Charles River Watershed Association

CHARLES RIVER CLIMATE ADAPTATION & FLOOD MITIGATION

IMPLEMENTATION PLAN

Land Acknowledgement

CRWA would like to acknowledge that here in Massachusetts, we are on sacred land that was stolen and holds history of violence and slavery. We recognize the Massachusetts, Nipmuc, and Wampanoag peoples as the traditional stewards of this land. We honor the legacy life, knowledge, and skills stolen due to violence and colonization.

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EXECUTIVE SUMMARY

The Charles River Climate Compact (CRCC) led by Charles River Watershed Association (CRWA), and working with technical partner Weston & Sampson and engagement experts Communities Responding to Extreme Weather (C.R.E.W) are partners in the Building Resilience Across the Charles River Watershed Initiative. Addressing flooding at a regional scale is absolutely critical as activities in upstream communities impact flooding in downstream areas, simply understanding flooding impacts requires good information about the entire landscape, not just one community, and certain flooding challenges cannot be addressed by just one City or Town.

Together, and with input from the public, we have prepared the Charles River Climate Adaptation Flood Mitigation Implementation Plan (Plan). This Plan provides an overview of the development of the Charles River Flood Model (CRFM), a tool the team has developed to predict where and when flooding is likely to occur as our climate changes and to test flood mitigation actions prior to making investments or policy decisions. It also documents the team's work to identify and test flood reduction strategies across the watershed, at both large and small scales.

The model demonstrates that flooding from both typical and extreme rain events will be considerably worse by 2070. As a result of this work, the team has identified actions and recommendations (see text box) for the region to begin to adapt to the expected flooding impacts from climate change. The team also developed an accompanying Toolkit to support local actions. This Initiative is finding opportunities to address this challenge over the coming decades before it becomes too late.

This Initiative also resulted in identification of over 50 opportunity sites for flood mitigation projects across the watershed. Concept designs were developed with public input for three of these sites; these are:

- Adjustments to the outlet structure, wetland restoration, and green stormwater infrastructure implementation at Hardy Pond in Waltham
- Flood storage and green stormwater infrastructure at Oakland Park in Medway
- Flood storage and green stormwater infrastructure at Albemarle Park, and green infrastructure opportunities along Cheesecake Brook in Newton

An implementation pathway was laid out for each of these projects. Public engagement is critical in this planning Initiative, and the Team engaged numerous residents to date and plans to continue this engagement going forward. There was and continues to be a focus on engaging climate vulnerable residents. Interested parties should sign up for CRWA's newsletter to stay informed about the Initiative and to be made aware of future opportunities to provide input and feedback, including opportunities to comment on this report. The Team will continue this Initiative to work to better understand future flooding and the actions that can be taken to address it, and to work to implement these actions on the ground. This work was funded by the Massachusetts Municipal Vulnerability Preparedness (MVP) program and we are grateful for their support. Vulnerability Preparedness (MVP) program and we are grateful for their support.

RECOMMENDATIONS

1. **Planning recommendation:** set flood reduction targets
2. **Aggressive actions needed:** even the most effective watershed-wide mitigation scenarios tested do not fully mitigate an increase in flooding by 2070 (vs. present day)
3. **Select and take actions matched to the local landscape**, locations in the watershed, and community priorities
4. **Combined & layered solutions:** no one action likely to be a panacea
5. **Target new and re-development,** especially impervious surfaces
6. **Continue to seek local improvements** like priority projects identified in the plan

1.0 INTRODUCTION

The Charles River Climate Adaptation Flood Mitigation Implementation Plan (Plan) is the result of over eighteen months of work and the collaborative effort of multiple Charles River watershed municipalities, Charles River Watershed Association (CRWA), Weston and Sampson (W&S), Communities Responding to Extreme Weather (C.R.E.W.), and hundreds of watershed residents who took the time to participate in project surveys and meetings.

Climate change has resulted in significant weather impacts to Massachusetts including extreme storms, heat waves, more frequent drought, sea-level rise, storm surge, and inland flooding. The Northeast has seen an 10% increase in average annual precipitation over the past five decades, and the amount of precipitation falling during very heavy precipitation events (99th percentile) increased by 55% between 1958 and 2016, the greatest increase nationwide. Adapting to this continually changing climate will require significant effort and investment. Understanding the impacts of climate change is a key component of adapting, the better we understand the impacts, the more prepared we will be to address them.

This Plan summarizes the best available information about where and under what conditions flooding is likely to occur in the middle and upper Charles River watershed. The Plan also offers recommendations at various scales for strategies to reduce the impacts of precipitation-based flooding in the Charles River watershed. This Plan is intended to be a living document that is updated regularly as more information about climate change and climate impacts become available and as additional tools and strategies are identified and popularized to address flooding impacts. The Plan includes particular focus on environmental justice populations and critical infrastructure (such as emergency response locations, shelters, hospitals, etc.) as the impacts of climate change will not be borne equally by watershed residents. Populations particularly vulnerable to the impacts of climate change that also have fewer resources available to them to prepare for or recover from disasters should be a key focus of public resources targeted toward reducing the impacts of flooding.

Arlington
Bellingham
Boston
Cambridge
Dedham
Dover
Franklin
Holliston
Medway
Millis
Natick
Needham
Newton
Norfolk
Sherborn
Waltham
Wellesley
Weston
Wrentham
Watertown

1.1 BACKGROUND

1.1.1 Charles River Climate Compact

The Charles River Climate Compact (CRCC) is a coalition of communities in the Charles River watershed, convened by Charles River Watershed Association (CRWA), that work on climate adaptation by sharing information and experiences, and taking a watershed view of climate adaptation and mitigation strategies. CRCC's mission is to work collaboratively to increase climate resilience for people, and the natural ecosystems in the Charles River watershed by taking a regional approach to implementing climate adaptation and mitigation solutions. When the CRCC was established in 2019 participants identified flooding as a primary issue that needed to be addressed at the regional level, while also expressing concern around the lack of data on future flooding in their communities. Historically municipalities have relied on FEMA flood maps to predict where flooding will occur, but climate change is bringing a significant change to precipitation patterns in our region, making FEMA flood maps an inadequate or incomplete tool for municipal leaders.

Nature-based solutions (NBS): Nature-Based Solutions (NBS) are adaptation measures focused on the PROTECTION, RESTORATION, and/or MANAGEMENT of ecological systems to safeguard public health, provide clean air and water, increase natural hazard resilience, and sequester carbon. Incorporating NBS in local planning and design projects produces long-term solutions that benefit human and natural systems.

Source: MA Municipal Vulnerability Preparedness Program

The Building Resilience across the Charles River Watershed Initiative was launched in 2020 by a subset of Charles River Climate Compact communities and CRWA, with technical partner Weston and Sampson and public engagement partner Communities Responding to Extreme Weather (C.R.E.W). The goal of this ongoing effort is to build climate resilience across the watershed by identifying and implementing nature-based solutions (NBS) that effectively reduce the impacts of precipitation-based flooding.

Figure 1.1 C.R.E.W. engagement at the Medway Pride Day event

1.1.2 Charles River Flood Model

A key component of this work has been the development of the Charles River Flood Model (CRFM). The CRFM is a computer flood model of the upper and middle Charles River watershed that identifies where and when flooding will occur under various present day (baseline) and future rainfall scenarios. The CRFM uses a software called PCSWMM to simulate flooding across the study area. The technical details of developing, calibrating and validating the CRFM are available in the Charles River Flood Model report, found on the CRWA website, and in two technical summary memos in Appendix 1.

The model has also been used to simulate the benefits of numerous flood mitigation strategies and projects, with a focus on nature-based solutions. As a regional project, this initiative is focused on solving regional flooding issues that impact multiple communities or where the solution may lie in a different community from the problem, as opposed to very localized flooding which may be caused by local infrastructure issues. Additionally, this initiative aims to build consistency across the region with respect to planning for future flooding and with the actions communities can collectively take at the local level to build resilience at the watershed level. This has resulted in the regional recommendations included in this Plan.

The Charles River Flood Model study area is the upper and middle Charles River watershed. The cities of Boston and Cambridge, which border the Lower Charles River Basin, already had detailed models demonstrating the impacts of both freshwater and coastal flooding in their communities prior to the launch of this initiative. The CRFM geographic extent covers whole or part of 33 municipalities and a total area of 273 square miles. Stormwater infrastructure, which in urban areas, defines where and how stormwater runoff flows is incorporated into the model as detailed in Table 1.1. In the communities where no stormwater infrastructure is included, runoff is still modeled using elevations and flooding impacts from rivers and streams running through those communities are included in the model.

Figure 1.2 Choate Park Dam in Medway, courtesy of Tim Rice

Table 1.1 Summary of stormwater pipes included in the CRFM by community

Stormwater Infrastructure	Communities
Stormwater pipes >12" included	Medway and Sherborn
Stormwater pipes >24" included	Dedham, Franklin, Milford, Natick, Needham, Newton, Norfolk, Waltham, Watertown, and Wellesley
No stormwater infrastructure included (data unavailable and/or communities did not participate in this initiative)	Arlington, Ashland, Bellingham, Belmont, Boston, Brookline, Dover, Foxborough, Holliston, Hopkinton, Hopedale, Lexington, Lincoln, Medfield, Mendon, Millis, Walpole, Wayland, Weston, Westwood, and Wrentham

2.0 BASELINE AND FUTURE FLOOD CONDITIONS

The CRFM is used to assess where and when precipitation-based flooding will occur as our climate changes. Baseline flood conditions are simulations of present-day flooding impacts. See the Phase I Charles River Flood Model report, found on the CRWA website, and the two technical summary memos in Appendix 1 for more details on calibrating and validating the model against actual historical storm events.

Two types of modeling scenarios were run for future conditions across the full study area: no action scenarios and flood reduction strategy/nature-based solution scenarios. No action scenarios are summarized in this section and represent potential flooding that will occur if no actions are taken to mitigate flooding and no changes occur across the watershed landscape (i.e. assumes current land use). Flood reduction strategy scenarios are discussed in Section 3; these assume both landscape changes and flood mitigation activities. The same rainfall/storm events are applied to both types of scenarios.

Table 2.1 Summary of Modeling Scenarios

Design Storm	Timeline	Watershed Scale No Action Scenarios	Watershed Scale NBS Scenarios	Priority Project Scale
Baseline (present conditions)				
2-yr 2 hour	Present day (NOAA 14 data from late 1900s/early 2000s)			x
2-yr 24 hour		x	x	x
10-yr 2 hour				x
10-yr 24 hour		x	x	x
100-yr 24 hour		x		
Future Conditions				
2-yr 24 hour	2030	x		
10-yr 24 hour	2030	x		
100-yr 24 hour	2030	x		
2-yr 2 hour	2070			x
2-yr 24 hour	2070	x	x	x
10-yr 2 hour	2070			x
10-yr 24 hour	2070	x	x	x
100-yr 24 hour	2070	x		

2.1 RAINFALL / STORM SCENARIOS

Multiple storm sizes and time horizons were simulated in the model (Table 2.1). The storms and time horizons selected were informed by project team input; planning horizons were also informed by public input. The project team demonstrated a preference for seeing results for longer-term and more severe events, this is in line with planning horizons for infrastructure investments. The public demonstrated a preference for shorter time horizons (within 30 years), more in line with what an individual may expect to see in their lifetime.

Future rainfall projections were developed following the latest recommendations from the Climate Resilience Design Standards Tool championed by the State's Resilient Mass Action Team (RMAT). The rainfall projections in this Tool were developed by Cornell University as part of the Massachusetts Executive Office of Energy and Environmental Affairs (EEA) Massachusetts Climate and Hydrologic Risk Project[1]. These rainfall projections are available at the same spatial resolution as the NOAA Atlas 14 data. Since the Charles River Flood Model (CRFM) covers a relatively large geographic area, spatial variability of future rainfall projections for the watershed was assessed to check how rainfall amounts and storm sizes vary across the watershed sub-basins. However, since the maximum spatial variability in rainfall projections among the sub-basins is within 5%, basin-wide area-weighted average rainfall projections were used for clarity and simplicity.

2.1.1 Baseline Climate Scenarios

Design rainfall depths for a baseline climate were derived from NOAA's Atlas 14: Precipitation-Frequency Atlas of the United States for Stormwater Management (NOAA 14). NOAA 14 values represent the industry-standard design rainfall depths for events under a late 1900s/early 2000s (baseline) climate condition. Select design storms are presented for the 2-,10- , 25-, 100-, and 500-year recurrence intervals in Table 2.2. NOAA 14 design rainfall depths associated with these events represent the watershed area-weighted average values, which were estimated by weighting the NOAA 14 values for each community based on the percentage area of the community that falls within the study area.

The 2-year 24-hour design storm refers to a storm that has a 50% chance of occurring in any given year. For the Upper and Middle Charles River Watershed, the 2-year storm that falls over a 24-hour duration has a rainfall depth of 3.3 inches. The 2-year storm that falls over a 2-hour duration has a rainfall depth of 1.5 inches.

2.1.2 Future Climate Scenarios

To evaluate future design storm depths, Weston & Sampson used Intensity Duration Frequency (IDF) projections from Cornell University developed as part of EEA's Climate and Hydrologic Risk Project. These IDF curve projections are available from for each 0.5 °C warming starting from 0.5 °C to 8 °C. The annual average temperature change for the Watershed is projected to be 2°C, 3°C, and 4.5°C for 2030, 2050, and 2070 scenarios, respectively. A comparison of the 24-hour design storms for the watershed between the present day NOAA Atlas 14 values and the future projections by the 2030, 2050 and 2070 planning horizons for the 2-yr, 10-yr 25-yr, 100-yr and 500-yr return periods are presented in Table 2.2.

[1] *Steinschneider, S., & Najibi, N. (2022). Observed and Projected Scaling of Daily Extreme Precipitation with Dew Point Temperature at Annual and Seasonal Scales across the Northeastern United States, Journal of Hydrometeorology, 23(3), 403-419.* https://journals.ametsoc.org/view/journals/hydr/23/3/JHM-D-21-0183.1.xml

Table 2.2 Proposed 24-hour design storm rainfall depths for future scenarios used in the Charles River Flood Model

Recurrence Interval	Present Day Baseline (in) (NOAA Atlas 14)	2030 Cornell IDF Projections (in) (2 °C Average Annual Temperature Change)	2050 Cornell IDF Projections (in) (3 °C Average Annual Temperature Change)	2070 Cornell IDF Projections (in) (4.5 °C Average Annual Temperature Change)
2-yr	3.34	3.82	4.09	4.53
10-yr	5.22	5.97	6.39	7.07
25-yr	6.39	7.31	7.83	8.66
100-yr	8.19	9.38	10.04	11.11
500-yr	11.18	12.80	13.69	15.16

**Note the CRFM has been run for the 2-yr, 10-yr and 100-yr return periods for the 2030 and 2070 planning horizons.*

Based on these projections, today's 100-yr storm (1% chance of occurring in a given year) is likely to be a 25-yr (4% chance of occurring in a given year) storm by 2070. In other words, what is a very rare event in today's climate will become a more common event within the next fifty years. Similarly, today's 25-yr storm (4% chance of occurring in a given year) is likely to be a 10-yr storm (10% chance of occurring in a given year) by 2050.

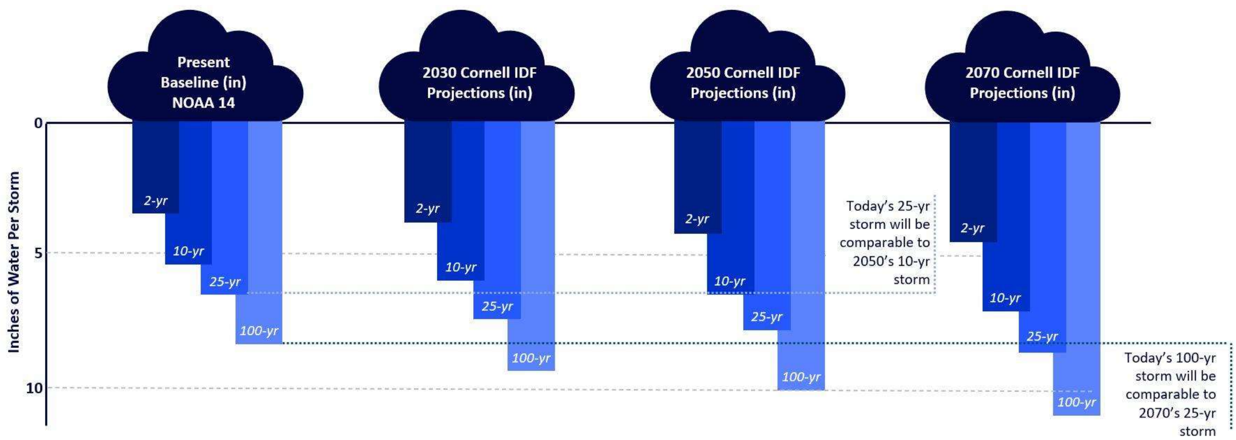


Figure 2.1 Projected future increase in precipitation scenarios in the Charles River watershed

2.2 CHARLES RIVER FLOOD MODEL RESULTS FOR BASELINE AND FUTURE UNDER NO-ACTION SCENARIOS

Using the calibrated Charles River Flood Model, and baseline (present day) and future climate design precipitation depths identified in Table 2.2, Weston & Sampson simulated nine storm events, including:

- Present day 2-, 10-, and 100-year events (3)
- 2030 2-, 10-, and 100-year events (3)
- 2070 2-, 10-, and 100-year events (3)

Flooding was evaluated for these conditions on both a watershed-wide scale and on a town or sub-basin scale.

2.2.1 Watershed-Wide Results

To understand how flooding will change under future climate scenarios, Weston & Sampson compared outputs for future climate simulations against simulations of corresponding present day rain events. In general, comparisons of present day and future climate conditions were made by considering the total inundated area, the number of critical infrastructure (e.g., schools, fire departments, police departments, etc.) expected to be inundated, and total runoff volume. Watershed-wide estimates of inundated area, impacted critical infrastructure, and total runoff volume are summarized below in Tables 2.3, 2.4, and 2.5, respectively, for the nine design storm scenarios. Figure 2.2 demonstrates example areas within the watershed where flooding is increased by late-century for the 10-year storm compared to present day.

Table 2.3 Total inundated area (acres) watershed wide by design storm

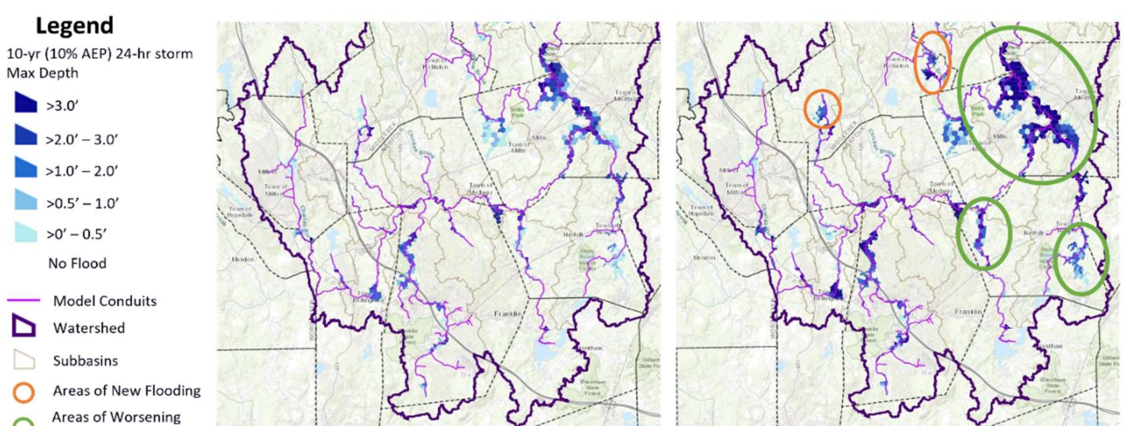
Climate Scenario	Total Inundated Area (acres) by Storm Event (Recurrence Interval)		
	2-year	10-year	100-year
Baseline (Present Day)	3,523	7,659	11,991
2030	4,409	8,925	13,089
2030 Increase Above Baseline, acres (% change)	886 acres (25%)	1,266 acres (17%)	1,098 acres (9%)
2070	6,256	10,673	14,605
2070 Increase Above Baseline, acres (% change)	2,733 acres (78%)	3,014 acres (39%)	2,614 acres (22%)

Table 2.4 Impacted critical infrastructure watershed wide by design storm

Climate Scenario	Number of Critical Facilities Impacts by Design Event (Recurrence Interval)		
	2-year	10-year	100-year
Baseline (Present Day)	33	49	61
2030	38	51	71
Increase Above Baseline, # of Facilities (% change)	5 (15%)	2 (4%)	10 (16%)
2070	41	57	77
Increase Above Baseline, # of Facilities (% change)	8 (24%)	6 (12%)	16 (26%)

Table 2.5 Total runoff in millions of gallons (MG) watershed wide by design storm

Climate Scenario	Total runoff (MG) by Design Event (Recurrence Interval)		
	2-year	10-year	100-year
Baseline (Present Day)	3,373	8,336	18,644
2030	4,382	10,758	23,113
Increase Above Baseline, MG (% change)	1,009 (30%)	2,422 (29%)	4,469 (24%)
2070	6,266	14,575	29,925
Increase Above Baseline, MG (% change)	2,893 (86%)	6,239 (75%)	11,281 (61%)

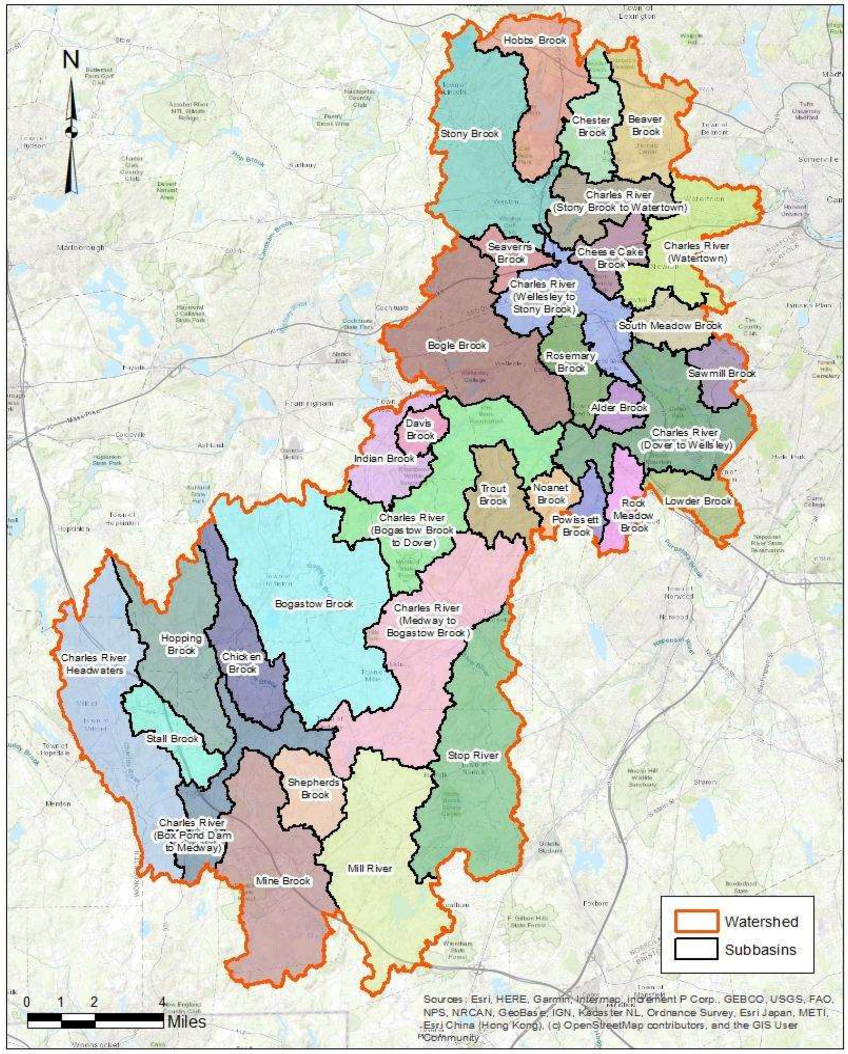


10-yr Storm Present
(5.22 inches in 24 hrs)

10-yr Storm 2070
(7.07 inches in 24 hrs)

Figure 2.2 Comparison of flooding results for Baseline (Present Day) 10-year and 2070 10-year design storms, circles highlight areas of new or worsened flooding

2.2.2 Sub-basin Specific Results



To understand the distribution of flood impacts at different locations, results were evaluated for each of the 34 sub-basins, one for each of the 26 named tributaries and eight along the main stem of the Charles River itself. These 34 sub-basins are shown in Figure 2.3 and the associated towns are listed in Table 2.6[2].

Changes in flooding caused by climate change vary across the watershed. A summary of the expected flooding and associated impacts to critical infrastructure for the baseline and 2070 10-year events for each sub-basin are found in Table 2.7. On average, inundated areas in the watershed are expected to increase by 39% for the future (2070) 10-year; however, some sub-basins will experience minimal increases in flooding extents, such as Sawmill Brook, while others like Alder Brook, will see increases in flood prone areas as high as 1451% for the 10-year storm by 2070. In five sub-basins – Beaver Brook, Charles River (Box Pond Dam to Medway), Charles River (Dover to Wellesley), Charles River (Stony Brook to Watertown), and Hopping Brook – the increases in flood prone areas are expected to impact additional critical infrastructure. Figure 2.4 and Figure 2.5 present the anticipated percent increase of inundated area and total runoff, respectively, by 2070 for the 10-year storm compared to present day 10-year storm for the 34 sub-basins.

A handful of sub-basins will see a considerable increase in flooded area. An example of the flooding extent for the baseline 10-year event and 2070 10-year event is shown in Figure 2.6 for Dedham.

[2] The sub-basin identified as Charles River (Watertown) was added as part of the model update and expansion described in Appendix 1, which extended the model to include all of Watertown and Newton in the Charles River Flood Model.

Table 2.6 Cities/towns associated with each of the 34 sub-basins

Subbasin/Community	Arlington	Ashland	Bellingham	Belmont	Boston	Brookline	Cambridge	Dedham	Dover	Foxborough	Franklin	Holliston	Hopedale	Hopkinton	Lexington	Lincoln	Medfield
Alder Brook																	
Beaver Brook	X			X											X		
Bogastow Brook		X										X					
Bogle Brook																	
Charles River (Bogastow Brook to Dover)									X								X
Charles River (Box Pond Dam to Medway)			X								X						
Charles River (Dover to Wellsley)					X			X	X								
Charles River (Medway to Bogastow Brook)									X		X						X
Charles River (Stony Brook to Watertown)																	
Charles River (Watertown)					X	X	X										
Charles River (Wellesley to Stony Brook)																	
Charles River Headwaters			X									X	X	X			
Cheese Cake Brook																	
Chester Brook															X		
Chicken Brook												X		X			
Davis Brook																	
Hobbs Brook															X	X	
Hopping Brook			X									X		X			
Indian Brook																	
Lowder Brook								X									
Mill River											X						
Mine Brook			X								X						
Noanet Brook									X								
Powissett Brook									X								
Rock Meadow Brook								X									
Rosemary Brook																	
Sawmill Brook					X	X											
Seaverns Brook																	
Shepherds Brook											X						
South Meadow Brook						X											
Stall Brook			X														
Stony Brook																X	
Stop River										X							X
Trout Brook									X								

Table 2.6 (cont.) Cities/towns associated with each of the 34 sub-basins

Subbasin/Community	Medway	Mendon	Milford	Millis	Natick	Needham	Newton	Norfolk	Sherborn	Walpole	Waltham	Watertown	Wayland	Wellesley	Weston	Westwood	Wrentham
Alder Brook						X											
Beaver Brook											X	X					
Bogastow Brook	X			X					X								
Bogle Brook					X	X							X	X	X		
Charles River (Bogastow Brook to Dover)				X	X	X			X					X			
Charles River (Box Pond Dam to Medway)	X																
Charles River (Dover to Wellsley)						X	X									X	
Charles River (Medway to Bogastow Brook)	X			X				X	X								
Charles River (Stony Brook to Watertown)							X				X	X			X		
Charles River (Watertown)							X					X					
Charles River (Wellesley to Stony Brook)						X	X							X	X		
Charles River Headwaters		X	X														
Cheese Cake Brook							X										
Chester Brook											X						
Chicken Brook	X																
Davis Brook					X												
Hobbs Brook											X				X		
Hopping Brook	X		X														
Indian Brook					X				X								
Lowder Brook																X	
Mill River								X									X
Mine Brook																	X
Noanet Brook																	
Powissett Brook																X	
Rock Meadow Brook																X	
Rosemary Brook						X								X			
Sawmill Brook							X										
Seaverns Brook							X								X		
Shepherds Brook																	
South Meadow Brook							X										
Stall Brook	X		X														
Stony Brook											X		X		X		
Stop River								X		X							X
Trout Brook					X												

Table 2.7 Summary of inundation extents and impacted critical infrastructure for baseline and 2070 10-year events, by sub-basin

	Inundated Area (acres)			Critical Infrastructure		
Subbasin	Baseline 10-year	2070 10-year	% Change	Baseline 10-year	2070 10-year	Change
Alder Brook	0	2	1451%	0	0	0
Beaver Brook	78	119	53%	2	4	2
Bogastow Brook	592	908	53%	1	1	0
Bogle Brook	217	255	18%	0	0	0
Charles River (Bogastow Brook to Dover)	459	654	43%	2	2	0
Charles River (Box Pond Dam to Medway)	294	451	54%	2	3	1
Charles River (Dover to Wellsley)	480	1044	118%	3	6	3
Charles River (Medway to Bogastow Brook)	1,315	1694	29%	5	5	0
Charles River (Stony Brook to Watertown)	91	114	25%	3	4	1
Charles River (Watertown)	132	136	4%	0	0	0
Charles River (Wellesley to Stony Brook)	126	221	75%	3	3	0
Charles River Headwaters	301	350	16%	8	8	0
Cheese Cake Brook	18	22	22%	0	0	0
Chester Brook	115	139	21%	2	2	0
Chicken Brook	16	50	215%	1	1	0
Davis Brook	15	19	27%	0	0	0
Hobbs Brook	620	628	1%	2	2	0
Hopping Brook	242	339	40%	1	2	1
Indian Brook	51	140	175%	0	0	0
Lowder Brook	146	185	27%	0	0	0
Mill River	246	330	35%	1	1	0
Mine Brook	623	724	16%	3	3	0
Noanet Brook	0	0	0%	0	0	0
Powissett Brook	40	40	0%	0	0	0
Rock Meadow Brook	22	84	283%	2	2	0
Rosemary Brook	41	42	4%	1	1	0
Sawmill Brook	39	39	0%	0	0	0
Seaverns Brook	11	26	137%	1	1	0
Shepherds Brook	46	46	0%	0	0	0
South Meadow Brook	15	32	113%	0	0	0
Stall Brook	48	162	240%	0	0	0
Stony Brook	463	505	9%	5	5	0
Stop River	713	1063	49%	1	1	0
Trout Brook	46	110	139%	0	0	0
Total	**7,659**	**10,673**	**39%**	**49**	**57**	**16%**

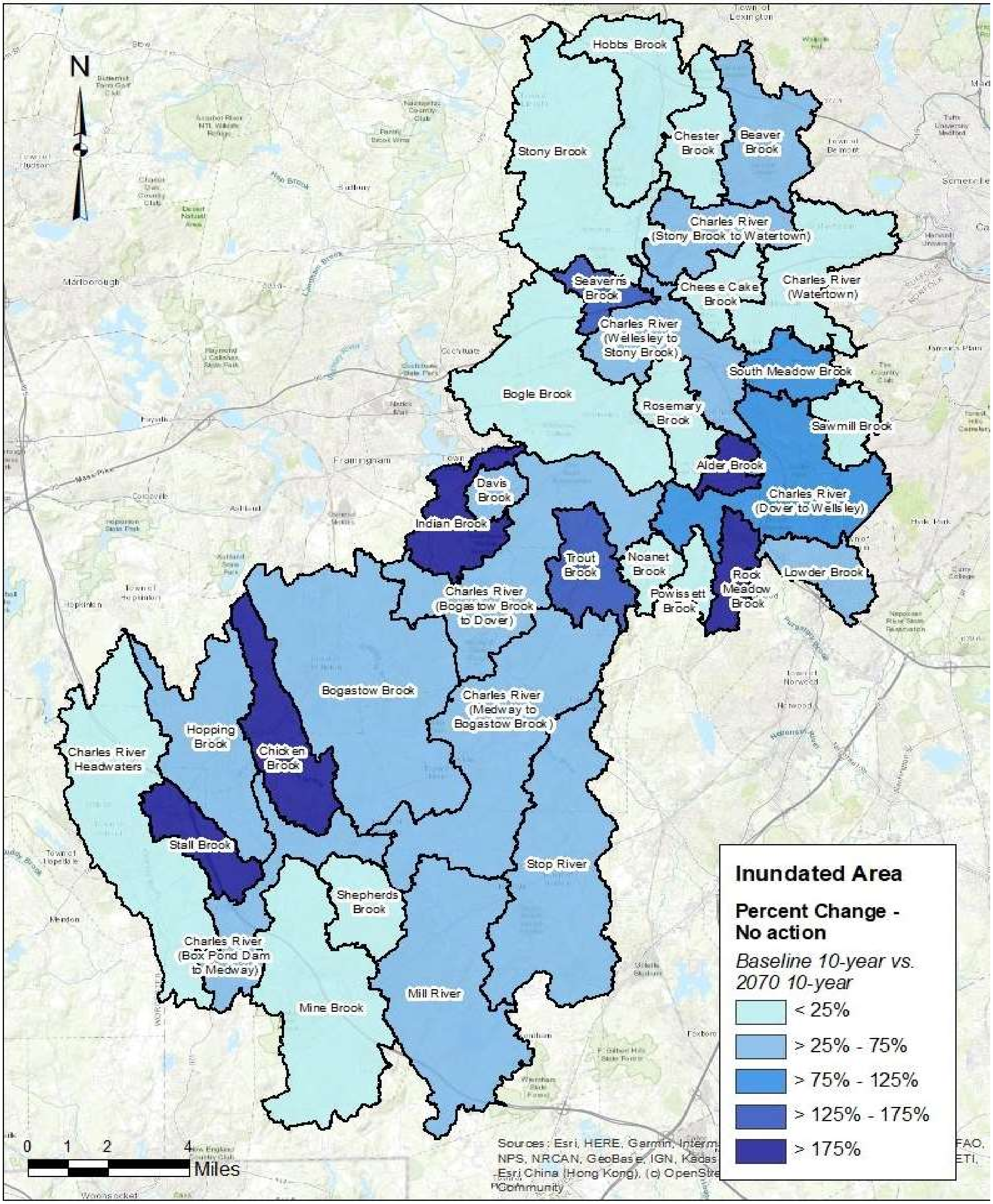


Figure 2.4 Map of the percent increase in inundated area during the 2070 10-year event versus the baseline 10-year event, by sub-basin

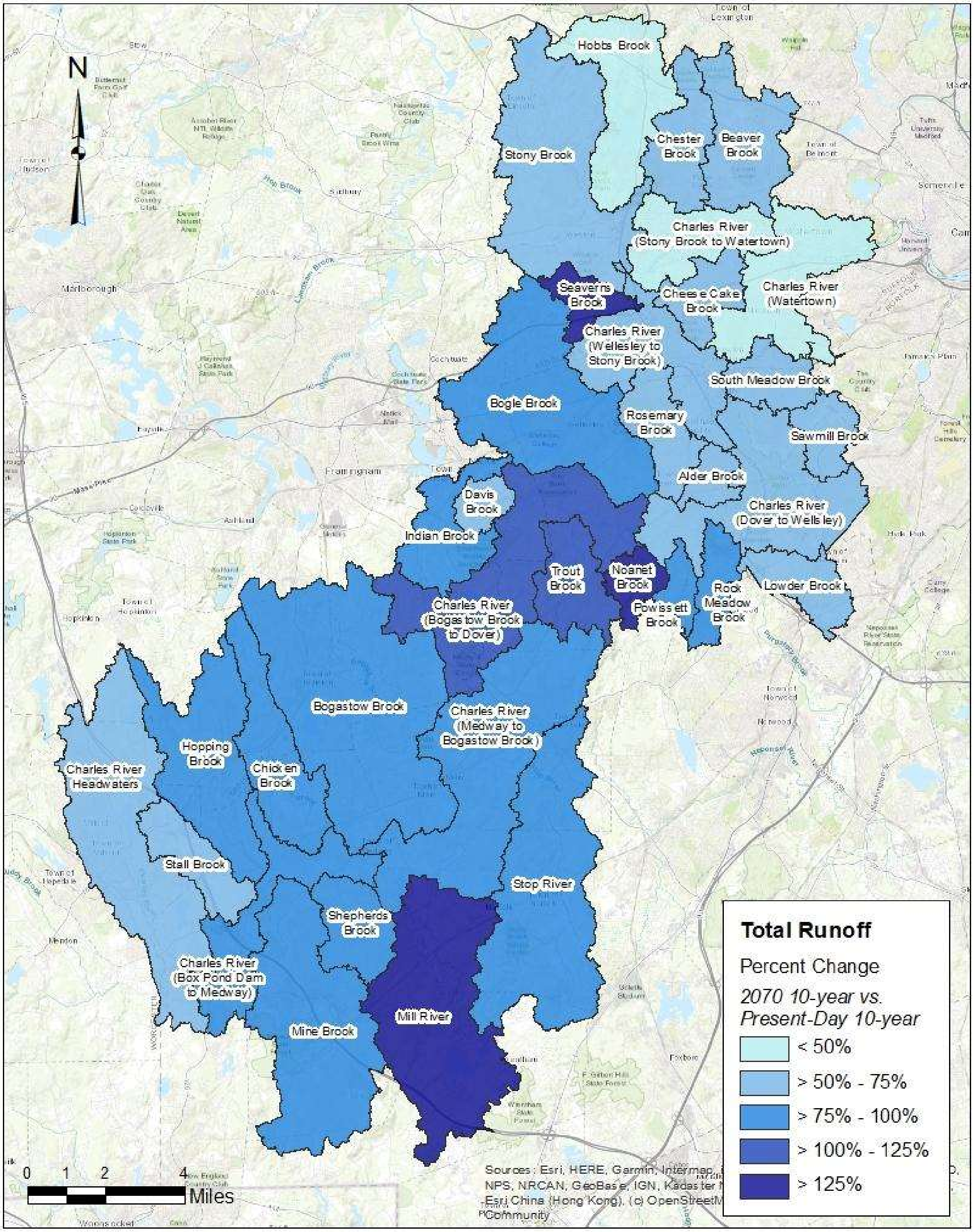


Figure 2.5 Map of the percent increase in total runoff volume during the 2070 10-year event versus the baseline 10-year event, by sub-basin

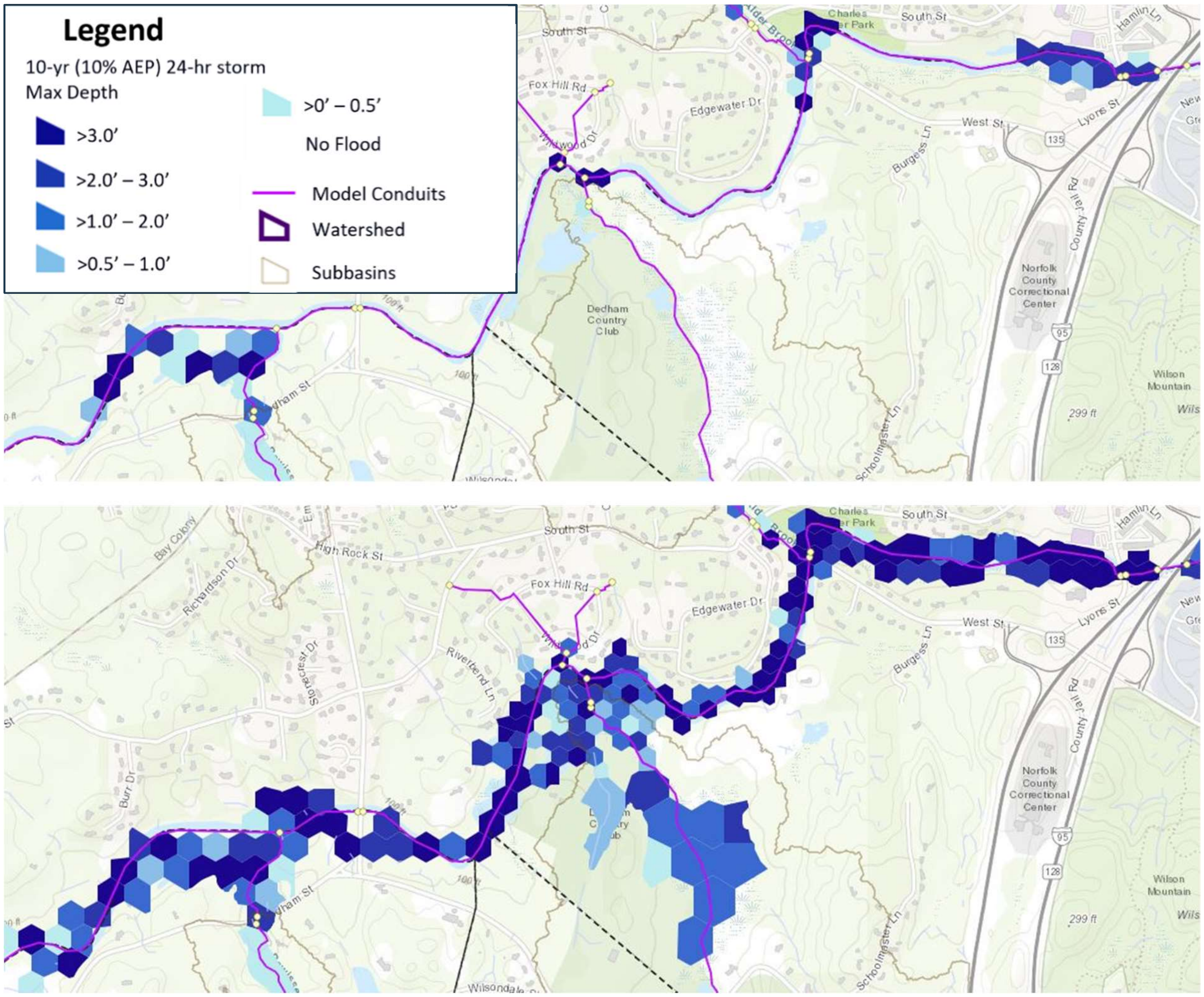


Figure 2.6 Comparison of flooding extents and depths during baseline 10-year (top) and 2070 10-year (bottom) design storm events in the Charles River in Dedham

As for the 2070 100-year event compared to the 100-year baseline, there are six sub-basins that will experience minimal increases of inundated area. The largest increase will be 92% within the Charles River (Bogastow Brook to Dover) sub-basin, with 1,321 acres inundated in the future event compared to 689 acres today. The sub-basin has a total area of 9,026 acres. Sixteen critical infrastructure assets that were not exposed to flooding in the baseline 100-year event will be exposed during the 2070 100-year event, twice as many compared to the 2070 10-year event (Table 2.8).

The Charles River (Watertown) sub-basin will experience the largest increase in total runoff in the 2070 100-year scenario with an increase of more than 125% above the present day baseline (Figure 2.7). During the 2070 10-year event, this same sub-basin is one of three that experiences the lowest increase in total runoff. This further exhibits the range of variability across the watershed and storm events.

Table 2.8 Summary of inundation extents and impacted critical infrastructure for baseline and 2070 100-year events, by sub-basin

	Inundated Area (acres)			Critical Infrastructure		
Subbasin	Baseline 100-year	2070 100-year	% Change	Baseline 100-year	2070 100-year	Change
Alder Brook	6	7	15%	0	0	0
Beaver Brook	127	134	6%	4	4	0
Bogastow Brook	1,133	1,256	11%	2	2	0
Bogle Brook	304	499	64%	1	6	5
Charles River (Bogastow Brook to Dover)	689	1,321	92%	2	6	4
Charles River (Box Pond Dam to Medway)	514	610	19%	4	4	0
Charles River (Dover to Wellsley)	1,254	1,485	18%	6	7	1
Charles River (Medway to Bogastow Brook)	1,897	2,228	17%	5	6	1
Charles River (Stony Brook to Watertown)	190	284	50%	4	4	0
Charles River (Watertown)	145	191	31%	0	1	1
Charles River (Wellesley to Stony Brook)	254	296	17%	3	3	0
Charles River Headwaters	387	500	29%	8	11	3
Cheese Cake Brook	24	30	23%	0	0	0
Chester Brook	148	166	12%	2	2	0
Chicken Brook	51	52	2%	1	1	0
Davis Brook	19	19	0%	0	0	0
Hobbs Brook	635	673	6%	2	2	0
Hopping Brook	345	377	9%	2	2	0
Indian Brook	158	265	68%	0	0	0
Lowder Brook	216	243	12%	0	0	0
Mill River	390	436	12%	1	1	0
Mine Brook	763	890	17%	3	3	0
Noanet Brook	0	0	0%	0	0	0
Powissett Brook	40	40	0%	0	0	0
Rock Meadow Brook	108	126	16%	2	2	0
Rosemary Brook	44	44	0%	2	2	0
Sawmill Brook	39	39	0%	0	0	0
Seaverns Brook	34	38	12%	1	1	0
Shepherds Brook	53	53	0%	0	0	0
South Meadow Brook	55	99	79%	0	1	1
Stall Brook	175	183	5%	0	0	0
Stony Brook	548	578	5%	5	5	0
Stop River	1,128	1,316	17%	1	1	0
Trout Brook	120	129	7%	0	0	0
Total	**11,990**	**14,603**	**22%**	**61**	**77**	**26%**

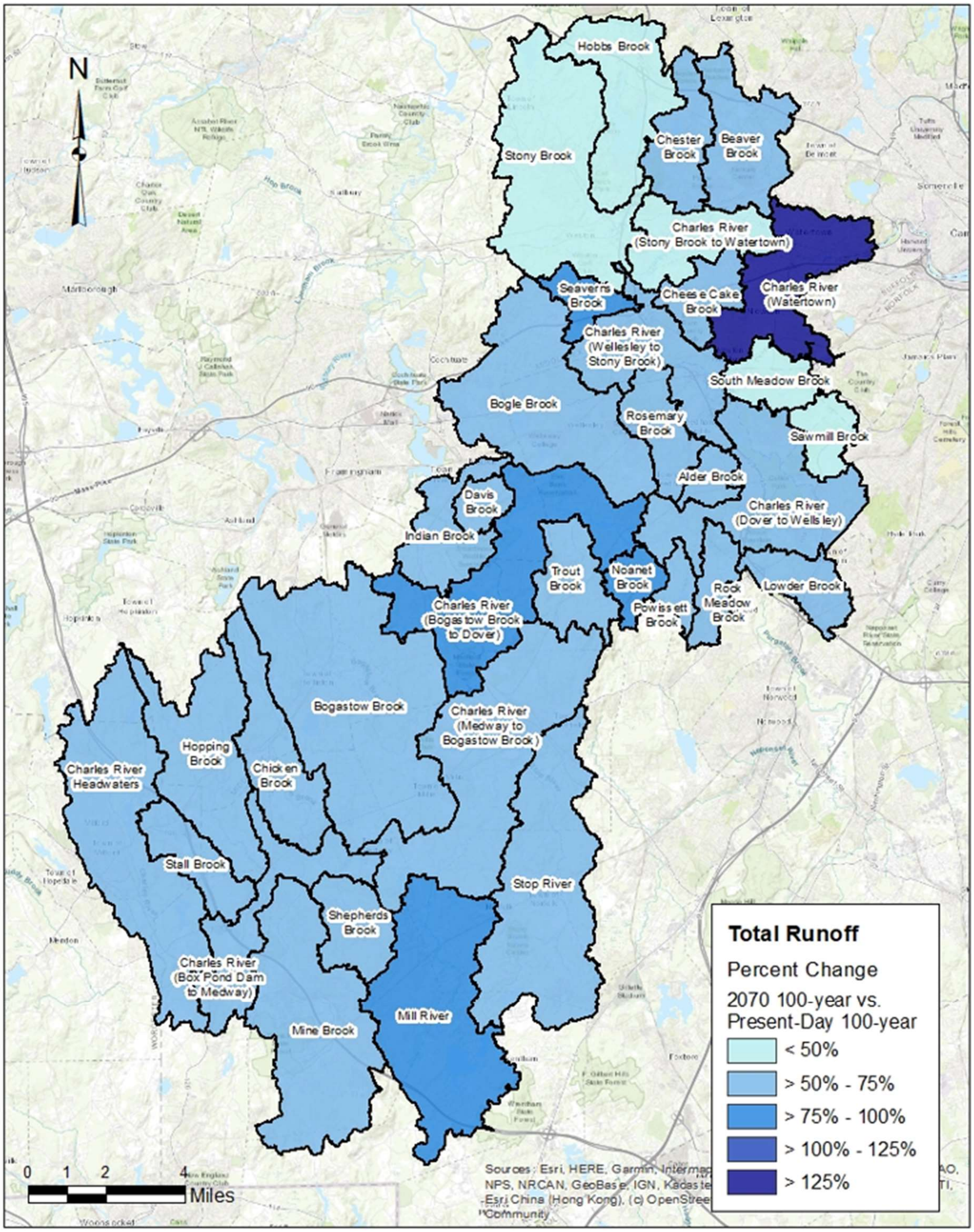


Figure 2.7 Map of the percent increase in total runoff volume during the 2070 100-year event versus the baseline 100-year event, by sub-basin

3.0 FLOOD REDUCTION PLAN

As summarized in Section 2, flooding impacts are expected to be severe across the watershed as a result of climate change, although impacts to vary by region. A variety of flood reduction strategies, at different scales and levels of detail, were simulated through the CRFM. Scenarios are tested in the model to assess their impact prior to making investments. The results of these "Action Scenarios", which are referred to as "Nature-Based Solution (NBS) Scenarios" for their use of nature-based flood reduction techniques are summarized in this section and the appendices. Each scenario is compared to both baseline and future no action conditions. As investments are made, it may be prudent to go beyond just mitigating the delta between future "no action" flooding and present-day baseline flooding to help build more resilience in our communities and account for some level of uncertainty. Investing in nature-based solutions is a low-risk way to do this as they provide a variety of co-benefits and therefore implementing these systems broadly will provide benefits well beyond flood control and are likely to be good community investments.

Flood mitigation/nature-based solution strategies were developed at two scales, the watershed-wide scale and the site scale. Watershed-scale scenarios are not site specific and assume broad-based change occurs across the watershed. Site scale designs, although still conceptual, are site specific and present a higher level of detail for a potential flood mitigation project at a specific location. Initial recommendations are provided based on the project findings. The team plans to continue to refine and test new strategies and engage with the public to further refine these recommendations and develop additional plans for taking on-the-ground actions.

Figure 3.1 Photo courtesy of Lisa Kumpf

3.1 Watershed Scale Nature-Based Solutions Strategies

Watershed scale NBS strategies were selected by the project team with input from the public. In 2021, the team used CRFM version 1.0 to model and assess the impact of multiple watershed scale flood mitigation strategies, which demonstrated modest flood reductions. Therefore, new watershed scale strategies were selected to be assessed using the CRFM v2.1.

3.1.1 NBS Scenario Selection

The project team and public each weighed in on the types of strategies they were interested in seeing modeled. The multi-lingual public survey received over 170 responses. Results from the public survey are displayed in Table 3.1.

Table 3.1. Public Input Survey Results

Which Nature-Based Solutions would you like to see in your community?	Which Nature Based Solutions would be possible in your community?
1. Wetland Restoration	**1. Green Stormwater Infrastructure**
2. Green Stormwater Infrastructure	**2. Land Conservation**
3. Land Conservation	3. Increase Tree Canopy
4. Less Paved Surfaces	4. Wetland Restoration
5. Increase Tree Canopy	5. Less Paved Surfaces

Green stormwater infrastructure and *land conservation* scored well with the public in response to both questions. The public survey included two categories not listed in Table 3.1: *dam removal* and *move development out of the floodplain*; both categories scored lower than the others, these were selected by less than 35% of respondents in both questions compared to 55 -75% for the categories in Table 3.1.

CRWA and Weston & Sampson developed specific watershed scale scenarios within these categories which the project team voted on, 7 of the possible options received support from more than 40% of the respondents, which were selected, however, the dam removal scenario was initially deemed an alternative due to the lack of support from the public. Additionally, although the *(Lack of) Land Conservation* scenario received support from 36% of project team respondents it was also selected as an alternative due to the high level of support from the public. Table 3.2. summarizes the watershed scale strategies assessed.

Table 3.2. Watershed-scale flood mitigation strategies

Category	Goal	Scenario #	Phase 2 Nature Based Solutions (NBS)
Green Stormwater Infrastructure (GSI)	Store more runoff in/under/near the impervious surfaces where much of it originates	1A	Green Infrastructure Storage: Green stormwater infrastructure (GSI) used across the watershed to store runoff from the future (by 2070) 2-yr rain event (4.5”) from half of the impervious cover in the study area
		1B	Storage on Large Impervious Parcels: Aggressive flood mitigation at large impervious parcels, assumes parcel 5 acres or larger with impervious cover is storing the difference in runoff between the future (by 2070) 2-yr and 25-yr storms (~4.1”) onsite
Reduce Impervious Cover	Generate less runoff	2	Impervious Cover Reduction: Impervious cover is reduced by 25% across the watershed
Upland/Pond Storage	Increase storage of existing ponds	3	Pond Storage and Management: Fourteen ponds, larger than 20 acres, are lowered by 1 ft before a rain storm to allow for extra storage in the pond
Wetland Restoration	Increase storage of existing wetlands	4	Wetland Restoration: Increase the size of the mapped wetlands by 20%
Open Space Development (Lack of Land Conservation)	Reduce expected increases in runoff by limiting future development; protect the inherent flood control benefits of natural lands	5A	Open Space Development *without* Stormwater Mitigation: 15% of land that is currently undeveloped and unprotected is developed without any flood control measures; no changes were assumed for any other areas of the watershed
Regulatory	Offset impacts of future development by requiring GSI	5B	Potential Future Development of Open Space *with* Stormwater Mitigation: Require GSI to store the difference in runoff between the future (by 2070) 2-yr and 25-yr storms from 50% of “new development” impervious cover
Dam Removal	Remove dams to lower flood levels upstream	Alt B	Dam removal: Remove non-flood control dams

3.1.2 NBS Scenario Results

Modeling of the eight NBS scenarios demonstrated the options with the greatest flood reduction potential. At the watershed scale, Green Infrastructure Storage (NBS-1A), Impervious Cover Reduction (NBS-2), and Pond Storage and Management (NBS-3) had the largest reductions in total watershed runoff volume, as seen in Figure 3.2. These options had the greatest reductions for the 2070 10-year event compared to the no-action scenario for the same storm.

The flood reduction benefits of Green Infrastructure Storage (NBS-1A) and the other scenarios vary by design storm with the largest benefits being observed for the smaller storms. For instance, this scenario is more effective in a future 2-yr event than a future 10-yr event. Summary tables in Appendix 3 provides additional detail on the watershed-wide nature-based solutions, including identification of flood reduction benefits for various design storms, the distribution of those benefits across the individual sub-basins, and map figures, which highlight areas that experience some of the greatest benefits.

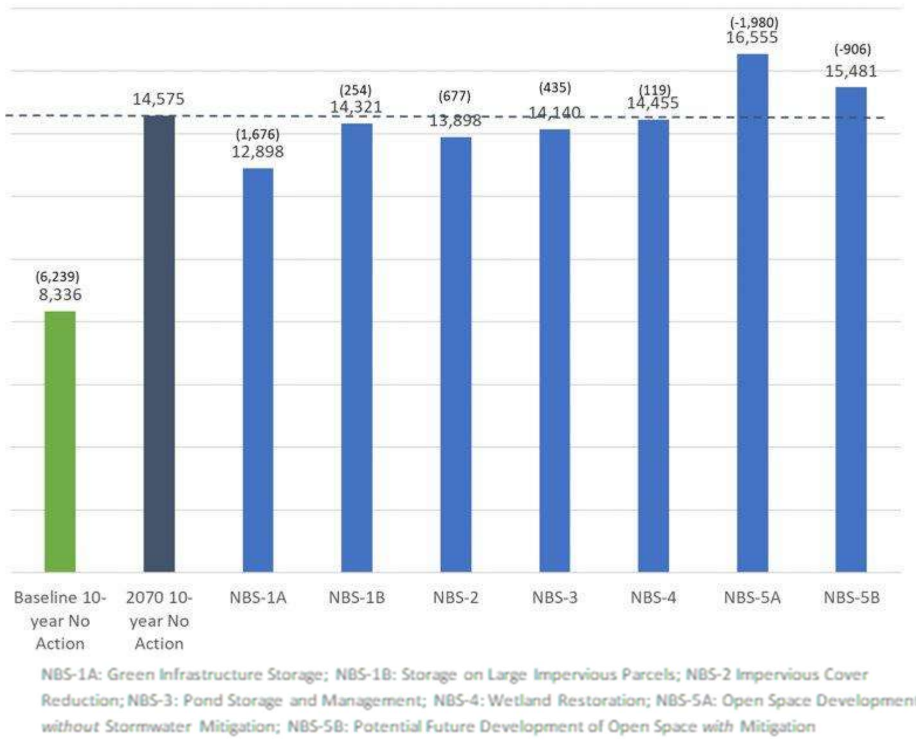


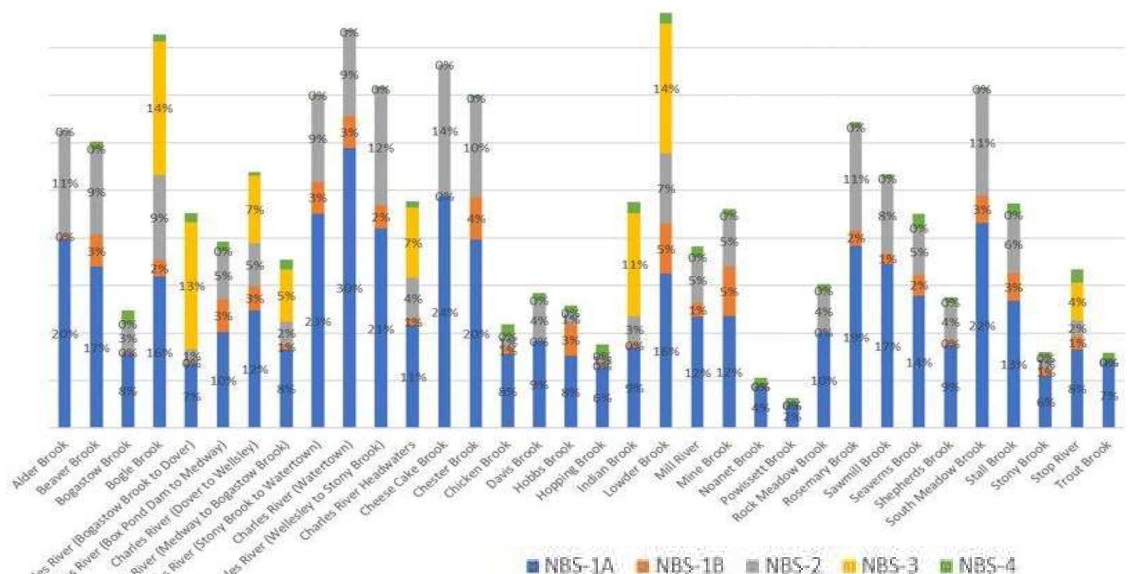
Figure 3.2 Comparison of Nature-Based Solutions and "No-Action" conditions in terms of total watershed runoff volume during the 2070 10-year design storm

There is considerable variability in flood reduction benefits across sub-basins and nature-based solutions, with some sub-basins responding favorably to a particular solution while others are barely impacted. For example, in Figure 3.3, Green Infrastructure Storage (NBS-1A) has the greatest flood reduction potential for the Charles River (Watertown) sub-basin, experiencing a 30% reduction in total runoff volume. Other sub-basins, like Hopping Brook and Stony Brook, saw 6% reductions under this scenario. Noanet Brook and Powissett Brook saw 4% and 2% reductions in runoff volume, respectively, for Green Infrastructure Storage (NBS-1A), yet that scenario is still considered the best option for those sub-basins, as they were not impacted or minimally impacted by the other NBS scenarios.

Figures 3.3 and 3.4 also highlight some of the differences in flood reduction benefits across the 34 sub-basins. For instance, there are a few sub-basins for which Pond Storage and Management (NBS-3) provides considerable runoff reductions, although the simulated benefits were quite small for most sub-basins. Impervious Cover Reduction (NBS-2) is more modest in terms of total runoff volume reductions than Green Infrastructure Storage (NBS-1A) but is also more equal in distribution of benefits compared to Pond Storage and Management (NBS-3), and is generally the second most effective scenario evaluated for most sub-basins. Wetland Restoration (NBS-4), however did not prove to be an effective strategy, it has a small flood reduction potential for most sub-basins. This is most likely because the increase in wetland area is quite modest. A small increase was assumed because of the current permitting challenges associated with working in or near wetlands.

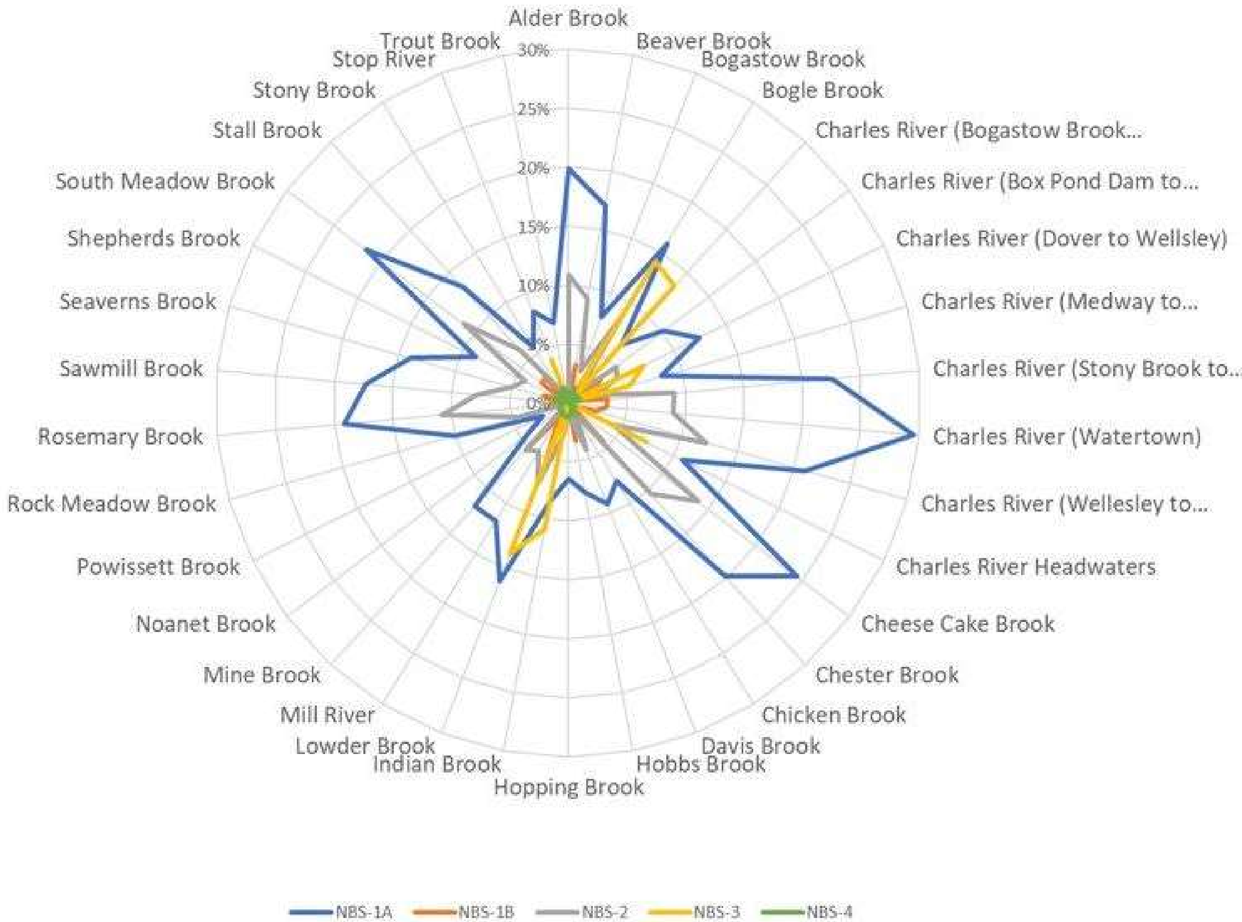
The impacts of developing undeveloped unprotected land (Open Space Development *without* stormwater Mitigation (NBS-5A)) highlight the potential increase in flooding if these spaces are not protected in the future. Watershed-wide, the 2070 10-year event is expected to increase total runoff volume by 14% (compared to 2070 10-year no-action) if about 17,000 acres of current green space is developed without any stormwater management considerations (NBS-5A). The sub-basins will see an increase in total runoff of at least 2%. The Charles River (Stony Brook to Watertown), Hobbs Brook, and Sawmill Brook sub-basins are among the lowest. Mill River and Seaverns Brook will have the largest increases in total runoff with 35% and 33%, respectively.

The Potential Future Development of Open Space *with* Stormwater Mitigation scenario (NBS-5B) demonstrates the importance of requiring stormwater management strategies during the potential development of undeveloped unprotected land. In this scenario, it was assumed that 50% of the undeveloped unprotected land is potentially developed using stormwater management strategies such that the 25-year post development runoff is less than the 2-year pre-development runoff by 2070. Under this scenario, there is 6% increase in runoff volume (compared to 2070 10-year no-action). To achieve these targets, at least half of this new development aggressively implements green infrastructure strategies to make post development conditions no worse than pre-development conditions. On a sub-basin scale, Mill River and Seaverns Brook will have the largest increases in total runoff with 17% and 16%, respectively under Potential Future Development of Open Space *with* Stormwater Mitigation (NBS-5B).



NBS-1A: Green Infrastructure Storage; NBS-1B: Storage on Large Impervious Parcels; NBS-2 Impervious Cover Reduction; NBS-3: Pond Storage and Management; NBS-4: Wetland Restoration; NBS-5A: Open Space Development *without* Stormwater Mitigation; NBS-5B: Potential Future Development of Open Space *with* Mitigation

Figure 3.3 Effectiveness of Nature-Based Solutions, on a sub-basin basis, in terms of total watershed runoff volume during the 2070 10-year design storm (column chart)



NBS-1A: Green Infrastructure Storage; NBS-1B: Storage on Large Impervious Parcels; NBS-2 Impervious Cover Reduction; NBS-3: Pond Storage and Management; NBS-4: Wetland Restoration; NBS-5A: Open Space Development *without* Stormwater Mitigation; NBS-5B: Potential Future Development of Open Space *with* Mitigation

Figure 3.4 Effectiveness of Nature-Based Solutions, on a sub-basin basis, in terms of total watershed runoff volume during the 2070 10-year design storm (radar chart)

3.2 SITE SPECIFIC STRATEGIES

The project team selected three sites through a multi-step identification and prioritization process described below. Concept designs were developed for each of these priority sites and the CRFM was used to quantify the flood reduction benefits of each concept design. The concept designs are intended to serve as an initial step in implementing these and many other flood reduction projects across the watershed. The concept designs demonstrate how flood mitigation activities, such as stormwater storage and infiltration, can be incorporated into municipal or private projects.

3.2.1. Priority Site Selection Matrix

Prioritization criteria were developed based on project goals, a review of prioritization criteria in similar initiatives, and input from the project team and the public (Table 3.3). The prioritization criteria were shared with the municipal project partners, who were then asked to nominate local projects that would meet these criteria. Project nominations were also sought from the public, this was an open-ended solicitation asking the public to provide information on any known flood reduction ideas, opportunities, or initiatives occurring in their community.

The prioritization matrix had two tiers. Tier 1 criteria were broader and intended to be the initial screening of projects. Tier 2 criteria were more detailed and intended to select the final priority projects. A scoring methodology was developed using a 0-2 range for each prioritization criteria in both Tiers 1 and 2. In the Tier 2 scoring methodology, flood mitigation benefits and habitat protection/creation were weighted more heavily than the other categories based on the project goals and public input.

Table 3.3. Flood Mitigation Project Prioritization Criteria Matrix

Tier	Category	Metric	Method of Determination	0	1	2
		Land owner support	Input survey	No/unknown		Yes
		Stage of project	Input survey	Opportunity identified	Conceptual design	Preliminary designs complete
		Access to water	Input survey	No/don't know		Yes, stormwater pipe nearby OR Yes, adjacent to stream.
			Activity/Use Limitation (AUL) sites, 21 (e) sites, and underground storage tanks as identified on MassGIS in 2016 with 200' buffer (same as NBS mapping tool) (two points for each conflict, and the three scores were averaged)	No conflicts	Two conflicts (actual score 1.33 points due to averaging)	All three conflicts
		Minimize site conflicts	Wellhead Protection Zone I areas as identified on MassGIS in 2016	Overlap > 1/4 acre	Overlap < 1/4 acre	No overlap
1	Site feasibility	Available (flat) space	Input survey	< 1 acre	1-4 acres	4+ acres
		Part of a multi-system approach in a subbasin with significant flooding impacts	Is it in the same subbasin as another submitted project? Is it in a priority subbasin?	Not in a priority subbasin or only project submitted for that basin	In a priority subbasin OR one of multiple projects submitted for the basin	In a priority basin AND one of multiple projects submitted for the basin
		Reduces flood damage	GIS: Impacted building square footage in the subbasin of the project based on flood predictions in the no action 2070 10-yr storm scenario	Subbasin has minimal potential flood damage (bottom tier)	Subbasin has moderate potential flood damage (middle tier)	Subbasin has most potential flood damage (top tier)
	Flood reduction	Reduces flooding in EJ neighborhoods	In subbasin with EJ neighborhood (GIS)	No		Yes
	Community support	Demonstrated community support	Input survey (Is there a community group/member/committee working in support of restoration at this site? Is the project identified in a community plan?)	No		Yes
Top 15 projects scored in Tier 2						
		Tree removal required	GIS review of aerial image; best professional judgement	Yes - forested area	Minimal	No
	Supporting healthy habitats / Habitat crea	Habitat Protection. Identifies areas that if conserved can protect core and critical aquatic and terrestrial habitat, sustain biodiversity, provide connectivity, and build ecosystem resilience in a changing climate. In urban areas habitat conversion, fragmentation, and degradation threaten the biodiversity of isolated natural spaces. This layer identifies habitat areas most important for conservation and preservation projects.	Habitat Protection (Tier 1) Identifies areas that if conserved can protect core and critical aquatic and terrestrial habitat, sustain biodiversity, provide connectivity, and build ecosystem resilience in a changing climate. In urban areas habitat conversion, fragmentation, and degradation threaten the biodiversity of isolated natural spaces. This layer identifies habitat areas most important for conservation and preservation projects.	Not within 200 ft. of parcel		Yes within 200 ft. of parcels
2		Provides recreation & greenspace	Green desert (GIS)	Does not overlap		Overlaps
	Recreation opportunity		Input survey (is there potential for the project to provide a recreational opportunity- passive or active)	No		Yes
		wetland resource area/protected conservation area	GIS (overlap with MassDEP Wetlands 100' buffer) & Input survey	Yes	Partially	No
	Permitting feasibility	Natural Heritage area & Areas of Critical Environmental Concern (ACEC)	GIS	Yes	Partially	No
	Regional co-benefit	Proximity to multiple cities/towns	GIS (within 1/4 mile of 2+ communities)	No		Yes
	Proximity to EJ neighborhood	Within 1/4 mile	GIS	No		Yes
	Flood benefits	Mitigates the cause of flooding	Based on the 2070 10-yr no-action scenario model, what are the key hydraulic constraints through the project area that can mitigate the identified cause of flooding (e.g. hydraulic capacity limitations, backwater controls, inlet capacity limitations, flooding extents (e.g.,. tributary with significant slope impact is limited), etc.)	bottom tier	middle tier	top tier

3.2.2 Priority Site Selection Results

Over 50 projects were identified and submitted by municipal partners, the general public, and CRWA (Appendix 2). Project submissions were reviewed for duplicates in the study area. A total of 52 sites were then scored through the Tier 1 criteria. The top fifteen scoring sites were then assessed through the Tier 2 criteria. Scoring results for projects scored in Tier 2 are summarized in Table 3.4. The identification of over 50 projects points to the significant amount of interest in the watershed to implement stormwater management and flood control projects.

Table 3.4 Priority Project Results

Scores	Projects
Top Scores (28-31)	**Hardy Pond, Waltham** 35R Coffee St., Medway **Oakland Park/CoA Center, Medway** Watertown Dam Wilson St and South St., Medfield
Second Place (24-26)	***40 & 27 Seekonk St., Norfolk*** 45 Broad Street, Medway 123 Holliston St., Medway **Albemarle Field, Newton** Burke Elementary School, Medway
Third Place (22-23)	Kelly Field, Wellesley Weston Town Center McGovern Elementary School, Medway Dopping Brook Road, Sherborn Eagle Dam, Wrentham

Once the scores were finalized the results were discussed with the full project team and it was decided that one project per community should be prioritized, dam removals should not be considered as priority projects due to the complexity of these such projects and as dam removal as a strategy has scored very low with the public in multiple outreach surveys, and projects for which concept designs are being developed through other initiatives would not be prioritized here. As a result, four projects, shown in bold in Table 3.4 were selected as priority projects. The project in Norfolk was not advanced for two reasons, this two-part project included a culvert redesign (40 Seekonk), which the Town already had concept level designs for, and a land acquisition (27 Seekonk) which hit a roadblock during the project.

3.2.3 Priority Project Concept Designs

3.2.3.1 Hardy Pond

Hardy Pond is located in Waltham, MA and forms the headwaters of Chester Brook, a tributary that confluences with Beaver Brook before discharging to the Charles River. Currently, its outlet structure is a 25-foot concrete, spillway weir. A large wetland system forms directly west of the pond, but its flow and connections are constrained by areas of previous development and urban fill. Hardy Pond is situated within a dense, suburban neighborhood and Lazazzero Playground to the south.

The concepts developed for Hardy Pond focus on developing more dynamic storage capacity while improving water quality. They can be implemented individually or as a set of phased projects and the options considered are illustrated in Figure 3.5a (without the berms) and Figure 3.5b (with berms). Below is a breakdown of each concept and intention followed by descriptions of the types of nature-based solutions being proposed.

Concept 1 – Multi-Stage Outlet Control Structure and Fish Ladder

In this concept, a multi-stage outlet control structure is proposed to regulate the water flow out of Hardy Pond. The proposed multi-stage outlet control structure will allow the pond elevation to be raised or lowered to accommodate anticipated storm events. Remotely or manually operated, the control structure will utilize adjustable levels to modify the outlet size and elevation. Additionally, a proposed fish ladder adjacent to the outlet control will help reduce the disruption this structure can have on the migration of fish between the Chester Brook and Hardy Pond.

Concept 2 – Earthen Berms

In this concept, earthen berms would protect residential properties near the Pond and allow for raising the pond elevation by an additional 1 foot. Earthen berms made of compacted soil will act as a barrier to protect existing low-lying properties adjacent to the pond while allowing water to rise in the event of a storm. The plans show approximate locations and extents for where berms may be useful, and would require additional survey work and coordination with property owners in the future.

Concept 3 – Fill Removal

In this concept, urban fill would be removed from the adjacent wetlands to increase the storage capacity of the wetland area west of the pond. The plan highlights locations of fill to be removed that were part of previous urban development of the neighborhoods surrounding the pond. Urban fill contains introduced soils and other materials that impact the flows and connectivity of the wetland to the pond. Removing this fill will allow the floodplain to expand and increase the storage capacity of the pond and wetland system.

Concept 4 – Stormwater BMPs Bioretention & Stabilization

In this concept, stormwater treatment systems, including bioretention and stabilization strategies are proposed to improve the water quality of stormwater runoff that currently outfalls directly into the pond. These systems work with the existing drainage network by intercepting stormwater runoff from impervious surfaces before it enters catch basins and redirects it to surface storage areas that allow for infiltration. Treatment occurs through UV exposure, plant root uptake, soil microbes and by slowing water. These green infrastructure stormwater treatment systems can include bioswales or bioretention.

Incorporated Nature Based Solutions

Bioretention

Bioretention uses soil, plants and microbes to treat stormwater before it is infiltrated or discharged. It contains shallow depressions, known as "cells", that are filled with high void soils, with a thick layer of mulch, and planted with dense vegetation. As runoff enters the cells, it slowly infiltrates. The Hardy Pond site utilizes bioretention in Concept 4 alongside the residential developments to slow runoff creating more opportunities for infiltration and improve water quality before entering the pond.

Bioswales

Bioswales or sunken planters capture and hold stormwater runoff and allow it to slowly infiltrate through soil media, thus reducing flooding. Roots uptake water as well as nutrients in the runoff. These systems provide water quality benefits by removing pollutants. They can be installed along sidewalks, in medians, and parking lot edges to directly treat runoff from surrounding impervious surfaces. These components can retain stormwater for future use or detain it before it flows back into the drainage system after the storm event.

Water quality benefits in the Charles River Watershed resulting from these nature-based solutions are quantified by phosphorus load reduction in pounds reduced per year. The bioretention systems conceptualized at the Hardy Pond site are estimated to have a phosphorus load reduction of 1.13 pounds per year. Calculations and references can be found in Appendix 5.

Wetland Restoration

Hardy Pond concept 3 would improve the health of the Pond's adjacent wetlands by removing urban fill and restoring those areas to healthy wetland habitats. This helps promote a natural flood plain adjacent to the pond and provides a healthy wetland habitat in a densely developed suburban area.

Figure 3.5a Hardy Pond concepts (with no berms) Figure 3.5 Hardy Pond concepts

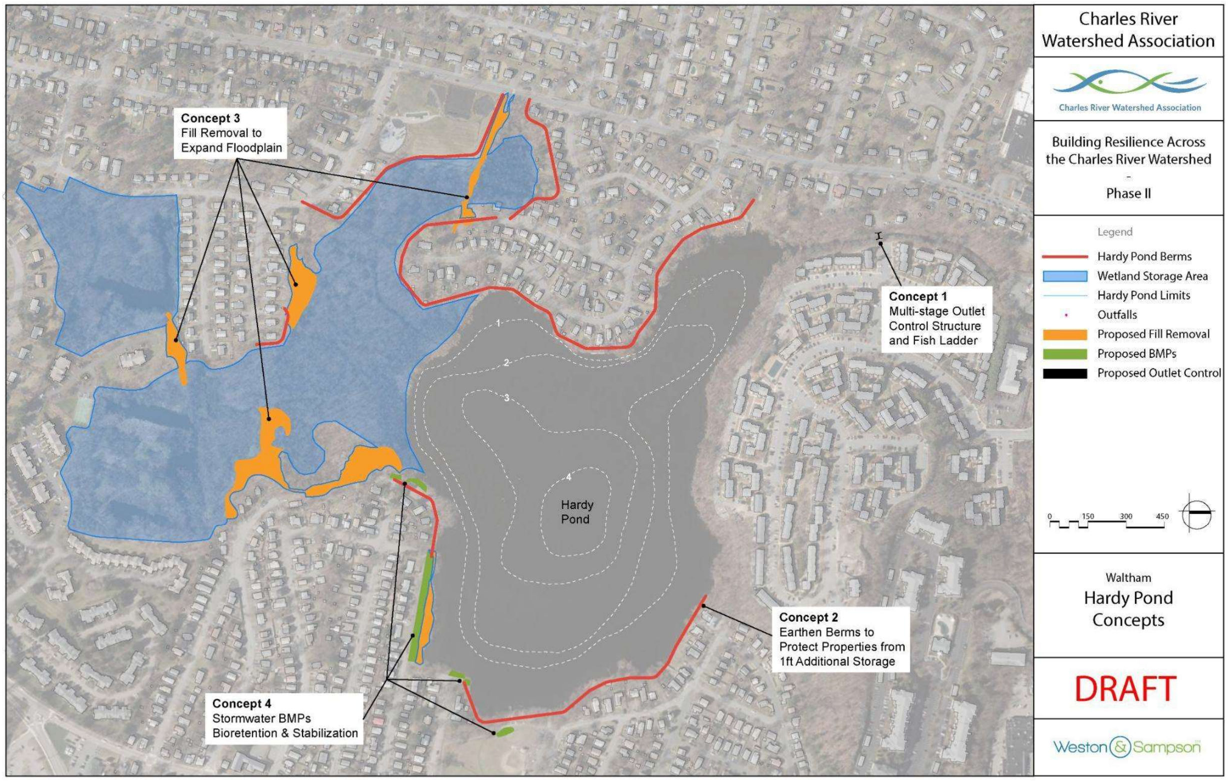


Figure 3.5b Hardy Pond concepts (with berms)

3.2.3.2 Medway Site

Oakland Park in Medway utilizes the large recreational, open, and parking areas adjacent to the Council on Aging property along Oakland St. The property is perched above a large wetland area that lines the site to the south and east. During stakeholder meetings, the subsurface was characterized as sandy or fast draining which benefits strategies like infiltration. There are also two Wellhead Protections Zones that overlay the site and influenced the proposed concepts, i.e., needing to treat runoff before storing and infiltrating. These concepts can be implemented individually or as a set of phased projects. The different concepts considered for this site are illustrated in Figure 3.6.

Concept 1 – Combined BMPs and Underground Storage Below Smaller Recreational Field

This concept envisions the combination of a stormwater quality bioswale with underground storage to contain stormwater runoff from Oakland St. and surrounding properties. The bioswale hugs the edge of the field while avoiding the root zones of the existing, mature trees. Through curb cuts runoff can be directed into the bioswale and stored temporarily on the surface before infiltrating into the underground storage beneath the playing surface. A full build out of the underground storage is approximately 17,000 sq. ft.. The depth of the storage has the potential to range from 1 to 3 feet and does not impact the playability of the field surface or use. This implies that the maximum potential flood storage volume can range from17,000 cu.ft. to 51,000 cu.ft.

Concept 2 – Combined BMPs and Underground Storage Below Large Recreational Field Space

This concept functions similarly to Concept 1. This area of the site has a larger recreational surface, allowing for a potential full build out of 90,000 sq. ft. of underground storage. Alongside the northern and southern edges of the field are stormwater quality bioswales. Runoff falling directly on the field and from the eastern edge of the parking lot will flow into the vegetated bioswales that temporarily store water on the surface before allowing infiltration into the underground storage. The depth of the storage has the potential to range from 1 to 3 feet and does not impact the playability of the field surface or use. This implies that the maximum potential flood storage volume can range from 90,000 cu.ft. to 270,000 cu.ft.

Concept 3 – Combined BMPs, Underground Storage, and Roof Rain Harvesting

The third concept proposes collecting stormwater from portions of Oakland St, the lower parking lot, and the roof of the building into a 9,000 sq. ft. underground storage area east of the building. Runoff from Oakland St. will enter a roadside bioswale with surface storage. As water infiltrates through the soil, underdrains will pipe water from the bioswale to the underground storage. Harvesting rain from the roof is as simple as modifying the downspout to drain directly into the same underdrain pipe as the bioswale along Oakland St. Pretreatment of the roof rain with charcoal filters can easily be incorporated into the downspout modification if required. The eastern bioswale intercepts stormwater flowing from the impervious parking surface in the lower lot. Similarly, the bioswale adds surface storage, allows infiltration and treatment of runoff before it enters the same underground storage area.

Incorporated Nature Based Solutions

Underground Storage

The design and implementation of underground storage is increasingly flexible and partly based on the subsurface site conditions and restrictions. The key is to create high porosity volumes underground while maintaining structure and loading capacity above the system. Underground Storage may come in the form of gravel wetlands, pre-cast vault systems, and even modular crate-like designs. Storage chambers can be for reuse, detention, infiltration, or controlling the flow of on-site stormwater runoff. Underground storage is a key component of the Medway site with around 116,000 sq. ft. of proposed underground storage. These concepts envision underground storage as either gravel wetlands or modular systems that are open-bottomed and allow infiltration.

Bioswales

Bioswales or sunken planters capture stormwater runoff and allow it to slowly infiltrate through soil media, thus reducing flooding. Roots uptake water as well as nutrients that remain in the soil. These systems provide water quality benefits by removing pollutants, i.e., sediment, excess nutrients, road-related chemicals. They can be installed along sidewalks, in medians, and parking lot edges to directly convey runoff from surrounding impervious surfaces. These components can store water for future use or detain it before it flows back into the drainage system after the storm event. Bioswales are also a key stormwater quality BMP being implemented in the Medway site's three concepts. Water stored in underground storage must be filtered before being stored, thus implementing bioswales help improve water quality and slow down infiltration.

The bioswales conceptualized at the Medway site have been estimated to have a phosphorus load reduction of 1.92 pounds per year. Following the bioswale water quality treatment, the stormwater will then be treated in the underground chambers, removing an estimated additional 11.44 pounds of phosphorus per year. In total, these systems will remove a total of 13.36 pounds of phosphorus per year. Calculations and references can be found in Appendix 5.

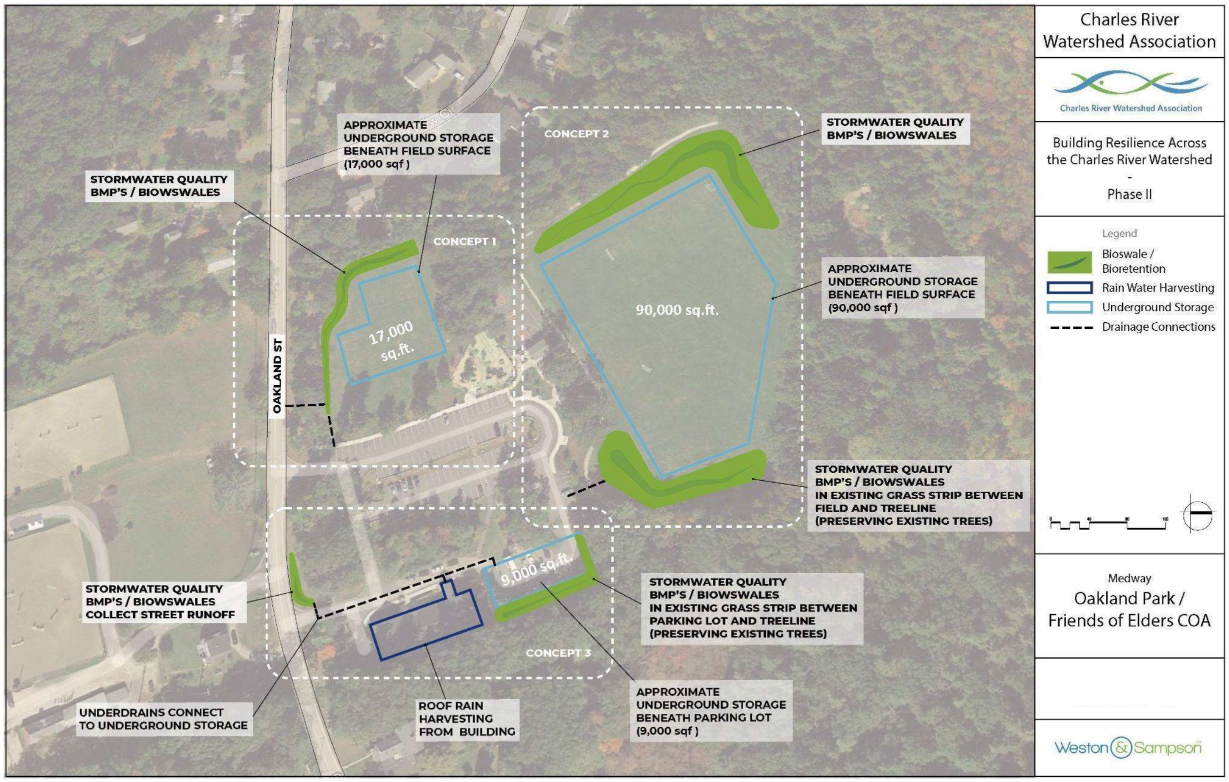


Figure 3.6 Medway Oakland Park/Friends of the Elders COA concepts

3.2.3.3 Newton Site

Albemarle Field and the Cheesecake Brook linear park are situated in the downstream area of the Cheesecake Brook close to its confluence with the Charles River. The three proposed concepts incorporate spaces along the brook as well as within and under Albemarle Field, a large athletic complex. They are categorized as Brook/Roadway, Park Surface, and Subsurface Options and include various types of projects. Currently, the City of Newton is looking into improvements for Albemarle Field that include field & court alignments, utilities, and improvements to general park amenities. The stormwater concepts developed for this project considered the potential future layouts of the park so they can easily be implemented in coordination with the park project. The different concepts considered for this site are illustrated in Figure 3.7.

Concept 1 – Cheesecake Brook / Roadway Options

The first concept utilizes permeable paving and bioretention to improve water quality and limit stormwater runoff flowing directly into Cheesecake Brook. Along this stretch, the brook flows through a straight stone channel and is bound by Albemarle Road. The roadway has numerous curb cuts and asphalt-line trenches that direct runoff directly into Cheesecake Brook. Proposed bioretention cells are placed at these existing curb cuts to intercept runoff and treat it before it flows in the brook. The bioretention cells are placed in areas that will not impact existing trees that line the brook. Permeable paving is suggested under parking lanes along both sides of Albemarle Road to reduce runoff while preserving parking spots.

Concept 2 – Park Surface Options

This concept focuses on utilizing BMPs / bioswales, bioretention, and roof rain harvesting to collect, temporarily store, and treat stormwater. The surface concepts utilize the proposed open spaces and planting areas created in the improvement plan to place these stormwater features. Along the raised, east edge of the park, two bioretention areas will collect and treat runoff originating from the school. Lining the western edge of the park, long bioswales will collect runoff from the fields and will incorporate tree plantings. Rain harvesting from the pool buildings can be collected by modifying the downspout structures. These elements will have underdrains that connect them to the underground storage areas included in Concept 3.

Concept 3 –Subsurface Storage Options

The third concept considers diverting stormwater from an existing conduit that crosses through the park and placing it into underground storage areas beneath the playing surfaces via perforated pipes. The storage can be designed as a gravel wetland or chambers-like structures. Overflow from the underground storage reconnects back to the original conduit if needed.

There were two approaches considered for Concept 3: Full Site (decentralized) and North Site (centralized). The full site approach identified three areas for storage providing around 138,000 sq. ft.. The north site is 112,000 sq. ft. with a potential to expand the footprint 95,200 sq. ft toward Craft St if needed. Decisions to move with one approach versus the other should consider the future final design of the park surface and playing field alignments as well as other surface improvements.

Incorporated Nature Based Solutions

Permeable Paving

Roadways and sidewalks are big contributors to stormwater runoff. Replacing impervious surfaces with permeable pavement allows for reduced runoff and slower infiltration back into the ground or stormwater system. Permeable pavement can be used where stable, hard surfaces are needed along streets, sidewalks and in parking areas and can be used in conjunction with underground storage. In Concept 1 of the Newton site, inserting permeable paving under the parking lanes reduces runoff going into the Cheesecake Brook.

Bioswale

Bioswales or sunken planters capture stormwater runoff and allow it to slowly infiltrate through soil media, thus reducing flooding. Roots uptake water, as well as nutrients that remain in the soil. These systems provide water quality benefits by removing pollutants, i.e., sediment, excess nutrients, road-related chemicals. They can be installed along sidewalks, in medians, and parking lot edges to directly convey runoff from surrounding impervious surfaces. These components can stormwater for future use or detain it before it flows back into the drainage system after the storm event. In Concept 1, bioswales on this site are used to replace the paved curb cuts that are increasing runoff rate and not improving water quality. In addition, bioswales are lined on the edges of the recreational field to reduce runoff rate and improve stormwater quality. They also include proposed trees that work within the broader park design.

Bioretention

Bioretention uses soil, plants and microbes to treat stormwater before it is infiltrated or discharged. It contains shallow depressions, known as “cells”, that are filled with high void soils, with a thick layer of mulch, and planted with dense vegetation. As runoff enters the cells, it slowly infiltrates. The Newton site utilizes bioretention with a rain garden in Concept 2, to reduce the rate of runoff and service as an educational aspect for the park and nearby school.

Underground Storage

The design and implementation of underground storage is increasingly flexible and partly based on the subsurface site conditions and restrictions. The key is to create high porosity volumes underground while maintaining structure and loading capacity above the system. Underground storage may come in the form of gravel wetlands, precast vault systems, and even modular crate-like designs. Storage chambers can be for reuse, detention, infiltration, or controlling the flow of on-site stormwater runoff. Underground storage is a key component of Concept 2 and Concept 3 of the Newton site as they retain overflow water from the Cheesecake Brook River during storm events.

The bioswales conceptualized at the Newton site are estimated to have a phosphorus load reduction of 5.7 pounds per year. Additionally, the underground storage at the Newton site are estimated to collectively reduce 20.08 pounds per year of phosphorus. In total, these systems will remove a total of 25.78 pounds of phosphorus per year. Calculations and references can be found in Appendix 5.

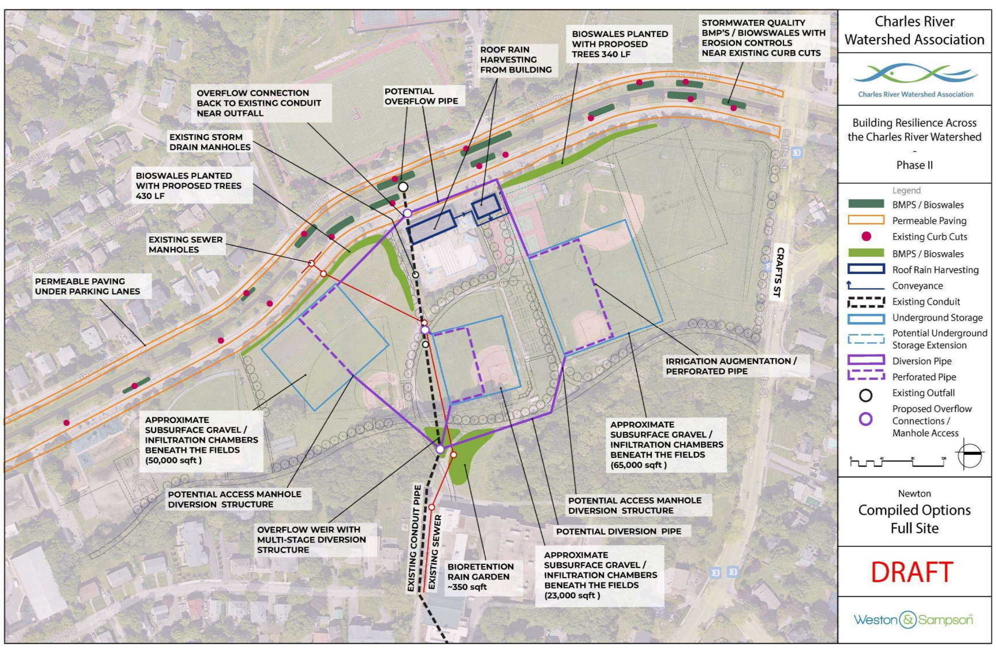


Figure 3.7 Complied concept options for the Albemarle Park Site

Community meetings were held for each priority project which included breakout room discussions. A summary of community feedback is provided in Table 3.5.

Table 3.5 Summary of Input Provided at Community Meetings on Priority Projects

Project Site	Community Inputs
Oakland Park, Medway	● Support for the use of pervious pavement ● Questions about impacts to local water supply
Hardy Pond, Waltham	● Raising pond levels was suggested in a report from the 1980s ● Challenges the pond is facing include sedimentation, erosion, overgrowth of plants (algae, aquatic invasives- adding to sedimentation and loss of water depth) ● Need to understand the downstream system ● Interested in understanding what criteria would be used to evaluate when to raise and lower an actively-controlled outlet structure, and what that means for pond health, flood risk, Flood Insurance Rate Maps, shoreline buffer zone vegetation, property boundaries (some of which are defined based relative to the high water line), and fish access. ● Higher water levels could be good for recreation in the summer and reduce cyanobacteria blooms. ● Greatest concern is that good communication with neighbors around pond is essential -people fear flooding of basement, may be unaware of real flooding dynamics ● Worried that people's perception may get in the way of what is happening ● Include adjacent wetlands as potential for flood storage
Albemarle Park, Newton	● Will this cause more bugs? ● What is the timing of this, how can it be funded, park redesign is moving forward ● I am concerned that the proposed artificial turf represents an impermeable surface. The project needs to take runoff from that surface and any chemicals from the turf into consideration. ● There is so much federal infrastructure money about right now. This should be a bigger project and deal with the roadway runoff that is going directly into the brook through 12 paved swales on the east side of the brook.

3.2.4 Implementation Pathway

In general, the next steps for each project include finalizing the designs, securing funding, continuing community engagement efforts, and implementing the project. As each project has unique elements, challenges and opportunities, Table 3.6 lays out a broad brush implementation pathway for each priority project.

Table 3.6 Implementation Pathways for the Three Priority Projects

Project Site	Design & Permitting	Funding	Community Input	Other Considerations
Oakland Park, Medway	Final design and construction package needed; address any wetland permitting needed; potentially phase the project	Identify and secure funding, possible sources include: MVP grant, Water Management Act Grant, Land and Water Conservation Fund State and Local Assistance Program, Federal Earmark, Federal Infrastructure Funding	Heavily used park and playground, need to engage local youth soccer and other park users, adjacent to the Senior Center - need to engage seniors	
Hardy Pond, Waltham	Conduct a thorough review of permitting requirements as they may be extensive for this project, finalize project design, evaluate project phasing	Identify and secure funding, multiple funding sources may be needed for various project elements, possible sources include: MVP Grant, Federal Earmark, Federal Infrastructure Funding, BRIC Grant	Continue to work with Hardy Pond Association, conduct outreach to abutters and engage pond residents in community discussion and decision making process, engage broader communities of Waltham and Lexington and downstream residents	Potential to add fish passage into the pond which has been an interest of some residents for many years. Addition of a fish passage may be a required part of any project per MGL Part 1, Title XIX, Chapter 130, Section 19.
Albemarle Park, Newton	Select preferred option and develop final design in coordination with field remodel; address any wetland permitting needed	Identify and secure funding, possible sources include: Federal Earmark, Federal Infrastructure Funding, Land and Water Conservation Fund State and Local Assistance, FEMA/MEMA grants	Integrate flood reduction elements with ongoing park redesign outreach and engagement efforts	Implement project in coordination with the scheduled field redesign and reconstruction

3.2.5 Priority Project Flood Mitigation Benefits

The Charles River Flood Model v2.1 was used to evaluate the potential flood mitigation benefits of each of the three priority projects. Those benefits were evaluated for eight different design storms:

- Baseline Climate, 2-year, 2-hour
- Baseline Climate, 10-year, 2-hour
- Baseline Climate, 2-year, 24-hour
- Baseline Climate, 10-year, 24-hour

- 2070 Climate, 2-year, 2-hour
- 2070 Climate, 10-year, 2-hour
- 2070 Climate, 2-year, 24-hour
- 2070 Climate, 10-year, 24-hour

The Hardy Pond project in Waltham was evaluated in terms of changes in maximum water surface elevation in Hardy Pond and the number of impacted houses around the pond. The number of impacted houses around the pond by design storm are shown in Table 3.7 below. As indicated in this table, the priority project is simulated to reduce flooding impacts to houses around the pond during the 2-year design storms as well as both 10-year, 2-hour design storms. During the 10-year, 24-hour event, the proposed project is expected to reduce the number of impacts to just a single home, down from 3 and 8 homes for baseline and 2070 climate conditions, respectively. A visual representation of the anticipated changes in flooding extents is shown in Figure 3.8 for the baseline 2-year, 2-hour design storm. The model was also used to evaluate potential benefits downstream of Hardy Pond, although no reduction in flooding extents and negligible reductions in flood depths were noted. Additional flood mitigation benefits are discussed in the Hardy Pond Waltham Flood Mitigation Benefit memo in Appendix 4.

Table 3.7 Summary of Impacted Houses at Hardy Pond

Duration	Recurrence Interval	Baseline Climate		2070 Climate	
		No Action	Proposed	No Action	Proposed
2-hour	2-year	1	0	1	0
	10-year	1	0	3	0
24-hour	2-year	1	0	3	0
	10-year	3	1	8	1

The Oakland Park site in Medway and the Albemarle Park site in Newton were evaluated in a similar manner. The Oakland Park project was evaluated in terms of changes in maximum flood depth in two nearby wetlands. One wetland, located east of the site, partially comprises the Army Corps' Charles River Natural Valley Storage Area. The other wetland, located south of the site, is in close proximity to the Town of Medway's Oakland Street Gravel Pack Well. Small reductions, approximately 0.1 feet, in the flood levels in both wetlands were noted during the design storms.

The Albemarle Park site in Newton was evaluated in terms of changes in maximum water surface elevation in Cheesecake Brook adjacent to the approximate center of the park and on changes in inundated area between Crafts Street and Watertown Street. Since the volume of runoff that reaches this site from the larger Cheesecake Brook watershed is significantly higher compared to the runoff generated at or from the vicinity of the site, changes in flood levels because of the proposed interventions at this site are negligible, less than 0.05 feet for the design storms considered.

Memos summarizing these simulated flood reduction benefits of the three priority projects are included in Appendix 4.

3.2.6 Flood Model Results Limitations

No new climate projections have been developed as part of the Charles River Climate Adaptation Flood Mitigation Implementation Plan (Plan) or as part of the Charles River Flood Model (CRFM). The climate projections and methodologies to establish projected values referenced in this report are based on best available climate science data and published literature available for the Commonwealth of Massachusetts at this time. The climate projections provided by others and underlying assumptions and uncertainties have not been independently reviewed by the project team developing the Tool. The limitations provided in the cited literature by others also apply to this technical report.

Actual climate conditions will vary and may be more or less extreme than the projections provided through this report. Climate projections are continually updated as climate science evolves. Therefore, it is recommended that the flood model results and findings be revisited based on future updates.

3.3 RECOMMENDATIONS

Based on the project findings, the team has identified six big picture recommendations.

1. **Planning recommendation: set flood reduction targets for the watershed.**

   The flooding impacts from climate change will be extensive. Determining a target level of control for the region or by municipality will help communities prioritize and implement solutions. None of the solutions modeled to date were able to bring future projected flooding down to present day flooding levels. This means either significantly more aggressive efforts will be required than what has been modeled to date, or we will need to be prepared to live with more flooding and develop ways to make flooding less harmful and damaging. Flooding is a natural occurrence; however, it becomes extremely problematic when it impacts our built environment when it can be devastating and deadly. Flood reduction targets could focus primarily on protecting vulnerable populations and lessening flooding impacts, as opposed to eliminating future flooding.

2. **Be aggressive: even the most effective watershed-wide mitigation scenarios tested to date do not fully mitigate an increase in flooding by 2070 (vs. present day); aggressive actions will be needed.**

   Think big and start acting now, significant effort will be required to mitigate future flooding.

3. **Select and take actions matched to the local landscape, locations in the watershed, and community priorities.**

   Conditions vary across the watershed from densely developed urban areas, suburban neighborhoods, and natural open spaces like forested areas and wetlands. In some communities and neighborhoods, the highest priority will be capturing and storing runoff from impervious cover. Other areas may be well-suited for aggressive open space protections and land conservation. Additionally, where a community or property is in the watershed also needs to be considered, some areas may be well targeted for aggressive storage, while others may need to be adapted to allow flooding for short periods of time or preserved as natural spaces that are safe to flood, protecting surrounding developed areas.

4. **Solutions will need to be combined and layered; no one action is likely to be a panacea.**

   While certain flood mitigation actions were found to be better suited to certain areas than others, it is likely that most areas will need to take a multi-pronged approach to flood reduction and protection. Taking one action is unlikely to solve the problem. There is no one project fix for flood reduction and management when factoring in climate change.

5. **Target new and re-development, especially impervious surfaces.**

   Model results to date demonstrate that storing runoff from impervious surfaces where it is generated is the most effective solution tested. Scenario 1A, green stormwater infrastructure is used across the watershed to store runoff from the future (by 2070) 2-yr rain event (4.5”) from half of the impervious cover in the study area, effectively reducing flooding of over 1500 acres. CRFM version 1.0 modeling results also demonstrated that widespread implementation of green stormwater infrastructure was an effective strategy for flood reduction.

6. **Continue to look for local improvements like the priority projects identified in the Plan.**

   Individual projects can have a localized impact and/or help reduce near term flooding. Incorporating flood reduction into projects as they occur can be a cost-effective way to incorporate flood storage into the community. Over time, implementing multiple projects in problematic areas can have a larger cumulative effect on reducing flooding and/or mitigating flood damage.

These recommendations were presented at a public meeting in June 2022, attendees were asked whether they agree, disagree, or need more information about each of the recommendations. Recommendations #3, 4, 5, and 6 received 95% or greater agreement from attendees. Recommendation #1 had 74% agreement, with the remaining respondents wanting more information. Recommendation #2 received 84% agreement, with the remaining responses “Need More Information.”

3.4 TOOLKIT OF RESOURCES FOR IMPLEMENTATION

Across the country municipalities are demonstrating leadership in taking action to mitigate and adapt to the impacts of climate change. As a result, there are many examples of local actions municipalities can take to increase climate resilience. Taking action at the local level is an important and necessary step, however, most municipalities are acting independently of their neighbors and actions are not necessarily coordinated across the region. Effectively reducing flooding and flooding impacts, particularly on vulnerable communities in downstream areas, will require coordinated action across the watershed to achieve set flood reduction targets. Coordinating actions across a region can also help reduce "competition" for development, if communities are requiring the same aggressive flood reduction measures be taken, the development landscape will be the same across the region and developers will be prepared to take flood control measures seriously when working in greater Boston.

Coordinated actions will also help communities implement recommendation #3 *Select and take actions matched to the local landscape, locations in the watershed, and community priorities.* Model results demonstrate that developing currently undeveloped land, without incorporating flood reduction measures, will worsen downstream flooding. Undeveloped areas are providing value to downstream areas by serving as de facto flood control.

NATURAL VALLEY STORAGE AREA

The Charles River watershed has a history of success with regional, nature-based flood control projects. The Natural Valley Storage Area is a collection of non-adjacent wetlands across sixteen different watershed communities that were protected decades ago to collect and store rainwater and runoff to prevent flooding downstream. A total of 8,300 acres of wetlands are protected across the watershed.

Appendix 6 includes a summary of bylaws, zoning requirements, planning initiatives, and other actions communities have taken at the local level to help adapt to climate change. It also includes toolkits and templates available to municipal leaders to help them address climate impacts. A few key resources are summarized below, additional information can be found in the Toolkit.

City of Cambridge Stormwater Regulations

Store the difference between the 2-year 24-hour pre-construction runoff hydrograph from the site and the post construction 25-year 24-hour runoff hydrograph from the site utilizing the City's projected rainfall data for the 2070 storm event . . . As a general rule, for properties discharging into the City of Cambridge municipal drainage system the City will provide a drainage level of service capacity to accept and transport up to the 2-year storm event. The stormwater runoff detention requirement states that the total volume of runoff generated between the pre-development 2-year 24-hour storm peak discharge and the post development 25-year 24-hour storm peak discharge shall be retained.

Many stormwater regulations do not target quantity and targeting future storm events, as this rule does, is even more rare. This regulation was simplified slightly to serve as the basis for NBS Scenario 1B, where it was applied to large impervious parcels. While this scenario demonstrated moderate improvements, the impact was not significant at the watershed scale because it applied to 2,309 impervious acres across the watershed. Having this as a standard regulation would, over time, capture more properties and more runoff. It would, however, still likely need to be paired with other flood reduction measures.

Floodplain Zoning and Regulations

There are a variety of ways communities can limit development or require special protections and activities in flood prone areas. Metropolitan Area Planning Council (MAPC) has numerous recommendations for and examples of using Floodplain Overlay Districts in local zoning. The Town of Norwell requires additional review and approval for development in the floodplain, the Town will grant permission for construction if the project complies with the ordinance's goal of reducing damage from floodplain seasonal flooding and to prevent the pollution of Town water from flooding. Recommendations developed through a Town of Wrentham MVP grant advised the Town to create a zone within the floodplain district which attaches additional protections to an area larger than the Special Flood Hazard Area such as flood elevations, proof of past flooding, or specific elevations. Communities in the watershed could consider using flood model results for this purpose, to limit future development in areas that are likely to flood.

Installing and Promoting Green Stormwater Infrastructure (GSI)

Numerous cities and towns have developed green infrastructure guides and/or plans that provide useful technical, design, and maintenance information about GSI. Communities have also developed a variety of tools for requiring or encouraging GSI on private development such as requirements in stormwater ordinances/regulations and zoning requirements.

Protecting Open Space

Watershed communities can utilize the Nature Based Solutions Conservation Tool, an online mapping tool, to identify land conservation opportunities in their community that may have climate resilience benefits. Local open space plans and master plans provide good opportunities to identify open space acquisition targets and/or specific parcels. There are also funding sources available to support land conservation such as MVP grants, Community Preservation Act funding, and private foundations. Modeling scenarios that assumed development of undeveloped land demonstrated a considerable increase in flooding.

Wetland Protection and Restoration

Many communities have passed local wetland bylaws with accompanying regulations that can serve as models for increasing local protection of these important resources. The City of Boston and the Town of Arlington both have strong wetlands ordinance which considers climate change as a reason for wetlands protection. The state also has funds available for wetland restoration projects through the “in lieu fee” program.

Adaptive Control Technology for Reservoir Storage

A case study in Beckley, West Virginia analyzed the benefit of using continuous monitoring and adaptive control (CMAC) technology to control pond levels for water quality improvement, channel protection, and flood mitigation. Results showed increased nutrient removal efficiency and mitigation of downstream flooding.

The Toolkit in Appendix 6 also provides resources on the following topics: resilience planning, drought mitigation and response, tree protection, integrating climate change adaptation into local planning processes, native species support, and resources to learn about funding opportunities.

4.0 PUBLIC ENGAGEMENT SUMMARY

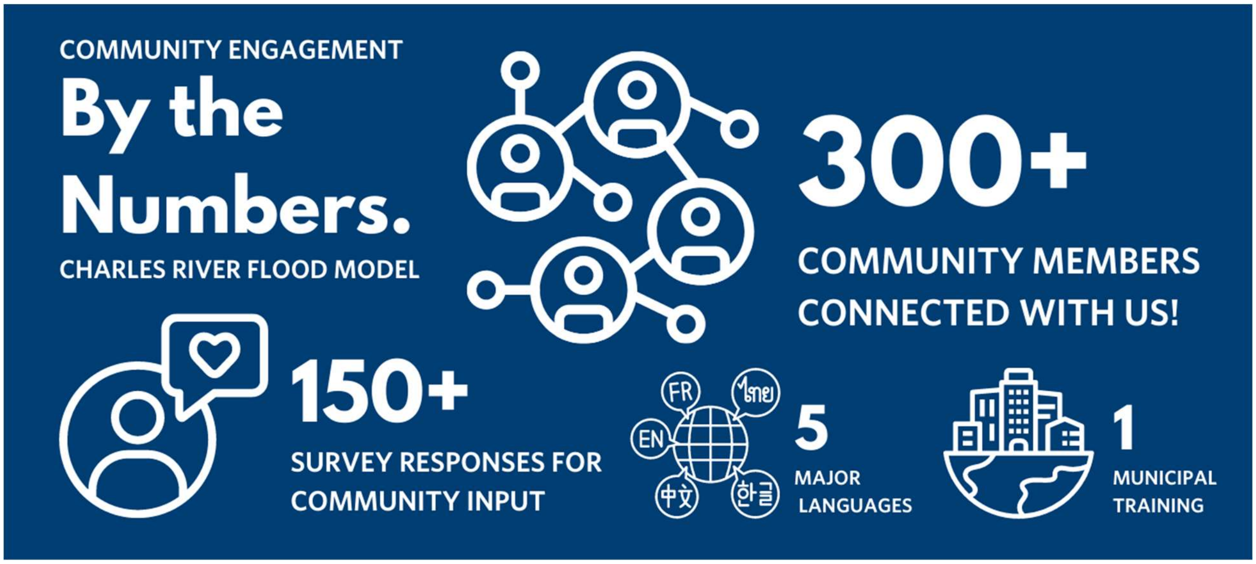


Figure 4.1 Community engagement by the numbers

The goals for public engagement for this initiative are:

- Raise awareness about the flooding impacts of climate change with watershed residents, with a focus on engaging climate vulnerability residents
- Build trust in the CRFM as a planning tool that local officials should use for decision making and policy setting
- Get input and feedback on modeling scenarios to test actions that have public support
- Get feedback from residents on site specific projects as they move through the design and implementation process

This initiative was launched during the COVID-19 pandemic and therefore most of the earlier engagement was online, in the Spring of 2022, however the team attended a total of 7 in-person community events to connect with watershed residents. These were in six communities, 3 of them (Newton, Waltham and Arlington) have Environmental Justice (EJ) populations. For each event, C.R.E.W. and CRWA brought posters and flyers with a project summary and information on how the specific community would be impacted by future flooding events showing the CRFM results (Figure 4.1). Posters and flyers were also translated to one or two languages other than English relevant to the community where the events took place. An interpreter was present during in-person events in communities where it was relevant to effectively engage residents with limited English proficiency.

To engage community members and learn what types of solutions residents were interested in seeing in their communities, the project team created a 'Bean-and-Jar' activity that gave residents and opportunity to cast their vote using a bean and placing it into a jar labeled with the types of nature-based solution being considered for the community (Figure 4.2). An estimated 300 watershed residents were engaged across 7 in-person events.

C.R.E.W. also distributed flyers, with project summary, links and QR code to the project website, storymap and survey, to local businesses and community locations (libraries, town centers, etc.). In addition, the team conducted outreach to local organizations and community groups. These included the Hardy Pond Association, of the Waltham Land Trust, and Friends of Albemarle Park with respect to the priority projects, these groups will continue

to be engaged around these projects. Other groups and organizations engaged include the YMCAs located in the watershed and participation in their annual Healthy Kids Day events.

Virtual public meetings were held on the priority project sites in Medway, Waltham and Newton, promotional materials were shared via social media and email. These events were open to the public, specifically residents in those communities, to engage with the team and provide input to the concepts for each site. Feedback is summarized above in Table 3.5. To increase accessibility and participation in the public events, live Spanish interpretation was available for the Newton event. Recordings were posted to YouTube following the event along with an accompanying feedback survey. As noted in Table 3.6 additional public engagement will be necessary as these projects advance toward implementation.

C.R.E.W. also hosted a Climate Vulnerable Communities training for the project's municipal partners. This training highlighted ways to engage more community members in climate planning by reducing barriers to participation with a focus on seniors and non-English speakers. Presentations covered how to incorporate live interpretation for Zoom meetings and webinars and a panel discussion with members of the Mass. Senior Action Council.

Lastly, the team presented two public webinars reporting on the results of the flood model to date. The first public webinar in February highlighted the results of the model at the watershed level. The second webinar in June of 2022, highlighted model updates, including updated storm simulations and the expansion of the model, and concept designs for priority sites chosen for the project. The team presented recommendations based on the model findings and, as described above, received feedback on these recommendations from attendees.

Table 4.1. Community Events Summary

Date	Event Title	Location	Event Type	Participants Engaged
02.02.2022	Building Resilience in the Watershed	Virtual	Public webinar	Residents, town staff & municipal partners
04.23.2022	Waltham Charles River Cleanup	Waltham, MA	Tabling and community flyering	Residents, EJ communities
04.24.2022	Newton's Earth Day Festival	Newton, MA	Tabling and community flyering	Residents, EJ communities
04.27.2022	Medway and Waltham Priority Project Event	Virtual	Input on priority projects	Residents & town staff
04.30.2022	Weston Earth Day	Weston, MA	Tabling and community	Residents

			flyering	
05.03.2022	Climate Vulnerable Communities training	Virtual	Training on equitable engagement of climate vulnerable communities	Municipal partners, climate vulnerable communities
05.06.2022	Arlington's EcoWeek - Green Infrastructure Tour	Arlington, MA	Tabling and community flyering	Residents, EJ communities
05.16.2022	Newton Priority Project Event	Virtual	Input on priority projects; live Spanish translation	Residents & town staff
05.21.2022	Medway Pride Day	Medway, MA	Tabling and community flyering	Residents
05.21.2022	Natick DPW Day	Natick, MA	Tabling and community flyering	Residents, EJ communities
06.18.2022	Waltham Riverfest	Waltham, MA	Tabling and community flyering	Residents, EJ communities
06.22.2022	Building Resilience in the Watershed	Virtual	Public Webinar on the flood model results; recording with Spanish audio	Residents, municipal partners & town staff

Other press articles, releases, social media posts were published to promote the project, invite residents to participate, and share feedback surveys. This is summarized in Table 4.2.

Table 4.2 Media Outreach Summary

Media Outreach	Example posts
5 Press Articles on Climate Compact and CRFM	August 3, 2021: Towns band together to prevent flooding disasters (Boston Globe)
1 CRWA Press Release	Press Alert: State Awards CRWA + 19 Communities $233K for Climate Resilience
19 Twitter posts	Feb 1, 2022 - Join us and see how we use the CRFM
11 Facebook posts	Jan 28, 2022 - Building Resilience Event invite
5 Instagram posts	February 15, 2022 - Nature-Based Solutions Survey
12 Monthly River Current newsletter	February 2022 River Current
Social Media Video	Youtube

In addition to the project outreach team's efforts, municipal partners also did outreach in their own communities to their residents and colleagues. Outreach by the municipal participants include presentations to local Conservation Commissions, local Select Boards, and local Planning Boards; sharing social media posts; content in local newsletters; tabling with community specific posters and flyers; materials at Town buildings; and discussions/ CRFM demonstrations at inter-departmental staff meetings.

Finally, in response to other watershed/regional groups' interest in replicating this initiative, CRWA presented at a meeting of the SuAsCo Climate Resiliency Coalition about our experience developing a regional flood model with a large group of communities. CRWA and Natick presented at the Slow the Flow Work Group run by Massachusetts Ecosystem Climate Action Network (MassECAN) addressing the same topic. CRWA and Weston & Sampson also met directly with the Neponset River Watershed Association (NepRWA).

Appendix 7 is an outreach summary which includes images of project outreach materials.

5.0 CONCLUSION AND NEXT STEPS

Flooding is going to get worse in the Charles River watershed. Flooding from a 2-yr rain event by 2070 is projected to flood nearly double the amount of land a 2-yr event of today would flood. This is not an issue that each community can solve on their own, it requires a regional approach. The Charles River Climate Adaptation Flood Mitigation Implementation Plan is intended to be a living document that evolves as this initiative evolves. This Plan begins to chart a path forward but by its very nature, this work is constantly progressing due to a variety of factors listed below, and therefore planning efforts need to be adaptive.

- Climate science and our understanding of local climate impacts are improving as our understanding of the situation becomes more robust and as we progress into the future without taking drastic measures to reduce greenhouse gas emissions.
- On the ground conditions change. The model uses a snapshot of watershed conditions at one moment in time, however, conditions are constantly changing as properties get developed and redeveloped, and restoration measures are implemented.
- The pool of interested and affected residents and community groups is constantly changing as people move into the area, people's interests change, young people become interested in the work, new community groups form, etc.
- Communities invest in local data, either by investigating and inventorying their stormwater system or developing detailed municipal scale stormwater system models that need to be integrated into the regional model.
- The needs of the municipal partners change based on targeted action and public interest.
- The field of climate adaptation policy and regulation is constantly evolving as local actors take initiative to protect their residents.

The Charles River Flood Model is a robust tool for community leaders to use in decision making and policy setting. The technical team's work to improve the accuracy and breadth of the model have greatly increased the utility of the tool for municipal participants. The team, with public input, developed multiple flood reduction strategies/nature-based solutions scenarios to test through the model. Results show that adding additional storage into the landscape, particularly targeted toward impervious cover runoff, is effective at

TESTIMONIAL FROM NATICK STAFF

The Town of Natick faces the reality of flooding because of storm events regularly. In the storms of July and September 2021, residents within the Charles River watershed experienced significant flooding due to precipitation and some dealt with direct impacts to their homes. This model helps the Town develop comprehensive plans to manage future rainfall protections and guide homeowners on improvements to their property to protect homes. This project has provided significant value to current permit reviews, grant funding applications for stream assessments, and future developments under The Massachusetts MS4 stormwater permit, and that the update performed under this phase of the project and any future updates funded will only increase that value.

reducing flooding, *but* a lot of green infrastructure and flood storage will be needed to get future flooding under control. New development, even when it incorporates some flood control measures, has the potential to make flooding worse; flood control on new development and redevelopment sites should be taken seriously. This may be an issue best addressed at the regional scale, so communities do not have drastically different requirements from their neighbors.

The Recommendations included in this report are considered initial recommendations. It is anticipated that recommendations will evolve as the work evolves. Recommendations were presented to the public for feedback at a virtual event and support was extremely strong. The team compiled a Toolkit of existing resources to support local partners in taking steps toward implementing the recommendations.

Next Steps

There is a lot of work to be done, near term next steps for the Building Resilience Across the Charles River watershed initiative include the following:

- Get additional feedback and comments from the project team and the public on the Plan
- Run additional model runs and/or combined scenarios to quantify the impacts
- Discuss and track implementation activities with the Charles River Climate Compact (CRCC)
- Work with the CRCC and residents to establish flood reduction targets
- Advance site-specific projects, Albemarle Park in particular may be well positioned for near term implementation
- Help local communities secure funding for flood reduction projects, today's funding landscaping offers some exciting opportunities, such as Federal earmarks and infrastructure spending or state bond funds, however it can be difficult to navigate and opportunities can come up quickly with very short submission deadlines
- Advance additional flood reduction projects identified in Appendix 2 to concept design and implementation
- As COVID 19 restrictions ease, conduct more in person engagement to bring more community members into the planning process and identify opportunities for community members to advance flood reduction goals