Climate Resilience Initiatives

Guided by the Vulnerability Assessment findings, which identified and quantified the impacts of future climate change, the City should undertake a set of climate resilience initiatives to address Boston's climate risks. These initiatives will increase Boston's ability to thrive in the face of intensifying climate hazards, leading to stronger neighborhoods and improved quality of life for all residents.

Image courtesy of Bud Ris

The climate resilience initiatives build on a broad set of efforts undertaken to date by the City and other actors to prepare Boston for climate change. To develop the initiatives, Climate Ready Boston reviewed past climate adaptation plans, interviewed a broad range of local stakeholders, and examined best practices from other cities across the world that are contending with climate change impacts.

The City will need dedicated public and private partners, as well as significant additional resources, to advance these initiatives and implement comprehensive climate adaptation.

Climate Resilience Principles

Climate Ready Boston draws on five principles for successful resilience to climate change based on lessons from other cities. These principles are outlined below:

Image courtesy of Sasaki

Generate multiple benefits.
Effective climate resilience initiatives both reduce risks from climate hazards and create other benefits. Resilience initiatives that produce multiple benefits generate more resources to support their implementation and sustainability. Flood barriers that also provide recreational open space, developable land, or upgraded roadways represent examples of multiple-benefit solutions. Non-physical interventions also can offer multiple benefits, such as programs that help businesses and households make operational changes to reduce their flood risk while also lowering utility costs or reducing insurance premiums. Multiple-benefit approaches enable Boston to address some of the other pressing challenges that it faces beyond climate risks.

Incorporate local involvement in design and decision-making.
Effective resilience initiatives require on-the-ground knowledge and sustained community support for implementation and long-term operations and maintenance. Local stakeholders can help illuminate critical resilience opportunities in their communities and generate creative ideas for solving multiple challenges at once.

Climate Ready Boston / Boston Harbor Now Workshop

Create layers of protection by working at multiple scales. Layers that are independently effective can also work together to provide mutual support and reduce the risk of a failure associated with a single line of defense. For example, to address extreme heat, adding green infrastructure (e.g., increasing tree canopy), in combination with building-scale adaptations (e.g., using cool roofing and paving materials or increasing energy efficiency), is more effective than doing either independently. Shading from the tree canopy reduces the cooling load on the building, and the retrofitted building radiates less heat, with a failure to either layer having less impact because of the other.

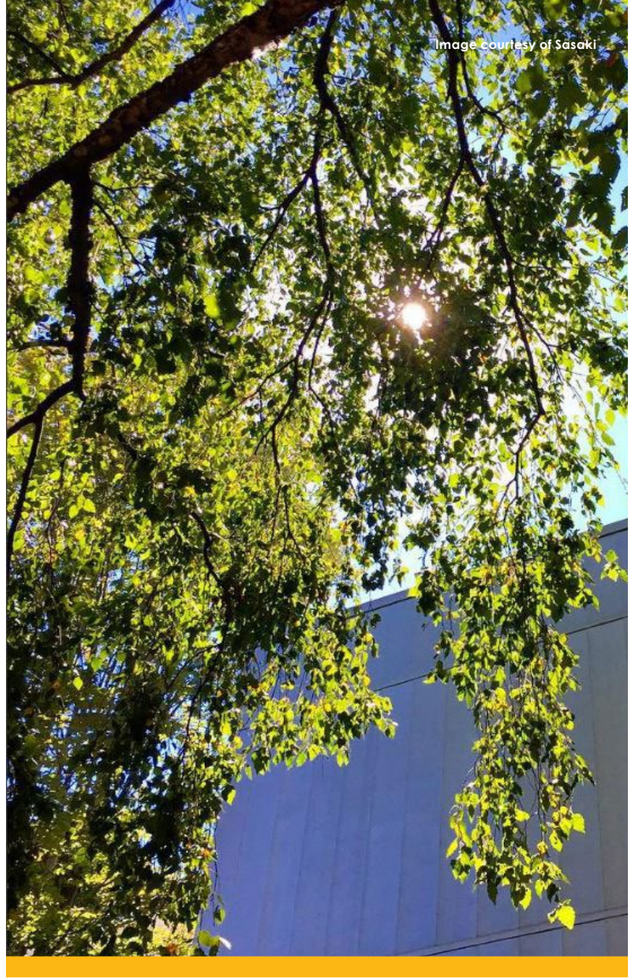


Image courtesy of Sasaki

Leverage building cycles. Buildings and infrastructure experience regular cycles of rehabilitation and replacement over time. Taking adaptation actions within the context of the building cycle can reduce disruption and cost, as in the case of green infrastructure installed as part of a road reconstruction project, rather than as a standalone project that would still require digging up roads. While the building cycle progresses, operational changes, as opposed to physical adaptations, can be made to reduce risks. For example, retailers can move the inventory stored in the basement of their stores onto shelves to reduce flood damage in the near term, before local flood defenses are built.


Image courtesy of Sasaki

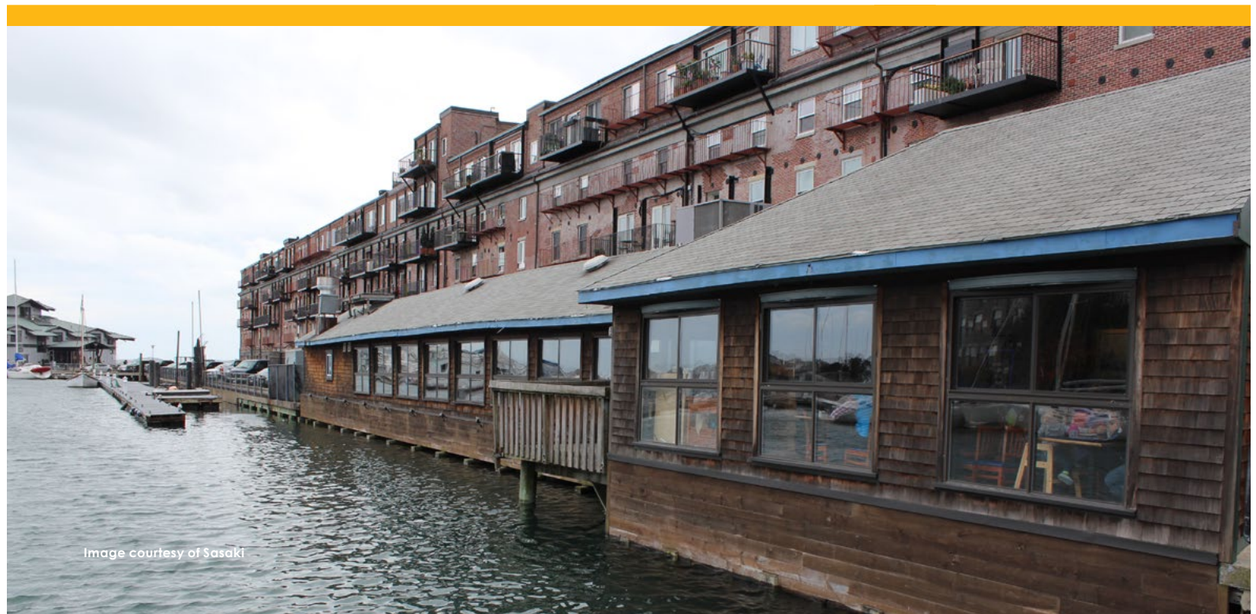


Image courtesy of Sasaki

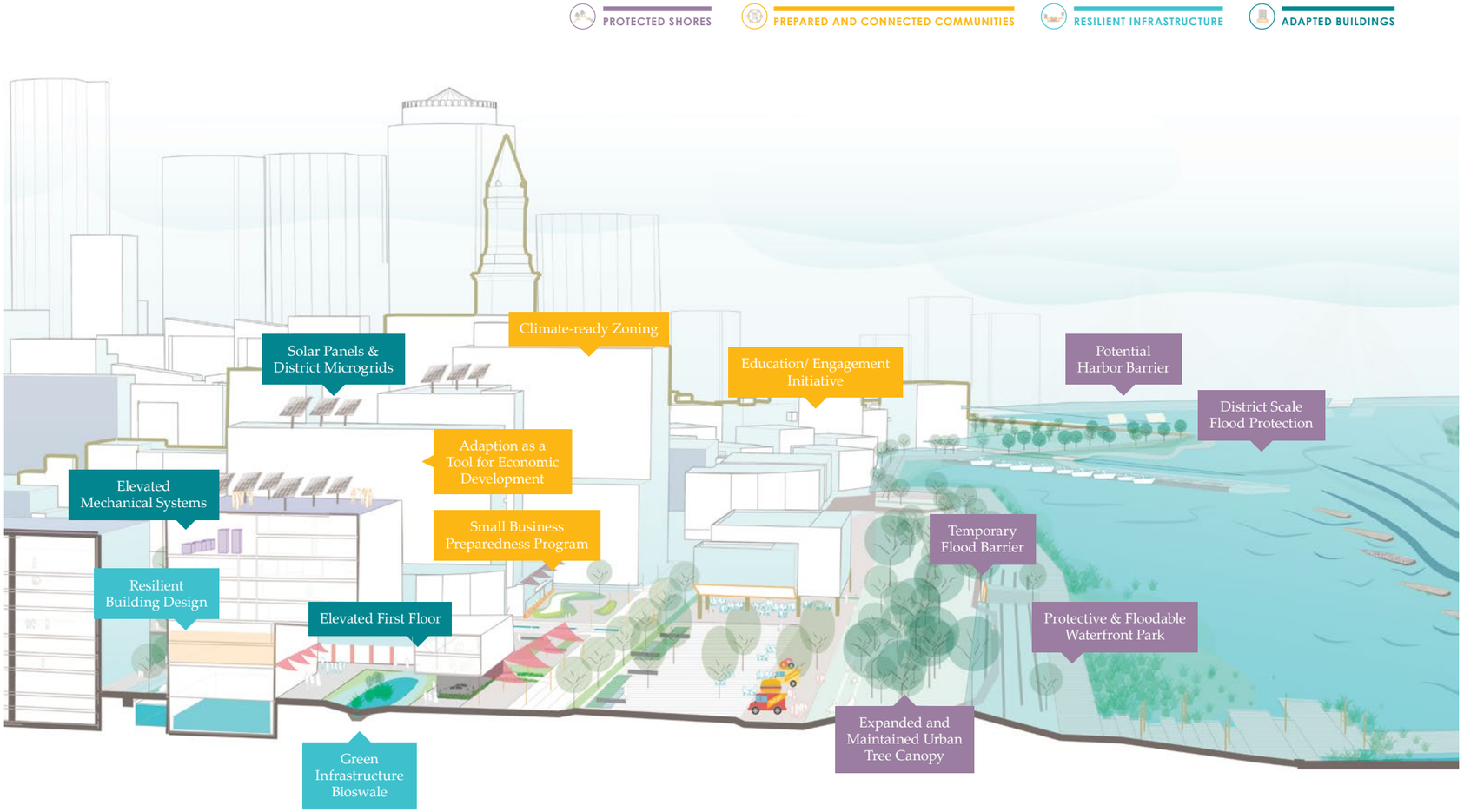
Design in flexibility and adaptability. Climate conditions will continue to change over time, and climate resilience initiatives must be designed to adapt to them. For example, the 24-hour rainfall for a 10-year storm is projected to increase through the century. To be effective, the stormwater system must be flexible enough to adapt to this increase in extreme precipitation. In practice, this often means decentralized, distributed stormwater storage across cities that can be expanded without disrupting the gray stormwater system. Similarly, the elevation of 1 percent annual chance floods is also projected to increase throughout the century. Buildings can be built today with high ground-floor ceilings so that the ground floor can be raised as sea levels rise over time, without creating undesirably low floor-to-ceiling heights.

Layers and Strategies

Climate resilience initiatives are actions that Boston can undertake to improve its preparedness for climate change. They respond to the geographic extent, frequency, and severity of the three key climate hazards the city faces. The initiatives tied to extreme heat and stormwater flooding are meant to be applied citywide, given the geographic dispersion of those hazard impacts, while those tied to coastal and riverine flooding are targeted to the specific waterfront and inland areas exposed to this hazard.

The climate resilience initiatives have been organized into 5 layers and 11 strategies. The first layer is an understanding of Boston's future climate conditions, the foundation on which other initiatives rely. The remaining layers represent an approach to building resilience at different scales: the community, shoreline, infrastructure assets, and buildings. The layers are designed to support and reinforce each other. For example, a building that has been retrofitted for flood risk (Adapted Buildings) is more resilient if it sits behind a district-scale flood protection system (Protected Shores) that prevents the flooding of adjacent buildings and streets. It is even more resilient when its users are aware of and have prepared for climate risks (Prepared and Connected Communities), and the manmade and natural infrastructure that serves it is climate ready (Resilient Infrastructure).

Within each layer, individual initiatives are clustered under strategies, with the initiatives under each strategy reinforcing each other and driving toward related outcomes.



VISUALIZING MULTIPLE LAYERS OF CLIMATE READINESS

LAYERS	OUTCOMES
Updated Climate Projections	Ensure that decision making in Boston is informed by the latest Boston-specific climate projections.
Prepared and Connected Communities	Support educated, connected, empowered communities in pursuing operational preparedness, adaptation planning, and emergency response.
Protected Shores	Reduce Boston's risk of coastal and riverine flooding through both nature-based and hard-engineered flood defenses.
Resilient Infrastructure	Prepare the infrastructure systems that support life in Boston for future climate conditions and create new resilient systems.
Adapted Buildings	Create a regulatory environment and financial and other tools to promote new and existing buildings that are climate ready.

Layer 1

UPDATED CLIMATE PROJECTIONS

Strategy 1: Maintain up-to-date information on future climate conditions in Boston

INITIATIVE 1-1. UPDATE BOSTON-AREA CLIMATE PROJECTIONS PERIODICALLY

The City should establish the Greater Boston Panel on Climate (GBPC) to serve as the continuation of the Boston Research Advisory Group (BRAG), which developed the Climate Projection Consensus for Climate Ready Boston. The GBPC should consist of leading climate scientists from local and regional institutions, organized into working groups focused on key climate factors, such as extreme temperatures, sea level rise, coastal storms, and precipitation.

The GBPC should be charged with two responsibilities. First, the GBPC should produce an updated set of climate projections for the Boston area every five years, building on the 2016 Climate Projection Consensus. These projections should reflect the most up-to-date data and theoretical understanding and include consideration of multiple emissions scenarios and time periods, extending at least 100 years in the future. As part of the process of developing climate projections, the GBPC also should fill research gaps in local climate change knowledge. Second, the GBPC should assist local and state agencies in applying those conclusions to policy, design, and regulation. In particular, the GBPC should provide information to the Infrastructure Coordination Committee to support the development of planning and design standards (see Initiative 6-1, p.118), and to the Boston Planning and Development Agency to support efforts to incorporate climate readiness into zoning standards and land-use planning (see Initiative 9-2, p.135).

The Environment Department should oversee the GBPC's work, and the City should identify funding for the work of the GBPC.

INITIATIVE 1-2. CREATE FUTURE FLOOD MAPS TO SUPPORT PLANNING, POLICY AND REGULATION.

The City should create a set of flood maps that show the extent and depth of future flooding, possibly including indications of wave action, moving water, and channelization hazards. The future flood maps should be based on the latest climate projections from the Greater Boston Panel on Climate (GBPC; see Initiative 1-1, p. 84), as well as policy decisions regarding acceptable levels of risk. These policy decisions should be made in collaboration with local and state agencies and will require consideration of four key parameters:

- **Emissions scenario.** The GBPC will create climate projections for multiple greenhouse gas emissions scenarios. Future flood maps should reflect a decision regarding which emissions scenario is the most appropriate to use for planning, policy, and regulation. For example, a decision to use the business-as-usual scenario would mean setting a lower level of acceptable risk and more stringent regulatory standards than a decision to use the moderate-reduction emissions scenario.
- **Projection likelihood.** Each emissions scenario includes a range of likely outcomes for sea level rise and other climate factors. Future flood maps should reflect a decision about which outcome from within this range should be used. For example, the median projection of sea level rise has a 50 percent chance of being exceeded; a stricter standard may require that the sea level rise assumption used should have at most a 15 percent chance of being exceeded.
- **Appropriate time periods.** The GBPC will create climate projections for multiple time periods. Future flood maps should reflect multiple time periods, corresponding to decisions regarding the minimum expected life of buildings and infrastructure. This is critical for planning, designing, and regulating for the flood risk an asset will face during its expected life, rather than just the risk that it faces today. For example, in its Climate Change Preparedness Checklist, the Boston Planning and Development Agency currently assumes that large buildings in Boston have a design life of at least 60 years.
- **Flood probabilities.** Future flood maps should show the extents and depths of various probabilities of flooding. These multiple probabilities will support decisions regarding acceptable levels of risk. For example, an infrastructure agency may decide that a local road serving a very small area should face no more than a 1in 100 annual chance of inundation during its useful life, while a major artery or evacuation route should face no more than a 1 in 1,000 annual chance of inundation.

Local and state agencies, with guidance from the Environment Department, should use the resulting flood maps for planning, policy, and regulations. For example, the Infrastructure Coordination Committee should incorporate them into planning and design standards (see Initiative 6-1, p.118), and the Boston Planning and Development Agency should use them for setting appropriate zoning standards within the future floodplain (see Initiative 6-1, p.118).

In conjunction with the work of the GBPC, the City should update future flood maps every five years, reflecting updated climate projections, ongoing policy decisions regarding acceptable levels of risk, and changes in the natural and built environment.

CASE STUDY: NEW YORK CITY PANEL ON CLIMATE CHANGE

In 2008, Mayor Bloomberg convened the New York City Panel on Climate Change, an independent body of scientists, to develop localized climate projections. In September 2012, the New York City Council passed Local Law 42, which requires the NPCC to meet at least two times per calendar year to review the most recent scientific data on climate change and its potential impacts on New York City. The NPCC is required to release updated local climate change projections at least every three years, with the last set of projections released in 2015.

CLIMATE READY BOSTON'S FUTURE FLOOD MAPS

Climate Ready Boston produced maps that reflect future conditions for three sea level rise scenarios (9, 21, and 36 inches) for the purpose of conducting high-level assessments of flood risk and developing climate resilience initiatives. These scenarios are not necessarilythe appropriate ones for detailed planning and regulation.

STANDARDS FOR ACCEPTABLE FLOOD RISK LEVELS

FEDERAL FLOOD RISK MANAGEMENT STANDARD

In January 2015, President Obama signed Executive Order 13690, which established national flood risk standards for all federally funded projects in and near floodplains. Under the order, federally funded projects must adhere to one of three standards. They can use projections informed by the best available data and methods, build two feet above the current 1 percent annual chance flood elevation for standard projects and three feet above for critical buildings like hospitals and evacuation centers, or build to the 0.2 percent annual chance flood elevation.

DUTCH FLOOD RISK MANAGEMENT STANDARD

The Netherlands government recently revised flood risk management standards for national flood defenses. The new standards are based on the level of protection required to provide a basic level of safety for people behind flood defenses and to minimize severe economic losses. For flood defense systems to be considered to provide a basic level of safety, the individual annual risk of dying due to flooding at a particular location must no higher than 1 in 100,000, taking into consideration evacuation possibilities. The economically efficient level of protection is that which minimizes the sum of expected damages and required protection investments. Where one of the two standards (basic safety and economic efficiency) leads to a higher level of protection, the stricter standard is used.

Sources: "Federal Flood Risk Management Standards." FEMA. http://www.fema.gov/federal-flood-risk-management-standard-ffrms.

H. van der Most, I. Tanczos, K. M. de Brujin, and D. Wagenaar. "New Risk-Based Standards for Flood Protection in the Netherlands." Paper Presented at the Sixth International Conference on Flood Management, Sao Paulo, Brazil. 2014.

Layer 2

PREPARED AND CONNECTED COMMUNITIES

Boston residents, businesses, institutions, and community groups are essential partners in climate adaptation, given their role as the day-to-day stewards of Boston's neighborhoods. In preparing for climate change, the City will work closely with these groups to learn from their local expertise, identify and incorporate their adaptation-planning priorities, overcome challenges to successful adaptation, and partner in planning efforts. Throughout both adaptation planning and implementation efforts, the City will engage in two-way communication with residents, businesses, institutions, and community partners, wherein it is actively engaged in both sharing and receiving information.

The City will connect with residents through a variety of methods and channels, with a special focus on ensuring that it reaches socially vulnerable populations. Recognizing Boston's large population of renters and students, the City will make a strong effort to connect these groups with information and resources and engage them in planning efforts. The City will provide pathways for residents to participate in climate-related volunteering efforts, such as the Boston Medical Reserve Company, and to take part in Resilience Area Planning Committees. To conduct effective outreach to Boston's population, City agencies will partner with a broad range of resilience-focused nonprofits, business groups, community development corporations, and other community-based organizations.

Building on its commitment to inclusive growth, the City will use its climate adaptation efforts as a tool to enable more residents to fully participate in Boston's economy. Where possible, the City will link resilience investments to investments in housing, transportation, open space, job growth, and neighborhood services in order to increase safety, economic opportunity, and livability for all residents. Because resilience improvements may increase property values and thereby potentially affect affordability for residents, the City, led by the Office of Resilience and Racial Equity, will work to address these impacts by developing a resilience and racial equity toolkit. This toolkit can be used to evaluate policies and practices in order to make sure that racial equity and social cohesion form the foundation of the City's decision-making processes.

Strategy 2: Expand education and engagement of Bostonians about climate hazards.

INITIATIVE 2-1. EXPAND CITYWIDE CLIMATE READINESS EDUCATION AND ENGAGEMENT CAMPAIGN

The City should leverage its existing emergency preparedness and climate adaptation outreach efforts to develop and implement a long-term education campaign targeted to all Bostonians with a special focus on socially vulnerable populations. In the short term, the City's education campaign should focus on sharing the results and implications of Climate Ready Boston with all Boston residents. In the intermediate and longer term, the campaign should support both individual climate preparedness efforts and neighborhood engagement in district-scale climate adaptation planning through the Local Climate Resilience Committees (see Initiative 4-2, p.102).

This education campaign should be coordinated by a consortium of partners within the City. The consortium can include Greenovate Boston and the Environment Department, the Office of Emergency Management, the Boston Public Health Commission, the Office of Neighborhood Services, the Office of Resilience and Racial Equity, the Boston Planning and Development Agency, the Inspectional Services Department, and the Department of Neighborhood Development. The consortium should partner with a broad range of resilience-focused nonprofits, business groups, local community development corporations, local small businesses, and other community-based organizations.

The consortium can act as a coordinating committee for all outreach related to Climate Ready Boston. The consortium should perform two functions. First, it should coordinate both the independent citywide education campaign and the more targeted campaigns that will be undertaken for specific groups, including property owners (see Initiative 2-2, p.90), small businesses (see Initiative 2-3, p.92), and facilities serving vulnerable populations. For example, the Office of Emergency Management runs the "Ready Boston" community preparedness campaign that takes an all-hazards approach (natural or manmade) to informing the public about the risks that they face and what they can do to protect themselves. Second, the consortium will identify opportunities to integrate resilience into existing education campaigns. Across both of these functions, the consortium will ensure integrated and coordinated messaging.

In the short term, the consortium can lead the development of print and online materials in multiple languages and coordinate in-person and social media outreach. The materials should summarize the key findings from Climate Ready Boston, focusing on Boston's three major climate hazards: coastal and riverine flooding, stormwater flooding, and extreme heat. The materials should clearly explain the risks that Boston faces, the time frames over which the city faces them, and the

DIGITAL EQUITY AND ENGAGEMENT

High-speed Internet infrastructure is a tool that all Bostonians need to engage in the educational, economic, and civic pursuits that are critical to a future of equity and opportunity. The City is committed to providing Bostonians with access to high-speed Internet, along with the skills and tools to leverage this technology, to build the individual, family, and community capacity necessary for preparedness. To this end, the City is taking the following steps to support digital equity and engagement:

- The City is expanding the availability of high-speed Internet in places where Bostonians work, learn, play, and engage in civic life, including Boston Public Library branches, Boston Centers for Youth and Families, Boston Public Schools, Main Streets districts, and other important public gathering places.
- The City is working to ensure that community members and local businesses are equipped with the digital tools and skills that they need to take advantage of opportunities and create the future of Boston. City agencies and local nonprofit organizations, such as Tech Goes Home, are collaborating to offer one-time and ongoing digital-skills training, such as basic computer and Internet use, coding, and media production.
- The City is working to support a more competitive broadband marketplace so that households and businesses can choose among a range of high-quality, affordable high-speed Internet options. The City is facilitating collaboration across departments to streamline permitting for broadband infrastructure, support innovative technology during the design and construction of Boston's built environment, and remove building-level barriers to broadband access and choice.

potential impacts of those risks on Boston's people, property, infrastructure, and economy. In the long term, the campaign should seek to increase both the emergency and long-term preparedness of Bostonians, both by building out a network of climate readiness volunteers and preparing Bostonians to engage district-scale climate adaptation planning through Resilience Area Planning Committees (see Initiative 4-2, p.102).

To build out a network of climate-readiness volunteers, the City can tap into the existing Boston Medical Reserve Company (BMRC). BMRC is a citywide volunteer group that receives funding through the U.S. Department of Health and Human Services and is coordinated by the Boston Public Health Commission's Office of Public Health Preparedness. It trains both medical and nonmedical community members in emergency and long-term preparedness. Climate-readiness volunteers can help support both **on-the-ground responses to acute events**, such as assisting neighbors during heat waves and proactively reporting stormwater flooding in their communities, and **longer-term adaptation**—for example, by helping care for young trees to expand the urban canopy.

INITIATIVE 2-2. LAUNCH A CLIMATE READY BUILDINGS EDUCATION PROGRAM FOR PROPERTY OWNERS AND USERS

The City should develop and run a Climate Ready Buildings Education Program to inform property owners and other groups about current and future climate risks facing their buildings and actions they can undertake to increase their preparedness. This education program will be connected to, but also distinct from, the citywide education campaign because of its specific focus on building readiness. It should be linked to building audit and retrofit financing programs (see Initiative 10-1, p.138).

While the Climate Ready Buildings Education Program will focus on property owners, it also will include outreach to three other groups who play a critical role in the use or upgrading of Boston's building stock:

- Tenants, given that the majority of Boston residents are renters and they have the capacity to advocate for resilience upgrades;
- Developers with projects in the pipeline; and
- Design, construction, and property management professionals required for the construction or retrofitting of resilient buildings.

PROPERTY OWNER TYPE	TOUCHPOINT
Large commercial property owners	Their participation in industry groups (e.g., NAIOP Commercial Real Estate Development Association, Greater Boston Real Estate Board, A Better City, and Urban Land Institute).
Market-rate multifamily residential owners	Required registration of their rental property through **DND**. Their participation in industry groups.
Affordable multifamily residential owners	Their application for housing development or rehabilitation financing from **DND**. Their coordination with community development corporations.
Owner-occupants, especially low-to moderate-income owner-occupants	Their participation in homeownership counseling or application for rehabilitation financing through **DND's Boston Home Center and in partnership with local CDCs.**
Owners of small business space	Their application for capital upgrade assistance through Main Streets program.

The Climate Ready Buildings Education campaign should be led by the Boston Planning and Development Agency, the Inspectional Services Department, and the Department of Neighborhood Development (DND). These entities can do outreach to property owners at key touchpoints. For all owners, these points include when they seek development approvals and permits from the Boston Planning and Development Authority and Inspectional Services Department and when they are subject to code enforcement from the Inspectional Services Department. In addition, the City should use outreach to property owners conducted as part of Boston's Community Rating System application (see Initiative 11-2, p.145). Finally, some additional touchpoints by specific owner type are summarized in the table.

The campaign should share print and online resources and potentially include in-person workshops with property owners and other stakeholders. The purpose of the campaign is to build a prepared community of building owners and users across Boston, recognizing the need for broad awareness, because owners and tenants turn over relatively quickly in Boston. The campaign should perform the following functions:

- Educate stakeholders about buildings at risk from climate change hazards over different time periods, taking into account both direct impacts to buildings and indirect impacts to supporting services.
- Inform building owners about the timing and severity of their exposure and the risk levels to which they should be planning. Ideally, this would involve providing owners with information about not only flood depths but also wave heights and moving-water hazards, and also the effects of heat, because these factors affect appropriate adaptation strategies.
- Inform building owners about the need to make both operational changes (e.g., developing continuity of operations and evacuation plans and securing adequate insurance) and physical upgrades to improve resilience. In addition,
- Inform building owners about opportunities to combine climate mitigation and adaptation by making energy-efficiency improvements to their buildings. This may include solar power generation or design elements such as high-

SUPPORTING INDIVIDUAL FINANCIAL PREPAREDNESS

The out-of-pocket costs associated with an acute event, such as coastal flooding that temporarily displaces residents from their homes and prevents them from accessing nonsalaried jobs, can be a significant stress for low- and moderate-income households. Today, 46 percent of Boston's residents are liquid-asset poor, meaning that they do not have enough savings to live above the poverty level for three months if they suffer an income disruption such as losing a job.

For this reason, the City should continue to support low-income households in both saving for emergencies and doing long-term asset building through the efforts of the Office of Financial Empowerment (OFE). For example, as one tool to build preparedness, OFE can continue to promote use of myRA federal savings accounts to residents during its financial counseling, financial-literary education, and tax preparation assistance sessions. The myRA program offers free retirement savings accounts to households without access to an Individual Roth Account (IRA) or 401(k) account who make less than $191,000 per year. While deposited funds can be withdrawn from accounts at any time without penalty, accrued interest can only be withdrawn once the account holder reaches the age of 59. By enabling Bostonians to save for retirement but also be able to access funds in the event of an emergency, myRA accounts can potentially serve as a useful tool to advance preparedness goals.

Source: "Financial Insecurity in Boston: A Data Profile," Family Assets Count.

EXISTING PARTNERSHIPS WITH PROPERTY OWNERS

The City can leverage its existing experience working with property owners to educate them about climate change mitigation and adaptation challenges. Since November 2013, the Boston Planning and Development Authority has required all development projects subject to Article 80 large project review (50,000 square feet and over) to analyze and describe their climate preparedness.

OUTREACH THROUGH PROACTIVE CODE ENFORCEMENT

The City should conduct outreach to private property owners about two relatively inexpensive actions that can reduce their flooding risk.

- **Installation and maintenance of backflow preventers:** The Massachusetts Uniform State Plumbing Code requires backflow preventers to be installed for all buildings with plumbing fixtures located below the manhole cover serving the building (i.e., with any kind of water connection below street level). These preventers stop contaminated sewage from flowing back into a building's systems during sewage overflow events. However, current compliance rates for both installation and maintenance are estimated to be low.
- **Installation and maintenance of tide gates on private storm drain outfalls:** BWSC controls the majority of public storm drain outfalls in Boston, but does not control private storm drain outfalls that run from private properties to the ocean or other waterways, such as the Charles River, Neponset River, and Fort Point Channel. BWSC estimates that there are approximately 1,000 private outfalls in Boston. They have completed mapping of all private outfalls along Fort Point Channel, although other outfalls still need to be identified through fieldwork done at low tide. With sea level rise, outfalls that lie at low elevations along waterways subject to tidal influence will need to be tide-gated to prevent them from backing up and flooding the buildings or sites that they serve.

reflectance "cool roofs" that can reduce property owners' cooling costs while also reducing the urban heat island effect.

- Educate building owners about how they can participate in district-scale adaptation planning efforts, including larger-scale flood defenses that potentially could reduce the need for individual defenses, while also providing education about site-specific mitigation to support multiple layers of protection.

INITIATIVE 2-3. CONDUCT OUTREACH TO FACILITIES THAT SERVE VULNERABLE POPULATIONS TO SUPPORT PREPAREDNESS AND ADAPTATION

As a separate effort, but closely linked to its Climate Ready Buildings campaign, the City should conduct outreach to owners and operators of privately owned facilities that serve significant concentrations of vulnerable populations but that are not currently required to have operational preparedness and evacuation plans under state and local regulations. The purpose of this outreach should be to encourage the owners and operators of these facilities to develop operational preparedness and evacuation plans for situations in which sheltering in place is not feasible, as well as to make needed capital upgrades.

Under current regulations, municipal facilities and healthcare facilities (hospitals, healthcare clinics, and nursing homes) licensed by the Massachusetts Bureau of Healthcare Quality are already required to have operational preparedness and evacuation plans. The City can work with local community development corporations to identify facilities for outreach, with target facilities likely to include privately owned affordable housing complexes, substance abuse treatment centers, daycare facilities, food pantries, small nonprofit offices, and others. The City should encourage facility managers to use planning resources provided by the Federal Emergency Management Agency to develop continuity of operations plans. The City should also prioritize these facilities for climate resilience audits (see Initiative 10-1, p.138) and backup power installation (see Initiative 10-3, p.143).

INITIATIVE 2-4. UPDATE THE CITY'S HEAT EMERGENCY ACTION PLAN

Because the frequency and intensity of heat waves are expected to increase with climate change, the City should continue its efforts to update its heat emergency action plan to reflect both current and likely future needs. The City's action plan lies within the City's Emergency Operations Plan Annex on Extreme Temperatures.

The revised action plan should enhance the framework for coordination during heat events across the City, state agencies, and nonprofit partners critical to preparedness and response. Key state agencies include the Department of Conservation and Recreation, which owns and operates public pools, and the Massachusetts Bay Transit Authority, which operates THE RIDE fleet. The revised plan should ensure that there is a clear set of roles and responsibilities for each partner and define the actions to be undertaken under both heat advisory and heat emergency conditions. In addition, the plan should set a clear set of protocols for the City and its partners to communicate with Bostonians about heat risks across a broad range of channels, including phone, radio, print, online, social media, and in-person outreach.

In addition, in the revised plan, the City should standardize its definitions for both heat advisory and heat emergency events. The Elderly Commission defines a heat emergency as three consecutive days with maximum temperature exceeding 86 degrees Fahrenheit and relative humidity exceeding 68 percent, and a heat advisory when these conditions are in effect for one or two days. The Mayor's Office currently defines a heat emergency as three or more days with maximum temperature exceeding 90 degrees Fahrenheit.

In standardizing its definitions, the City should recognize that different thresholds for taking action to address heat risks may be appropriate for different populations.

In addition, the City should partner with community nonprofits to expand access to facilities with cooling capacity in areas that currently have limited access to municipally owned emergency shelter facilities or that have access only to pool facilities, which are not suitable for the elderly, medically ill, or small children. The City should prioritize installation of backup power at shelter facilities to reduce their risk of losing cooling capacity during heat waves (see Initiative 10-2, p.142). The City also should refine its existing systems to provide transportation to facilities with cooling capacity for older adults and disabled people, with these systems including using the Elderly Commission's Senior Shuttles and MBTA's THE RIDE fleet. The City should partner with community nonprofits and healthcare providers to help disabled residents who lack cooling capacity in their homes register for THE RIDE, if interested, in advance of heat events. In addition, the City should work with the MBTA to reduce the time required for reservations during heat emergencies so that the reservation period is not a barrier to usage.

The City may need to partner with the MBTA to identify additional resources to support this type of service. To serve physically homebound people who cannot leave their homes without assistance, the City should work to help them obtain energy-efficient air conditioners or other means of cooling.

To take advantage of the important role that strong peer-to-peer relationships and community ties play in reducing negative health impacts during heat waves, the City should make heat a major focus of its citywide education and engagement campaign (see Initiative 2-1, p. 88). Communications should help Bostonians understand heat health risks, heat illness symptoms, cooling center locations and hours, and available transportation and emergency services. In addition, as part of its citywide campaign, the City should work to establish a network of neighborhood-level volunteers who can check on socially vulnerable populations, such as seniors, the disabled, and the homeless, during heat waves. The City can leverage existing volunteer networks, such as the Boston Medical Reserve Company, and community nonprofits to help build out these networks. In addition, as part of its outreach to owners and operators of facilities serving concentrations of vulnerable populations, the City should encourage them to educate their clients about heat risks (see Initiative 2-3, p.92). The City can encourage nutrition vendors, home care agencies, and visiting nurses to increase phone and in-person check-ins during heat events.

Finally, the City should work with its partners (state agencies and nonprofits) to improve tracking of the need for public heat support services in Boston to evaluate if services are keeping pace with demand. These metrics include emergency shelter usage, transportation requests, and healthcare service requests. Under a separate set of initiatives (see Strategy 6, p.118), the City will prioritize green infrastructure development in areas that are subject to the urban heat island effect and have high levels of air pollution and socially vulnerable populations.

INITIATIVE 2-5. EXPAND BOSTON'S SMALL BUSINESS PREPAREDNESS PROGRAM

Small businesses play a critical role in employing Boston residents and driving the Boston economy, with 44 percent of Boston's employees in private, for-profit businesses working in small businesses.[1] Because small businesses face challenges in preparing for and recovering from climate change impacts, the City should launch a preparedness program to increase their readiness. The City should leverage the strong existing relationships that it has with small businesses through its Main Streets and Renew Boston Small Business programs to launch Small Business Preparedness Program. The program should be targeted towards small businesses that are exposed to coastal and riverine or stormwater flooding in the near term, because of the potential for physical damage, focusing particularly on Main Streets districts that are exposed under these conditions. The program also should provide information on heat risks.

As part of this effort, the City can facilitate in-person workshops to help small business owners increase their preparedness in five ways:

- Better understand their risks from climate hazards, including coastal and stormwater flooding and extreme heat.
- Develop business continuity plans.
- Evaluate whether they have adequate insurance coverage.
- If they own their space, prioritize necessary physical upgrades for their specific building.
- If they do not own their space, communicate the importance of resilience improvements to property owners.

As needed, the City should partner with the insurance community in Boston to address barriers to insurance coverage to small businesses. The City is undertaking a separate set of initiatives to address insurance availability and cost under Strategy 11 (see p.145). Finally, the City should help connect small business owners and, as relevant, their landlords with the resilience audit program (see Initiative 10-1, p.138). Because cost is a major barrier to making resilience improvements, the City should investigate funding models for building-level resilience improvements under Initiative 10-4 (see p.143).

[1]Source: "Small Business Plan." City of Boston

Strategy 3: Leverage climate adaptation as a tool for economic development

INITIATIVE 3-1. IDENTIFY RESILIENCE-FOCUSED WORKFORCE-DEVELOPMENT PATHWAYS

The Office of Workforce Development can explore developing required skill profiles for resilience-focused jobs at a range of skill levels, based on Boston's planned resilience initiatives. For example, potential resilience-focused jobs may include performing resilience audits of buildings and installing and maintaining green infrastructure. To prepare Bostonians for these jobs and create a pipeline of local workers prepared to undertake resilience projects, the Office of Workforce Development then should create a plan to incorporate resilience skills development into Boston's existing job-training programs and establish resilience-focused workforce-development pathways. The Office of Workforce Development also should work to incorporate resilience retrofit skills training into its existing construction pre-apprenticeship and apprenticeship training programs.

INITIATIVE 3-2. PURSUE INCLUSIVE HIRING AND LIVING WAGES FOR RESILIENCE PROJECTS

The City can consider the hiring of graduates of Boston's resilience workforce-development programs for firms working on resilience projects that receive City funding or land. In addition, the City can explore whether City-sponsored resilience projects can pay employees a prevailing or a living wage to support economic opportunity for all Bostonians. Under the initiatives set out in Imagine Boston 2030, the City is advocating for a higher minimum wage to improve economic mobility for Boston workers and help ensure that all Boston residents are able to earn a family-sustaining wage.

USING CLIMATE INVESTMENTS TO ADVANCE EQUITYEQUITY

In the coming years, the public, private, and nonprofit sectors will be making large investments in climate mitigation and adaptation. Earlier this year, the City released its Economic Inclusion and Equity Agenda, which provides a detailed overview of the City's ongoing programs, policies, and initiatives to address racial and economic disparities in Boston. The agenda provides context for the City's work across four themes: income and employment, wealth creation, business development, and economic mobility. To fulfill its commitment to inclusive growth, the City should undertake the initiatives under Strategy 3 to ensure that these investments yield maximum benefits to residents in terms of job creation, workforce development, and entrepreneurship opportunities.

BOSTON'S EXISTING RESIDENT JOB POLICY

City agencies should leverage the existing Boston Resident Job Policy to increase resident employment on City-sponsored development projects and support equity in hiring and contracting. Under this policy, developers and contractors agree to make best-faith efforts to employ 50 percent residents, 25 percent people of color, and 10 percent women across all trades.

Climate Ready Boston / Boston Harbor Now Workshop

INITIATIVE 3-3. PRIORITIZE USE OF MINORITY- AND WOMEN-OWNED BUSINESSES FOR RESILIENCE PROJECTS

The City can request that City-sponsored resilience projects prioritize minority and women-owned businesses for spending on capital and operating and maintenance costs. The Mayor's 2016 Executive Order on Procurement set spending goals for minority and women-owned business enterprises (MBE and WBE, respectively) competing for City construction, architecture, engineering, and professional services contracts.[2] The spending goals, which range from 10 to 25 percent MBE and 15 to 20 percent WBE utilization, depending on the type and size of the contracts, can be applied to all City-sponsored resilience projects.

[2] "An Interim Executive Order Promoting Equity in Public Procurement." Executive Order of Mayor Martin J. Walsh, 2016.

MAIN STREETS PREPAREDNESS PROGRAM MODELS

For the Main Streets Preparedness Program, the City can draw on precedents from both within and outside the Boston metro. The Metropolitan Area Planning Commission has been working with the City of Cambridge to assist Cambridge's small businesses in recovering quickly from business disruption. New York City's Business Preparedness and Resiliency Program (BPREP) offers resilience planning workshops, building assessments, grants for building retrofits, and online tools for assessing vulnerability and potential adaptation strategies.

Source:"Business Preparedness and Resiliency Program (PREP)." The City of New York.

EMERGENCY SHELTERS

The City and community organizations currently operate many facilities throughout Boston that offer cooling capacity during heat waves. The City will work with community organizations to ensure that these facilities are open whenever necessary, accessible to all who need them, and feature backup power in case of power outages.

BOSTON'S EXISTING WORKFORCE-DEVELOPMENT PROGRAMS

The Office of Workforce Development can leverage a number of existing workforce-development programs to explore providing the infrastructure for climate resilience-focused job training. In particular, the Office of Workforce Development can use the framework of the Greater Boston American Apprenticeship Initiative, which includes the Building Pathways and YouthBuild programs, to offer construction pre-apprenticeship and apprenticeship opportunities. The Greater Boston Apprenticeship Initiative was launched in the fall of 2015 with a U.S. Department of Labor grant. Building Pathways is a six-week pre-apprenticeship program run by the Metropolitan Boston Building and Construction Trades Council that provides women and people of color with an introduction to careers in the building trades, gives them the opportunity to earn key certifications, and provides them with guaranteed placement into an apprenticeship program. YouthBuild Boston is a 12-week pre-apprenticeship program to youth ages 14–24 that offers them the opportunity to earn key certifications in preparation for building trades apprenticeships. The Office of Workforce Development also can explore incorporating resilience skills development into the Mayor's Youth Summer Jobs Program and Operation Exit, an intensive career-readiness and occupational skills training program that prepares at-risk youth and young adults for buildings trades apprenticeships.

PRECEDENT: CITY OF NEW ORLEANS WORKFORCE-DEVELOPMENT PROGRAM

In recent years, New Orleans has become a national leader in resilience workforce development, and is poised to extend this role through its winning project under the U.S. Department of Housing and Urban Development's National Disaster Resilience Competition, "Reshaping the Urban Delta." New Orleans's program offers several useful best practices for Boston:

- Defining short-term and long-term workforce-development objectives. New Orleans has committed to both train unemployed and underemployed working-age individuals for job readiness in the short term and develop the next generation of design and construction professionals in the long term. It has set a target that over 10 percent of resilience project jobs will be filled by unemployed or underemployed individuals.
- Developing a clear set of workforce-development pathways. New Orleans has prioritized environmental services and water-management-sector workforce development. It has elected to focus on these sectors because they have both local demand and export potential.
- Incentivizing firms to exceed workforce-development targets. When bidding out contracts, New Orleans encourage respondents to exceed Section 3 training and hiring requirements for low- or very-low-income residents by making the additional costs incurred to provide extra training eligible for reimbursement as long as they are deemed reasonable.
- Supporting workforce-development accountability. New Orleans has implemented a rigorous tracking system to ensure that workforce-development graduates hired by contractors are receiving pledged training and employment opportunities.

Source:"City of New Orleans Application to HUD National Disaster Resilience Competition." City of New Orleans, 2015.

Layer 3

PROTECTED SHORES

Strategy 4: Develop local climate resilience plans to coordinate adaptation efforts

INITIATIVE 4-1. DEVELOP LOCAL CLIMATE RESILIENCE PLANS TO SUPPORT DISTRICT-SCALE CLIMATE ADAPTATION

The City should develop local climate resilience plans to address climate adaptation in areas of geographically concentrated climate risks. The priority local climate resilience plans should be for East Boston, Downtown, Charlestown, South Boston, and Dorchester, which face the greatest risk from coastal flooding in the near term. For these and subsequent local climate resilience plans, all climate hazards should be addressed, including coastal and riverine flooding, extreme heat, and stormwater flooding.

Local climate resilience plans should coordinate all climate adaptation efforts within a district. This would allow the City and its partners to use limited resources more wisely and avoid the duplication of investments, not only in capital projects but also in planning, design, and operations. District coordination also offers opportunities for the City or its partners to capture some or all of the value created by climate readiness efforts in order to finance these investments and to integrate other community priorities—such as housing affordability, economic opportunity, access to quality open space, and safe and efficient mobility—in tandem with climate adaptation. At the district scale, climate readiness efforts can be integrated with locally specific initiatives to advance multiple goals simultaneously.

The local climate resilience plans should include the following:

- **Community Engagement** (see Initiative 4-2, p.102). To understand current challenges facing residents, businesses, and institutions and to develop creative solutions to address these challenges, the City should work with district stakeholders through local climate resilience committees. Representative of their neighborhoods, these committees should gather data, provide input on potential resilience actions, and identify potential co-benefits of climate adaptation such as increased access to economic opportunity for an improved public realm. Engagement with the local climate resilience committees should be a feature of all components of local climate resilience plans.

- **Land Use Planning for Future Flood Protection Systems** (see Initiative 5-1, p. 106). To support the feasibility of district-scale flood protection systems, the Boston Planning and Development Agency should establish Flood Protection Overlay Districts in strategically important "breach points" where floodwaters can enter and inundate large inland areas. New development proposals at these breach points would need to demonstrate the potential for integration into future flood protection systems. This is particularly important in areas where waterfront development is currently proceeding rapidly and may introduce new challenges for the creation of future flood protection infrastructure.

- **Flood Protection Feasibility Studies** (see Initiatives 5-2, 5-3, pp. 106, 110). The City should apply a consistent framework for evaluating the feasibility of district-scale flood protection alternatives. Key considerations include flood risk reduction benefits; additional benefits like recreation or economic development; environmental impacts; cost; land ownership; permitting; and intergovernmental coordination.

- **Infrastructure Adaptation Planning** (see Initiative 6-1, p.118). The City should work with the Infrastructure Coordination Committee to develop district-scale infrastructure adaptation plans to prepare existing infrastructure—and design new infrastructure—for climate change. This may include opportunities for joint capital planning, such as the elevation of a road combined with upgrades to the stormwater management system or coordination with district-scale flood protection infrastructure.

- **Coordination with Other Plans** (see Initiative 9-5, p.138). The City should coordinate with other planning processes such as Imagine Boston 2030, 100 Resilient Cities, Special Planning Areas, or Municipal Harbor Plans to ensure that district-scale climate adaptation is incorporated into area plans and, where appropriate, codified into the Zoning Code.

- **Development of Financing Strategies.** The City should evaluate and, as necessary, provide implementation support for financing strategies to support district-scale adaptation. The strategies may include federal and state infrastructure funds, special assessment districts, resilience business improvement districts or joint capital planning structures to collect funds from the beneficiaries of adaptation projects. Assessment districts could help the City to fund capital and operating expenses for district-scale resilience investments by levying a small tax on the properties that benefit. Joint capital planning among agencies and other actors could enable larger-scale interventions that reduce the need for individual interventions and pool resources from the agencies that benefit from the large-scale interventions.

- **Development of Governance Structures.** The City should evaluate and, as necessary, provide implementation support for governance structures for managing the implementation, operations, and maintenance of adaptation actions. These governance structures may include formation of a special assessment district governing board, resilience business improvement district, or public-private partnership. The form of the governance structures should be guided by the type and financing needs of resilience actions to be undertaken.

LOCAL CLIMATE RESILIENCE PLANS FOR DISTRICT-SCALE ADAPTATION

The City should develop local climate resilience plans for East Boston, Downtown, Charlestown, South Boston, and Dorchester, which face the greatest risk of geographically concentrated coastal flooding. For these and subsequent local climate resilience plans, all climate hazards should be addressed, including coastal and riverine flooding, extreme heat, and stormwater flooding, as should additional community priorities.

PRECEDENT: CLIMATE CARE COMMUNITY PARTICIPATION MODEL

The Climate CARE (Community Action for Resilience through Engagement) program in East Boston is being led by the Neighborhood of Affordable Housing (NOAH), with funding from the Kresge Foundation. The program consists of two major components. First, it employs local residents as "Climate Canvassers" to educate East Boston residents about current and future climate risks in a multiyear outreach effort. Second, it brings together local residents, public-sector entities conducting adaptation planning, and planning, design, and engineering experts in working groups to discuss community input and priorities, with the goal of developing a set of pilot design projects. Climate CARE builds on earlier work done by NOAH and the University of Massachusetts-Boston and the University of New Hampshire, with funding from the National Oceanic and Atmospheric Administration. NOAH and its partners held workshops in May and June 2014 to map key assets and generate preliminary adaptation strategies, including a set of multipurpose flood barriers.

INITIATIVE 4-2. ESTABLISH LOCAL CLIMATE RESILIENCE COMMITTEES TO SERVE AS LONG-TERM COMMUNITY PARTNERS FOR CLIMATE ADAPTATION

The City should work with local residents, businesses, and institutions in each resilience planning area to form a local climate resilience committee to help guide district-scale climate adaptation activities (see Initiative 4-1, p.100). The committees should help identify local challenges and develop creative solutions, ensure that other local initiatives—such as economic development or open space planning—are integrated with climate adaptation, and steward the ongoing adaptation process over time.

Local climate resilience committees may take a variety of forms and may have multiple missions depending on the needs of each neighborhood and other planning and development initiatives. A committee may be staffed by a community-based organization with a long-term presence in the area and the capacity to work productively with local residents and public agencies. The committees should help to disseminate information about climate-related risks and gather feedback on local residents' priorities for climate adaptation. The development of these local climate resilience committees should fit within Greenovate's existing efforts to establish a climate action network.

Strategy 5: Create a coastal protection system

As discussed in the Climate Ready Boston Vulnerability Assessment, Boston faces significant and increasing coastal flood risk due to a combination of sea level rise, high tides, and coastal storm events. A key component of the multilayered strategy for addressing this risk is to create a robust system of coastal protection infrastructure that responds to community needs and ecological dynamics.

There are generally three **categories of coastal protection:**

1. **"Gray," or hard-engineered coastal infrastructure,** such as levees, floodwalls, or gates. Typically, gray coastal infrastructure is necessary to protect built-up areas from severe flood events like coastal storms, as it is designed to be strong enough to withstand coastal forces and high enough to reduce risk from storm surge.
2. **"Green," or nature-based, coastal infrastructure,** such as wetlands or living shorelines. Green coastal infrastructure alone is typically most appropriate for protecting against chronic flooding events like future high tide or minor storms, rather than severe coastal storm events. This is because it is

SUMMARY OF INITIATIVES TO CREATE A COASTAL PROTECTION SYSTEM

#	INITIATIVE	SUMMARY
5-1	Establish Flood Protection Overlay Districts and require potential integration with flood protection	Based on preliminary hydrological analyses, establish new overlay districts in potential flood protection system locations and require that development proposals do not prevent the future creation of flood protection infrastructure.
5-2	Determine a consistent evaluation framework for flood protection system prioritization	Determine a framework through which alternative flood protection systems would be consistently evaluated, and which is compatible with the framework used by the U.S. Army Corps of Engineers, a key implementation and funding partner.
5-3	Prioritize and study the feasibility of district-scale flood protection	Using a consistent evaluation framework (Initiative 5-2), study the feasibility of district-scale flood protection in a number of locations, prioritizing those that face the greatest risk.
5-4	Launch a feasibility study of a harbor-wide flood protection system	Using a consistent evaluation framework (Initiative 5-2), study the feasibility of a Harbor-wideharbor-wide flood protection system.

EXAMPLE FLOOD PROTECTION DESIGNS

unlikely to reach the elevation necessary to sufficiently reduce storm surge, even if it does dissipate wave energy and slow-moving water.

Green coastal infrastructure may feature certain advantages over gray coastal infrastructure in terms of ecological benefits, long-term adaptability, and lifetime maintenance costs. However, it can be particularly challenging to site in urban areas, since it generally has a much broader footprint than gray infrastructure and requires specific environmental conditions that foster ecological function and habitat suitability.

3. **Hybrid coastal infrastructure,** which incorporates both "gray" and "green" components. Examples of hybrid infrastructure include reinforced dunes or living shorelines that contain engineered levees. These infrastructure types are designed to withstand coastal forces and storm surge during extreme events and may provide some of the benefits of green coastal infrastructure, with similar challenges for finding appropriate sites.

There are two **scales** of coastal protection that are possible for Boston:

1. **District-scale coastal protection.** These are infrastructure investments at or near the waterfront that can reduce flood risk for a specific area within Boston. In each case, some type of flood barrier would need to be constructed, connecting two points of high ground in order to reduce flood risk in low-lying areas. Generally, these defenses would be more cost effective in narrow low-lying areas where floodwaters can enter and inundate large inland areas and less cost-effective in broad, low-lying exposed areas.
2. **Harbor-wide coastal protection.** These are offshore interventions in Boston Harbor that can reduce flood risk for all of Boston, as well as neighboring cities. These interventions could be used to achieve two outcomes:
    - Decreasing Boston Harbor's tidal range. Boston Harbor's tidal range could be lessened by narrowing or shallowing the inlets between Harbor Islands. Reducing the openings between islands acts to reduce the exchange of water and moderate the tidal range. This would effectively lower the high tide (and raise the low tide) in the harbor, reducing tidal inundation as well as storm surge inundation.
    - Blocking storm surge. Boston could be protected from storm surge by installing a system with operable gates that could be temporarily closed during storm events to prevent storm surge from penetrating into Boston Harbor from the North Atlantic.

There may be potential solutions that would decrease Boston Harbor's tidal range without including an operable gate to block storm surge. However, since any operable surge barrier would require construction in the harbor, such a solution would also end up decreasing the tidal range.

See Initiative 5-2 (p. 106) for further discussion of the potential implications of flood protection infrastructure.

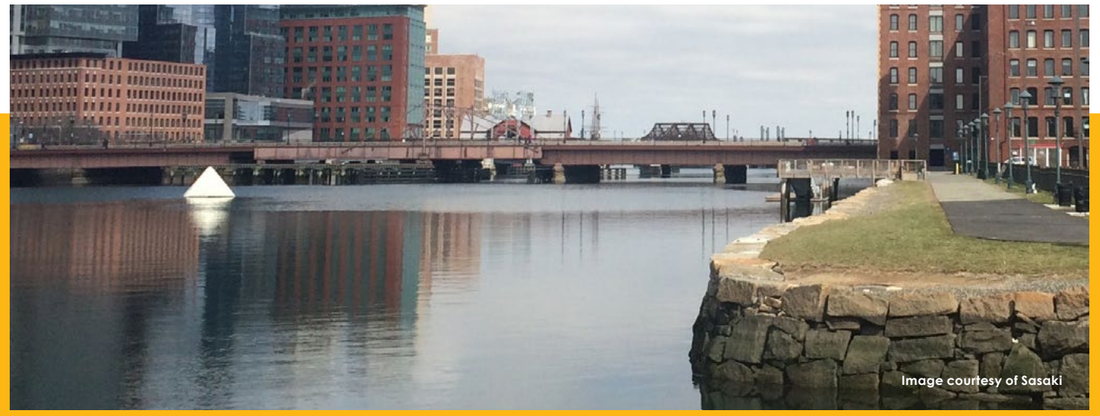


Image courtesy of Sasaki

THE MULTIPLE LAYERS APPROACH

Resilient solutions are independently effective (provide benefits on their own) but can also be applied in multiple layers to increase effectiveness. This multiple-layers approach is applied to the flood protection strategy described here, where both district-scale and harbor-wide flood protection plans are advanced simultaneously.

While the pursuit of both district-scale and harbor-wide flood protection may at first seem duplicative, there are a number of reasons to pursue them in parallel:

- Time. The smaller scale of the district-scale interventions means that they would likely be less expensive, complex, and time consuming to implement than a harbor-wide intervention would be. Many Boston neighborhoods face significant coastal flood risk today and would benefit from district-scale interventions as soon as they are implemented. Even if harbor-wide and district-scale interventions were aggressively pursued, there could be a period of years or even decades between when a district solution would be operational and when a harbor-wide solution could be in place.
- Scale. The cost and complexity of a harbor-wide intervention may prevent it from ever being fully implemented.
- Co-Benefits. District-scale flood protection and harbor-wide interventions offer different opportunities for co-benefits, such as parkland, transportation infrastructure, or additional developable land.
- Negative Impacts. While the flood risk reduction benefits of a harbor-wide intervention may be far greater than those of a district-scale intervention, the potential for negative impacts on the regional ecology and economy would also be far greater.
- Risk of Failure. If a harbor-wide intervention were to fail and there were no district-scale flood protection, the results could be catastrophic. At the same time, however, district-scale interventions are also not fail-proof, as they can be overtopped. For this reason, even buildings behind flood protection structures should retrofitted or built to climate-ready standards, and communities should be prepared for severe storms.
- Regular Tidal Inundation. Some areas like South Boston and East Boston will face monthly inundation once sea level rise passes a certain threshold later this century. A harbor-wide intervention alone may not be able to prevent all tidally induced flooding, requiring a multiple-layers approach over the long term.

THE HARBOR ISLANDS AND FLOOD RISK

The Harbor Islands play an important role in mitigating tides and wave action between the Atlantic Ocean and Boston's shores. They slow the rate at which water can enter and exit the harbor, decreasing the difference in elevation between high tide and low tide, and they also dissipate the energy of waves entering the harbor. As sea levels rise, the Harbor Islands are at risk of shrinking. Currently, a team of public and nonprofit partners are studying the erosion of the Islands and the potential for installing submerged breakwaters—including using materials from the U.S. Army Corps of Engineers' dredging of the harbor channels—to act as wave attenuators which would promote shoreline protection and possibly provide habitat for species like eelgrass. The team includes the City of Boston, the U.S. Army Corps of Engineers, the Massachusetts Office of Coastal Zone Management and the Division of Marine Fisheries, The Nature Conservancy, and Northeastern University.

BOSTON'S EXISTING COASTAL PROTECTION STRUCTURES

In addition to flood protection provided by natural waterfront areas such as the Belle Isle Marsh, Boston is already protected by a number of manmade coastal protection structures. The Massachusetts Department of Coastal Zone Management conducted an inventory and assessment of publicly-owned coastal structures in 2015, and identified a total of 110 structures in Boston, with 18 structures in East Boston, 16 in Charlestown, 13 in Downtown Boston, 36 in South Boston, and 27 in Dorchester. Approximately $46 million in rehabilitation funds would be required to bring all structures up to an "A" condition rating, with $23 million of that required for structures that are in "D" or "F" condition. Given that well-maintained structures are necessary to provide effective protection, there is a resilience opportunity associated with restoring and upgrading Boston's existing structures.

INITIATIVE 5-1. ESTABLISH FLOOD PROTECTION OVERLAY DISTRICTS AND REQUIRE POTENTIAL INTEGRATION WITH FLOOD PROTECTION

The Boston Planning and Development Agency (BPDA) should petition the Boston Zoning Commission to create new Flood Protection Overlay Districts in areas that are strategically important for potential future flood protection infrastructure. These areas are low-lying "breach points" near the waterfront where floodwaters could enter neighborhoods and where targeted district-scale interventions could yield significant risk reduction (see Initiative 5-3, p.110). The purposes of the Flood Protection Overlay Districts are first to recognize that the rapid pace of development occurring in strategically important areas today could increase the cost and complexity of potential future district-scale flood protection, and second, to provide a regulatory mechanism to address that situation. Drawing on the findings from the Vulnerability Assessment, and specifically the locations of key inundation points, Climate Ready Boston has identified a set of potential locations for flood protection systems that could address inundation points by connecting places of high ground (see map, "Potential Flood Protection Locations," and the Focus Areas chapter of this report).

Within a Flood Protection Overlay District, a developer would be required to submit a study of how the proposed project could be integrated into a future flood protection system; options may include raising and reinforcing the development site or providing room for a future easement across the site. The BPDA should engage in conversations with the development community to develop guidelines for such studies and determine a minimum project size for this requirement so that small projects are not unnecessarily burdened. Proposals should consider the feasibility of nature-based flood protection systems that may include dunes, landscaped berms, or created salt marshes or oyster reefs.

INITIATIVE 5-2. DETERMINE A CONSISTENT EVALUATION FRAMEWORK FOR FLOOD PROTECTION PRIORITIZATION

The City should establish a framework through which alternative district-scale and harbor-wide flood protection systems would be consistently evaluated. While this framework should be guided by local priorities, it must also be compatible with the framework used by the U.S. Army Corps of Engineers, who would be an indispensable partner on studying, permitting, funding, and implementing any flood protection infrastructure.

It is critical to consistently quantify the social, environmental, and economic benefits of each alternative intervention—with particular attention to social equity and the needs of socially vulnerable populations—so that they can be weighed both against the costs of the project and against each other. Any evaluation framework must compare a baseline "without project" scenario, in which flood risk continues to increase with sea level rise, to "with project" scenarios, in which flood risk is managed through appropriate interventions.

The key considerations for an evaluation framework for district-scale and harbor-wide flood protection systems include: flood risk reduction benefits; additional benefits, such as quality of life impacts; environmental impacts; cost; land ownership; permitting and regulations; and intergovernmental coordination. Each consideration is discussed further below.

- **Flood risk reduction benefits.** The primary goal of a flood protection system is to reduce the flood risk for residents, businesses, property, and infrastructure, ensuring that Boston can continue to thrive as sea levels rise.

  The information in the Climate Ready Boston Vulnerability Assessment is an initial attempt at quantifying flood risk and therefore the potential for risk reduction. For example, there are currently over 90,000 Bostonians and 12,000 buildings in the areas expected to be inundated during a 1 percent annual chance flood event under a 36-inch sea level rise scenario (2070s or later). Under this scenario, the expected economic losses[3] in the City of Boston from such a flood event would be over $14.2 billion. The potential flood risk reduction benefits at specific locations are detailed in the Focus Area chapter.

  These estimates only consider current people and property in Boston, and do not take into account population growth or future development. Further studies should verify the flood risk reduction potential of multiple district-scale and harbor-wide intervention designs, considering Boston's neighbors who also face flood risk from the harbor, as well as future city and regional growth.

  - *Residual flood risk.* The City must consider "residual risk," or the risk remaining after the flood protection system is built. This includes the risk that a flood event of greater magnitude or intensity occurs than the one selected as the basis for design, as well as increased risk due to the diminished drainage capacity of the area behind the flood protection system.

  - *Induced flood risk.* The City must also consider potential impacts on areas outside the flood protection system, which could potentially face greater risk of flooding due to the displacement of water by the flood protection system.

[3]Includes direct physical damage, displacement costs, and stress factors. See Vulnerability Assessment for details.

FINANCING A FLOOD PROTECTION SYSTEM

Through its General Investigation Program, the U.S. Army Corps of Engineers (USACE) helps communities study and construct flood risk management projects. Typical feasibility studies take three years to complete, and cost up to $3 million, with costs split evenly between the federal government and the local sponsor. If the project is found to have federal interest and a favorable benefit-cost ratio, the federal government can fund up to 65 percent of construction costs, with the local sponsor contributing the remainder, as well as all operations and maintenance costs. For the USACE to pursue study and construction through the General Investigation Program, Congress must provide authorization and appropriate funds. The City should work with its senators and congressional representatives to advance this agenda in Congress.

While this federal process can be extremely helpful for advancing flood protection projects, it typically takes years to even begin a feasibility study. Given the urgency of these projects, Boston should advance studies outside of the USACE process—but using a framework that is compatible with USACE methodologies—to both accelerate the timeline of the studies and increase the likelihood that the USACE would eventually get involved. This was the approach taken by six proactive Texas counties around Houston and Galveston, which are currently funding a comprehensive flood protection study using the USACE's process and with the USACE engaged as reviewers. The goal is to reach a consensus with key stakeholders and then pass the study to the USACE, who should be able to use the study findings, model, and data for future phases to save on costs and accelerate the overall study timeline.

Even if there is significant federal financial support for a harbor-wide intervention, Boston and its neighbors would still be required to finance a large portion of the project.

- **Additional benefits.** To maximize both the total benefits of a flood protection system and its potential to generate revenue for its own construction, design alternatives should advance other community goals in addition to flood risk reduction. For example, flood protection systems could be used to create new recreational and ecologically productive open spaces through green coastal infrastructure, new or newly protected land for residential or commercial development, or new transportation infrastructure. There are many existing and proposed examples from around the world of flood protection being incorporated into other investments that improve quality of life in a city. Brooklyn Bridge Park, for example, was built with shoreline riprap, a constructed marsh, and lands elevated well above the floodplain, protecting the park and some inland areas from damage during Hurricane Sandy. These benefits can also help avoid, or mitigate, any negative quality of life impacts. For example, a system that requires the construction of a vertical wall may block physical or visual access to the waterfront; a system that utilizes a landscaped berm would improve waterfront access and opportunities for recreation, education, and tourism.

- **Environmental impacts.** Any flood protection system would have both immediate and lasting impacts on the region's complex ecosystems, including effects on water quality and coastal habitats.

  In assessing environmental impacts, it is crucial to compare them to a baseline "without project" scenario in which there is no harbor-wide intervention and the sea continues to inundate land with increasing frequency. For example, a harbor-wide intervention would likely disturb Belle Isle Marsh, Neponset River, and other intertidal wetlands in the harbor by altering salinity, nutrient, and toxin loads and other biochemical factors. However, without a harbor-wide intervention or adjacent land for these wetlands to migrate to over time, sea level rise will more quickly convert these areas to open water and eliminate the benefits wetlands provide. Because sea level rise will threaten key habit areas with or without flood protection interventions, expected future environmental conditions with and without interventions need to be understood.

  Although district-scale flood protection infrastructure would not have the same scale of environmental impact as a harbor-wide intervention, it would still have consequences for local natural systems. Impacts on ecological systems, such as species habitat, and public health, such as water quality, must be studied. On the other hand, both harbor-wide and district-scale flood defenses would have some near- and long-term ecological benefits that should be further understood. For instance, baseline "without project" scenarios would include uncontrolled flooding in many urban and industrial areas, heightening Boston Harbor's exposure to toxins. By reducing the probability of flooding, harbor-wide and district-scale flood defenses would reduce the probability of toxic releases that would harm harbor ecosystems.

- **Cost.** The planning, design, construction, environmental mitigation, and annual operations and maintenance activities for a coastal protection system would all require significant expenditures.

  Primary cost drivers for solutions such as the harbor-wide intervention would be the large gate structures and marine walls,which would span 1.5 to 3.5 miles and require deep foundations to withstand the forces of storm events.

  For district-scale defenses, cost is affected by flood protection location and typology and the physical and urban conditions of the location where defenses are being built. Cost considerations include the relative size of the flood protection system, its relative complexity (e.g., deployable gates across road intersections make systems much more expensive to build and operate), and opportunities to integrate flood protection with other infrastructure and redevelopment to reduce and share costs.

- **Land ownership.** Flood protection systems will likely span multiple parcels of land. To minimize the cost and complexity of flood protection, public land should be used wherever possible. In order for FEMA to certify a flood protection project, which is necessary for realizing National Flood Insurance Program savings, the project must be publicly owned and maintained. If any private land were incorporated into a project, it would require an easement to allow 24-hour access for maintenance activities. To reduce challenges associated with private ownership, especially fragmented private ownership, public parcels or rights-of-way are preferred wherever possible.

- **Permitting and regulations.** Regulations affect the feasibility of flood protection both directly, by setting the parameters for the permitting process, and indirectly, by controlling the types of uses that can occur near the defenses and therefore the ability to raise funds from nearby properties.

  As with any major water infrastructure project, a number of local, state, and federal agencies would need to approve a coastal protection system.

  At the local level, the Boston Conservation Commission is the agency responsible for reviewing projects impacting wetlands, under the Massachusetts Wetlands Protection Act.

  At the state level, the Office of the Secretary of Energy and Environmental Affairs is responsible for administering the Massachusetts Environmental Policy Act (MEPA), the primary environmental law that governs major actions taken by Massachusetts governments. In addition, the state Department of Environmental Protection administers Chapter 91, the Massachusetts Public Waterfront Act, which includes requirements for public access and water-dependent uses. The MassWildlife Natural Heritage and Endangered Species Program administers the Massachusetts Endangered

FLOOD RISK REDUCTION BENEFITS

As sea levels rise, the potential benefits of a harbor-wide intervention, in terms of avoided impacted people and economic losses, will increase. This table of potential flood risk reduction benefits only includes the current people and property in Boston; the actual avoided losses would be larger because they would include areas outside Boston and because the region's population and economic activity are expected to continue to grow.

	9" SLR (2030s-2050s)	**21" SLR** (2050s-2100s)	**36" SLR** (2070s-2100s)
Population exposed to 1 percent annual chance flood	16,000	43,000	90,000
Buildings exposed to 1 percent annual chance flood	2,000	6,000	12,000
Estimated economic losses from a 1 percent annual chance flood	$2.3 billion	$6.2 billion	$14.2 billion

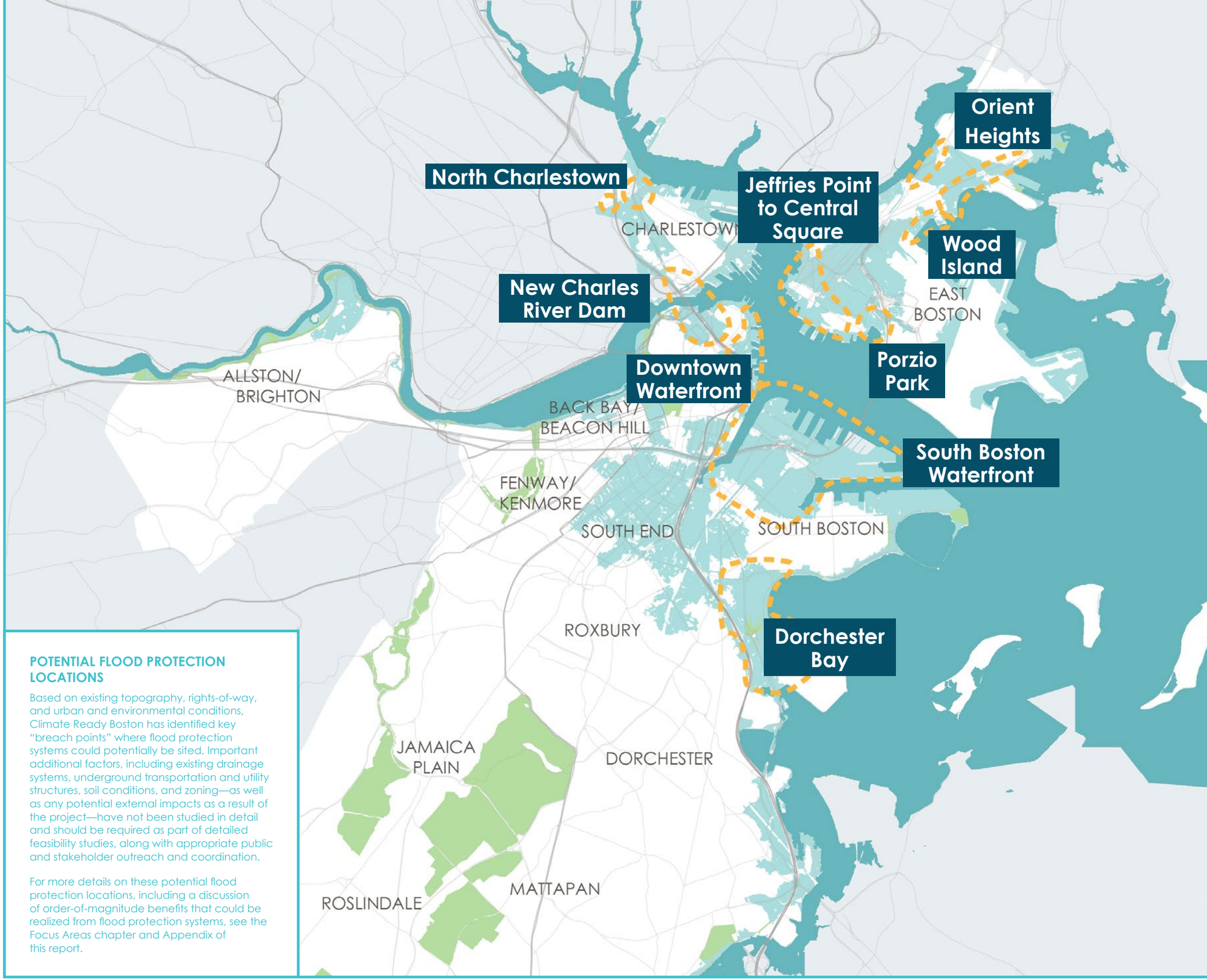
Species Act. Finally, the Massachusetts Office of Coastal Zone Management (CZM) would need to be involved in project review to ensure that the proposed activities are consistent with Massachusetts's enforceable coastal program policies and to conduct a federal consistency review for any project requiring federal permitting or funding.

At the federal level, the U.S. Army Corps of Engineers would likely lead coordination with other federal agencies, including the U.S. Fish and Wildlife Service and the Environmental Protection Agency. Regulators would consider project impacts on the natural environment, historic and cultural resources, and the navigability of Boston Harbor by commercial and recreational vessels.

- **Coordination with other municipalities and government entities.** Harbor-wide and district-scale interventions are likely to require close collaboration with neighboring cities and towns, such as Cambridge, Chelsea, Winthrop, and Quincy, as well as the state and regional agencies.

INITIATIVE 5-3. PRIORITIZE AND STUDY THE FEASIBILITY OF DISTRICT-SCALE FLOOD PROTECTION

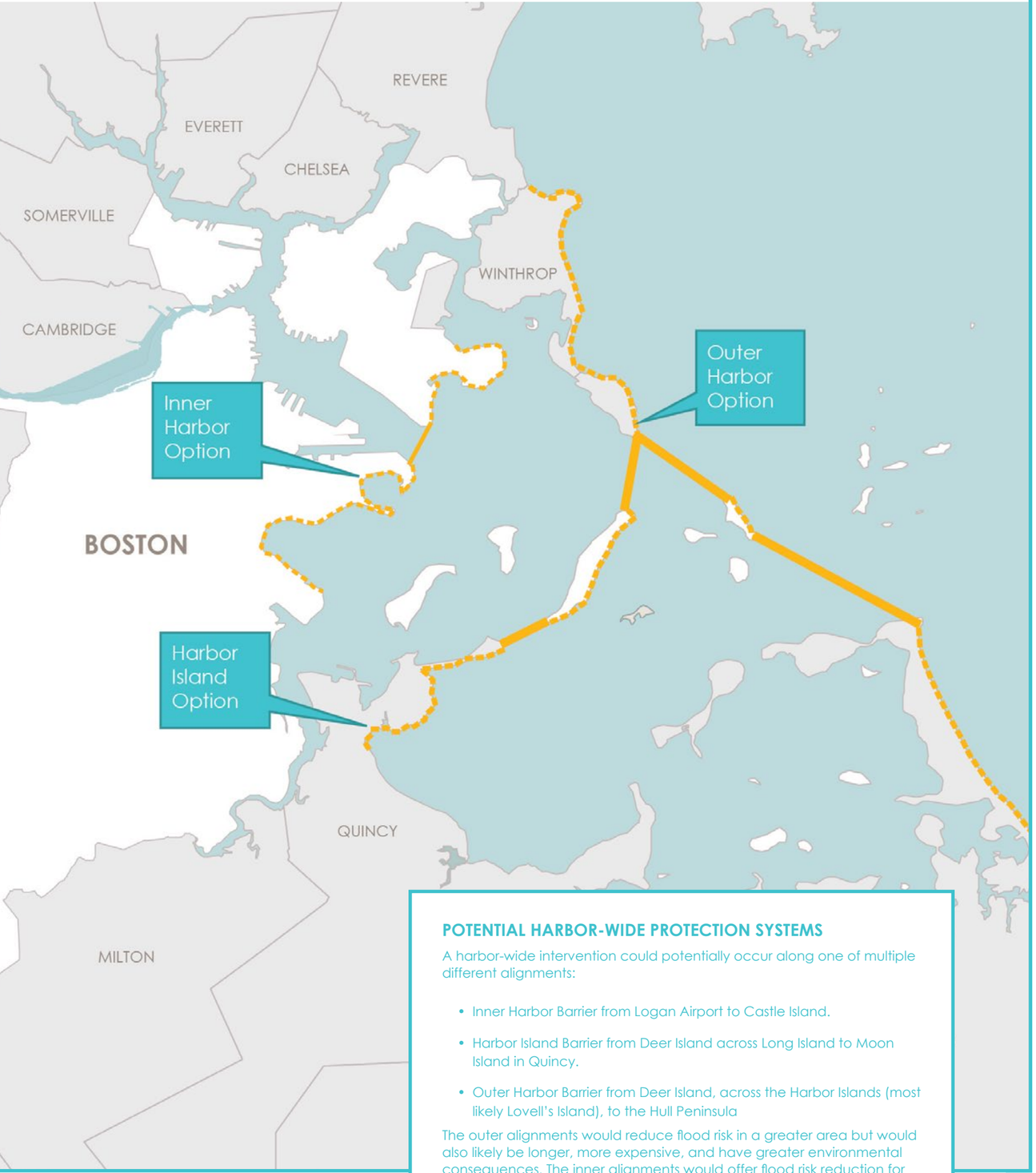
Applying a consistent evaluation framework (see Initiative 5-2, p.106), the City should study the feasibility of district-scale flood protection in a number of locations and prioritize them based on costs and benefits to populations, businesses, property, and infrastructure. For more details on potential flood protection locations, including a discussion of order-of-magnitude benefits that could be realized from each, see the Focus Areas chapter and Appendix of this report. These feasibility studies should take place in the context of local climate resilience plans (see Initiative 4-1, p.100), featuring engagement with local communities, coordination with infrastructure



POTENTIAL FLOOD PROTECTION LOCATIONS

Based on existing topography, rights-of-way, and urban and environmental conditions, Climate Ready Boston has identified key "breach points" where flood protection systems could potentially be sited. Important additional factors, including existing drainage systems, underground transportation and utility structures, soil conditions, and zoning—as well as any potential external impacts as a result of the project—have not been studied in detail and should be required as part of detailed feasibility studies, along with appropriate public and stakeholder outreach and coordination.

For more details on these potential flood protection locations, including a discussion of order-of-magnitude benefits that could be realized from flood protection systems, see the Focus Areas chapter and Appendix of this report.



POTENTIAL HARBOR-WIDE PROTECTION SYSTEMS

A harbor-wide intervention could potentially occur along one of multiple different alignments:

- Inner Harbor Barrier from Logan Airport to Castle Island.
- Harbor Island Barrier from Deer Island across Long Island to Moon Island in Quincy.
- Outer Harbor Barrier from Deer Island, across the Harbor Islands (most likely Lovell's Island), to the Hull Peninsula

The outer alignments would reduce flood risk in a greater area but would also likely be longer, more expensive, and have greater environmental consequences. The inner alignments would offer flood risk reduction for smaller areas but may also have fewer implementation challenges (see "Boston Harbor and Harbor-Wide Flood Protection," p.115).

adaptation, and considerations of how flood protection would impact or be impacted by neighborhood character and growth.

The *location and design options* of flood protection systems determine their positive and negative impacts and implementation feasibility. In connecting areas of high ground to one another, many flood protection systems must span more than one type of location or design. Location and design options for district-scale flood protection include the following:

- **In-water.** Within a water body, a flood protection project would likely be an operable gate. In-water defenses can restrict navigable channels. In addition, they are likely to require higher elevations to protect against flooding due to wave heights, which can block visual and physical access to water.
- **Water's edge.** At the water's edge, there are many types of potential flood protection designs. As with in-water barriers, defenses at the water's edge are likely to require higher elevations to protect against flooding due to wave heights.
- **Upland.** There are many types of flood protection designs upland from the water as well. Compared to in-water or water's edge defenses, upland flood protection systems provide a comparatively smaller area of risk reduction. However, they are not likely to be as tall as defenses in the water or at the water's edge, since the ground elevation is higher, and wave energies dissipate over land. Still, upland flood protection can interfere with visual and physical connections within a neighborhood. In addition, they may cross roads, requiring deployable gates, or cross privately owned land.

See "Example Flood Protection Designs" (p.102) for a sample of various design options.

INITIATIVE 5-4. LAUNCH A HARBOR-WIDE FLOOD PROTECTION SYSTEM FEASIBILITY STUDY.

The City, in collaboration with regional partners, should study the feasibility and desirability of a harbor-wide flood protection system and compare it to the alternative of multiple district-scale defenses, using a consistent evaluation framework (see Initiative 5-2, p. 106). Partners may include the Metropolitan Area Planning Council (MAPC) and its Metro Boston Climate Preparedness Task Force. In addition, early and frequent engagement with the Massachusetts Office of Coastal Zone Management and U.S. Army Corps of Engineers would be critical, as well as ongoing engagement with the Boston Harbor Islands National and State Park. Studying such a significant intervention in detail is a major undertaking in its own right, and such studies elsewhere have been multiyear efforts requiring significant public resources and structured coordination.

As part of comparing the feasibility and desirability of multiple harbor-wide and district-scale alternatives using a consistent evaluation framework (see Initiative 5-2, p.106), a study would need to consider a number of location and design options for a harbor-wide intervention, including the following:

- **Alignment options.** A harbor-wide intervention could potentially occur along one of multiple different alignments. The outermost alignment would stretch from Deer Island and across the Harbor Islands (most likely Lovell's Island) to the Hull Peninsula. An alignment closer to the shore would stretch from Deer Island across Long Island to Moon Island in Quincy. Finally, an Inner Harbor alignment would stretch from Logan Airport to Castle Island. As a very basic comparison, the outer alignments would reduce flood risk in a greater area but would also likely be longer, more expensive, and have greater

Image courtesy of Bud Ris

environmental consequences. The inner alignments would offer flood risk reduction for smaller areas, but may also have fewer implementation challenges.

- **Sizes of gaps and gates.** For each approach to a harbor-wide intervention—only decreasing tidal range, and doing so with an operable surge barrier—there are questions related to the optimal size of harbor openings, with respect to both reducing flood risk and minimizing negative impacts. A feasibility study would need to explore how narrow the harbor mouth would need to be in order to sufficiently reduce the tidal range to reduce flood risk. For the surge barrier option, there would be some narrowing of the harbor mouth by virtue of the in-water infrastructure necessary to support the barrier. A feasibility study would need to explore the size, number, and locations of gates necessary to provide flood risk reduction while minimizing the impacts on the environment and navigation. For both options, attention must be paid to how the tide levels and salinity of the harbor would change, along with the consequences for local and regional ecosystems.
- **Project phasing.** Based on best practices from other locations, it is critical that resilience solutions be adaptable and flexible. Any harbor-wide intervention would be a very large investment, built to reduce flood risk for generations to come. However, as discussed in the Climate Projection Consensus (see p.01) there is uncertainty regarding future sea levels after about 2050, both because of the complex nature of climatic systems and because they are heavily dependent on the success of global efforts to reduce emissions. To address this uncertainty, the City should explore how to minimize the probability of designing to too high or too low a standard. For example, it may be worthwhile to narrow the tidal range in a way that would accommodate the addition of a surge barrier at a later point in time.

BOSTON HARBOR AND HARBOR-WIDE FLOOD PROTECTION

The challenges of implementing a harbor-wide flood protection system, as well as the potential environmental impacts, are significant. However, Boston Harbor also has distinctive characteristics that may make it more amenable to a harbor-wide flood protection system than are other cities' harbors:

- **Harbor depth.** The harbor is relatively shallow. Aside from the major shipping channels, which have been dredged to accommodate large vessels and are currently being deepened, much of the harbor is about 20 feet deep. The $310 million Boston Harbor Dredging Project will deepen the Outer Harbor 40-foot channel to 51 feet, the Inner Harbor 40-foot channel to 47 feet, and the Reserved Channel to 47 feet. Feasibility studies of channel narrowing or barrier construction should consider the impact of channel deepening.
- **Public land.** Almost all of the land that would need to be incorporated into a harbor intervention—from Deer Island through the Harbor Islands—is publicly owned and therefore can more readily accommodate a public flood protection project.

There are also a number of factors that would make construction of a harbor-wide flood barrier challenging, including impacts on ecological communities resulting from changing tidal conditions and salinity levels; the impacts on water quality because of decreased exchange of water between the harbor and the ocean; the potential for conflicts with commercial shipping, recreational boating, and water transportation; and the risk of inducing flooding in areas on the Atlantic Ocean side of a harbor-wide flood defense.

Source: "Boston to Begin Dredging in 2017." The Journal of Commerce, November 2015.

Layer 4

RESILIENT INFRASTRUCTURE

Strategy 6: Coordinate investments to adapt infrastructure to future climate conditions

INITIATIVE 6-1. ESTABLISH AN INFRASTRUCTURE COORDINATION COMMITTEE

RESILIENCE RATE CASE

The utilities that serve the Boston metro region may seek funds for resilience capital projects as part of their rate cases to the Massachusetts Department of Public Utilities (DPU) so that they can cover the costs of required resilience investments. For example, Con Edison included a $1 billion request for funds to support resilience capital upgrades from 2013 to 2016 as part of its electric, gas, and steam rate cases filed in January 2013. Should the utilities pursue this approach in Boston, the City may want to consider whether to support such a request. The Greater Boston Panel on Climate Change could be available to provide expert testimony about future climate conditions and the need for resilience investments to address utility system vulnerabilities.

STANDARDS DEVELOPMENT WORK TO DATE

In developing system standards, the ICC should leverage significant work done by its members to date. For example, the Boston Water and Sewer Commission has developed recommendations for the 10-year, 24-hour design storm, annual rainfall totals, and elevation at which outfalls are required to be tide-gated. In addition, the Massachusetts Port Authority has developed recommendations for design flood elevations as part of a new flood-proofing design guide. For existing facilities, the design flood elevation is the maximum water elevation with a 0.2 percent annual probability of exceedance in 2030 based on the Boston Harbor Flood Risk Model (BH-FRM), plus three feet of freeboard. For new facilities, the design flood elevation is defined by the maximum water elevation with a 0.2 percent annual probability of exceedance in 2070 based on the BH-FRM, plus three feet of freeboard. The Massachusetts Department of Transportation has put forward recommendations for elevations at which to deploy temporary and permanent protections for Central Artery and tunnel assets.

ICC Formation

The Mayor should work with the Governor of Massachusetts and other key stakeholders to establish a standing Infrastructure Coordination Committee (ICC), consisting of key private and public infrastructure owners and operators in the Boston metro area. The ICC should serve as the primary vehicle for coordination between the City and these entities on how to set design standards and track investments in climate resilient infrastructure. The committee also can be used as a framework to support coordination on other issues, as required.

The continued reliability of the infrastructure systems that meet Boston's transportation, water and sewer, energy, communication, and other needs is necessary for both Boston's continued prosperity and its residents' safety and health. The ICC is needed because Boston does not have direct control over all of the infrastructure that serves its population and economy, relying partially on regional systems. Climate Ready Boston's Vulnerability Assessment revealed that Boston's infrastructure systems are vulnerable to near-term and long-term climate impacts. Discussions conducted through Climate Ready Boston's Infrastructure Advisory Group indicated that infrastructure owners and operators do not have full information on their systems' vulnerability to changing climate conditions, especially in regard to upstream and downstream impacts. Both the City and infrastructure operators have a vested interest in understanding and addressing vulnerabilities to create resilient infrastructure systems. The ICC should provide a forum to bring together the key actors who regulate, operate, and own infrastructure so they can align their efforts, in terms of both setting and implementing standards to meet future climate conditions.

The key members of the ICC should include representatives from all of the major infrastructure systems, including transportation, water and sewer, energy, telecommunications, and environmental

BOSTON-AREA ICC PRECEDENTS

The ICC should build on four important efforts that have been undertaken in Boston and the metro region to date to convene key public and private infrastructure operators about issues directly or indirectly related to resilience. For Climate Ready Boston, in 2015, the City convened the Infrastructure Advisory Group to collect data about vulnerable assets and infrastructure system interdependencies and discuss possible resilience initiatives. In 2016, the Boston Planning and Development Agency convened the Smart Utilities Planning Committee to do coordinated, proactive utility planning for the Dorchester Avenue corridor. In 2014, the Office of Emergency Management convened the Natural Hazards Mitigation Plan Steering Committee, comprised of representatives of key City departments and commissions with responsibility for hazard mitigation, to guide the Boston Natural Hazards Mitigation Plan Update. In 2011, as part of the process for preparing Massachusetts's first Climate Change Adaptation Report, a mandate of the 2008 Global Warming Solutions Act, the Massachusetts Executive Office of Energy and Environmental Affairs convened both the Climate Change Adaptation Advisory Committee and the State Agencies Steering Committee. Through these groups, Boston and the Commonwealth have started the process of building institutional knowledge and overcoming barriers to data sharing.

NON-BOSTON ICC PRECEDENTS

To date, there have been efforts to establish entities similar to the ICC in other cities, most notably in New York City. In 2008, Mayor Michael Bloomberg convened the New York City Climate Change Adaptation Task Force (CCATF), a group of public and private infrastructure operators, to assess climate risks to their assets and identify strategies to protect them. Mayor Bloomberg charged the CCATF with developing an inventory of at-risk infrastructure assets, supporting coordinated adaptation planning, and creating design guidelines for new infrastructure. The New York City Panel on Climate Change (NYCPCC), an independent body of climate scientists, advised the CCATF. In 2013, following Hurricane Sandy, Mayor Bloomberg convened the Special Initiative for Rebuilding and Resiliency (SIRR) to develop a comprehensive roadmap for resilience building in NYC, leveraging the work of the CCATF.

In addition, as part of Con Edison's electric, gas, and steam rate cases filed in January 2013, the New York State Public Service Commission convened the Storm Hardening and Resiliency Collaborative to provide guidance on how the funds should be spent. The collaborative brought together academic experts to support Con Edison in adaptation planning.

Sources: "A Stronger More Resilient New York." Special Initiative for Rebuilding and Resiliency, City of New York, June 11, 2013.

"Storm Hardening and Resiliency Collaborative Report." Consolidated Edison Company of New York Inc. December 4, 2013.

DEVELOPMENT OF STANDARDS BY ICC WORKING GROUPS

WORKING GROUP	KEY MEMBERS	STANDARDS TO BE DEVELOPED
WATER AND SEWER	Boston Water and Sewer Commission, Massachusetts Water Resource Authority, Department of Conservation and Recreation, Public Improvement Commission	• 10-year, 24-hour design storm • Annual rainfall totals • Elevation at which public and private outfalls are required to be tide-gated • Elevation and level of protection requirements for assets critical to maintaining service • Performance design standards
TRANSPORTATION	Massachusetts Bay Transit Authority, Massachusetts Department of Transportation, Massachusetts Department of Conservation and Recreation, Boston Transportation Department, Boston Public Works Department	• Elevation and level of protection requirements for assets critical to maintaining service (roads, bridges, tunnels, rail, subways, buses, water transit, and transportation support facilities) • Performance design standards
ENERGY	Eversource, National Grid, Veolia, Boston Environment Department, Massachusetts Department of Public Utilities	• Elevations and level of protection requirements for critical assets and facilities • Performance design standards
TELECOMMUNICATIONS	Verizon, Comcast, Department of Innovation and Technology	• Elevations and level of protection requirements for assets critical to maintaining service • Level of access and continuity of service for broadband and Wi-Fi access • Performance design standards • Redundancy

assets, that are critical to the City of Boston's operations. These individuals should include participants from City departments, state agencies, private utilities, and adjacent municipalities that interact with or affect Boston's infrastructure systems. The ICC will be coordinated closely with the Metro Boston Climate Preparedness Task Force, which has been convened by the Metro Mayors Coalition.

ICC Duties

To strengthen Boston's resilience, the ICC should be charged with four duties:

First, the ICC should use the updated climate projections to develop planning and design standards across member agencies for retrofitting or constructing all major infrastructure systems to a standard set of future climate conditions. The ICC should work with the City to define levels of acceptable risk. Members should be organized into working groups by major infrastructure system, with the groups to include transportation, water and sewer, energy, telecommunications, and environmental assets, in order to develop specific planning and design standards by system.

Second, ICC members should collaborate to identify cascading vulnerabilities and opportunities for joint adaptation projects that could improve effectiveness or cost efficiencies by addressing multiple systems' vulnerabilities at once. The ICC should provide a framework for members to detect and reduce vulnerabilities that fall within larger systems that affect their assets but are out of their direct control. In addition, the ICC should provide a forum for members to share information, consult with each other about adaptation projects they plan to individually undertake, and work together to identify efficiencies and important community co-benefits, including advancing equity.

Third, ICC members should develop adaptation plans, tied to capital improvement plans, in order to upgrade their vulnerable assets over time to meet the agreed-upon planning and design standards. ICC members can use the Climate Ready Boston Vulnerability Assessment data as the basis for their adaptation planning. However, they may need to conduct asset-specific vulnerability assessments. Members should be asked to develop adaptation plans within five years of the initial planning and design standards being released. These plans should consider adaptation both across their systems as well as within specific focus areas prioritized by the City for coordinated adaptation planning. Capital projects should be prioritized based on the following:

- Timing and level of assets' exposure to climate change risks
- Consequences of assets' full or partial failure, including frequency and severity of service disruption
- Cost and feasibility
- Opportunity to advance equity and protect socially vulnerable populations. The City should charge ICC members with paying particular attention to vulnerable populations who may be disproportionately impacted by full or partial infrastructure failure.

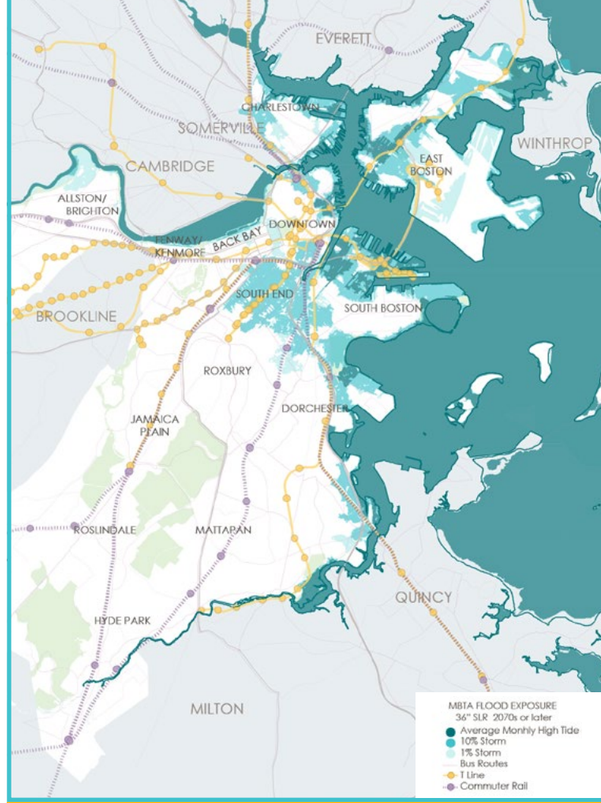
Finally, members should provide the City with regular reports on their progress in developing adaptation plans and bringing their assets up to planning and design standards. The Environment Department should annually summarize those reports to inform joint adaptation planning and identify gaps in adaptation across systems.

INITIATIVE 6-2. CONTINUE TO COLLECT IMPORTANT ASSET AND HAZARD DATA FOR PLANNING PURPOSES

To maximize the benefit of the data collected and produced as part of Climate Ready Boston, Climate Ready Boston should transfer non-confidential data on public and private infrastructure assets to the Department of Information Technology (DoIT). The objective of this initiative is to establish a central place for the storage of key data about infrastructure systems to create an integrated dataset and allow for the identification of upstream and downstream vulnerabilities. For the Vulnerability Assessment, Climate Ready Boston requested information on public and private infrastructure assets from a broad range of city and state agencies and private infrastructure operators, and reconciled and verified the submitted data. DoIT should coordinate with the Boston Regional Intelligence Center (BRIC) database to explore holding and storing data that is sensitive or proprietary.

INITIATIVE 6-3. PROVIDE GUIDANCE ON PRIORITY EVACUATION AND SERVICE ROAD INFRASTRUCTURE TO THE ICC

To guide adaptation planning by ICC members, the Office of Emergency Management (OEM), Boston Transportation Department (BTD), and Department of Public Works (PWD) should work with the utilities to identify roads to prioritize for adaptation planning. These roads should include first those that are part of Boston's evacuation network and second those that are required to restore or maintain essential services, for example, by delivering personnel or backup power (mobile generators or fuel) to critical facilities. OEM should share the list with the Massachusetts Department of Transportation (Mass DOT) and Department of Conservation and Recreation (DCR). The City should support Mass DOT in continuing its efforts to develop an emergency response plan for tunnel protection or closure in the event of a major storm, in line with the recommendations from the 2015 FHWA/Mass DOT Central Artery and tunnels vulnerability assessment.



MBTA VULNERABILITY ASSESSMENT

To support the ICC, the City should request that the Massachusetts Bay Transportation Authority (MBTA) expand its asset-level vulnerability assessment from the Blue Line, currently in progress, to its entire public transit system. Prior to the current Blue Line study, vulnerability assessment of the MBTA's assets and services has been limited to assets within the Central Artery corridor (e.g., South Station, Silver Line, Aquarium Station, and North Station) included in MassDOT's Federal Highway Administration-funded study. The MBTA's system-wide vulnerability assessment should include detailed analyses of physical infrastructure assets and supporting systems, and consider not only the relative importance of specific assets, but also their upstream and downstream interdependencies, with particular attention to the energy supplies on which MBTA's systems rely and potential impacts on vulnerable populations. The MBTA should consider the vulnerabilities of both the regional energy infrastructure on which it depends for maintaining service and its internal backup power supply, which ensures continued operation even when the power grid is unavailable.

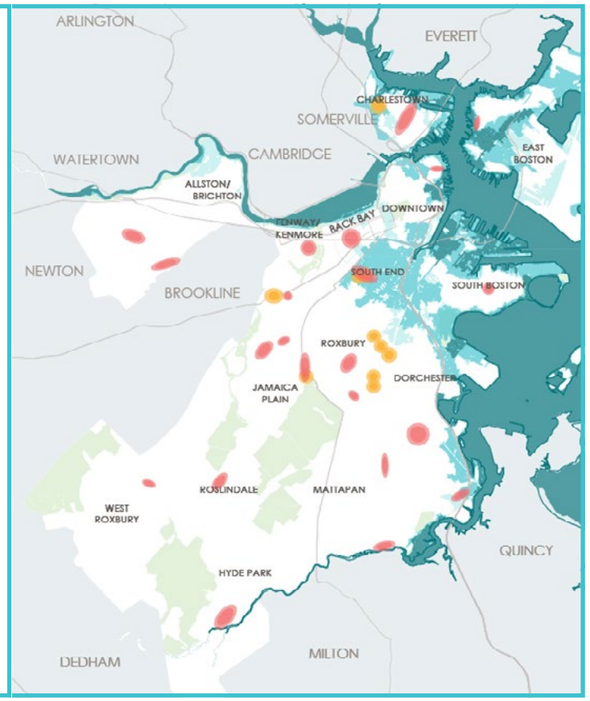
Strategy 7: Develop district-scale energy solutions to increase decentralization and redundancy

INITIATIVE 7-1. CONDUCT FEASIBILITY STUDIES FOR COMMUNITY ENERGY SOLUTIONS

The Boston Planning and Development Agency and Environment Department should work with the relevant members of the ICC and other stakeholders to use the findings from the BPDA's Boston Community Energy Study (2016) to develop action plans to pursue community energy solutions in areas with significant concentrations of critical facilities and socially vulnerable populations. Community energy solutions are local energy generation, energy storage technologies, district energy, and microgrids. The Community Energy Study identified 42 locations across Boston with high potential for community-based energy solutions, based on preliminary engineering and cost-benefit analyses. However, there is a need for further feasibility studies that evaluate other important factors, such as the state and capacity of existing infrastructure at potential sites, building retrofit costs, and street excavation costs. For example, parts of the Downtown, Charles River, and South Boston focus areas are served by an electrical grid that is not designed to export locally generated energy.

The BPDA and the Environment Department should prioritize further feasibility studies for potential energy justice and emergency microgrid sites, as identified by the Community Energy Study. Energy justice microgrid sites have the potential to serve clusters of affordable housing and critical facilities. Emergency microgrid sites have the potential to serve clusters of critical facilities.

PROPOSED COMMUNITY ENERGY SOLUTIONS



RAYMOND L. FLYNN MARINE PARK MICROGRID

The BPDA is working with Eversource to pursue a feasibility study for a pilot microgrid project at the Raymond L. Flynn Marine Park in South Boston.

Strategy 8: Expand the use of green infrastructure and other natural systems to manage stormwater, mitigate heat, and provide additional benefits.

With climate change, Boston faces more intense precipitation that will increase total stormwater volume and decrease water quality, rising sea levels that will inhibit stormwater outfalls from draining, and increasing temperatures. Under these conditions, large-scale expansion of green infrastructure in Boston has the potential to both increase the city's resilience and provide many co-benefits. Green infrastructure helps slow the pace of stormwater runoff, support on-site infiltration, and reduce pollutants entering waterways. It offers a decentralized approach to stormwater management that supports redundancy and adaptability because it can be expanded over time. It also may be less costly than gray infrastructure. Furthermore, green infrastructure can help mitigate the urban heat island effect by creating shade, reducing heat-absorbing materials, and emitting water vapor that cools the air. It also can help create an attractive environment, clean the air by filtering airborne pollutants, and reduce building energy costs through shading and recyclable water.[4]

[4] Source: "A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds." Stratus Consulting. August 24, 2009.

BOSTON'S USE OF GREEN INFRASTRUCTURE

In recent years, Boston has started to expand its use of green infrastructure, which encompasses a range of interventions, including porous pavement; bioswales; rain gardens; tree planters; green streets, alleys, and parking lots; green roofs; and constructed wetlands. Relative to gray infrastructure traditionally used to manage stormwater, green infrastructure has the potential to provide numerous environmental, economic, and social co-benefits.

In 2012, BWSC reached an agreement (consent decree) with U.S. Environmental Protection Agency and the Conservation Law Foundation to address pollution caused by stormwater runoff as required by the Clean Water Act, after these organizations asserted that BWSC was not moving quickly enough to do so. Under the agreement, BWSC committed to a seven-year plan to find and remove illegal sewage connections and expand its use of stormwater management best practices, including green infrastructure. BWSC also agreed to prepare a report identifying the stormwater best management practices most suitable for use in Boston, and to construct three demonstration green infrastructure projects at Central Square in East Boston, Audubon Circle, and City Hall Plaza. BWSC has provided the capital funding for these projects but partnered with BTD and PWD, which control the sites and are doing transportation upgrades, to construct the green infrastructure. BWSC also has agreed to fund and perform three years of required maintenance for these projects but does not have an ongoing maintenance plan beyond that.

In addition to BWSC, local nonprofits, including the Charles River Watershed Association (CRWA), have supported green infrastructure in Boston. CRWA led the development of two green infrastructure demonstration projects at Everett Street in Allston and Peabody Square in Dorchester, and also created a set of Green Street Guidelines for Allston-Brighton that identify potential green infrastructure interventions on three pilot streets.

Finally, the City has been actively supporting green infrastructure. The Boston Transportation Department incorporated green street strategies into Boston's Complete Streets Design Guidelines. In addition, the Boston Parks and Recreation Department has installed rain gardens in multiple city parks, and is evaluating opportunities for additional locations with current design projects.

Source: Marks, Alex. "Stormwater Management in Boston: To What Extent Are Demonstration Projects Likely to Enable Citywide Use of Green Infrastructure" MIT Thesis. 2014.

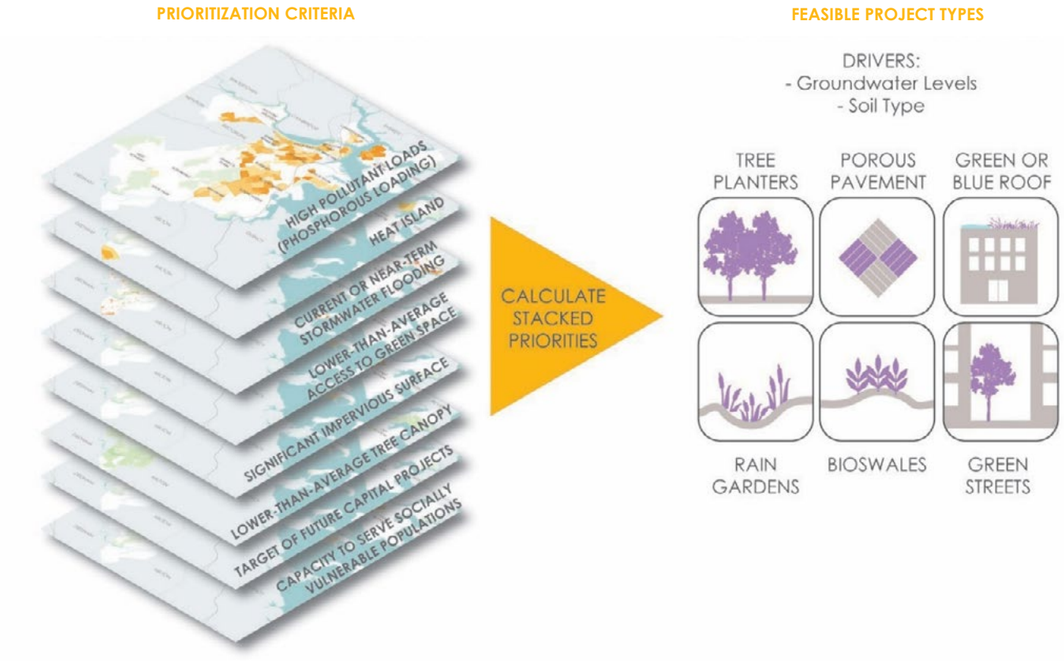
INITIATIVE 8-1. DEVELOP A GREEN INFRASTRUCTURE LOCATION PLAN FOR PUBLIC LAND AND RIGHTS-OF-WAY

The City should work with the Boston Water and Sewer Commission to develop a green infrastructure location plan for public land and rights-of-way in Boston. The green infrastructure location plan should identify high-priority sites for green infrastructure development, focusing on existing public land but also considering potential future public land that could be acquired to support multifunctional green space. This green space would provide stormwater management and other benefits. The purpose of the green infrastructure location plan is to increase the volume of water managed on-site on public land, as well as to identify potential opportunities to manage off-site stormwater.

The Energy, Environment, and Open Space Cabinet, which includes the Environment Department and Parks Department, should lead this effort, with the participation of other relevant City agencies, such as the Transportation Department, Public Works Department, and Boston Public Schools. The Boston Water and Sewer Commission is currently conducting a comprehensive analysis of its drainage system to identify high-priority locations for green infrastructure in Boston based on this type of infrastructure's capacity to reduce total pollutant loads. The Energy, Environment, and Open Space Cabinet should supplement this analysis by developing a set of other green infrastructure location prioritization criteria that serve other goals. Potential criteria are shown on the opposite page.

GOAL	PRIORITY LOCATIONS FOR GREEN INFRASTRUCTURE
IMPROVE WATER QUALITY TO MEET FEDERAL STANDARDS	Areas with high pollutant loads
MITIGATE CURRENT AND FUTURE CLIMATE CHANGE HAZARDS (EXTREME HEAT)	Areas that are daytime or nighttime land surface temperature hot spots (heat islands)
MITIGATE CURRENT AND FUTURE CLIMATE CHANGE HAZARDS (STORMWATER FLOODING)	• Areas that are subject to current or near-term stormwater flooding (lie at low elevations and have limited hydraulic capacity) • Upstream areas where green infrastructure construction could help reduce downstream stormwater flooding • Areas with large amounts of impervious surface
PROVIDE EQUITABLE ACCESS TO GREEN SPACE THROUGHOUT BOSTON	Neighborhoods with lower-than-average access to green space, especially those with high concentrations of socially vulnerable populations
IMPROVE NEIGHBORHOOD LIVABILITY AND HEALTH AND SERVE SOCIALLY VULNERABLE POPULATIONS	• Areas with higher-than-average air pollution levels • Areas with lower-than-average tree canopy
LEVERAGE PLANNED CAPITAL UPGRADES SO THAT GREEN INFRASTRUCTURE CAN BE INCORPORATED INTO THESE PROJECTS	Areas targeted for future capital projects, such as parks or roads upgrades

SITING GREEN INFRASTRUCTURE



To refine this list of criteria, the Energy, Environment, and Open Space Cabinet should draw on four sources:

- The findings from Climate Ready Boston;
- The green infrastructure location analysis currently being done by the Parks and Recreation Department for the assets that it owns;
- The Trust for Public Land's work on green infrastructure prioritization throughout Boston developed as part of its Climate Smart Cities initiative; and
- The Boston Water and Sewer studies to identify high-potential locations for green infrastructure based on pollutant loading and to define the most feasible types of green infrastructure for these locations.

The City and BWSC then should collaborate to create a green infrastructure location plan that shows sites that meet multiple criteria so that they can be prioritized for green infrastructure construction.

INITIATIVE 8-2. DEVELOP A SUSTAINABLE OPERATING MODEL FOR GREEN INFRASTRUCTURE ON PUBLIC LAND AND RIGHTS-OF-WAY

The City should work with the Boston Water and Sewer Commission to develop a sustainable operating model for green infrastructure on public land, including trees. Currently, the lack of a sustainable funding and operating model for green infrastructure on public land is a major barrier that has limited its large-scale deployment. Green infrastructure assets require different maintenance procedures than gray infrastructure assets and must be properly maintained to preserve their functionality. Green infrastructure maintenance should be tied to efforts to support workforce development and inclusive hiring (see Strategy 3, p.95).

The Energy, Environment, and Open Space Cabinet should lead this effort, with the participation of other relevant City agencies, such as the Budget Department. The Energy, Environment, and Open Space Cabinet should be charged with four tasks. First, it should establish a clear division of responsibilities that defines which entities are responsible for constructing, maintaining, and evaluating the performance of different types of green infrastructure. Second, it should evaluate the total capital and operating and maintenance costs associated with large-scale deployment of green infrastructure in Boston and recommend a "triple bottom line" approach to evaluating costs and benefits. An excellent model is the framework developed by Philadelphia that considers long-term financial, social, and environmental benefits against costs.[5] Third, the Energy, Environment, and Open Space Cabinet should recommend a toolkit of green infrastructure financing strategies to support both capital and operating and maintenance costs, recognizing that Boston may require new sources of funds to expand green infrastructure use. Fourth, it should identify opportunities to create streamlined, standardized green infrastructure maintenance processes that create cost efficiencies. The Energy, Environment, and Open Space Cabinet should review best practices from other cities that are national leaders in the large-scale deployment of green infrastructure, such as New York City, Philadelphia, Washington, DC, Seattle, and Portland.[6]

PHILADELPHIA'S "GREEN CITY, CLEAN WATERS" GREEN INFRASTRUCTURE PROGRAM

In its 2009 Combined Sewer Overflow Long-Term Control Plan, "Green City, Clean Waters," Philadelphia committed to invest $1.6 billion over 20 years to create a citywide network of green stormwater infrastructure, as opposed to a single, multi-billion dollar, 35-foot-diameter tunnel under the Delaware River. Philadelphia's green infrastructure best practices include the following:

- Establishing a large-scale program, focused on converting one-third of Philadelphia's existing impervious surface (about 4,000 acres) to green infrastructure
- Using a "triple bottom line" approach to evaluate the benefits of green infrastructure compared to gray infrastructure
- Setting up both regulatory requirements and financial incentives (stormwater credits for constructing and maintaining green infrastructure) to promote private provision of green infrastructure
- Developing a green infrastructure audit program to help customers with high stormwater fees to reduce their fees through green infrastructure implementation

Source: "Green City, Clean Waters: The City of Philadelphia's Program for Combined Sewer Overflow Control."
Amended by the Philadelphia Water Department, June 1, 2011.

[5] Source: "A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds." Stratus Consulting, August 24, 2009.

[6] Source: "Green City Clean Waters: The City of Philadelphia's Program for Combined Sewer Overflow Control." Amended by the Philadelphia Water Department, June 1, 2011.

INITIATIVE 8-3. EVALUATE INCENTIVES AND OTHER TOOLS TO SUPPORT GREEN INFRASTRUCTURE

The City and Boston Water and Sewer Commission should evaluate a set of incentives and other tools to reduce impervious surfaces, increase on-site stormwater retention and management, and create green infrastructure on public and private property. For example, the City can explore the creation of a green infrastructure revolving fund and a system that provides owners with savings on their water bills in exchange for green infrastructure creation and maintenance. To fund incentives and other tools, the City and the Boston Water and Sewer Commission should consider a stormwater fee, which has been implemented effectively in other municipalities. The Boston Water and Sewer Commission is currently evaluating the feasibility of such a program. If implemented, the stormwater fee would charge property owners based on the amount of impervious surface on their property. BWSC's feasibility study should include an evaluation of the fee's economic impact on different types of property owners, particularly low-income owner-occupants and affordable housing providers.

STORMWATER REGULATION IN BOSTON

BWSC issues stormwater permits for new private development in Boston, and has the authority to require on-site stormwater retention and "other stormwater management measures" (Source: Section 14, Article IV, "Regulations Governing the Use of Sanitary and Combined Sewers and Storm Drains of the Boston Water and Sewer Commission"). In general, BWSC requires property owners to infiltrate a volume of rainfall on-site equal to no less than one inch across the surface. The Groundwater Conservation Trust oversees stormwater management in the designated Groundwater Conservation Overlay District (GCOD) under Article 32 of the Boston Zoning Code. The GCOD requires projects to infiltrate a volume of rainfall on-site such that the project results in no negative impact on groundwater levels. The Boston Planning and Development Agency also is able to institute site plan requirements as part of the Article 80 process.

INITIATIVE 8-4. DEVELOP DESIGN GUIDELINES FOR GREEN INFRASTRUCTURE ON PRIVATE PROPERTY TO SUPPORT CO-BENEFITS

The City should request that the Boston Sewer and Water Commission develop design guidelines and set maintenance protocols for green infrastructure on private property to encourage installations that deliver significant co-benefits, such as increased access to green space. In addition to their efforts to support green infrastructure on public property through the green infrastructure location plan (see Initiative 8-1, p.124), the City and BWSC also should prioritize the development of green infrastructure on private property in order to introduce it into neighborhoods where there may be limited public sites. Stormwater flooding in Boston tends to primarily impact residential buildings, making on-site solutions attractive.

BWSC is well positioned to develop design these guidelines following the completion of its studies to identify feasible locations and types of green infrastructure. The current trend in Boston has been for property owners to install dry wells, which are expensive but need to be properly maintained to function effectively. BWSC does not have retrofitting requirements for sites that were built prior to its requirements.

The BPDA should evaluate the opportunity to reinforce these design guidelines through changes to the Boston Zoning Ordinance. This approach has been used successfully by the City of Portland. In Portland, the Stormwater Management Manual outlines design guidelines, which are authorized by Portland City Code Chapter 17.38, passed in 2008 and therefore enforceable.[7] In conjunction with development of the design guidelines, the BRA and BWSC should assess the need to provide incentives to achieve specific types of green infrastructure on private property.

[7] Source: Chai, Shutsu K. "Managing Stormwater in Watertown: Overcoming Obstacles to Change." MIT Thesis. 2009.

INITIATIVE 8-5. DEVELOP AN ACTION PLAN TO EXPAND BOSTON'S URBAN TREE CANOPY

Currently, the Parks and Recreation Department is planning to conduct an inventory of Boston's existing tree canopy to evaluate the current state of Boston's urban forest. Using the findings from this inventory, the Parks and Recreation Department should set criteria to prioritize where the City plants street trees. Expansion of Boston's tree canopy should support the City's green infrastructure efforts. Trees can help manage stormwater, mitigate heat in multiple ways, and reduce air pollution.

The City should explore strategies to overcome physical barriers to the establishment of large trees in Boston. Large trees contribute significantly to Boston's canopy and are less likely to die than smaller trees, but they require space and a sufficient volume of soil for roots to thrive. The City must balance many priorities when planning its sidewalks, such as safely accommodating pedestrians and providing space for needed furniture, but street trees should be an important part of this equation. In its new Complete Streets Guidelines, the City has set standards for sidewalk construction that establish preferred and minimum widths for the greenscape and furnishing zone, ranging from 6 to 1.5 feet. The City should collaborate with private partners to implement the preferred standards in the development of new sidewalks or retrofitting of existing sidewalks, while still meeting American with Disability Act requirements for a minimum pedestrian zone of 4 feet, to support the establishment of large trees.

In addition, as part of its climate readiness education campaign, the City should conduct outreach to private property owners about the importance of designing and constructing around existing trees, avoiding tree removals, and protecting large trees on private property.

The City should establish a Heat Overlay District in neighborhoods with the highest need for trees to help coordinate the actions of public and private actors. The District could perform the following functions:

- Set larger tree pit-size minimum requirements and increase the use of structural soil and permeable pavements where pit size is constrained. The City's Complete Streets Guidelines have set the minimum width of the greenscape and furnishing zone necessary to support street tree installation as 2.6 to 6 feet.
- Require utilities and PWD to set protection of existing trees as a primary goal in projects, so that existing trees do not always lose out to space for bike lanes, parking, or utilities.
- Establish a review process for removal of trees over a certain size on private properties.
- Establish minimum lot shade coverage requirements for private properties.

INITIATIVE 8-6. PREPARE OUTDOOR FACILITIES FOR CLIMATE CHANGE

As an ICC member, the Parks and Recreation Department should develop an adaptation plan, tied to a capital investment plan, to prepare its outdoor facilities for climate change. The Parks and Recreation Department will identify facilities where resilience improvements are needed to address near-term flooding impacts, and evaluate whether the improvements are feasible to incorporate into existing planned capital upgrades or will require a new work stream. To address extreme heat, the Parks and Recreation Department will evaluate opportunities to increase shade trees and structures, reduce heat-absorbing surfaces, and add "spray" water features and water fountains as part of all capital upgrades.

INITIATIVE 8-7. CONDUCT A COMPREHENSIVE WETLANDS INVENTORY AND DEVELOP A WETLANDS PROTECTION ACTION PLAN

The Conservation Commission should conduct a comprehensive wetlands inventory to define priority sites for wetlands restoration and inland buffer areas that must be protected to enable habitats to migrate inland as sea levels rise. The wetlands inventory should consist of mapping all existing wetlands, analyzing the functions (ecosystem services) performed by them, and identifying sites that are of high resource value and are at high risk due to development or climate impacts.

Following the completion of this inventory, the Conservation Commission should develop an action plan for protecting wetlands to preserve environmental quality and help in protecting against climate impacts. The action plan should define the pathways that the City can use to protect wetlands, including regulation (e.g., a Local Wetlands Ordinance) and acquisition of key sites. This could include a Local Wetlands Ordinance (LWO) that enables the Conservation Commission to protect additional wetlands types, protect already-covered types to a greater degree, and take future climate impacts into account during project review. The LWO could give the Conservation Commission jurisdiction over a buffer area adjacent to lands subject to current coastal storm flowage, based on likely sea level rise, and establish performance standards for all protected areas.

WETLANDS REGULATION IN MASSACHUSETTS

Depending on their location and attributes, wetlands have the opportunity to mitigate all three types of climate risks that Boston is facing: extreme heat, stormwater flooding, and coastal and riverine flooding. Coastal wetlands can help reduce the speed and force of waves coming onshore during storm surge events and can prevent water from coming inland if the wetlands have elevated edges. Inland wetlands can help convey and filter stormwater runoff and reduce flow into stormwater treatment systems. Due to their vegetation, wetlands can mitigate urban heat. Wetlands also absorb large quantities of carbon dioxide from the atmosphere, accumulated over hundreds and thousands of years, and store it as carbon sinks, thereby helping to mitigate global warming. Tidal wetlands are at risk from sea level rise and need to have the ability to migrate inland, or they may be lost, even with restoration efforts. Wetlands loss not only prevents future carbon capture but also releases stored carbon, increasing greenhouse gas levels in the atmosphere.

Currently, the Boston Conservation Commission regulates activities in coastal and inland wetland resource areas through the Commonwealth's 1972 Wetlands Protection Act (WPA) and accompanying regulations. The WPA recognizes eight important public values or functions provided by wetlands and protects them in 12 types of Coastal Resource Areas and 5 types of Inland Resource Areas. Coastal Resource Areas include Lands Subject to Coastal Storm Flowage (LSCSF), which perform important functions related to protecting from storm damage and assisting with flood control. Individuals performing any work that removes, fills, dredges, or alters any resource area must obtain a permit, or Order of Conditions, from the Conservation Commission that defines requirements to be met before, during, and after the work.

While the state WPA provides protection to many types of wetlands, it has some limitations. First, the state WPA does not protect all types of wetlands. Second, while it defines specific performance standards for Inland Resource Areas, it does not establish specific performance standards for Coastal Resource Areas or buffer areas. Coastal Resource Areas have general standards or none at all. Work done within buffer zones can have significant impacts on Coastal Resource Areas. Third, it does not allow the Conservation Commission to take into account projected future or cumulative effects of climate change, including sea level rise, when reviewing project impacts. However, the Commonwealth allows municipalities to enact local wetlands ordinances that enable them to protect more wetlands types; protect existing types to a greater extent, including by establishing performance standards; and take into consideration future conditions. The City should support state efforts to develop performance standards for Coastal Resource Areas and evaluate the role of a local wetlands ordinance.

Layer 5

ADAPTED BUILDINGS

Strategy 9. Update zoning and building regulations to support climate readiness

These initiatives build on the Boston Planning and Development Agency's Resiliency Policy, which has required all large project proposals to analyze and describe their climate preparedness through a Climate Preparedness Checklist since 2013. Boston should now take the next step of incorporating climate readiness across its building regulations.

Current zoning and building codes do not yet institutionalize climate readiness:

- **Current regulations do not consider future climate conditions.** Building standards for flooding refer to FEMA's Flood Insurance Rate Maps (FIRMs), which are based on historical information. While a building constructed to these standards may be climate ready today, as sea levels rise, it will face continuously increasing risk.
- **Current regulations discourage adaptation.** In order to become more climate ready, many buildings would need to elevate their first floors and mechanical systems. However, regulatory limits on height and bulk often discourage such elevations.
- **Current regulations foster a site-scale approach to climate readiness.** While individual new and renovated buildings have some requirements to build to certain climate-ready standards, there are no regulatory mechanisms to build in a way that would provide broader district-scale flood risk reduction and address the impact of individual retrofits and adaptation projects on overall flood risk and urban design. Regulations also do not protect the beneficial functions of storm damage prevention and flood control provided by the coastal floodplain.

The initiatives under this strategy follow three basic principles:

- **The City should prioritize areas in which it has independent authority.** While the City controls its own zoning code and can directly amend it, it does not control the building code and will therefore need to work with the Commonwealth (see Background: Regulatory Context for Buildings, p.133).
- **The City is the ultimate long-term investor in all local properties.** While individual and institutional property owners have a limited time horizon for owning certain properties and therefore may not want to invest in long-term solutions or interventions where benefits accrue to future owners, the City has a moral and financial interest in making sure that buildings remain safe and maintain their value for generations. This is especially true in Boston, where approximately two-thirds of City revenues come from the property tax.[8] To continue to offer quality services, the City must protect its tax base in both the short and the long term.
- **Flexibility and adaptability are essential; there is more than one way to prepare for climate change.** Many buildings built today will still be standing at the end of the century. At that time, as described in the Climate Projection Consensus (see p.01), sea levels are likely to be three to seven feet higher. Given this range, it is possible to build in ways that will allow adaptation over time. For example, one approach for new buildings would be to have high ground-floor ceilings so that the ground floor can be raised as sea levels rise over time, without creating undesirably low floor-to-ceiling heights.

[8] Source: "Revenue Estimates and Analysis for Fiscal Year 2017." Boston Office of Budget Management. 2016.

BACKGROUND: REGULATORY CONTEXT FOR BUILDINGS[9]

BUILDING CODE

In Massachusetts, the building code is established at the state level by the Board of Building Regulations and Standards (BBRS) and administered at the local level by the City of Boston's Inspectional Services Department (ISD). The City does not have authority to establish building code requirements that are stricter than the state building code without approval from the Commonwealth (see Initiative 9-5, p.138).

In the Massachusetts Building Code, flood-resistant construction standards apply to all new or substantially renovated structures within the Special Flood Hazard Area (SFHA), as defined by the currently effective FEMA Flood Insurance Rate Maps (FIRMs). The SFHA is the area exposed to a 1 percent annual chance flood, and most areas within the SFHA are assigned a base flood elevation (BFE), the elevation to which floodwater is expected to rise during a 1 percent annual chance flood. FIRMs outline three subareas within the SFHA:

- Zone V, subject to wave action with wave heights of 3 feet or more;
- Coastal Zone A, subject to wave action with wave heights of 1.5 to 3 feet; and
- Non-Coastal Zone A, subject to waves less than 1.5 feet in height.

The 8th Edition of the Building Code, which is currently in effect, requires the following for new or substantially renovated structures:

- In Zone V, the lowest horizontal structural member is required to be elevated at least two feet above the BFE
- In Coastal and Non-Coastal Zone A, lowest floors are required to be elevated at least to the BFE.

In early 2016, the BBRS approved a draft of the 9th Edition of the Building Code, which requires public review and final approval before it takes effect. The draft update includes the following new requirements for new or substantially renovated structures:

- In Coastal Zone A, the requirements for Zone V apply; and
- In Non-Coastal Zone A, the lower floor is required to be elevated, and the building equipment is required to be elevated or flood-proofed to at least one foot above the BFE. Facilities essential for emergency response and recovery, or that contain hazardous materials, require elevation to two feet above the BFE or the 500-year flood elevation, whichever is higher.

ZONING CODE

The Boston Zoning Code is shaped by the Boston Planning and Development Agency (BPDA), adopted by the Boston Zoning Commission (BZC), and enforced by the Inspectional Services Department (ISD). The following articles of the Zoning Code are most relevant for climate readiness:

Article 25 is Boston's flood-resistant construction zoning requirement. The City adopted Article 25 in order to comply with the National Flood Insurance Program, which requires municipalities to adopt flood-resistant construction standards before any property owners in the municipality can buy federally backed flood insurance. Article 25 does not contain any additional requirements beyond those included in the Massachusetts Building Code.

Article 80 sets forth guidelines for four types of BPDA development review: small projects (adding more than 20,000 square feet), large projects (adding more than 50,000 square feet), planned development areas (new overlay zoning districts for project areas larger than 1 acre), and institutional master plans (projects relating to academic and medical campuses). The review process can include an assessment of a project's impacts on transportation, the public realm, the environment, and historic resources.

Article 37 is Boston's green building zoning requirement, administered by the Interagency Green Building Committee (IGBC). It requires all projects 50,000 square feet or larger to be certifiable under the U.S. Green Building Council's LEED process. Since 2013, the BPDA has also required all large projects to complete a Climate Preparedness and Resiliency Checklist, which is also reviewed by the IGBC. In the checklist, applicants document the climate-preparedness measures incorporated into the project's design.

Article 32 created Boston's Groundwater Conservation Overlay District. It is monitored by the Boston Groundwater Trust. The purpose of the article is to ensure projects do not reduce groundwater levels in specific areas to prevent wooden pilings under buildings from rotting. Developers are required to conduct a study of their project's effect on groundwater and install recharge systems for excavation, construction, and rehabilitation of any area greater than 50 square feet.

WETLANDS PROTECTION ACT

The Massachusetts Wetlands Protection Act (M.G.L. Ch. 131, § 40) and Regulations (310 CMR 10.00) are designed to ensure that the public's interests in wetland resource areas are preserved. In Boston, the regulations are administered by the Conservation Commission. The jurisdiction of these regulations includes coastal beaches and dunes, intertidal flats, salt marshes, eelgrass, ponds, lakes, rivers, streams, and flood zones (defined as Special Flood Hazard Areas on the currently effective FEMA Flood Insurance Rate Maps) as well as 100-foot buffer zones around wetlands.

[9] Source: "Incorporating Improved Coastal Flood Resiliency Measures into Boston's Waterfront Regulations." Boston Harbor Now Climate Resilience Committee. 2016.

SUMMARY OF INITIATIVES TO UPDATE ZONING AND BUILDING REGULATIONS

#	INITIATIVE	RELEVANT REGULATION OR PROCESS	RECOMMENDED CHANGES
9-1	**Establish a planning flood elevation to support zoning regulations in the future floodplain**	Boston Zoning Code	Establish a **Planning Flood Elevation** for all buildings within the future 1 percent annual chance flood zone.
9-2	**Revise the zoning code to support climate-ready mechanical systems**	Boston Zoning Code	Using the **Planning Flood Elevation** (Initiative 9-1), amend provisions of the Zoning Code (allowable height, bulk, and use) to ensure they promote and do not discourage **climate-ready new construction and retrofits.**
9-3	**Promote climate readiness for projects in the development pipeline**	Development Approval Process	Offer developers with already-approved project an opportunity to adopt **climate ready new construction standards** (Initiative 9-2) based on the **Planning Flood Elevation** (Initiative 9-1) without needing to undergo a completely new City review process.
5-1	**Establish Flood Protection Overlay Districts and require potential integration with flood protection systems (see Protected Shores layer, p.98)**	Boston Zoning Code	Establish a **new overlay district in potential flood protection locations** and require that development proposals do not prevent the **future creation of flood protection infrastructure.**
9-4	**Pursue state building code amendments to promote climate readiness**	Massachusetts Building Code	Advocate to the state to adopt a new **minimum elevation for building mechanical systems** based on the **future 1 percent flood elevation** at the end of a system's design life.
9-5	**Incorporate future climate conditions into area plans**	Strategic Planning Areas, Planned Development Areas, Municipal Harbor Plans, and Institutional Master Plans	**Incorporate future climate considerations** into major neighborhood planning efforts.

INITIATIVE 9-1. ESTABLISH A PLANNING FLOOD ELEVATION FOR ZONING REGULATIONS IN THE FUTURE FLOODPLAIN

The Boston Planning and Development Agency (BPDA) should petition the Boston Zoning Commission to revise the zoning code to incorporate the extents and depths of future flooding, as documented in appropriate future flood maps (see Initiative 1-2, p.84). This would be a first step toward correcting a flaw in Boston's current floodplain regulations, which is that they rely on FEMA Flood Insurance Rate Maps that are based primarily on historical flood data and therefore do not include risk due to a changing climate.

In order to incorporate the extents and depths of future flooding, the BPDA should establish a planning flood elevation (PFE) for each project through the following steps:

- Institute standard planning time periods for new buildings, which may vary based on construction type. In the existing Climate Change Preparedness and Resiliency Checklist, the BPDA generally requires that large buildings in Boston consider climate change for at least the next 60 years.
- Use future flood projections (see Initiative 1-2, p.84) to determine whether each project is expected to be within the future 1 percent annual chance floodplain during the applicable planning time period.
- For each project within this future floodplain, determine the 1 percent annual chance flood elevation at the end of the planning time period. This is the planning flood elevation (PFE).

As noted under Background: Regulatory Context for Buildings (see p.133), Boston does not have the authority to mandate minimum elevations for buildings. However, Boston can incorporate the PFE into zoning regulations to both remove obstacles for existing buildings that want to voluntarily adapt, and require new buildings to be built to standards that would encourage future adaptation (*see Initiative 9-2*).

INITIATIVE 9-2. REVISE THE ZONING CODE TO SUPPORT CLIMATE-READY BUILDINGS

The Boston Planning & Development Agency (BPDA) should petition the Boston Zoning Commission to revise the zoning code to ensure regulations on the use, height, and bulk of buildings promote and do not discourage climate-ready new construction and retrofits. Under current regulations, property owners may avoid elevating their properties or mechanical systems or taking other climate-readiness measures because they would be violating the zoning code or sacrificing buildable area.

The BPDA should also ensure that the zoning revisions encourage a quality streetscape and pedestrian activity even as buildings are elevated and flood-proofed. The elevation or flood-proofing of a building's first floor could create a blank wall, leading to an uninviting streetscape, but this effect can be counteracted through design solutions such as planters, raised yards, front steps, or latticed walls.

The following are potential revisions to the Boston Zoning Code that could support climate-ready buildings and desirable urban design. Each requires further analysis to evaluate financial and design implications.

POTENTIAL ZONING REVISIONS	APPLICABLE FOR EXISTING BUILDINGS?	APPLICABLE FOR NEW BUILDINGS?
Measuring the maximum height of a building within a future floodplain from the building's PFE, rather than from grade. This would allow owners to build or retrofit to climate-ready standards without sacrificing buildable area.	○	○
Allowing first floors that are below the PFE to be converted to a use other than for human occupancy, wet flood-proofed, and removed from the total floor area calculation. This could not only reduce the occupants' flood risk and owners' insurance costs, but it could also allow the addition of new stories to buildings with the necessary structural capacity. The revenues from the addition of new stories could help finance the building retrofits.	○	
Allowing subgrade basements in the future flood zone to be filled in and removed from the total floor area calculation.	○	
Allowing mechanical systems, cables, and other wiring equipment to be elevated above the PFE and removed from total floor area calculation, or allowing mechanical systems to be moved outdoors, if such a move is required to achieve the elevation of systems without sacrificing buildable floor area. The movement of mechanical systems outdoors must not interfere with egress paths.	○	
Explicitly permitting temporary flood control devices in setbacks and public access areas in ways that reduce the potential for adverse impacts to adjacent properties.	○	○
Requiring that the minimum ceiling height for ground floors be measured from the PFE. This would result in additional ground-floor floor-to-ceiling height so that, as sea levels and flood elevations rise, buildings can adapt by raising the first floors while still maintaining desirable floor-to-ceiling heights.		○
Requiring that buildings raised significantly above grade feature ground-level design elements that activate the street. This would prevent the negative impact on pedestrian experience that can occur when buildings are elevated and feature only blank exterior walls below the first floor. Elevated commercial spaces can also retain their ground-floor storefront and provide access (stairs and ramps) to the raised first floor as part of an indoor vestibule.	○	○
Increasing the total roof area that solar panels can cover without counting as an additional floor.	○	○
Requiring or incentivizing design elements, such as planted green roofs or high-reflectance cool roofs, which limit stormwater runoff or mitigate the urban heat island effect.	○	○

INITIATIVE 9-3. PROMOTE CLIMATE READINESS FOR PROJECTS IN THE DEVELOPMENT PIPELINE

Upon amending the zoning code to support climate readiness (see Initiative 9-2, p.135), the BPDA should immediately notify all developers with projects in the development pipeline in the future floodplain that they may alter their plans in a manner consistent with the zoning amendments (e.g., raising their first-floor ceilings without violating building height limits) without needing to go through the entire BPDA permitting process again. The BPDA should notify the owner/developer, architect, engineer, and contractor of record for each project. The BPDA would assess the legal bounds of instituting this expedited review process. Other local, state, or federal approvals may still be necessary.

There are currently hundreds of projects in Boston that have been approved for construction but not yet built. Many of these projects are in areas that are either currently in the floodplain or will be during the life of the building, and the buildings have not been planned to incorporate future flood risk. Many developers are not aware of the future risk, and even if they are, they might not want to elevate their buildings and sacrifice buildable area. This proposed approach would encourage developers to make relatively small additional investments in climate readiness without sacrificing buildable area or delaying project timelines.

RELATED INITIATIVE:
INITIATIVE 5-1. ESTABLISH FLOOD PROTECTION OVERLAY DISTRICTS AND REQUIRE POTENTIAL INTEGRATION WITH FLOOD PROTECTION SYSTEMS

The City should establish a new overlay district in potential flood protection locations and require that development proposals do not prevent the future creation of flood protection infrastructure (see p.106 for more details).

INITIATIVE 9-4. PURSUE STATE BUILDING CODE AMENDMENTS TO PROMOTE CLIMATE READINESS

The City should ask the Massachusetts Board of Building Regulations and Standards to institute stricter requirements for new or substantially improved buildings in Boston. The key new requirement would be higher minimum elevation of mechanical systems. Similar to Initiative 9-2 (see p.135), this would correct the current approach by defining a building's mechanical system elevation requirement based on the local Boston flood map for the end of the equipment's design life.

There are three potential pathways toward incorporating future flood conditions into the state building code, and Boston should pursue the most expedient pathway:

- Under Massachusetts General Law Chapter 143 §98, the City may request that the BBRS allow higher standards to be applied specifically within Boston.
- The City can work with regional partners, such as the Metro Boston Climate Preparedness Task Force, to request that the BBRS adopt a Stretch Climate Readiness Code with increased construction requirements. All municipalities in the commonwealth would then have the option of adopting the Stretch Climate Readiness Code.
- The City can work with regional partners, such as the Metro Boston Climate Preparedness Task Force, to recommend that the BBRS incorporate higher standards into the building code throughout the commonwealth.

INITIATIVE 9-5. INCORPORATE FUTURE CLIMATE CONDITIONS INTO AREA PLANS

The Boston Planning and Development Agency (BPDA) should incorporate future climate considerations into major neighborhood planning efforts across the city, including Strategic Planning Areas, Planned Development Areas, Municipal Harbor Plans, and Institutional Master Plans, which are ultimately codified in zoning. Long-term projections for extreme heat, stormwater flooding, and coastal and riverine flooding must all be considered as key variables for planning the future of Boston's neighborhoods.

For Municipal Harbor Plans, which set requirements for building dimensions, public access, and public benefits for waterfront areas, the consideration of future coastal and riverine flooding is particularly important. Future plans should ensure that, as sea levels rise, public access areas are not reduced. Public access areas should be elevated above future high tide elevations and either raised above the PFE or constructed to withstand future inundation, including saltwater tolerant plantings, paving, and equipment. Municipal Harbor Plans should also investigate the possibility of requiring the elevation of entire waterfront sites, a strategy that can provide flood risk reduction for inland areas but must be evaluated for each site to avoid increasing flood risk for adjacent properties (see Initiatives 5-1 and 5-3, pp.106 and 110).

PRECEDENT: ALLOWING MUNICIPALITIES TO ADOPT HIGHER BUILDING CODE STANDARDS (MASSACHUSETTS STRETCH ENERGY CODE)

The Commonwealth adopted the Massachusetts Stretch Energy Code in 2009. It is an alternative stronger energy code that municipalities can choose to use instead of the base code. It increases efficiency requirements for all new residential and many new commercial buildings and for residential additions and renovations that trigger building code compliance. The code was adopted by the City of Boston in November 2010.

Strategy 10: Retrofit existing buildings

Context: The Challenge of Retrofitting Boston's Buildings

Boston's existing building stock is diverse. It includes a broad range of owner types that have different levels of both building management expertise and access to financing to undertake building- and site-scale resilience improvements. Many buildings are historic, and while still able to adapt, such buildings face unique challenges in doing so while maintaining their historic character and architectural significance. In the near term, over 2,000 buildings across Boston have at least a 1 percent annual chance of inundation by coastal and riverine flooding, and almost 9,000 are exposed to frequent stormwater flooding. Considering that Boston has many older buildings not adapted for flooding or extreme heat risks, the need for retrofits is great. The City should work with property owners to promote access to the information and financial resources that they need to prepare their buildings for climate change.

RELATED INITIATIVE:
INITIATIVE 3-2. LAUNCH A CLIMATE READY BUILDINGS EDUCATION PROGRAM FOR PROPERTY OWNERS AND USERS

The City should develop and run an education program to inform property owners and other groups about current and future climate risks facing their buildings and actions they can undertake to increase their preparedness (see p.95 for more details).

INITIATIVE 10-1. ESTABLISH A RESILIENCE AUDIT PROGRAM FOR PRIVATE PROPERTY OWNERS

The City should establish a resilience audit program to help property owners identify potential building- and site-level resilience actions to address coastal and riverine flooding, stormwater flooding, and extreme heat. Through the Climate Ready Buildings Education Program, the City should encourage all at-risk property owners to evaluate their resilience.

To start, the City should prioritize the over 2,000 buildings that are exposed to coastal flooding at 9 inches of sea level rise under at least the 1 percent annual chance event. To further guide prioritization within this group, it should take into account exposure under more frequent events (monthly high tide and the 10 percent annual chance event), the criticality of functions housed within the building, exposure of socially vulnerable populations, and expected physical damages. A resilience audit should help property owners identify cost-effective, building-specific improvements to reduce flood risk, such as backflow preventers, elevation of critical equipment, and deployable flood barriers; promote interventions that address stormwater runoff or the urban heat island effect, such as green roofs or "cool roofs" that reflect heat; and encourage owners to develop operational preparedness plans and secure appropriate insurance coverage. The resilience audit program should include a combination of mandatory and voluntary, market-based and subsidized elements. This would be similar to the combination of energy audit requirements for large buildings in the City's Building Energy Reporting and Disclosure Ordinance (BERDO) and the subsidized, voluntary energy audits offered through the Renew Boston program.

Audits offered through a City program could include prequalified firms to conduct the resilience audits, reduced-cost audits for owners that demonstrate high levels of risk and financial need, and efforts to combine climate resilience audits with energy efficiency audits. Key internal partners for this effort include the Department of Neighborhood Development for at-risk affordable multifamily residential owners, the Boston

CURRENT AREA PLANNING INITIATIVES

The BPDA works with communities throughout the city to create area plans that guide long-term growth in Boston's neighborhoods. Three current planning initiatives are PLAN: Dudley Square; PLAN: South Boston Dorchester Avenue; and PLAN: Jamaica Plain / Roxbury. Among the many community priorities addressed in these and other plans, the BPDA should consider future climate conditions, including coastal flooding, stormwater flooding, and extreme heat, in order to help neighborhoods prepare.

A NOTE ON BUILDING REGULATIONS AND INCENTIVES

Many of the regulatory changes included here may increase the short-term costs of real estate development in Boston, even as they decrease risk and flood insurance costs. An alternative approach the City may pursue is to raise some required minimum standards, while offering incentives that motivate developers to exceed minimum standards. The City must think carefully about what resilience actions should be incentivized, as opposed to required. Developers may require incentives to take resilience actions if some of the benefits of such actions accrue to other property owners, or outside the developers' timeframe for evaluating investments.

RESILIENCY IMPROVEMENTS: COST AND FEASIBILITY FACTORS

FACTOR	CONSIDERATIONS
Flood Risk	
Annual chance flood depths	Higher flood depths present greater risk to buildings and reduce the range of potential feasible solutions.
Flooding frequency	Intermittent floods require different design solutions than regular flooding at high tide.
Wave action	Wave action increases flood depths, adds force against buildings, and potentially introduces debris. Wave action also impacts height and load requirements.
Moving water and channelization	Floodwaters can maintain significant momentum as they move landward, and can be channelized by solid foundations and other obstructions, resulting in increased velocity and volume of flow directed onto adjacent properties and infrastructure.
Structural	
Structure type	Structure type is an important factor in determining if dry flood-proofing, wet flood-proofing, or elevation is feasible.
Location of critical systems	The current location and required locations of critical systems are important in developing retrofit solutions.
Structural integrity	Structural reinforcement may be necessary but cost prohibitive or technically infeasible depending on the building.
Codes and standards	Substantially altering a building may trigger additional code and regulatory requirements that increase project costs.
Occupancy and operational requirements	The type of use may limit building layout options. For facilities that provide a public service, maintaining continuity of existing services is important and may lead to prioritization of mitigation actions that minimize impacts to current operations. ADA access and universal design considerations must be incorporated into resilient retrofits of public facilities.
Historic status	The historic status of the building may affect project design.

Home Center and Renew Boston for at-risk low- to moderate-income owner-occupants, and the Economic Development Department's Main Streets program for at-risk small businesses. Finally, the City should explore the creation of a system for disclosure of appropriate information from climate resilience audits, modeled after BERDO.

There are a number of factors that drive the cost and feasibility of resilience improvements. The table on page 68 summarizes factors related to coastal and riverine and riverine flooding, which generally presents a greater risk of structural damage to buildings than do the other hazards analyzed by Climate Ready Boston.

RESILIENCE AUDIT PROGRAMS

Existing Models in Boston

The City can leverage its existing energy efficiency audit programs as models for resilience audits. Renew Boston is a public-private partnership between the City, Eversource (formerly NStar), National Grid, Mass Save, community-based nonprofits, and Mass Save–certified contractors. The City launched the program in 2009, and it is funded by ratepayers through state requirements. Renew Boston offers free on-site energy efficiency audits (home energy assessments) to owners of single-family homes and small multifamily buildings with up to four units. Renters also are able to request audits. During the audit, the designated energy advisor may install energy-saving lightbulbs and power strips, low-flow shower and faucet heads, and programmable thermostats. The advisor then sends a follow-up report summarizing further recommended energy efficiency improvements and available funding sources. Through Mass Save, owners are eligible for a 75 percent discount (up to $2,000) for insulation and air-sealing services, with owners of two- or three-family buildings or condo owners complete recommended improvements building-wide able to receive a larger "whole building" discount. In the first half of 2016, Renew Boston completed more than 1,700 home energy assessments for owners and renters. Renew Boston also works with small businesses and large condominium associations and cooperatives. It offers a direct-install program that can pay for up to 70 percent of the total cost for retrofitting lighting and mechanical systems.

To guide the types of resilience improvements recommended under the audit program, the City can leverage existing responses to the Boston Planning and Development Agency's Climate Preparedness Checklist, plus two key reports by the Green Ribbon Commission and A Better City, "Building Resilience in Boston" (2013) and "Enhancing Resilience in Boston" (2015). The reports identified potential resilience actions that can be undertaken at the building and site level, their benefits, and their costs.

New York City Neighborhoods Multifamily-Specific Resiliency Technical Assistance Program

In partnership with the New York State Governor's Office of Storm Recovery, the Center for New York City Neighborhoods launched the Multifamily-Specific Technical Assistance Program (TAP) as a pilot program in 2016. The pilot program will provide 100 multifamily property owners serving low- to moderate-income residents in Sandy-impacted communities with on-site resilience audits by qualified engineering and building services firms, followed by one-on-one counseling to provide a set of recommendations for building resilience improvements based on the audit findings. Under a separate program, the Governor's Office of Storm Recovery also is working with community-based organizations to provide resiliency counseling to single-family building owners.

Source: "Request for Proposal for Resilience Counseling." Center for New York City Neighborhoods, Inc. June 15, 2016. http://www.renewboston.org/.

INITIATIVE 10-2. PREPARE MUNICIPAL FACILITIES FOR CLIMATE CHANGE

The Office of Budget Management (OBM), through its capital budget planning, will work with all City departments to prioritize adaptation projects to prepare at-risk municipal facilities for coastal and riverine flooding, stormwater flooding, and extreme heat risks. It is recommended that OBM use the findings from the Climate Ready Boston Vulnerability Assessment (see p.12) and the City's 2013 identification and prioritization of at-risk municipal facilities to identify at-risk facilities. OBM should prioritize facilities for retrofits based on three factors:

- Vulnerability, in terms of the timing and extent of exposure
- Consequences of partial or full failure, in terms of the number of users impacted, the likely duration of service interruption, and expected damage to the facility relative to market value or replacement value
- Criticality, with highest priority for impacts on life and safety

OBM may want to develop standardized risk scores to quantify, understand, and communicate relative risk among facilities. The OBM should partner with the Public Facilities Department to estimate the costs of adaptation projects. In addition, it should partner with Renew Boston Trust to evaluate the opportunity for resilience improvements to be combined with energy efficiency improvements.

To address coastal and riverine flooding risks, the City should prioritize adaptation at facilities exposed to flooding in the near term under 9 inches of sea level rise (1 percent or greater annual chance) that demonstrate high levels of criticality. In particular, the City should prioritize adaptation at police, fire, EMS, and Boston Housing Authority facilities that demonstrate both especially high levels of criticality and high frequency of exposure (e.g., exposed under the average monthly high tide or 10 percent annual chance flood event).

KEY MUNICIPAL FACILITIES EXPOSED TO NEAR TERM FLOODING

		EXPOSURE		
FOCUS AREA	FACILITY NAME	9 INCHES SLR AMHT	9 INCHES SLR 10% ANNUAL CHANCE STORM	9 INCHES SLR 1% ANNUAL CHANCE STORM
EAST BOSTON	Heritage Elderly Public Housing		●	●
	Engine 9, Ladder 2 (Fire)		●	●
	Police Department District A-7			●
DOWNTOWN	Ambulance 8			●
SOUTH BOSTON	EMS Harbor Patrol			●
	BPD Harbor Patrol			●
CHARLESTOWN	EMS Station 15			●

BOSTON HOUSING AUTHORITY FACILITIES AND FUTURE FLOOD EXPOSURE

Boston Housing Authority facilities are among the municipal properties that Boston should adapt to coastal and riverine flood risk. The City should prioritize adaptation at facilities exposed to flooding in the near term under 9 inches of SLR for high-probability events (10 percent annual chance event or monthly high tide).

To address extreme heat risks, as well as other causes of power outages, the City should prioritize backup power installation at facilities that demonstrate high levels of criticality. The City should promote solar photovoltaic generation and storage because this method supports reduced greenhouse gas emissions. In particular, the City should prioritize backup power installation at emergency shelters, which include Boston Centers for Youth and Family and Boston Public School facilities that serve as such. The City should also evaluate the need for cooling capacity across its facilities. The City is currently installing solar photovoltaic battery storage to support critical loads for at least three days in the event of an extended power outage at four BCYF facilities that also serve as emergency shelters.

INITIATIVE 10-3. EXPAND BACKUP POWER AT PRIVATE BUILDINGS THAT SERVE VULNERABLE POPULATIONS

The City should support solar photovoltaic generation and storage in private buildings that serve vulnerable populations. These buildings would receive outreach under Initiative 2-3 (see p.92). Targeted facilities should include affordable housing complexes, substance abuse treatment centers, daycare facilities, food pantries, and small nonprofit offices, for example.

The Environment Department should leverage past analyses of high-potential locations for solar to identify sites for backup installations. For example, the Community Energy Study identified districts that are suitable for community solar projects based on a high density of rooftop solar potential (i.e., the capacity to support large-scale solar projects with a minimum 500 kW of solar production). The City also has partnered with Mapdwell to identify the rooftop solar potential of all residential and commercial buildings in Boston.

In addition, the Environment Department should partner with Renew Boston Trust to evaluate the opportunity for resilience improvements to be combined with energy efficiency improvements.

INITIATIVE 10-4. DEVELOP TOOLKIT OF BUILDING RETROFIT FINANCING STRATEGIES

Because expanded access to financing will facilitate resilient building retrofits, the City should identify a toolkit of financing strategies that could be used to fund retrofits for both municipal and non-municipal buildings. These financing strategies can tap public, private, and nonprofit capital to make retrofits accessible to Bostonians with a range of incomes.

The City should collaborate with firms conducting resilience audits to develop profiles of retrofit costs by different building types. The profiles should be used to size the resilience financing need and guide financing strategy development for different building types. The City should then work with key partners, including Boston's lending, asset management, and insurance communities, to evaluate ways to quantify and monetize the benefits of climate resilience improvements and create a market for resilience in Boston. These benefits can include direct economic gains (i.e., incremental property tax increases), avoided losses (i.e., avoided structural, contents, and inventory damage), and cost savings (i.e., savings from reduced energy and water usage).

Through Renew Boston Trust (see call-out box), the City should explore ways to subsidize resilience improvements with energy efficiency improvements. The City should also identify ways to incorporate resilience upgrades into planned capital improvements for both public and private buildings and realize cost efficiencies from doing so. For example, the City may be able to incorporate resilience upgrades into housing repair loan programs for low- to moderate-income owner-occupants supported by the Boston Home Center. The Boston Home Center offers permanently deferred interest loans for critical repairs, where the City recovers its costs when the home is sold.

For non-municipal buildings, the City should prioritize developing retrofit financing pathways for buildings that provide a public benefit, have high levels of exposure, and are likely to experience challenges accessing financing. These buildings include the following:

- Affordable housing projects
- Non-municipal community facilities, especially those that provide critical services to vulnerable populations (food pantries, daycare centers, substance abuse treatment facilities)
- Low- and moderate-income homeowners
- Small businesses, especially those serving low- to moderate-income communities
- Historic buildings, where preservation requirements, often important to neighborhood character, may increase retrofit challenges and costs

RENEW BOSTON TRUST

The City created Renew Boston Trust (RBT) in 2016 to expand financing for energy efficiency improvements in Boston by monetizing future savings. In theory, RBT offers a potential pathway to use the savings from energy efficiency improvements to cross-subsidize resilience improvements. Currently, the proposed RBT model is focused on energy efficiency improvements to two types of buildings:

- Municipal buildings: Under the proposed model, City departments with responsibility for buildings will submit energy efficiency capital projects to RBT. RBT will combine projects to create aggregations that meet strict underwriting criteria ensuring their future energy cost savings will cover repayment of their upfront capital costs. RBT then will establish a performance-based contract with an energy service contractor to design and install the aggregated project, with the contractor guaranteeing that the project will be done on time and deliver the promised savings. The City will advance the cost of the project, and be reimbursed over time using the savings or contractor guarantee payments.
- Nonprofit institutions that are able to use state and City finance authorities for tax-exempt borrowing: Under the proposed model, groups of smaller nonprofits will join together to submit an aggregated energy efficiency project to RBT, which will review the project structure and confirm that it meets strict underwriting criteria. The nonprofits will then request that a state or City finance authority pursue financing for the project on their behalf and hold title to it during the repayment period. The authority then will partner with a lender, who will advance the cost of the project, and establish a performance-based contract with an energy services contractor, who will do the project. The authority will provide the improvement to the nonprofits, and they will repay the lender through passed-through rent payments. At the end of the repayment period, the nonprofits will purchase the project from the authority.

Strategy 11. Insure buildings against flood damage

Affordable access to appropriate levels of flood insurance coverage is critical to protecting property owners' investments and neighborhoods' stability. Property owners with proper and affordable insurance can more easily recover from their losses after a flood event, while those without can face severe financial distress. Furthermore, properties without adequate insurance may remain in a state of disrepair, leading to negative economic and social impacts on their neighborhoods. The National Flood Insurance Program is the primary source of flood insurance for owner-occupants, smaller residential properties, and small businesses. Generally, large commercial businesses carry flood insurance purchased from private insurers.

INITIATIVE 11-1. EVALUATE THE CURRENT FLOOD INSURANCE LANDSCAPE

The City should conduct a study of the current flood insurance landscape in Boston for owner-occupant and multifamily residential buildings to identify affordability challenges created by recent legal changes to the National Flood Insurance Program (NFIP)[1] and the projected floodplain expansion. The City should evaluate the level of coverage in current and projected future high-risk floodplains (1 percent annual chance flood event) by number and type of buildings. It should use NFIP policyholder and claims data provided by FEMA to provide a baseline of existing coverage. It should also conduct outreach to property owners, managers, and industry practitioners to provide insight into current understanding of flood insurance laws, level of coverage, understanding of building-level risk, and willingness to undertake building- and site-level adaptations. The City should evaluate strategies to help property owners respond to major increases in insurance premiums.

INITIATIVE 11-2. JOIN THE NATIONAL FLOOD INSURANCE PROGRAM COMMUNITY RATING SYSTEM

The City should work with FEMA Region I staff and the Massachusetts Insurance Services Office to begin the process of participation in the National Flood Insurance Program's (NFIP) Community Rating System (CRS). The CRS is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed minimum NFIP requirements. Based on the extent of best practices used to reduce damage to insurable property, increase insurance coverage, and take a comprehensive approach to floodplain management, the CRS discounts citywide NFIP flood insurance premium rates. The discount applies to both public and private purchasers of insurance. In order to enter the CRS, Boston must enter a formal application with NFIP, conduct an inventory of at-risk assets and initiatives in place to address risks, conduct a site visit with FEMA, and engage in a 6- to 12-month evaluation process. Boston has a site visit scheduled with FEMA this year.

INITIATIVE 11-3. ADVOCATE FOR REFORM IN THE NATIONAL FLOOD INSURANCE PROGRAM

The City should collaborate with leaders in other major cities on the East Coast to support 2017 reforms to the National Flood Insurance Program (NFIP) that promote flood insurance affordability in Boston. Key items for advocacy include the following:

- Taking into account alternative or partial flood mitigation strategies—such as flood-proofing mechanical systems or moving some mechanical components above the base flood elevation—when determining flood insurance rates, instead of requiring buildings in the 100-year floodplain to comply with all NFIP guidelines in order to realize any rate reductions.
- Considering expanding the types of non-residential space that residential buildings are permitted to maintain below the base flood elevation beyond parking, lobbies, storage, and crawl space to potentially include uses that support residential dwelling units, such as laundry rooms, building management offices, or common spaces.[10]
- Establishing a district-scale NFIP Community Rating System so that Boston and other cities can receive credit for improving flood risk management neighborhood by neighborhood.

[10] Subsidies for certain NFIP policies are currently being phased out, resulting in premium increases of 18 to 25 percent per year. Certain policies are also facing increasing deductible limits and surcharges. The NFIP requires reauthorization by Congress in 2017 and may be substantially changed.

Image courtesy of Sasaki