster declaration triggered the launch of the Federal Emergency Management Agency's (FEMA's) Individual Assistance Program through which residential property owners, businesses, and institutions without flood insurance were eligible to apply for relief to pay for storm-related expenditures and repairs. Across the seven counties, more than 27,000 individual claims were approved for nearly $59 million in disaster assistance, while reimbursements to state and local governments totaled $25 million. In the MAPC region, 18,400 claims were approved for $30 million dollars in disaster assistance.

Unfortunately, storms of such historic (and damaging) proportions are projected to become more common in the future. Average annual rain and extreme events are projected to increase. Annual precipitation in Eastern Massachusetts was already 10 to 15% higher in 1986–2015 than it was in the early 20th century (1901–1960).[3] The intensity of individual rain events has increased as well. The number of intense two-day storms increased by 74% from 1901 to 2016, and the heaviest rain events of the year now drop 55% more precipitation than the rainiest days of the midcentury, and an additional 40% increase is projected by the end of the century.[4]

Scientists have high confidence that the frequency and intensity of large rain events will continue to increase during the 21st century.[5] For the northern U.S., winter and spring months are likely to see most of this increase, and a larger share of precipitation is likely to fall as rain instead of snow due to warming temperatures.[6] As a result, the coming decades will bring more extreme weather events such as those of March 2010 when significant rainfall amounts, falling in the winter as rain rather than snow on frozen or saturated ground and while vegetation that could slow and retain runoff is still dormant.

Furthermore, changing weather patterns may also result in different—and unexpected—impacts. Stormwater flooding is poorly represented by existing FEMA flood insurance rate maps (FIRMs). A key finding of this report is that more than 90% of the March 2010 claims were for properties outside FEMA Special Flood Hazard Areas (SFHAs). SFHAs are 1% chance flood zones where properties are subject to Massachusetts Building Code flood compliant regulations, and property owners with federally backed mortgages must purchase flood insurance.[7]

MAPC research and homeowner interviews found that stormwater flooding takes a significant financial, physical, and emotional toll. Unfortunately, households don't have relevant information about the potential risk of stormwater flooding at a potential home; there is not a robust toolkit of policies and interventions that could reduce the impact of stormwater flooding. In order to better understand the impact of this storm and identify strategies for mitigating future damage, MAPC sought more information about the properties that had been damaged and the nature of that damage.

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3 Fourth National Climate Assessment, Volume 1, U.S Global Change Research Program, p. 209 CSSR2017_FullReport.pdf (globalchange.gov)

4 ibid, p. 212

5 ibid, page 207

6 ibid, page 207

7 Since these claims are considered confidential information, the database is stored on a secure server at MAPC accessible only to a limited number of vetted staff members; and our maps and other data products do not provide the precise location of any claim.

Through agreement with FEMA and the Massachusetts Emergency Management Agency (MEMA), MAPC received a dataset with information about 18,400 approved Individual Assistance Program claims (referred to as "Disaster Assistance" claims). We also requested and received data about 900 claims filed through the federal flood insurance program ("Flood Insurance" claims). Both data sources include the address of the property, the amount of the claim, and other information.

A key aspect of preparing for future flooding is being able to predict what locations will be most susceptible. Massachusetts is fortunate to have resources predicting frequency, extent, and severity of future coastal flooding, but there is no comprehensive modeling study available to our communities that predict locations that may be vulnerable to the type of flooding that occurred in March 2010. Stormwater flooding, often also described as urban or inland flooding, occurs when the volume runoff from precipitation exceeds the capacity of natural and built drainage systems. It is characterized by moderate to shallow standing water in low-lying areas and water flowing into below-ground spaces such as basements, garages, and subsurface infrastructure including subway stations and underpasses. While March 2010 captured headlines, MAPC's hazard planning work indicates that damaging stormwater flooding happens regularly throughout our region. Stormwater flooding will increase as a result of more frequent and intense precipitation events associated with climate change.

Fortunately, the flood claims resulting from the March 2010 storms and disaster declaration leave us a trail that we can use to better understand stormwater flooding. Through a partnership with MEMA for the purposes of hazard mitigation planning, MAPC has been granted access to the 18,400 March 2010 disaster claim records. In the following report, we use these records to answer the following questions:

- How many households were impacted? What portions of the region were most impacted?
- Do the patterns of flood claims correspond with FEMA Flood Insurance Rate Maps (FIRMS) high hazard areas?
- Are there physical or environmental factors that help explain the patterns of stormwater flooding and corresponding claims?

Our analysis found that the vast majority of damage took place outside FEMA SFHAs, and the widespread nature of the flooding means that it is hard to identify specific physical predictors of where flooding is likely. Based on this analysis and lessons learned from local planning work, MAPC developed recommendations for policy measures that could improve our understanding of stormwater flooding, reduce the incidence of such flooding in the future, and improve the adaptive capacity of residents, businesses, and governments.

Data and Methods Overview

Flood Claims Data

MAPC combined two data sources to create the dataset for this analysis. FEMA and MEMA provided information about 18,480 unique claims made under Disaster Declaration 1895 from March 2010. The Massachusetts Department of Conservation and Recreation provided 915 unique claims filed with the National Flood Insurance Program (NFIP) in March and April 2010, covering 100 MAPC member municipalities.[8] In total, we analyzed 19,395 approved and unique disaster assistance and flood insurance claims. The confirmed flood locations identified through these data sources are not a comprehensive list of properties in the MAPC region that experienced flooding during this event (or which would experience flooding in a similar event). But given the number of observations, distribution across the region, and strong motivation for property owners to file claims, we feel it is safe to assume they are a representative sample of stormwater flooding locations.

Disaster claims and insurance claims were geocoded to a point location (latitude and longitude) based on their address and were then combined into a single spatial dataset (referred to as "March 2010 Flood Claims"), as shown in Figure 3. That information was then combined with the Massachusetts Land Parcel Database, which contains data about building characteristics (including a count of housing units on each parcel), as well as MassGIS data on specific building locations. Only claims on parcels with a residential land use code (as assigned by the local assessor) were used in the analysis. A complementary dataset of all residential parcels that did not have a Disaster Assistance or Flood Insurance claim was also developed for comparison. All address and location information about flood claims are stored on a secure MAPC server with limited staff access. (The locations mapped throughout the main body of this report are shown with enlarged location markers and at slightly perturbed locations to comply with federal privacy requirements.)

8 Flood insurance claims records for the Town of Reading were not available.

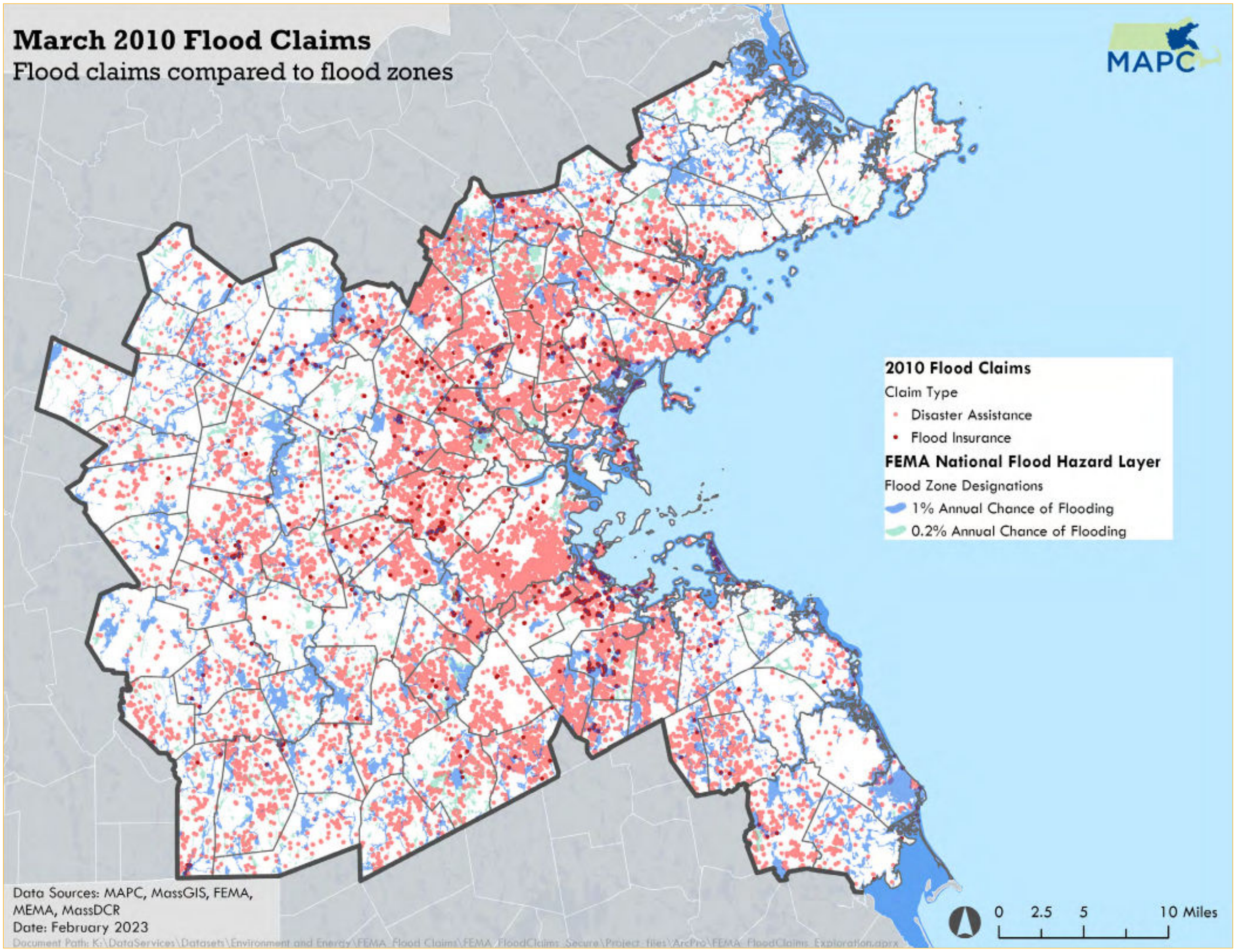

Figure 3: Geocoded disaster assistance and flood insurance claims mapped with FEMA's National Flood Hazard Layer

Once claims had been joined to parcel and building information, we aggregated the data to 2010 census block groups. Block groups with fewer than 50 households were excluded. We summed up the number of housing units on parcels with a claim ("affected units") as well as the total number of housing units recorded for all parcels in the block group. We then calculated the Housing Unit Claim Rate, which is the number of affected units as a percent of all parcel housing units in the census block group. This calculation assumes that if flood damage occurred on a given parcel, all residential units on the parcel were impacted to some extent.

Property and Incident Characteristics

We analyzed the following factors associated with the combined flood claims/parcel dataset (Table 2):

Table 2

Feature	Categories
1: Flooding indicator	Flood claim filed for building
	No flood claim filed for building
2: Depth of flooding (Disaster claims only)	2 inches or less of flooding
	Between 2 and 4 inches of flooding
	Between 4 and 6 inches of flooding
	Between 6 and 8 inches of flooding
	Between 8 and 10 inches of flooding
	Between 10 and 12 inches of flooding
	Between 1 and 2 feet of flooding
	Greater than 2 feet of flooding
3: Damage estimate	Damage estimate for flood claim ($)
4: Amount compensated	Amount compensated for flood claim ($)
5: "Year built" record of tax parcel record at building (MassGIS)	Built pre-1940
	Built between 1940 and 1980
	Built after 1980

Factors Related to Flooding

We cross-referenced the dataset of residential buildings in MAPC with several other datasets often related to flooding and added this information to each parcel/building record (both those with a flood claim and those without.)

Proximity to flood zones, wetlands, and hydrologic features

For each structure in the MAPC region, we calculated distance from the mapped structure to nearest current FEMA flood zones, MassDEP wetlands, and USGS hydrologic features. We include the following categories (Table 3):

Table 3: Proximity to flood zones, wetlands, and hydrologic features

Feature	Categories
1: Special Flood Hazard Area (SFHA) — 1% annual chance of flooding (FEMA zones A, AE, AH, AO, or V)	In 1% flood zone
	Within 100 ft of 1% flood zone
	Between 100 and 200 ft of 1% flood zone
	Greater than 200 feet of 1% flood zone
2: 0.2% annual chance of flooding (FEMA zone shaded X)	In 0.2% flood zone
	Within 100 ft of 0.2% flood zone
	Between 100 and 200 ft of 0.2% flood zone
	Greater than 200 feet of 0.2% flood zone
3: Minimal flood hazard zone ('unshaded X zone') (FEMA)	In minimal flood hazard zone
4: MassDEP wetlands	In wetland
	Within 100 ft of wetland
	Between 100 and 200 ft of wetland
	Greater than 200 feet of wetland
5: Hydrologic features — ponds, lakes, reservoirs, rivers, and streams (MassDEP)	In hydrologic feature
	Within 100 ft of hydrologic feature
	Between 100 and 200 ft of hydrologic feature
	Greater than 200 feet of hydrologic feature

Soil and slope conditions

We examined other conditions that often are associated with poor drainage (Table 4). This includes soil hydrologic group, which is based on infiltration and runoff potential, slope, and USDA Basement Suitability Class, which encompasses slope, flooding frequency, depth to bedrock, and depth to water table.

Table 4: Soil and Slope conditions

Feature	Categories
6: Soil hydrologic group class at building location (National Resources Conservation Service)	A (high infiltration, low runoff potential)
	B (moderate infiltration)
	C (slow infiltration rate)
	D (very slow infiltration rate)
7: Slope Code (MassGIS)	1 – negligible incline
	2 – 5-10% incline
	3 – 10-15% incline
	4 – 15-20% incline
	5 - 20-25% incline
	6 – More than 25% incline

Structure-Level Analysis: Physical/spatial characteristics of flood claims

Through a series of crosstabs and tests of statistical significance, we compared characteristics of buildings with flood claims to all buildings in the region. We sought to understand what characteristics might be disproportionately present in properties with flood claims as compared to properties without flood claims. In other words, we were trying to answer the question: “Is there a significant difference between buildings with flood claims and those without?” For tests of statistical significance, we used a p-level of .05.

Limitations

This list of flood indicators does not encompass all factors that could possibly be related to stormwater flooding; instead, they represent factors for which there is public data that can be easily accessed and analyzed. For each flood indicator, the metric associated with a building represents characteristics of that indicator on the building's parcel or at its roofprint. We therefore do not analyze how nearby characteristics might impact conditions on a property. For instance, a concentration of impervious surfaces draining toward a parcel could impact flooding on the parcel, but that is not captured in this analysis.

Woburn Flooding Analysis

In addition to a regionwide quantitative analysis conducted with the factors above, the findings and policy recommendations in this report draw from work MAPC conducted with City of Woburn officials in 2021 to investigate the extent and causes of stormwater flooding. Woburn was one of the more heavily impacted MAPC communities in March 2010, with the number of claims and percentage of residential properties impacted both in the top 20% of the region. Nearly 400 residents, representing almost 4% of residential properties, filed disaster and flood insurance claims. Through outreach to residents, review of March 2010 assistance calls to the fire department, and city records of sump pump locations, we documented an additional 165 residential flooding locations. The project also included phone interviews with 44 residents who were willing to be interviewed about their flooding experiences.

Findings

Assessing Damage

Distribution of claims

We estimate that 1.8% of residential structures in the MAPC region had flood claims filed based on damages experienced in March 2010. In ten municipalities, flooding affected at least 4.9% of residential structures, and in some cases up to 6.5%. The most affected municipalities were in two clusters: one south of Boston (Stoughton through Milton) and one north of Boston (Bedford to Lynnfield). These clusters correspond with the areas that experienced the heaviest rainfall during March 2010. The ten municipalities with the greatest percentage of claims per structure are listed in Table 5.

Table 5: Municipalities with greatest percentage of claims per structure

Municipality	**Total number of claims**	**Percent of structures with flood claims**
Randolph	551	6.5%
Sharon	358	6.3%
North Reading	281	6.1%
Milton	467	5.8%
Stoughton	447	5.8%
Braintree	587	5.7%
Wilmington	415	5.6%
Bedford	222	5.6%
Burlington	351	5.0%
Lynnfield	195	4.9%

Figure 4 shows the prevalence of claims at the census block group level. The value for each block group is calculated as the number of claims divided by the number of residential structures in that block group. The map shows that claims were not evenly distributed across the region: in some block groups (the lightest shade), claims were filed for fewer than 1% of residential structures; whereas in the darkest block groups, more than one in ten residential structures had a claim filed.

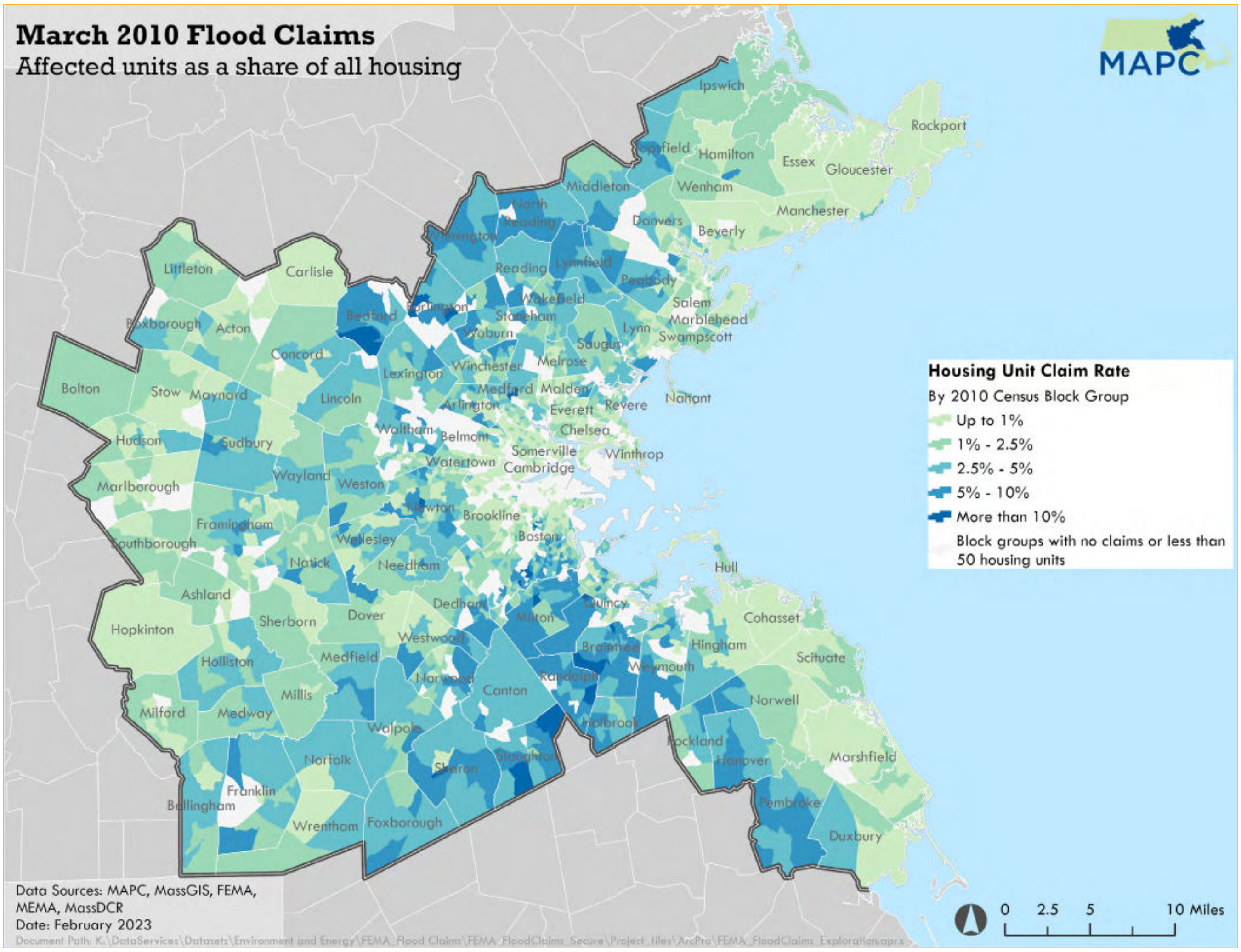

Figure 4: Housing impact rate (number of claims per 100 structures)

One reason for the spatial variation in claims is that precipitation during the storms was not even across the region. Figure 5 shows the distribution of rainfall across the region during March 2010, which roughly corresponds to the pattern seen in the Housing Unit Claim Rate.

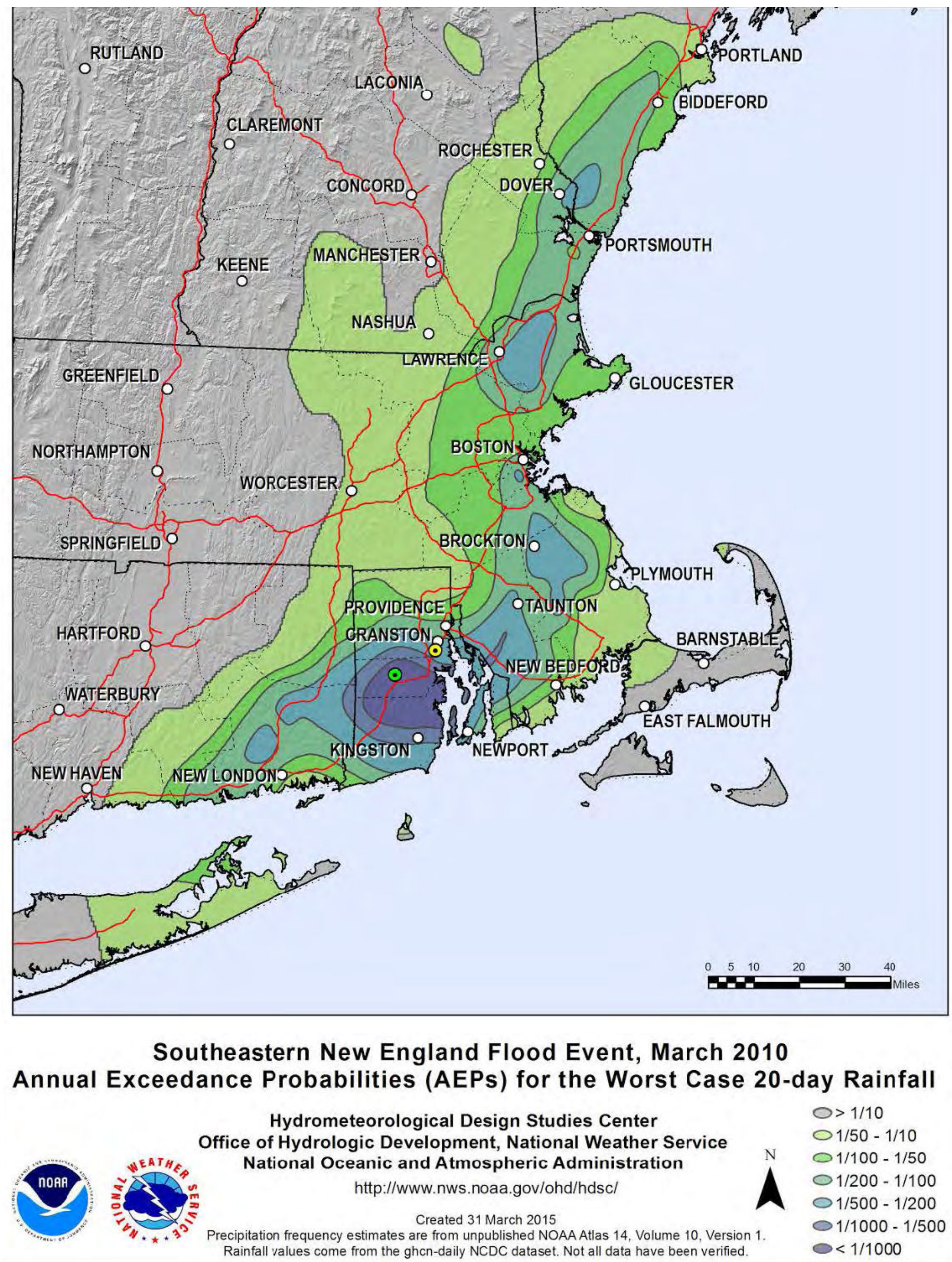

Figure 5: Patterns of rainfall from March 2020. Darker colors represent areas where there was more rainfall.

Depth of Flooding (Disaster Claims Only)

As noted above, the data on disaster assistance claims include a field reporting the depth of flooding in the affected structure. We analyzed that subset of flood claims (Figure 6) and found that 87% of disaster assistance claims were for flooding depths of less than one foot. Narrowing further, 71% of claims were for flooding of six inches or less. This suggests that in future flooding scenarios, damage to utilities or other structural assets might be reduced considerably if infrastructure was raised six to 12 inches off the lowest floor.

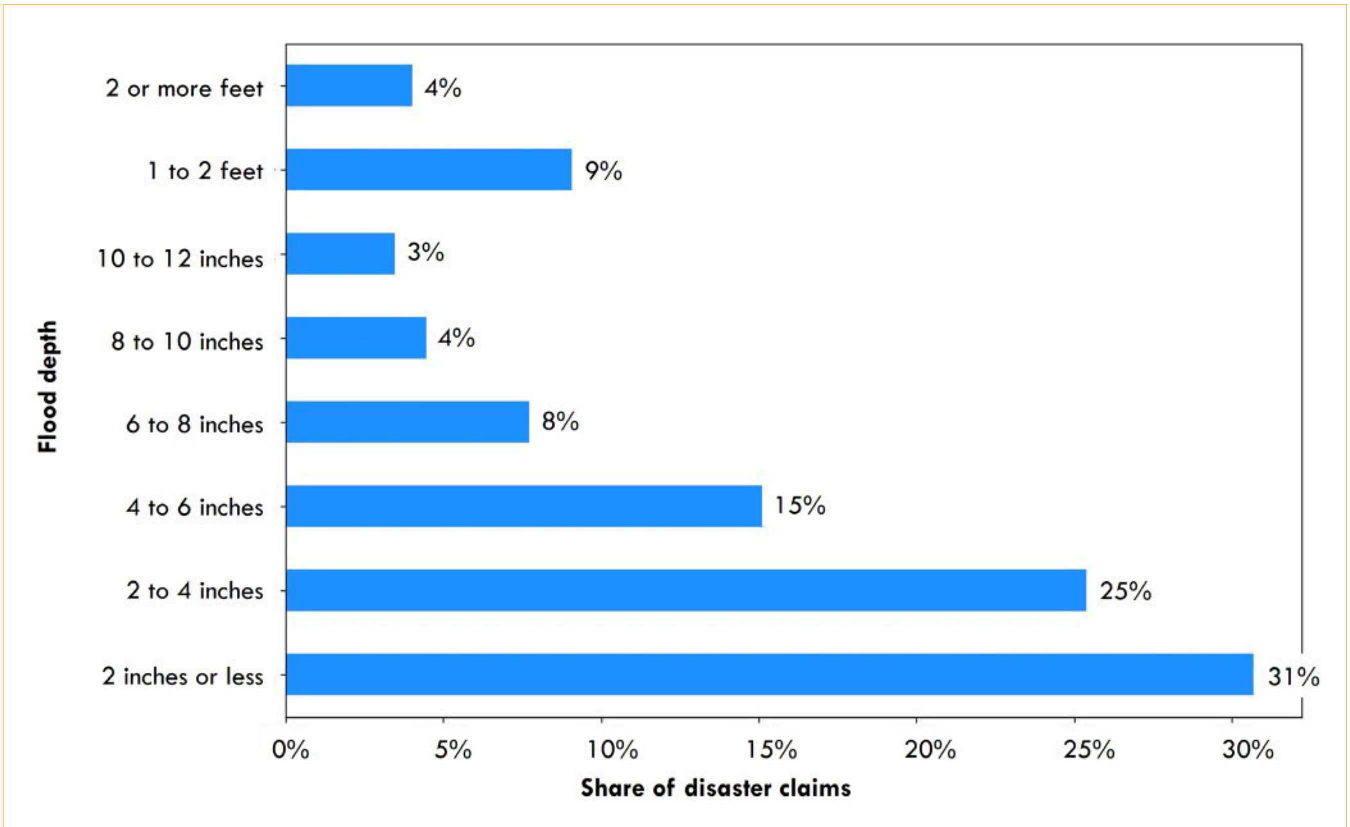

Figure 6: Distribution of reported flooding depths, disaster assistance claims

Assistance Provided

In total, residential properties in the MAPC region that filed disaster assistance claims experienced an estimated $34 million in damages initially identified as potentially eligible for reimbursement. The average damage estimate per claim was $1,942, with a maximum damage estimate of $87,626. The average amount awarded per claim was $1,762, with a maximum award of $29,900. Overall, more than $30 million was awarded to residential property owners in the MAPC region.

The municipalities with the highest damage estimate per claim are listed in Table 6 and include Middleton ($3,324 per claim), Wenham ($3,324 per claim), and Carlisle ($3,294 per claim).

Table 6

Municipality	Number of disaster assistance claims	Average damage estimate per claim
Middleton	93	$3,324
Wenham	16	$3,324
Carlisle	15	$3,294
Quincy	839	$3,263
Essex	9	$3,254
Wilmington	415	$2,889
Arlington	390	$2,864
Littleton	48	$2,859
Hanover	208	$2,807
Weston	104	$2,690

Of the 915 flood insurance claims filed, the NFIP approved payment for 784 claims. The average paid claim was $10,526, with a maximum payment of $500,000. Ten percent of the paid flood insurance claims exceeded the $29,900 cap on disaster assistance claims; the average payment for these claims was $93,039.

Flood insurance and disaster assistance cap payments and limit reimbursement for damages based on the requirements of the programs. They do not pay for all the costs associated with flood damage. While it may be that properties with flood insurance experienced more damage than those without, the dramatic difference in reimbursement between the two programs highlights the degree to which paid disaster claims likely fell short of actual flood damage incurred.

Flood Zones Claim Rate

MAPC overlaid the flood claims data and mapped flood hazard areas to determine how much of the damage occurred in areas identified by FEMA as susceptible to flooding. Specifically, we looked at the 1% and 0.2% annual chance flood zones. We calculated — at the block group level — the share of flood claims on properties within these flood zones; this statistic is referred to as the Flood Zone Claims Rate, and ranges from 0% to 100%, with an average rate of 7.3%. Of the 2,000 census block groups in the MAPC region with recorded flood claims, 81% had a Flood Zone Claims Rate of 0%, meaning none of the claims were made for properties in the 1% and 0.2% annual chance flood zones. Figure 7 shows the Flood Zone Claims Rate for each block group analyzed in this study.

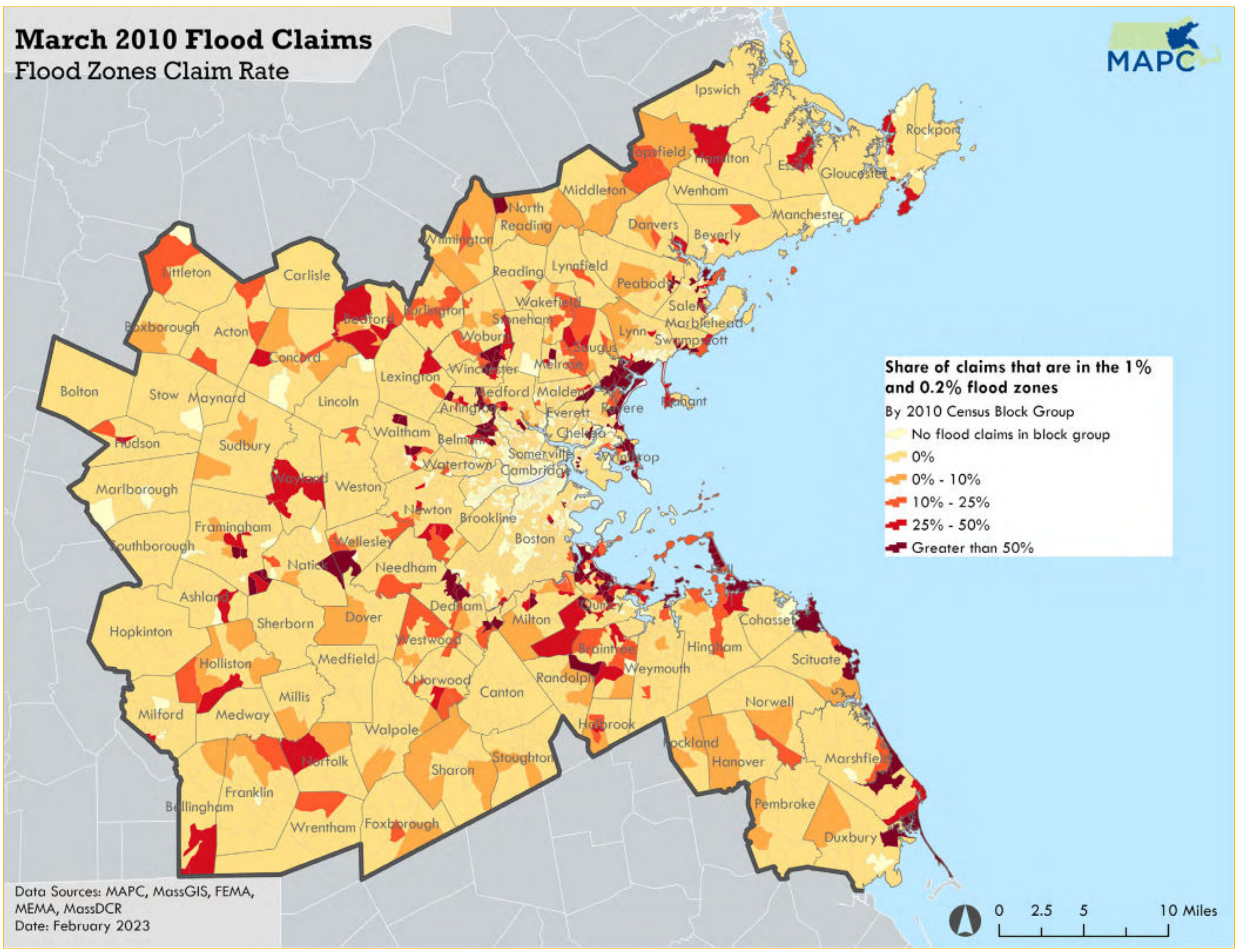

Figure 7: Flood Zones Claim Rate by 2010 census block group

Regionwide, we found that 93% of disaster assistance claims and 40% of flood insurance claims were located outside the 1% and .2% flood zones. As FEMA flood maps are a primary source of flood risk information, this analysis raises significant concerns about the region's current understanding of, and ability to prepare for, stormwater flooding.

There are a variety of reasons why existing flood maps might not fully represent the risk of stormwater flooding. FEMA flood mapping is a nationwide effort that is focused on riverine and coastal flooding. It covers only areas with expected flood depths of greater than one foot, typically accounts for drainage areas of larger than one square mile, and relies on nationally available datasets and standardized methods to assess risk.

Meanwhile, stormwater flooding tends to be highly variable and is likely the result of many highly localized factors, such as: wetlands and filled wetlands; impervious surfaces; stormwater infrastructure failures; depth to groundwater; slopes and depressions; flat areas with poor drainage; soil conditions; and intensity of precipitation event. For a variety of data availability and methodological reasons, FEMA flood maps do not account for these factors.

In order to assess whether the prevalence of flood claims is correlated with mapped flood hazards, we calculated a Flood Zone Claim Rate that represents a normalized measure of how many units in the block group are in mapped 1% and 0.2% flood hazard areas.

Flooding Indicators

To explore what factors may be useful predictors of stormwater flooding, we assessed what building or environmental factors were over- or under-represented among buildings with flood claims. Indicators include presence in 0.2% and 1% annual chance flood zones, distance to water bodies and wetlands, slope, hydrology, and year the structure was built. We compared the flood claim rate for buildings with a given characteristic to the average flood claim rate for the region (1.85%) to determine what types/locations of buildings were associated with a higher incidence of flooding. Figure 8 summarizes findings from this analysis.

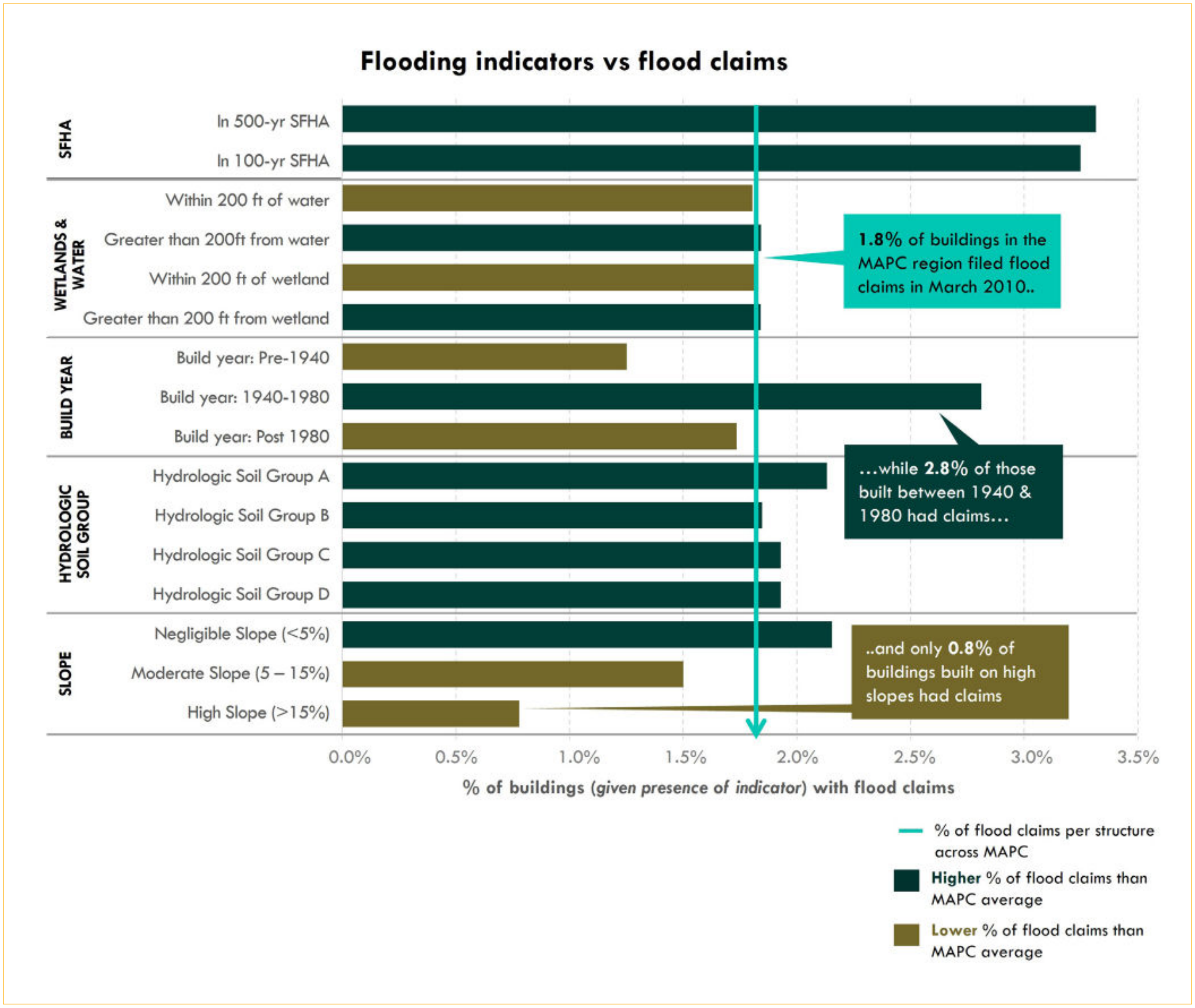

Figure 8: Flooding Indicators vs Flood Claims.

The regional flood claim rate is shown as a bright teal line in the chart. Property indicators associated with a lower claim rate are shown in gold; indicators with a claim rate above 1.85% are shown in dark teal. Not surprisingly, the factor associated with the highest rate of flood claims was presence in a mapped flood hazard area. Properties in an SFHA (either 1% or 0.2%) had a claim rate that was twice the regional average.

Another factor associated with above-average claim rates is the age of the building. Specifically, about 2.8% of residential buildings constructed between 1940 and 1980 suffered damage and made a claim, versus only 1.7% of buildings built after 1980 and 1.3% of buildings built before 1940.

Other factors associated with above average flood claim rates include: flat/low slope topography (2.15%); and Group A soils with high infiltration and low runoff potential (2.13%). Properties least likely to have a flood claim are those built on steep slopes (0.8% to 1.5%), and properties built before 1940 (1.3%).

None of these are determinative, and the vast majority of properties with any given characteristic did not report damage. Yet they do start to paint a picture of stormwater flooding patterns. Some are intuitive (stormwater flooding is more likely in flat areas), but others provide new insight. For example, the claim rate was similar in the 1% and 0.2% flood hazard areas, suggesting that mapped flood probabilities are not very predictive of how many properties may be damaged by stormwater flooding during major storms.

Notably, pre-1940 buildings tend to have lower claim rates than those built later. Residential buildings of this era tend to be in urbanized areas with centralized stormwater infrastructure or in and around historical town and village centers. Additionally, land was more plentiful during this time, so marginal locations like wetlands were easier to avoid. During the mid-20th Century, the region saw major suburban expansion and widespread development of moderate density single family subdivisions with few environmental regulations. As a result, many new homes were built on filled wetlands or adjacent to poorly drained areas. The adoption of the Clean Water Act and Wetlands Protection Act, growth of local wetland regulations, strengthening of septic system regulations, and a pivot to "growth management" planning (e.g., residential downzoning) in the 1980s may have all contributed to a reduction in the number of new homes built on or near wetlands and poorly drained areas in the latter part of the century and the first decade of the 2000s. In addition, the region's earliest FEMA flood maps and flood resilient building codes were adopted in the mid to late 1970's, perhaps improving the safety of structures and also discouraging development in flood prone locations. This insight is important because it suggests certain building typologies may tend to be more exposed to stormwater flood risk, offering the possibility for scalable engineering solutions suitable to many buildings of similar age and type.

The overall impact of a given factor is also influenced by the prevalence of that factor among all residential buildings. For example, though properties in the 1% flood zone are twice as likely to have filed a flood claim, they comprise only 4.5% of properties in the region, and therefore only 9% of total claims. Figure 8 depicts the share of all residential properties and share of flood claim properties with each given characteristic.

This chart shows that at least six in ten properties with a claim were in a relatively flat area, within 200 feet of an existing wetland, and/or on sandy soils with a high infiltration rate. But then again — so are the majority residential properties. In contrast, the biggest disparity is between the share of residential structures that were built mid-century and the share of claims filed for these properties. Only 33% of residential buildings were constructed between 1940 – 1980, but they constitute 51% of all flood claims.

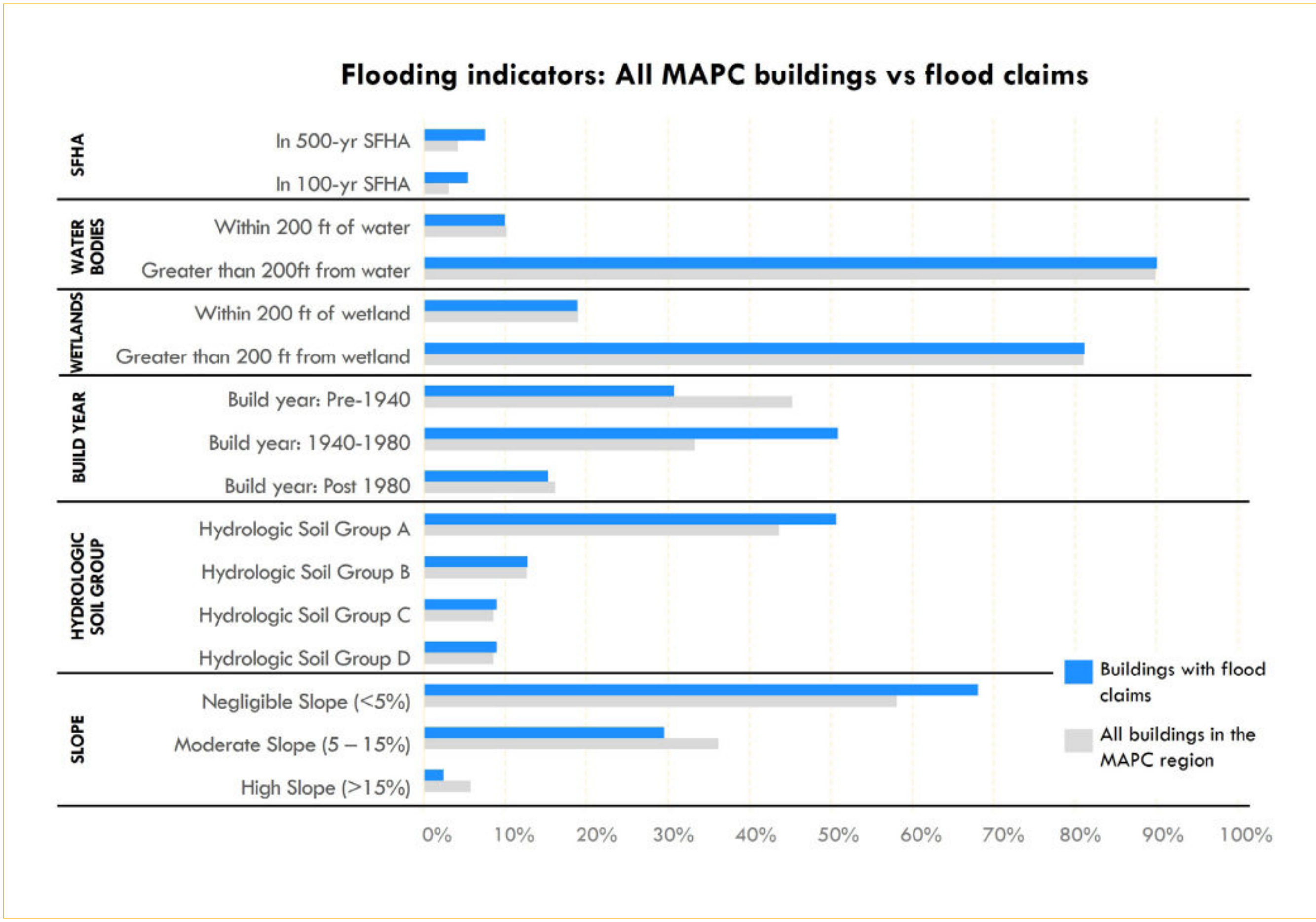

Figure 9: Broken down by flooding indicators, percentage of (blue) all residential properties with confirmed flooding and (grey) all residential properties in the region. Indicators where the blue line is longer than the grey line indicate that these characteristics are disproportionately seen at buildings with flood claims.

Flood Zones

A key finding from this analysis is that 91% of all flood claims are for structures located outside of 1% and 0.2% annual chance FEMA flood zones. Comparatively, 97% of structures in the MAPC region are located outside of those zones. In other words, the problem of stormwater flooding is widespread across the region and not limited to mapped flood zones. This implies a need for understanding other factors that may be associated with stormwater flooding.

Build Year

As noted above, the incidence of flooding varies by the age of structure, with those built between 1940 and 1980 more likely to have a flood claim than buildings built earlier or later. Table 7 provides key statistics by building age.

Table 7: Residential property proximity to wetland and rate confirmed flooding by building era.

Era	Percent of all residential properties built during era	Percent of buildings with flood claims built during era	Flood Claim Rate for properties built during era	Percent of properties from era within 200 ft of wetland
Before 1940	44%	30%	1.3%	3.8%
1940 – 1980	33%	51%	2.8%	8.6%
1980 – 2010	16%	15%	1.7%	11.1%

To explore the hypothesis that buildings constructed after 1940 were more likely to be located on flood-prone sites, we also compared the distribution of location within 200 feet of a MassDEP wetland by era (Figure 10). Compared to buildings constructed between 1940 and 1980 (77.3% of all buildings in MAPC) and after 1980 (70.1%), buildings constructed before 1940 are much more likely (88.1%) to be located greater than 200 feet from wetlands.

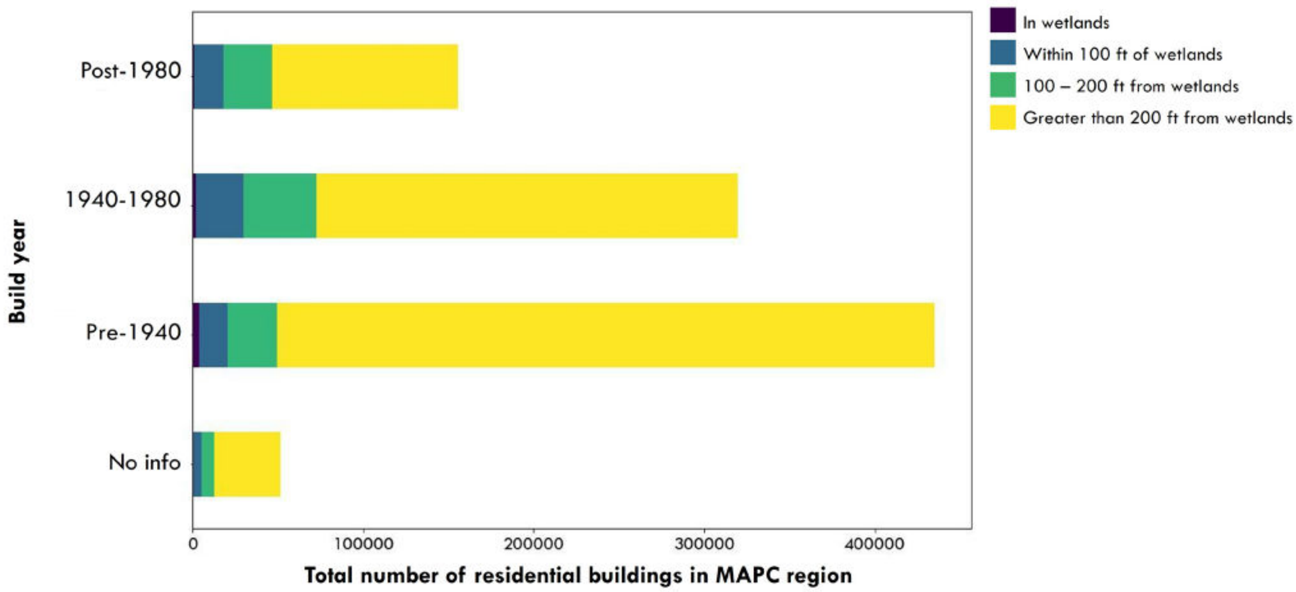

Figure 10: Count of residential buildings constructed in each "era", broken down by distance to MassDEP wetlands.

Narrowing further, we found that homes built before 1940 had the lowest rate of confirmed flooding (1.3%) and were least likely to be located within 100 feet of a MassDEP wetland (3.8%), while properties constructed between 1940 and 1980 were twice as likely to be located within 100 feet of a wetland and had the highest rate of confirmed flooding (2.8%). While wetland proximity is likely not the only factor that contributes to the higher rate of flooding, this finding suggests the importance of regulations that prevent development and/or require enhanced environmental protections near wetlands.

Residential properties constructed between 1980 and 2010 were more than twice as likely to be located within 100 feet of a wetland but had a flood claim rate (1.7%) only slightly above homes built before 1940 (1.3%). This disparity suggests that the landscape and building design for wetland-proximate, post-1980 buildings is somewhat more resilient to stormwater flooding than those built in earlier eras.

Another explanation could be the nature of land that was developed mid-century versus since 1980. In other words, some of the major tracts developed in the region from 1940 – 1980 were simply more flood-prone than tracts developed 1980 – 2010. In summary, the differences in rate of confirmed flooding by year built, both near and farther away from wetlands, suggest that building practices may reduce buildings' vulnerability to the negative impacts of flooding and high groundwater, but further investigation is needed to confirm the factors most influential in the region.

What about wetlands that have been filled or drained?

The findings above suggest that proximity to current wetlands may play a role in stormwater flooding risk. It is also possible that damaged properties near wetlands were themselves built on former wetlands that were filled to enable development. In several instances, municipal officials who reviewed March 2010 claims locations as part of developing Local Hazard Mitigation Plans were able to connect clusters of claims to locations with known buried streams or filled wetlands. Prior to the adoption of state and federal wetland protection laws, almost one-third of Massachusetts's wetlands were destroyed by draining or filling, often for urban and agricultural expansion. This modification of wetlands failed to account for their ecological importance; wetlands are a critical resource for filtering water, preventing flooding and storm damage, and supporting wildlife.

In order to investigate the potential relationship between filled wetlands and stormwater flooding, MAPC accessed an 1892 map of wetlands in the City of Newton, MA and overlaid the locations of flood claims. We compared this to a map of existing wetlands (from MassDEP) and flood zones. These two maps are shown in Figure 11. These maps document a substantial reduction in the extent of wetlands all throughout Newton, as a result of filling or draining. They also show that while some clusters of 2010 flood claims are well outside existing mapped wetlands, they seem to be located on sites that were mapped as wetlands more than 100 years ago but have since been drained, buried, and/or filled in.

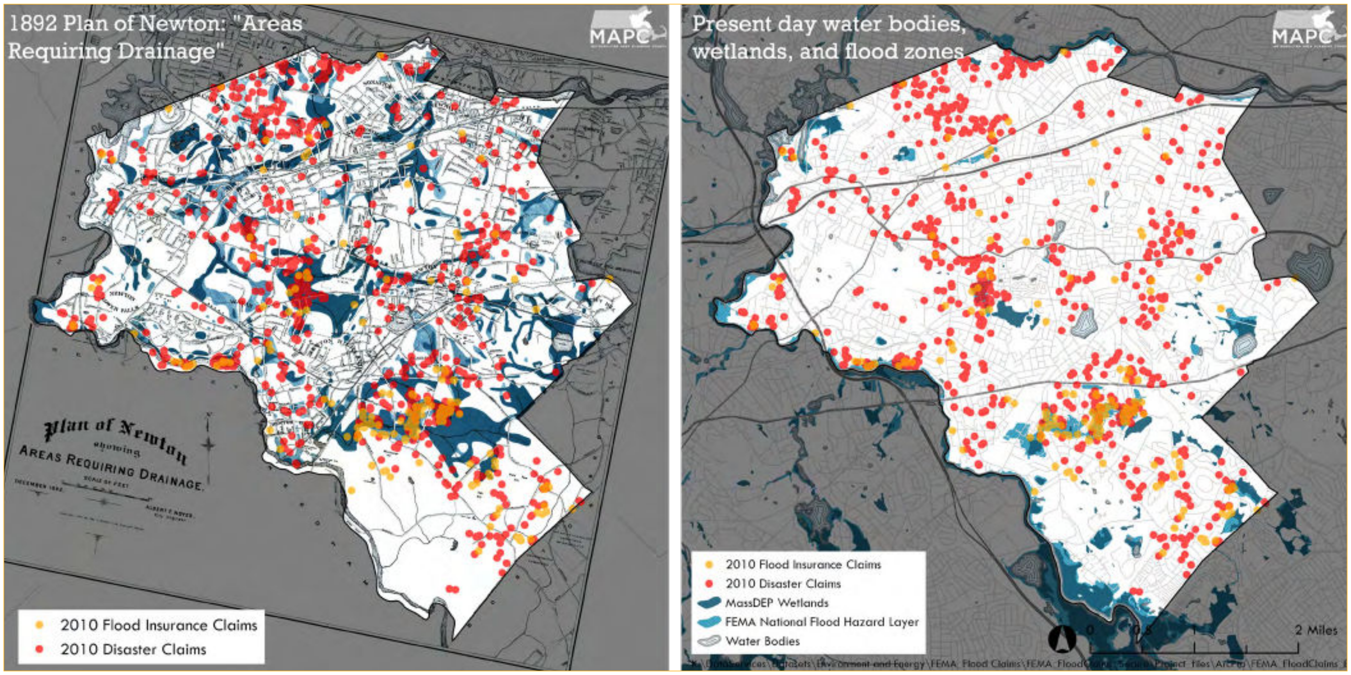

Figure 11: (left) 1892 Plan of Newton depicting historic wetlands (in blue) compared to flood claims (red and yellow points); (right) MassDEP wetlands, water bodies, and FEMA flood zones compared to flood claims.

While these observations suggest a connection between historic wetlands and recent flooding, these connections could not be fully explored in this project due to data limitations. The historical wetland map of Newton is only available as an image, not a dataset, so that statistical analysis of historic wetland proximity was not possible in this project. MAPC is now working with Tufts University students and the Norman Leventhal Map and Education Center at the Boston Public Library to digitize historic maps and evaluate the connection between historic wetlands and stormwater flooding in a more robust way.

Stories from the Sump Pump: Woburn Residents on the Toll of Flooding

Flood Claims demonstrate the widespread and poorly understood issues of stormwater flooding, but they don't begin to show the human experience during such flood events. In 2021, MAPC reached out to residents in the City of Woburn to learn how they are affected by local flooding. We wanted to know what kind of flooding was occurring, what damage it caused, and how people cope with recurring issues. We found that frequent flooding took a severe emotional and financial toll on affected households, many of whom were unaware of the risk before they moved into the home.

Working with the City of Woburn, MAPC inventoried residential properties known to be affected by flooding. We reviewed March 2010 Flood Claims, March 2010 assistance calls to the fire department, city records of sump pump locations, and we solicited information from the public. Through that process, we documented an additional 165 residential flooding locations ("local flood records") not associated with a March 2010 Flood Claim. Together, the combined dataset of 2010 flood claims and local flood records comprise 555 flooding incidents spread widely across the city and occurring entirely outside Special Flood Hazard Areas. These are mapped in Figure 12.

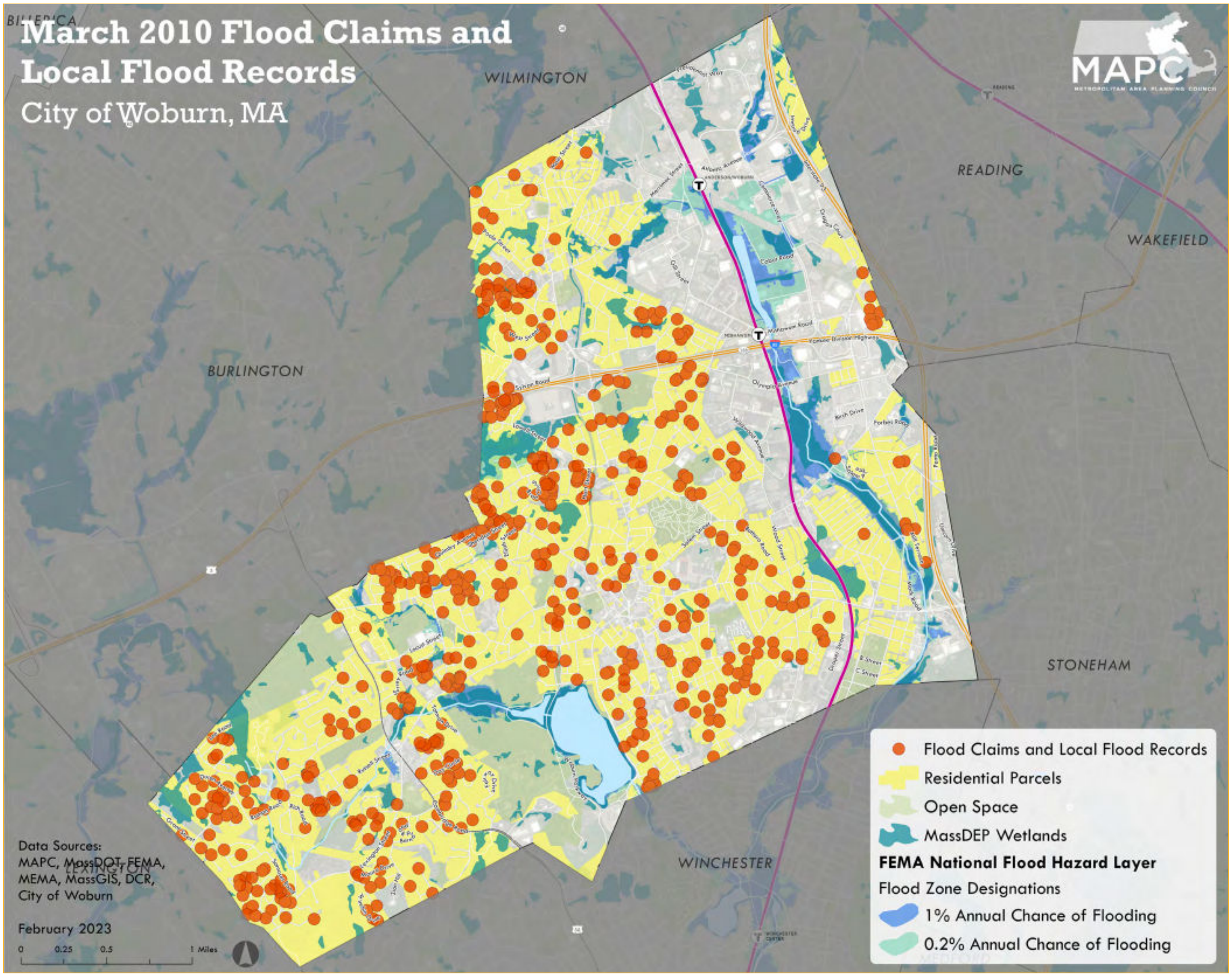

Figure 12: 2010 residential flood claims and local flood records (red points) in Woburn, MA, compared to residential parcels (yellow) and flood hazards like wetlands, FEMA flood zones, and water bodies.

To reach residents who had been affected, the City of Woburn placed announcements in the local newspaper and on their website soliciting residents willing to be interviewed about their flooding experiences. MAPC received 60 responses and completed phone interviews with 44 residents. These phone interviews provided important information on possible causes of flooding, measures taken by residents to reduce flooding, and the emotional and financial toll of flooding.

A key finding is that more than 90% of interviewees reported localized flooding from rising groundwater resulting in damage from basement seepage. Roughly half reported yard ponding or stormwater overflow from the street associated with the basement seepage, the other half indicated that there was no pooling of stormwater. Only one person reported flooding from an adjacent brook. The remaining respondents described flooding that affected only yards, driveways, or the street.

Also of note is that five of our interviewees described wetland features directly adjacent to their properties that are not identified as DEP mapped wetlands. They were variously described as a marshy stream, a swale that used to be a brook, or as a drainage brook or ditch. The features were detectable through close examination with Google Earth or LIDAR Shaded Relief. This suggests that waterways that are unrecognized as wetlands, or do not meet the state wetlands definition, may be an important indicator of flooding risk.

We found that very few residents had prior knowledge of their flood risk. As a result, most experienced significant damage during their first flood and only thereafter took steps to protect their properties. This is perhaps not surprising as almost all the interviewees live outside the 1% and .2% chance flood zones — locations identified on FEMA maps as areas of "minimal flood hazard." These areas are typically described by building officials, residents, and real estate agents alike as "not in a flood zone."

MAPC has worked with more than 90 communities to draft local hazard mitigation plans. As part of the process, we work with experienced local officials to map known flooding locations. Despite their expertise, the March 2010 claims locations are also largely unrecognized by municipal staff. Local officials are highly knowledgeable about flood locations related to roadway flooding and overflowing streams and rivers. Understandably, they are less likely to identify basement flooding of the type revealed by our interviews.

While our project focused on March 2010, nearly two-thirds of our interviewees reported recent flooding. Our interviews took place in early fall 2021. Rainfall in Woburn in 2021 was well above average for July, August, and September, including several rain events of three, four, and five inches. Residents typically described issues with either chronic (multiple times per year) or occasional (once every few years) basement flooding. This highlights the frequency of flooding occurring during storms that do not rise to the level of declared disasters.

The many strategies residents employed to reduce flooding include pumps, generators, French drains, dry wells, sandbags, berms, patching or sealing foundations, elevating belongings and utilities, landscaping and regrading yards, and cleaning storm drains. Most commonly residents install sump pumps, usually accompanied by a French drain. In most cases, residents reported that their strategies reduce, but do not eliminate, flooding. Some residents expressed concern that they did not know what to do, said that their solutions had not worked, or that they doubted that any solution would work.

The degree of stress people reported was one of the more striking aspects of our interviews. Respondents described financial pressures and fears of future damage or of losing utilities if their pumps stop working during a power outage. A significant portion of those with basement flooding described moderate to severe anxiety during heavier rains. A dozen residents expressed concerns about mold. Their comments ranged from noting the need to react quickly to prevent the growth of mold, to the challenges of treating mold, to worries about the health of family members due to the existence of mold in the basement. Other worries include fear of contamination and electric shock.

The words of our interviewees reveal the impact flooding has on their day-to-day lives.

"Obviously, the flooding was not disclosed to us when we purchased. We had a rainstorm in the first two weeks. We got pumps and upgrades immediately. Just wish we knew that it happens. Even when we describe it — you don't quite grasp how catastrophic it is until you see the photos. People are appalled and shocked by the state of the backyard when it rains."

"I wish I had known before I bought the house that the neighborhood had been previously flooded. Later I learned we're not considered to be in a floodplain. . . . All this money I've spent hasn't helped, how much more can I afford to put out? I'm already in the hole 15K."

"I was a first-time home buyer. The left side of the house has sunk a bit because of water saturation. I'm a retired person, trying to hang on, I can't undertake the cost of too many more improvements."

"It's raining now, my heart is racing. I have to leave work and run home and drop a utility pump. It has just about broken me financially and emotionally."

"There is an undercurrent of just general stress. It puts us in a bad position future-wise. We want to be here, to put down roots. Now we're in a property we're not even sure what to do with. Should we invest? How would we sell? We wouldn't want to surprise the next family."

"Only constant surveillance keeps us from having flood damage. I spent Christmas Day last year pumping and shop vac-ing our basement out."

"It's constant stress with my basement, my sump pump. I always check immediately when I go home. I cancel plans when there's a storm because I'm afraid my generator will go out. I run down to the basement all the time to check the sump. Constant vigilance, if I didn't stay on top of it, I'd have troubles."

Recommendations

A. Enable more widespread access to federal flood claim data

MAPC's analysis demonstrates that SFHAs provides an incomplete picture of risk; access to flood claims data is essential to better understanding the problem and crafting solutions. However, federal requirements associated with FEMA flood insurance and disaster claims are a significant barrier to utilization of the data. In compliance with the Privacy Act of 1974, the Department of Homeland Security strictly limits access to flood insurance and disaster claims. Unauthorized release of information subject to the Privacy Act is a misdemeanor subject to fines of up to $5,0001. With assistance from staff at MEMA and the Massachusetts Department of Conservation and Recreation, MAPC gained access to the data under Privacy Act regulations that allow government entities to utilize the data for hazard mitigation planning. To comply with the terms of access, MAPC cannot provide claims addresses to municipal officials, and claims can only be mapped at a scale that assures no individual property is identified.

These limits on data sharing are understandably rooted in concerns about individual privacy. Restricting access to flood claim locations, however, privileges the privacy rights of current property owners over the needs of municipalities to identify and respond to flood risk, and over the rights of the public — including prospective property owners and tenants — to be adequately informed of risks. For example, Local Hazard Mitigation Plans must include an analysis of repetitive loss properties (properties with two or more federal flood insurance claims greater than $1,000 in any 10-year period). Repetitive loss properties are an important indicator of chronic flooding locations, but they tell only part of story, as they are a small subset of flood insurance claims, and individual assistance claims are not included. As a result, plans may omit analysis of problem areas.

The federal government has a stake in ensuring access to comprehensive data. After all, FEMA flood mitigation grants are directed to projects where the benefits (in terms of averted damages) exceed costs. A full accounting requires information about costs already incurred in prior disasters—something very hard to do without access to those claims. MAPC recommends the following actions to increase access to federal flood claims data:

1. FEMA should evaluate how information from flood claims can be aggregated and proactively share data with municipalities, Regional Planning Commissions, Councils of Governments, and state agencies responsible for emergency preparedness under the existing regulations. FEMA should prioritize assistance to overburdened and under-resourced communities to help them understand and act on this data.

2. Congress should revise the Privacy Act to make claims data available for hazard mitigation purposes during the next round of National Flood Insurance Program (NFIP) reform legislation. More detailed data will help state, regional, and local agencies plan for and mitigate inland flooding risk.

B. Track and utilize local flood risk data

There is much that can be done at the local level to identify and share flood risk information. Communities should routinely record and map flooding service calls to first responders and public works departments. In our experience, fire departments maintain historic data coded as "water calls." In Woburn, MAPC increased the database of flooding locations by more than 30% by adding fire department records, a list of homes with sump pumps, and the addresses of residents who responded to an interview request. Maps of flood claim locations should be widely shared with the public on municipal websites and in outreach materials, highlighting flood risks in locations outside the SFHA. As an example, the City of Woburn developed website materials and brochures that are available in all permitting departments: Protect Your Property from Flooding — City of Woburn (woburnma.gov).

C. Incorporate flood data into planning projects

Municipalities, regional planning commissions, and state emergency management agencies should analyze and incorporate flood data into stormwater management, hazard mitigation planning, capital investments, and other planning efforts. MAPC currently includes the 2010 data in hazard mitigation plans. State and regional agencies should prioritize assistance to vulnerable communities.

D. Require flood history disclosure

Woburn residents affected by flooding commonly expressed frustration that they had been unaware of flooding issues at their home before moving in. This is because flood claims data are kept confidential, and an owner has no obligation to share this information with prospective buyers. Massachusetts should adopt legislation requiring property sellers to disclose previous flood history. A study of New York, New Jersey, and North Carolina by Millman[2] highlights the financial implications of unrecognized flood risk. Milliman found that a home with previous flood damage has an average annual loss of $1,873 as compared to $83 for homes without prior flood damage. Lower income households have fewer resources and thus experience greater harm from such losses. Massachusetts is one of 15 states that has no statutory or regulatory requirements for a seller to disclose a property's past flood damages to a potential buyer. Examples of disclosure requirements adopted by other states include flood zone designation, previous water damage, nature, and frequency, location in a designated wetland, and prior claims for flood damage.[9]

Tenants may be particularly vulnerable to property loss from flooding. While flood insurance for apartment contents is available to renters, it is rarely purchased, often due to prohibitive cost, or due to a lack of awareness of its availability. Critically, flood insurance for contents in the most vulnerable locations — basement apartments — is not available for purchase under the NFIP. Massachusetts should require that landlords inform tenants of flood risk and previous flood damage to their units. Legislation adopted by New York State in December 2022 provides model language that requires notification to tenants when a unit is in a 1% or .2% chance flood zone and when the unit has previously been damaged by flooding.[10]

E. Finance property retrofits and repairs, prioritizing low-income households

The diffuse and unpredictable nature of stormwater flooding means that in many cases mitigation efforts must be dealt with at the parcel level, building by building. Mitigation and retrofit solutions include everything from sump pumps and landscaping to elevated utilities and waterproofed basements. Unfortunately, many homeowners will simply not have the money readily available to pay for those improvements.

The FEMA Flood Mitigation Assistance grant program focuses primarily on elevating and relocating buildings. Typically, the program pays 75% of the costs, and up to 90% depending on the flood history of the home. While the program is an important source of support, costs are reimbursed only after a project is complete. This is a bar to the participation of homeowners who do not have access to up-front funds to cover costs that typically exceed $100,000 for home elevations. In 2021, Maryland adopted the Resilient Maryland Revolving Loan Fund. The fund makes available low- and no-interest loans for building retrofits. The law allows municipalities to establish a graduated loan forgiveness program ranging from 50 to 100% forgiveness based on household income. Also in 2021, Congress adopted the Safeguarding Tomorrow through Ongoing Risk Mitigation (STORM) Act. The STORM Act provides funding for states to create hazard mitigation revolving loan programs. The funds can be used to support mitigation projects, including providing match for the FEMA Building Resilience Infrastructure and Communities (BRIC) grant program, and to support zoning changes that encourage

9 fema_state-flood-risk-disclosure-best-practices_07142022.pdf
10 Bill Search and Legislative Information | New York State Assembly (nyassembly.gov)

low-impact development. Forty percent of funds must be targeted to underserved communities. In December 2022, FEMA released an RFP for the first year of an anticipated five years of funding. Massachusetts should implement a revolving loan program, including funds targeted to low- and moderate-income residents, through application to the STORM program and/or with state funding.

Several states have adopted programs that provide retrofit support to property owners. Southern states developed programs in response to hurricane damage; California has a program that addresses seismic risks. Massachusetts should develop a program to provide retrofit advice and subsidize repairs. The My Safe Florida Home Program, in existence from 2006 – 2009, could serve as a model for Massachusetts. Established in response to hurricane damage, the program funded 400,000 free home inspections and provided more than 33,000 grants to retrofit properties[3]. The grants provided a 50% match and averaged $3,300. The program was available to homes in the coastal (wind-blown debris) zone and limited to homes with a property value of less than $300,000. An analysis of the program found that each dollar invested resulted in $1.50 in savings.

Localities in other parts of the country have adopted programs that provide retrofit advice and subsidize repairs, often with a focus on equity and support for under-resourced communities. The City of Wheaton, Illinois stormwater engineers conduct free drainage reviews to assess sources of flooding and offer retrofit solutions. Wheaton, Niles, and Northbrook, Illinois, all have programs that subsidize home drainage projects. Washington, D.C. is launching a program that will support free installation of backflow prevention valves and other retrofits. The program is funded with a FEMA grant requiring a local 25% match. The available funding will not be sufficient to cover all eligible homes, so applications will be prioritized based on equity considerations targeting low-income residents. Funds are provided on a reimbursement basis, but the District will provide up-front funds for residents who are not able to do so.

These programs could also be targeted to specific types of retrofits, such as utility elevation. Loss of heat and electricity as a result of flooding is particularly problematic because it often requires residents to move out of their house. A Massachusetts program focused on utility elevations and basement protection strategies would yield great benefits by reducing costly damage to critical facilities that provide heat and power.

Massachusetts should also consider opportunities for synergy with other programs that promote building improvements. For example, the Mass Save program provides in-home energy audits and discounts on home improvements. Often the audits result in the installation of new heating and cooling systems. Program staff should be cross-trained in basic flood protection principles so that new utilities are installed on upper floors or elevated within basements.

The Commonwealth should work with regional planning agencies and municipalities to develop retrofit support programs that protect homes before they are damaged by floods and prioritize support to low-income households. Communities have the advantage of local knowledge and access to homeowners and contractors seeking permits. Local flood information should be prominently displayed and reviewed with applicants for building, zoning, and wetlands permits. Building officials, with their knowledge of retrofit options and regular in-home site visits for permit inspections, are well placed to provide retrofit advice to residents. Potential funding sources may include CDBG home repair funds, FEMA mitigation programs, and local sources.

F. Fund stormwater management

A key impediment to improved local stormwater management is availability of funds. The resources required to maintain, let alone improve, aging municipal stormwater infrastructure is well beyond the capacity of most municipalities. New funding streams are needed to support this work over the long term. This is especially critical in urban locations home to Environmental Justice populations.

A dozen MAPC communities have adopted stormwater utilities that charge property owners a stormwater fee to support system improvements. MAPC should continue to support municipalities in adopting stormwater utilities and encourage fee structures and programs that provide financial incentives and support for property owners to reduce impervious surfaces and infiltrate stormwater on site.

G. Strengthen development and building regulations

Local stormwater regulations, floodplain overlay districts, and low impact development (LID) requirements can be strengthened to reduce stormwater flooding. Dedham and Winchester, for example, apply stormwater infiltration requirements to land disturbances of 500 square feet, a much stronger standard than the MS4 one-acre requirement. MA DEP draft stormwater regulations would update the current rainfall standards that date to1960 to current rainfall rates. While this is an important step, the state and municipalities should adopt rainfall standards that incorporate future projections applicable to the life of a project. MAPC should: support municipalities in incorporating and harmonizing LID requirements across the zoning code and regulations; continue to support communities in adopting stronger regulations; and promote progress in achieving the recommendations of the Climate Resilient Land Use Strategies website: Climate Resilient Land Use Strategies — MAPC.

As communities identify flood-prone locations, they should expand their Floodplain Overlay Districts to regulate new development and redevelopment. A challenge for municipalities is that local regulations cannot conflict with the State Building Code. This means, for example, that municipalities cannot prohibit basements outside the SFHA. There is, however, an option that communities can consider. Section 98 of Chapter 143 of the Massachusetts General Laws provides a pathway (to date untested) for municipalities to apply to the Board of Building Regulations and Standards for permission to establish more restrictive standards based on special local conditions. Communities could also expand their Floodplain Overlay Districts and adopt requirements that do not conflict with the building code. Options adopted by some municipalities include prohibiting development in flood risk areas outside the SFHA and/or requiring a Special Permit for development in those locations. Through the special permit process, communities could require evidence that land is not subject to flooding and set higher standards for review, taking care that such standards do not become a reason to prohibit the development of affordable or mixed-income housing.

Massachusetts can also take steps to help make existing buildings more resilient to flooding. Flood damage to heating and electric systems is expensive and increases the likelihood of temporary displacement from the home. Yet it is also often avoidable: 71% of the 2010 disaster claims had depths of six inches or less. The state should amend the building code to require all new and replacement utilities be elevated at least six inches above the basement floor. Ideally the state should require or encourage placement of utilities above grade. The NFIP has recognized the financial impact of utility damage, recently instituting a 5% flood insurance discount if utilities are located above grade.

H. Promote innovative insurance strategies to address the needs of low-income households

Many low-income residents are priced out of flood insurance markets. As previously noted, renters in the most vulnerable basement locations do not have access to coverage as the NFIP does not insure contents in basements. Moreover, as flood insurance focuses on property damage, it does not address immediate cash needs, which may include finding alternate housing and transportation, and replacing food, medicine, and clothing. Parametric insurance, which provides a cash payment within days of a triggering event, is a lower-cost solution that could address immediate needs. In Puerto Rico, for example, cash payments of up to $10,000 depending on hurricane wind intensity are made within 72 hours of the storm event. Holders of policies have unrestricted use of the funds to address their priority needs. New York City, in cooperation with a local non-profit organization, is currently piloting a project that will provide parametric insurance to local residents.

I. Improve understanding of the causes and impacts stormwater flooding

MAPC's analysis of flood claims demonstrates the widespread nature of stormwater flooding but provides only a few clues about what natural and built environmental factors contribute to the issue. Our interviews in Woburn provide a glimpse into how residents experience the emotional and financial toll of recurring flooding, but not yet a full picture. In order to develop policies and programs that are well-targeted and meet a community's most pressing needs, we need to better understand contributing factors and how residents are affected.

For example, MAPC's analysis of stormwater flooding demonstrated that incidents are associated with proximity to existing wetlands and may be more prevalent among homes built on wetlands that have been filled or drained. Understanding where such filled wetlands and homes exist could help planning for interventions and designing policies to mitigate future flooding. MAPC, Tufts University, and the Leventhal Map and Education Center have initiated the Uncovering Historical Wetlands project to explore this issue. A team of five Urban and Environmental Planning (UEP) graduate students will work to digitize historical maps, showing locations of drained or filled wetlands in a range of municipalities in the MAPC region. In doing so, they will develop a spatial dataset that enables analysis of how the destruction of almost one-third of Massachusetts's wetlands prior to the adoption of state and federal wetland protection laws impacts present-day conditions.

The predominance of groundwater sourced flooding in Woburn also highlights the need for better understanding of groundwater dynamics and comprehensive groundwater mapping to alert residents, developers, and municipalities to areas of greater flood risk.

Additional surveys and interviews with residents affected by flooding will improve the region's understanding of flooding and its impacts. Documenting flooding conditions and water pathways might help identify issues common throughout the region or in certain types of construction. This could support better estimation of repair costs or standardization of interventions.

Conclusion

March of 2010 brought historical levels of precipitation to Greater Boston, resulting in widespread damage to basements, yards, and homes throughout the region. Most of this flooding was well outside SFHAs; the effects were a more widespread version of what many homeowners experience on a regular basis. Our warming climate is likely to increase the frequency and intensity of rainfall, suggesting that storm events like March 2010 will happen more often. As a result, more and more residents will likely be affected by flooding events that are hard to predict but have a significant impact.

While we found evidence that stormwater flooding is relatively more common in homes built during the mid-20th Century and those near existing or filled wetlands, more research is needed to clarify these connections. In the meantime, steps can be taken to improve awareness and provide resources to mitigate flooding impacts. Better information about the extent of stormwater flooding can enable better planning and more informed home purchases. Grants and low-cost loans are needed to support property owners who wish to retrofit their buildings; these programs should be targeted to support vulnerable households that cannot as easily recover from a flood event. Further, better management of stormwater through management of new development, as well as retrofits of existing developments, could help redirect stormwater to where it will be infiltrated or otherwise slowed down. It is clear that a variety of strategies are needed to address this increasingly problematic impact of a changing climate.

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