THE URBAN IMPLICATIONS OF

LIVING WITH WATER

Urban Land Institute

Boston/New England

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THE URBAN IMPLICATIONS OF LIVING WITH WATER

THE KRESGE FOUNDATION

ULI Urban Land Institute Boston/New England

Contents

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+2.5’

ABOVE The Innovation District team at work during “The Urban Implications of Living with Water” charrette.
Image credit: Steve Lipofsky

THANK YOU

We wish to thank The Kresge Foundation for its support to explore climate resilience solutions and for the generous support that enabled ULI Boston to host "The Urban Implications of Living with Water." Without Kresge's financial support and the in-kind support of ULI Boston/New England member organizations: Arrowstreet, Nitsch Engineering, and CBT Architects; the charrette and report would not have been possible.

A special thank you to Arrowstreet Graphic Design who donated their time and expertise to produce this report.
We would also like to thank the 70+ ULI members, experts, staff, and community organizations and city officials who participated in the charrette and contributed to this report.

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Cover photo is courtesy of Tony Cammarata Aerial Boston Photographers.

We are beginning to feel the impacts of climate change. In addition to the wide collection of political, social, and economic issues that climate change is sparking in our communities, we are faced with physical impacts of rising seas on our built environment. The Urban Land Institute report that you are about to read focuses on the visible threats of climate change in Boston – specifically, sea level rise and its ancillary issues. The ideas contained here are representative of the opinions and approaches of 70+ industry experts, including engineers, architects, financial and real estate development professionals, property insurance specialists, and the creators of public policy. These experts met for a day-long conversation to develop integrated solutions for a future with water as a frequent and pervasive part of our daily lives. This one-day event was followed by months of discussion, and this report is the result of our collective efforts.
We accept that the seas are rising, the weather is changing, and our communities are at risk; and we recognize that no solution can be all-encompassing. It is our hope that this report will spark conversation, shift our understanding of what is possible, and aid us in reframing challenges into opportunities as we move toward this new era of development.

Thank you to everyone who participated, contributed, and supported the creation of this document, and a special thank you to The Kresge Foundation and the Urban Land Institute, without whose support this event and publication would not have been possible.

Sincerely,

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ABOVE History of Filling Tidelands in Boston.
Image credit: Boston Redevelopment Authority

EXECUTIVE SUMMARY

How does one protect and enhance the value of a real estate asset, community, and infrastructure as the climate changes and sea levels rise?

Building on the climate preparedness work done for the Mayor of Boston's Green Ribbon Commission, ULI Boston's "The Urban Implications of Living with Water" charrette was convened as an opportunity to explore resilient design solutions for development in the region. The charrette explored how to help land owners, developers, designers, and public officials act to protect their assets and communities from the risks associated with sea level rise and climate change.

ABOVE Dynamic Planning Diagram.

The issues focused on what ULI members and those involved in the industry can begin to do now to protect the quality of the urban experience and respond to the significant changes that are expected in the coming years.

Sea level rise implications for the Greater Boston region are significant, as a substantial percentage of these communities not only are bound by water but were also built on former marshlands which are susceptible to instability when saturated with water. Some or all of these areas may well be flooded twice daily during high tide by the end of the century, and more frequently during severe storms in the coming years. "The Urban Implications of Living with Water" charrette, a ULI Resiliency Grant project funded by The Kresge Foundation, embraces sea level rise, exploring the development opportunities for four urban typologies with distinctly different challenges.

Four sites in and around Boston were chosen for their similarities as well as their differences, and are meant to represent typologies rather than site-specific solutions. The intent was for the issues raised and solutions proposed to be replicable and have wider applicability beyond these given locations. For each site, interdisciplinary teams of ULI members were assembled that included expertise in development, finance, design, and insurance. They were teamed up with city leaders and local experts to expose opportunities for, and barriers to, climate preparedness.

The critical questions each team sought to address were:

- **What types of resilient strategies could be implemented over time, to upgrade and protect existing buildings and properties within the district?**
- **How can we develop new urban design solutions that address both sea level rise and more frequent storm events while maintaining a vibrant streetscape?**
- **How do we pay for this and what is the cost of doing nothing?**
- **What barriers to resiliency planning currently exist at the local, state, and/or federal levels?**
- **What development opportunities arise if we strategically rethink our relationship with water?**

"As a coastal city, Boston is particularly vulnerable to the impacts of climate change. Our Climate Action Plan, which is currently being updated, is helping us not only reduce our citywide carbon footprint, but also prepare for the impacts of climate change. Boston is fortunate to have such great partners in the design community that are helping us tackle this challenge."

- Mayor Martin Walsh

From policy to physical and financial challenges, several common themes emerged from the four sites:

Dynamic planning models: Pervasive across all the sites was the importance of dynamic planning, and the inextricable realities of the actual built environment and the financing vehicles that drive its creation. Charrette teams identified building-specific and district-wide solutions that could be implemented in coordinated phases to protect assets. In the Innovation District, for example, an adaptive master plan was proposed which would evolve over time to mitigate rising sea levels and more frequent storm surges. The plan reimagines the Harborwalk as an occupiable sea wall that would both protect the district and provide public recreational and development opportunities. In conjunction with a new Harborwalk, the street network, utilities, and buildings would be modified incrementally each decade to adjust to new predictions on sea levels and anticipated storm surges. We have time to create a more resilient built environment through a phased process and incremental improvements that account for development cycles, infrastructure lifecycles, evolving conditions for financing, and the changing insurability landscape.

New visions for urban design: All of the charrette teams identified solutions that pushed beyond boundaries of currently accepted urban design practices. Elevating ground floors, negotiating street grades with double sidewalks, and providing elevated walkways at the second floor of buildings were evaluated for all the sites. At the same time, charrette participants shared stories of trying to implement some of these modest solutions, such as raised sidewalks, and described how resistance still exists at the municipal level when deviating from current streetscape standards. For the two sites outside of Boston, Alewife and Revere, the common residential building type of five stories of wood construction over a concrete podium level of parking or retail was recognized as being inherently resilient and was reimagined as a master plan development solution that could be connected and coordinated across multiple property lines.

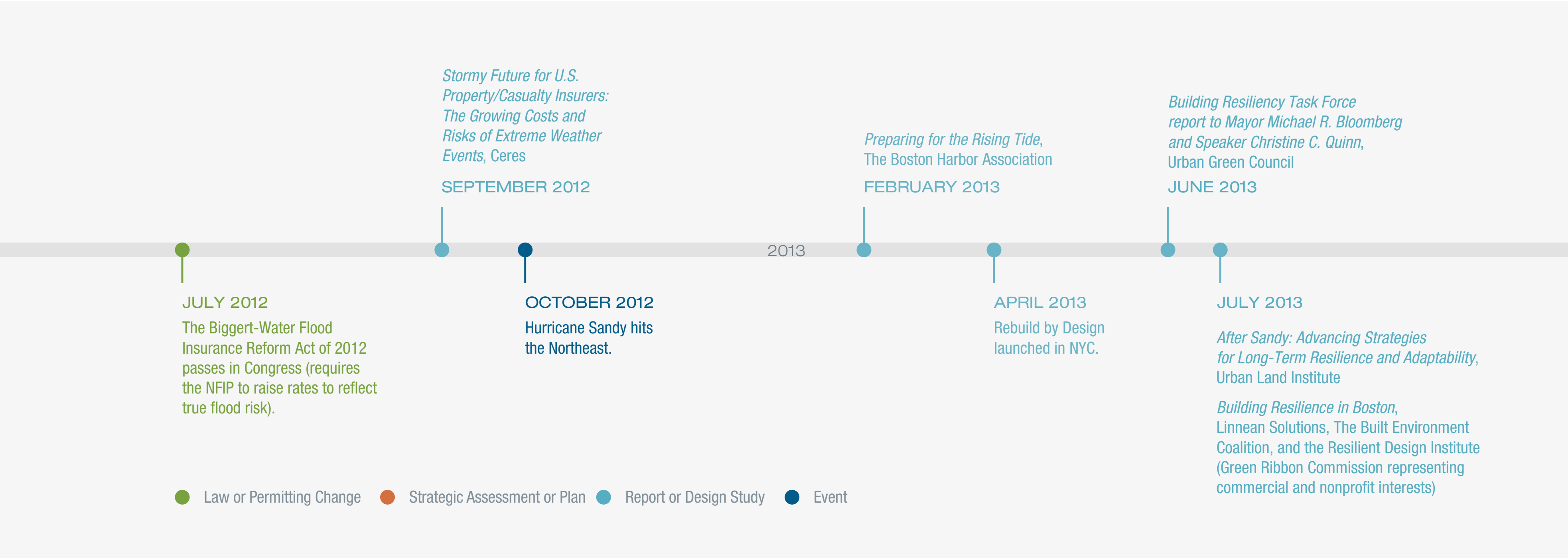
Development incentives and opportunities: The Alewife and Innovation District teams concluded that mitigation payments ought to be applied either directly to resiliency initiatives to benefit both the development and the community or, for those developers who are designing resilient components into their projects, these additional costs could be counted in lieu of mitigation. Additional ideas in South Boston included creating new development parcels within the rebuilt Harborwalk in exchange for developer support in raising and expanding the sea wall.

While there are numerous parallel initiatives on the strategic and policy fronts, it remains difficult to visualize what the new future of living with water means for our communities. The ULI Boston effort is unique in investigating the vision for a different future prepared for climate change and living with water.

Risk estimating and managing flood risks: Significant investment and new methods of evaluating acceptable risk will be required to prepare for the impacts of sea level rise on the built environment. Property owners, developers, governments, and especially those who provide the infrastructure for transportation, energy, communications, water, and waste will need to make these investments. Careful planning will be required to maintain the continuity and quality of the urban experience, and new strategies for building envelopes and floodproofing will need to become commonplace. While building a more resilient community will require investment over time, the cost of doing nothing could be profoundly disruptive and exponentially more expensive. Actions to prevent and reduce damages from extreme weather events not only protect people and property, they are a sound investment: one dollar spent on prevention saves four dollars in damages, according to FEMA and to a widely cited study by the Multihazard Mitigation Council of the National Institute of Building Sciences.[1]

The images and drawings included in this report are meant to provoke conversations among various stakeholders, continue the ongoing regional discussion, and become the jumping-off point for potential urban solutions. They should be used to spark discussions, identify risks and opportunities, and assist with understanding the issues and threats created by sea level rise on individual sites.

Integrating climate resilience measures in the regulatory and best practices processes will be complex and will require time, vision, and collaboration among decision-makers, stakeholders, and experts contributing to city building. It is hoped that the ULI "The Urban Implications of Living with Water" initiative provides a forum for integrating design and vision to the many ongoing discussions on sea level rise and its impact on the Boston metropolitan area.



ABOVE The Historical Perspective: Recent Events and Public Policy.

CONTEXT

Context of Boston (decision making): Hurricane Sandy[2] was a game changer for the Northeast. Many metropolitan areas, including Boston, have since been revising their preparedness measures for extreme weather events. Several state agencies and municipalities, including the cities of Boston and Cambridge, in addition to addressing emergency preparedness, are developing strategic plans and reviewing policies anticipating the impact of climate changes on urban infrastructure, businesses, and local populations. A number of these strategic assessments should be made public in the fall of 2014, making a large amount of data available for the first time to planners, designers, and stakeholders who will be able to use this information to inform their design decisions and risk analysis.

Northeast climate change context (science supporting the "impetus" for change): Historically, federal agencies and other bodies charged with estimating the probabilities of extreme weather events have been deriving their estimates from historical frequency data that have been assumed to reflect future probabilities as well. These estimates have not yet adequately factored in the effects of past and future climate change. As a result, the risks of damage from climate change based on these estimates may be badly understated.[3] Global sea level rise (SLR) and relative SLR in Boston have been respectively occurring at average rates of 0.07 inches/year (NOAA, 2012) and 0.11 inches/year (NOAA, 2013). Relative SLR in Boston has been higher than global SLR because the local landmass in Boston has been sinking at an estimated rate of 0.04 inches/year (the result of long-term geological processes[4]). Another contributing factor

SEPTEMBER 2013
NYC passes first group of regulations into law for construction in flood zones, wind risk analysis, and stormwater capture to minimize flooding. These laws are in direct response to Hurricane Sandy.

OCTOBER 2013
Climate Ready Boston: Municipal Vulnerability to Climate Change

NOVEMBER 2013
Preliminary FEMA maps issued for Boston, 100-year flood elevation increases by 4' for some sites in South Boston. It is anticipated that the new FIRMs will become effective for insurance and building permitting in August 2015.

BRA updates Article 80 Review Guidelines to require projects to submit a "Climate Change Resiliency and Preparedness Checklist"

2014

JANUARY 2014
Governor Patrick announces $50m for comprehensive climate change preparedness initiatives.

MARCH 2014
Homeowner Flood Insurance Affordability Act of 2014 repealed and modified provisions of the 2012 Biggert-Waters flood insurance law.

AUGUST 2014
Designing with Water, The Boston Harbor Association

SEPTEMBER 2014
"The Urban Implications of Living with Water," ULI Boston

FALL 2014 – SPRING 2015
EXPECTED COMPLETION DATES OF:

- Update to City of Boston Climate Action Plan
- MassDOT Boston Harbor Flood Risk Model
- Boston Water and Sewer Commission (BWSC): Capital planning process started in 2011.
- Massport Resiliency Guidelines
- MBTA Strategic Assessment of Facilities
- City of Cambridge: Climate Change Vulnerability Assessment

is the fact that over the last 50 years, Massachusetts' annual average precipitation has been increasing by more than two inches per decade, with greatest increases in spring, summer, and fall (NOAA, 2013). Drainage and flood protection systems have been designed to withstand more commonly occurring storm events that do not factor in projections based on new scientific evidence related to climate change.

Massachusetts policy and regulatory context: The Commonwealth of Massachusetts has been proactive in investigating options for adaptation to climate change. The Massachusetts Department of Transportation (MassDOT) is developing a Boston Harbor Flood Risk Model (BH-FRM) to determine inundation risk and flooding pathways, and to simulate the dynamic nature of flooding in the cities of Boston and Cambridge. Although the focus of the model is the Central Artery/Tunnel system, output from the model can be used by other interested parties. The BH-FRM simulates storm-surge-induced flooding that could occur from both tropical (hurricane) and extra-tropical (nor'easter) storm events for the present day and sea level rise scenarios for 2030, 2070, and 2100, and will constitute a valuable resource. Others including the Massachusetts Port Authority (Massport) and the Massachusetts Bay Transportation Authority (MBTA) have undertaken or are in the process of undertaking comprehensive strategic assessment of their facilities that could be vulnerable to climate change impacts.

In May 2009, the Massachusetts Secretary of Energy and Environmental Affairs (EEA) created the Massachusetts Climate Change Adaptation Advisory Committee, under the authority provided in the state's 2008 Global Warming Solutions Act. The committee was created to study strategies to adapt to climate change and make recommendations to mitigate future effects. The panel included representatives of transportation, built infrastructure, industrial and manufacturing organizations, consumer groups, utilities, conservation groups, and local government. In 2012, EEA formed an Adaptation Subcommittee to further enhance coordination and communication among state agencies and external stakeholders involved in implementing climate change adaptation recommendations. The subcommittee is composed of stakeholders from state and federal agencies, municipalities, regional planning agencies, non-governmental organizations, and academia. In 2013, the subcommittee developed recommendations for implementing

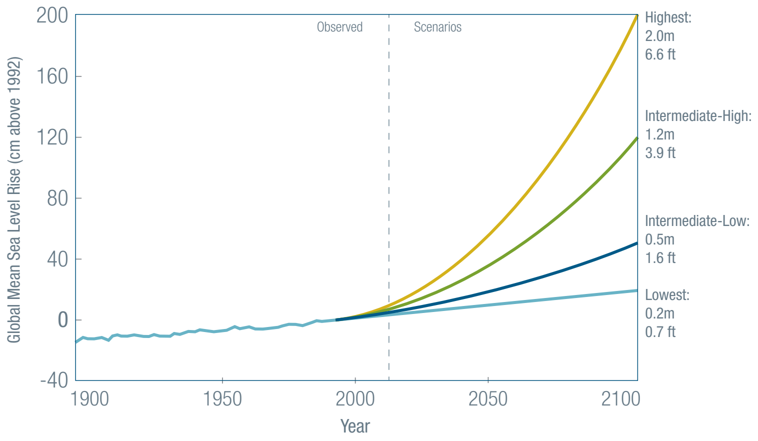
ABOVE The Revere Beach team at work during "The Urban Implications of Living with Water" charrette. *Image credit: Steve Lipofsky*

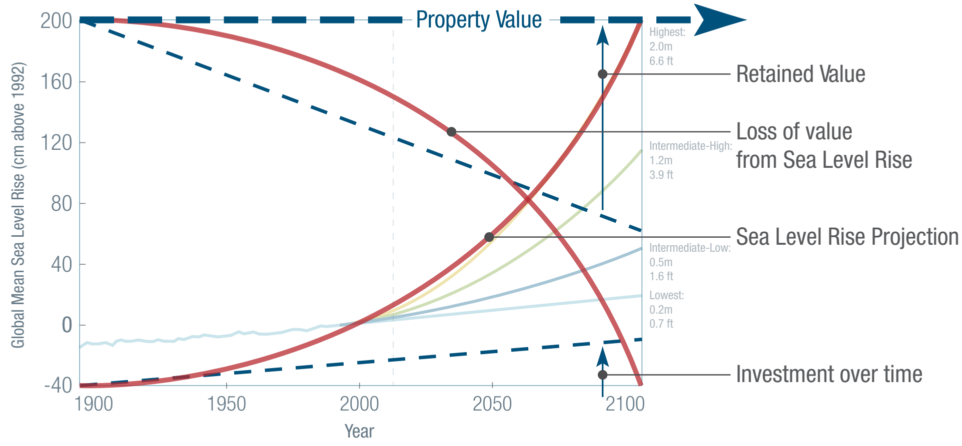
strategies from the Adaptation Report, shared information on projects and modeling efforts for vulnerability assessments, and sponsored a climate tools workshop for agency staff.

Massachusetts Governor Deval Patrick has established climate change adaptation as a top priority for EEA through the end of his administration. In 2014, the Patrick administration announced a $50+ million investment for a statewide plan addressing climate change in Massachusetts. These investments will address vulnerabilities in public health, transportation, energy, and the Commonwealth's built environment, and include investments in energy resilience, seawall repair, and green infrastructure, and the establishment of a State Climatologist position at University of Massachusetts Amherst.

At a municipal level, to name few key initiatives, the City of Boston is updating its Climate Action Plan, the City of Cambridge is proceeding with a Climate Change Vulnerability Assessment, and three South Shore communities (Scituate, Marshfield, and Duxbury) undertook a sea level rise study to identify critical assets at risk.

State and municipal government officials from the Massachusetts Executive Office of Energy and Environmental Affairs, MassDOT, the Boston Water and Sewer Commission (BWSC), the Massachusetts Department of Conservation and Recreation (DCR) (which manages the operations of the Charles River and the Amelia Earhart dams), Department of Environmental Protection, Massport, the City of Boston, and the City of Cambridge have been comparing climate





ABOVE (LEFT) Projections of sea level rise form 2010 to 2100, based on US National Climate Assessment 2012.[7]

ABOVE (RIGHT) Conceptual relationship between property value maintenance vs sea level rise on effected areas. Based on FEMA and the study by the Multihazard Mitigation Council of the National Institute of Building Sciences.

change projections, future scenarios, and model results of these climate change impacts to start informing a regional approach to this challenging issue.

Cost of inaction: When we examine the full costs of public programs that pay for disaster relief and recovery from extreme weather events – ad hoc disaster assistance appropriations, flood insurance, crop insurance, wildfire protection, and state-run “residual market” insurance plans – we can begin to understand the price to U.S. taxpayers of inaction on climate change and sea level rise. Each of these programs is highly exposed to catastrophic weather events. As climate change results in more frequent, volatile, and damaging extreme weather across the country, the potential liabilities of these public programs and the bottom line costs to taxpayers have increased and will continue to soar. In January 2013, Congress approved a $9.7 billion increase in the program’s borrowing authority, from $20.725 billion to $30.425 billion, to ensure the program would have adequate financial resources to cover its existing commitments for storm-related damages.[5] As of July 2013, the National Flood Insurance Program (NFIP) owed the U.S. Treasury approximately $24 billion.[6]

Taxpayers bear an additional burden – damages from extreme weather events that are neither insured by the private insurance market nor reimbursed by government programs. Continuing to ignore these escalating risks may be more comfortable than confronting the challenges of climate change; but inaction is the far riskier and more expensive path.

Actions to prevent and reduce damages from extreme weather events not only protect people and property, they are a sound investment: one dollar spent on prevention saves four dollars in damages, according to FEMA and to a widely cited study by the Multihazard Mitigation Council of the National Institute of Building Sciences.[1] Conversely, we exacerbate future losses by failing to adopt and enforce land use regulations that prohibit development in areas that are vulnerable to floods or wildfires; by failing to update and enforce building codes that mandate the use of weather-resistant construction practices and materials; and by failing to couple disaster assistance funding with obligations to take steps to protect against future extreme weather events.

ABOVE (LEFT): Dennis Carlberg, Director of Sustainability at Boston University draws out an idea at the Back Bay charrette session.
Image credit: Steve Lipofsky

ABOVE (RIGHT): David Bois, Principal at Arrowstreet, presents the Revere charrette team's ideas at the final pin-up session.
Image credit: Steve Lipofsky

Acknowledging extreme weather event costs and taking steps to minimize those costs has another benefit: it helps maintain the availability and affordability of private insurance. A strong insurance market can significantly finance the costs of reconstruction following a catastrophic event and enable individuals and businesses to rebound more quickly. Today, only about 50 percent of the damages in the U.S. caused by extreme weather events are privately insured. Developing innovative insurance models and products that increase the percentage of insured damages relative to uninsured damages would be an economic benefit to taxpayers, as well as a business opportunity for the private insurance sector. Boosting our resiliency to today's extreme weather events is an urgent priority. Investing concurrently in forward-looking measures that over time will reduce the climate-altering carbon emissions contributing to extreme weather is essential to our long-term physical and economic well-being.[8]

Timing of climate change impacts is key to planning: When the U.S. Army Corps of Engineers was designing the new Charles River Dam in the early 1970s, they assumed that sea level would rise at a rate of 0.6 feet per century. The 2014 National Climate Assessment projects that sea level may rise from about one to four feet by 2100, depending on how much more greenhouse gas emissions accumulate in the atmosphere. The National Climate Assessment projects an upper bound of about six feet for 2100.

Sea level rise will likely continue and persist for centuries or millennia. In any event, carbon pollution to date has locked in over four feet of sea level rise according to estimates. Our infrastructure, buildings, and systems were designed with a static climate or one of slow-moving changes in mind. Now designers need to plan for a dynamic climate where sea level rise will persist for a long time, with uncertainty about the rate and extent of change but with certainty that the sea will rise several feet at least.

Sea level does not rise all at once. It rises gradually over decades and centuries. This means there is some time to plan and implement protection and resilience measures. The flooding risks associated with sea level rise vary from permanent inundation to periodic floods that recede. The timing of inundation and storm surge flooding will depend on location. Topography, dams and levees, and other factors will determine the risks and their timing; so it is important to assess flooding risks on a location-specific basis to inform preparedness and resilience strategies.

Once the location-specific risks are understood, planners and asset owners can develop strategies that take into account development cycles, infrastructure life cycles, cost and benefits, co-benefits, procedural imperatives, and financial streams to plan and schedule the implementation of strategies. Critical thresholds (e.g., dam elevations relative to sea level) can be identified and rates of sea level rise can be monitored to inform decisions about when strategies need to be implemented. It will be a challenge to scale investments in fixed measures appropriately to meet estimated sea level elevations. Strategies that have flexibility can minimize regrets.

Individual property owners can't do it alone: Many individual property owners are taking risks associated with sea level rise and climate change seriously and taking steps in the design process to make a project/building more resilient to these future conditions. While these measures are necessary and an important step, they alone cannot make the project/building completely resilient. Rather than an autonomous entity that is bound by a property line, a project/building is part of much larger infrastructure systems (e.g., electricity, natural gas, water/sewer, stormwater, transportation) beyond its property line. As such, there is only so much that can be done individually. Once that threshold is reached, resiliency becomes a question of community and cooperation. Strong community leadership will be needed to create consensus among a multitude of stakeholders, public and private alike. At all scales, leadership and convening power is critically important to bring all stakeholders together to develop and implement solutions to a problem that extends beyond traditional boundaries and is uncertain in terms of time frame and magnitude of change. Nothing short of a cohesive vision will be required to address the impending impacts and resiliency challenges.

Water ignores property lines and jurisdictional boundaries: In order to tackle a problem that doesn't respect property or political boundaries, and instead involves systems that extend beyond them, solutions need to mimic the problem and provide integrated, system-level solutions that one owner, agency, or utility cannot solve alone. For example, a property owner may develop a water management plan that solves the problems for one site but may have adverse effects on adjacent or further downstream properties or systems.

A change in thinking and planning is required that starts at the smallest scale, i.e., beyond the property line, and extends to the district, neighborhood, city, and regional scales (as applicable). Solutions will require new ways of doing business between stakeholders and increased communication and transparency.

The challenge of adapting organizations for climate resilience: Urban designers, owners and developers of real estate, financial institutions, and governments are facing a daunting challenge. With data indicating a dramatic increase in sea levels over the coming years, organizations must determine how to create something today that can withstand the risk and uncertainty of tomorrow. How much will sea levels change? What do we design for?

Even as we face the need to address a growing demand for coastal flood resilience, the design process remains rooted in knowledge, customs, and standards drawn from history – not from what might happen in the future. So, we are faced with the question of whether to design with the customary approach, or with a focus on what science is telling us.

Despite the hard data, designers have yet to adopt a systematic method to evaluate trends over time and project future realities. We continue looking backward at data not very different from what was used to lay out old-fashioned neighborhoods and buildings – without careful analysis of water conditions. We have continued to respond to extreme weather and storm surges reactively, instead of developing new standards and practices to help us avoid disaster losses and costly recovery in the first place.

To reduce the extent of disasters like Hurricane Sandy which are occurring with increasing frequency, we must shift the paradigm and plan for a future where change, and water, is the new normal. Conventional statistical analysis that only looks at past data will fail to capture trends we need to account for. But what should the new design criteria be? How can we intelligently address the uncertainty of projections?

ALEWIFE QUADRANGLE
REVERE BEACH
INNOVATION DISTRICT
BACK BAY

OVERVIEW OF SITES

"The Urban Implications of Living with Water" charrette set out to explore a broad set of risks, opportunities, common themes, and divergent strategies related to sea level rise at four different neighborhoods and development projects in the Greater Boston area. These four sites were chosen for their similarities as well as their differences, and are meant to represent typologies rather than site-specific solutions. In addition, the sites have different time horizons for planning, which allowed for a greater breadth in ideas. The intent was for the issues raised and solutions proposed to be replicable and have wider applicability beyond these given locations.

Innovation District Representing the City of Boston's initiative to transform 1,000 acres of the South Boston waterfront, the Innovation District is illustrative of the complex design challenges where expensive, dense urban development meets the demands of a rising tideline. Located between Boston's transportation gateways, this area contains the largest tract of underdeveloped land in Boston. The neighborhood offers opportunity for growth, a strong existing knowledge base, and an outstanding location for generating new ideas, new services, and new products.

Back Bay Boston's historic Back Bay is one of the most walkable mixed-use neighborhoods in the nation – an integration of residential, retail, office, civic uses, and open spaces with easy access to the rest of the city on foot, on bicycles, and by mass transit. It is also among the most valuable real estate in the city. The Back Bay sits on marshland that was filled in over the course of the 19th century. Much of this new land lies less than four feet above today's high tide.

Revere Beach A 10-acre site in the middle of a crescent-shaped beach just minutes from downtown Boston, Waterfront Square at Revere Beach is the last remaining large area of undeveloped property on the beach. Ironically, the site opportunity is a direct result of coastal flooding resulting from the Blizzard of '78, which destroyed a significant amount of property along the beach front, prompting the state and city to take the land to allow for more appropriate development and the creation of parkland. Engineered modifications to the beach have resulted in a more stable barrier to coastal flooding; however, the area is still directly impacted by inland flooding. A direct connection to subway and the city's desire for smart development has created a development opportunity for increased density which has the potential to transform the region.

Alewife Quadrangle The Alewife Quadrangle is a 130-acre area in the western part of Cambridge that historically has been the location of low-rise, light industrial, and commercial activities. Following the 2006 Concord-Alewife Planning Study and subsequent rezoning, the area has started to see new housing developments, but there is significant potential for additional new development and redevelopment. While most of the Quadrangle area is currently in the 500-year floodplain, the prospect of more frequent episodes of intense precipitation and the possibility of Alewife Brook backup up from storm surges affecting the Mystic River presents challenges. Yet there is much value to the community to have an area for the types of uses that have recently located there.

LEFT: *Image credit: Shaun O'Rourke*

INNOVATION DISTRICT

"Since so much of the land in the Innovation District has yet to be developed, there is an opportunity here to think strategically and minimize future losses."

Representing the City of Boston's initiative to transform 1,000 acres of the South Boston waterfront, the Innovation District is illustrative of the complex design challenges where expensive, dense urban development meets the demands of a rising tideline. Located between Boston's transportation gateways, this area contains the largest tract of underdeveloped land in Boston. The neighborhood offers opportunity for growth, a strong existing knowledge base, and an outstanding location for generating new ideas, new services, and new products.

OPPOSITE PAGE Daily tidal fluctuations hide or reveal the topographical layers of the Harborwalk, creating an ever-changing landscape that interacts with the harbor rather than merely opposing it. Planting systems transition from mostly dry to increasingly more aquatic vegetation to adapt to rising sea levels. Perspective view of dune park.
Image Credit: Arrowstreet and Halvorson Design Partnership

ABOVE Aerial view of proposed Harborwalk. Functioning as both a raised sea wall and soft infrastructure boundary, the new Harborwalk could provide additional recreational and development opportunities along the waterfront.
Image Credit: Arrowstreet

Risk Profile

The Innovation District faces significant risk related to sea level rise over the next 100 years. The image on the following page shows South Boston with 7.5 feet of sea rise. As phasing of future tidal management is critical, so are the time horizons associated with these projections as it relates to the real development currently underway. In the near term, 2.5 foot rise is predicted by mid-century, whereas a 7.5 foot rise is predicted by 2100 and beyond.

Key Strategies

Rising sea levels create design opportunities. Rather than looking at rising tides as having a negative impact on the Innovation District, solutions to address rising sea levels should provide opportunities to improve our environment and our

ABOVE If no action is taken, this will be South Boston with 7.5' of sea level rise.
Image credit: Arrowstreet

relationship with the city. For example, instead of building a higher sea wall, what if the HarborWalk were re-envisioned as a place that would both protect the city from an additional three feet of sea level rise and provide a series of public amenities? This new HarborWalk could incorporate recreational areas and the landscape surrounding this new HarborWalk could function as both public space and soft infrastructure, absorbing water or mitigating the tidal impacts.

Measures should not only improve resiliency but have ecological benefits as well by enhancing biodiversity. Traditional hard/grey solutions should be balanced with soft/green measures through incentive programs, given that green spaces in themselves are a resiliency measure. Planted or porous surfaces act as sponges to help absorb and release water over time through groundwater transmission and evapotranspiration to reduce the impacts of increased storm and flood frequency, but also have the additional benefit of heat island mitigation to counter rising temperatures.

Take advantage of opportunities where they exist now, and plan for the future. The Innovation District presents significant opportunities as the majority of the District remains available for future development. While considerable amount of effort and time has gone into the planning of these sites, they do present opportunities to address resiliency. With the future unclear about exactly when the full impacts of sea level rise will occur, designing now for flexibility and the ability to adapt becomes critical. For example, with major street sections to be rebuilt, the typical 60 or 75 foot cross-section can be planned to be able to change when conditions warrant. The goal is to provide for current urban linkages across the district without limiting the ability to accommodate future needs. Such needs could take the form of green infrastructure or surface channels to move water safely and quickly back to the ocean.

Designing for sea level rise is not the same as preparing for the next superstorm. The majority of developments in Boston are preparing for emergency conditions such as hurricane-induced storm surges, not for consistent, pervasive conditions as a result of sea level rise. It is understandably difficult to think about living with higher water and frequent inundation as a long-term, permanent condition, specifically because priorities change when it is already so costly to build in the Innovation District that it would be almost impossible to make development financially feasible if additional resiliency measures for rising tides are required. Given current development costs, the strategies that are to be proposed should have minimal cost impacts to current development pro formas and allow building owners and the government to retrofit buildings and streets later, when sea level rise conditions reach critical levels.

Certainly, in many cases, the additional expense for design upgrades to adequately protect specific building systems from current storms and storm surges often are more expensive than the simple act of replacing the system itself. Building systems and program, specifically those at grade or lower, should be studied across their life cycle to weigh the concept of acceptable loss versus protection. For example, if a system, such as a fire pump assembly, should be expected to be replaced once every thirty years, but the studied threat profile indicates that irrecoverable damage due to storm is only expected once in fifty years, then there is no financial incentive to protect such a system from total loss. In such cases, building owners may choose instead to have emergency replacement plans and spare assemblies already available to ensure safe and timely replacement with limited occupational impacts. Undoubtedly, this form of life cycle study infers constant review and reassessment. Such a building management process should be a part of an annual review, and include conditions of building systems, current weather patterns, and current MHHW at the time of the review.

Timeline uncertainty is another common barrier to implementing resiliency or protective measures under current conditions. Due to current development costs in the Innovation District, designing flexibility into our buildings now to preserve the ability to adapt at a later date is a common recommendation.

One such example is designing space and structure on a higher floor to accommodate and carry major building infrastructure (e.g., electrical, mechanical, and/or plumbing) in the future and designing those systems to be able to be moved. Another example is to design floor-to-floor heights on the ground level to accommodate a future raised floor level on the ground floor. A third example is to design higher (i.e., second) floors to be able to connect building to building and create a raised retail level above the street/ground floor. Designing structure, grid modules, and other systems with this in mind would enable flexibility in the future. This also requires individual owners and project teams to increase communication and work together in their designs.

STATISTICS

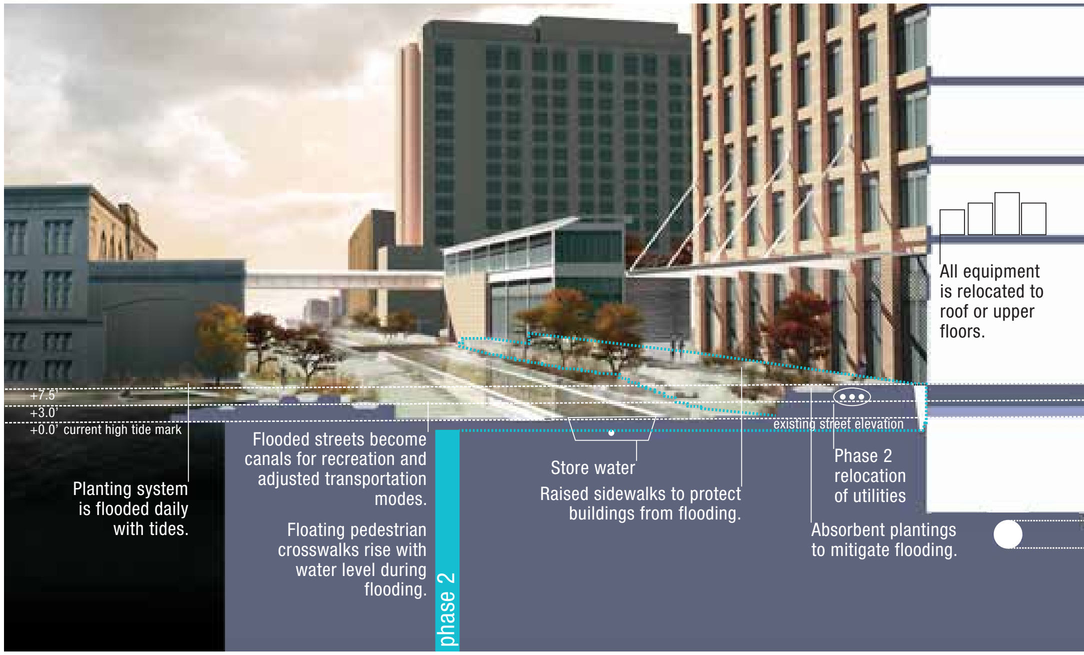
SITE AREA	1,000+ acres
ELEV. RANGE (MHHW)	+5.0 – 7.0'

KEY CHALLENGES

- Current costs of development
- Development density and spatial constraints for water management
- Regulatory frameworks
- Multiple stakeholders
- Urban fabric
- Transportation

KEY THEMES

- Flexible and adaptable uses – public realm and building
- Phasing – infrastructure and transportation
- Integrated public/private policy and partnerships or district level resiliency fund
- Stakeholder engagement
- Sea level changes as design opportunities



ABOVE (LEFT) **Phase 1: 1 - 20 Years**
Raise Harborwalk to serve as a seawall to protect against storm surges. Implement green infrastructure solutions and best practices for low impact development (LID). Take future conditions into account when sizing and designing drainage systems. Include tide gates at outfalls, which should be above low tide mark as much as possible to allow the system to drain eventually. Develop a long-term master plan for the district to address water management and issues of climate change.
Image credit: Arrowstreet

ABOVE (RIGHT) **Phase 2: 20 - 50 Years**
Raise pedestrian elements to protect buildings during increasingly frequent flooding. Begin conversion of basements, as current uses such as parking are likely not possible. Relocate critical service utilities beneath raised sidewalk. New grates installed for building protection drain back to existing drainage systems. Green infrastructure reduces strain on drainage system during dewatering following inundation events.
Image credit: Arrowstreet

Obstacles and Barriers

Dollars and sense. Who pays for resiliency? At what point do premiums become unaffordable? Which insurance companies are incorporating climate change impacts such as increasingly intense precipitation events and sea level rise into account when advising commercial and residential policyholders on how to reduce risks and prevent losses?

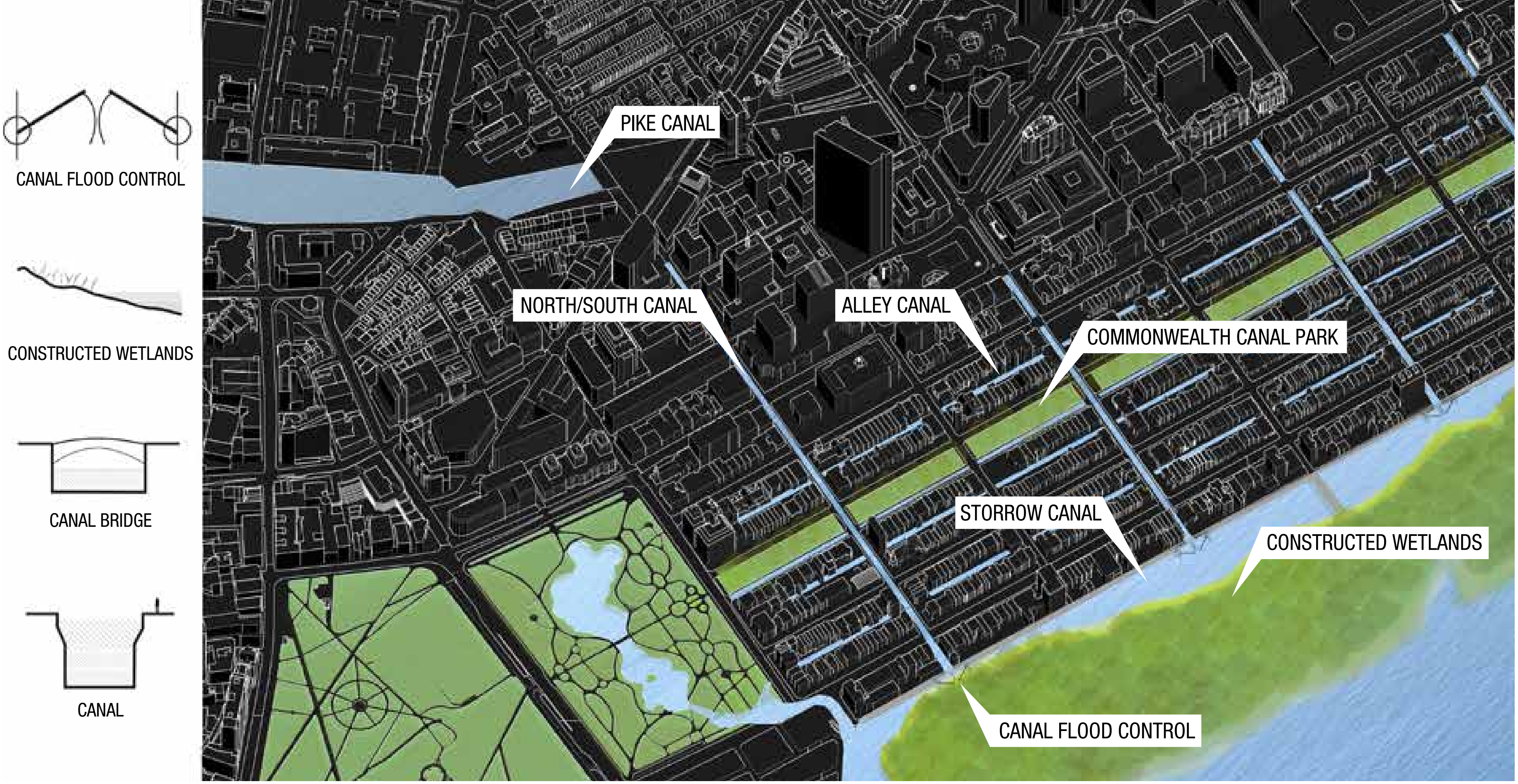
Are there incentives the City of Boston/Boston Redevelopment Authority could provide to encourage developers to implement resiliency into their projects, such as additional GFA/FAR or height relief? Although height relief is not an option in the Innovation District due to FAA restrictions associated with Logan Airport, it may be worth considering elsewhere in the city. Other ideas include “resiliency bonuses” to offset development costs. Some developers (Skanska, for example) are insuring their own properties rather than relying on outside insurance companies.

Another financial issue is that of not having complete data or knowing what vulnerability data is relevant for specific developers. Many developers are basing their designs on the storm surge and sea level rise scenarios described in the Boston Harbor Association report. While this is a good start, it doesn’t give developers the necessary information to design solutions specific to their site. Many public agencies (e.g., Massport, MassDOT, the City of Cambridge) are undertaking resiliency studies, many including modeling. The amount of information and knowledge is increasing and could be made publicly available so that development and design teams can better design their projects without each individually having to fund their own studies.

ABOVE **Phase 3: 50 - 100 Years**
Drainage system stays as conduit for storage systems beneath buildings, which now have large pump chambers for dewatering of basements repurposed as water storage. Tunnel network beneath buildings "knits" the underground systems together in a regionwide approach.
Image credit: Arrowstreet

Partnerships are critical. Strong leadership is essential to bring people and agencies together. Resiliency planning and emergency preparedness efforts are already underway by various city departments, state agencies, and utility providers. How can that information be disseminated most effectively? Why should private developers be expected to fund most of these design changes when success rests on district-wide solutions? How will the design of the public realm interface with private property and development? How can phasing be integrated?

One approach might be a District-wide resiliency fund into which all developers/owners would pay to finance infrastructure-scale resiliency measures, such as a seawall/harborwalk, canals, or green infrastructure. This could be similar in nature to the charges Massport already imposes on developers for District improvements. Is this feasible where cost of development runs high? Who will be its champion? There's only so much a single entity can do. At a certain point, resiliency becomes an issue of infrastructure, which is outside of a particular developer's or land owner's control. Larger district-, city-, and regional-scale solutions will be required. This is where leadership and convening power, as well as funding, likely from the public sector, is critically required.



BACK BAY

"The Back Bay holds some of Boston's most valuable real estate. Without changes to current infrastructure the neighborhood is vulnerable to flooding from both Fort Point Channel and the Charles River Dam."

Boston's historic Back Bay is one of the most walkable mixed-use neighborhoods in the nation – an integration of residential, retail, office, civic uses, and open spaces with easy access to the rest of the city on foot, on bicycles, and by mass transit. It is also among the most valuable real estate in the city. The Back Bay sits on marshland that was filled in over the course of the 19th century. Much of this new land lies less than four feet above today's high tide.

OPPOSITE PAGE Interwoven Canal and Street System.
Image credit: Arlen Stawasz

ABOVE (LEFT) Boston with a rising sea level of 2.5'.
Image credit: The Boston Harbor Association

ABOVE (RIGHT) Boston with a rising sea level of 7.5', the level assumed for the purpose of the Back Bay Scenario.
Image credit: The Boston Harbor Association

Risk Profile

The 2014 National Climate Assessment projects that sea level may rise from about one to four feet with an upper end of 6 feet by 2100. The Eastern Seaboard is experiencing greater land subsidence than other parts of the nation, which puts Boston on the upper end of the range of probable sea level rise. While the top of the Charles River Dam is 6.8 feet above today's high tide, there appear to be several lower-lying areas that could allow the sea to reach the Back Bay neighborhood well before the dam is overtopped. This could happen before the end of the century, unless selective fortification measures are put in place.

Given the inherent vulnerability of this historic neighborhood to sea level rise, the "The Urban Implications of Living with Water" charrette provided an opportunity to envision the neighborhood for a new reality at a broadly conceptual level: to embrace a daily high tide above the elevation of the existing streets. In order to explore the concept of living with water, the team did not explore storm emergencies nor strategies for keeping the water out. There may be alternative infrastructure solutions for the Back Bay, but the charrette provided an opportunity to think creatively about integrating water into a historic neighborhood. While the cost of the vision outlined here is significant, the cost of doing nothing is severe; and managed retreat is untenable.

STATISTICS

SITE AREA	200+ acres
ELEV. RANGE (MHHW)	+4.0 – 5.0'

KEY CHALLENGES

- Retaining property value
- Preparing infrastructure for resilience
- Abandoning or reassigning uses in the lowest building levels to regular flooding
- Maintaining connectivity of the Back Bay to the rest of Boston
- Maintaining the integrity of existing structural elements
- Coordinating and finding consensus among the large number of existing owners and stakeholders

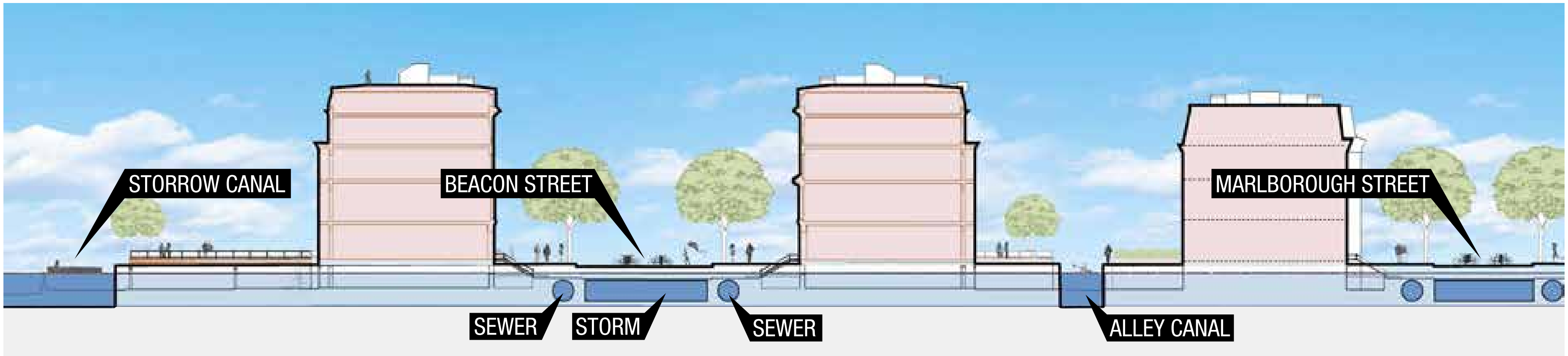
KEY THEMES

- Embracing daily flooding as an opportunity, not just a threat
- Preserving the nationally treasured historic building fabric
- Phasing infrastructure, landform, and tide control measures
- Integrated public/private policy and partnerships

Key Strategies

A new and changing urban experience for Boston. This vision for the future of the Back Bay, in light of climate change and sea level rise, includes integration of a canal system into the neighborhood to celebrate living with water much in the way Venice and Amsterdam have for centuries. To accomplish this, alternating north-south streets and east-west alleys will become canals. This will allow for the existing street grid to continue to function and serve the neighborhood, while intertwined with the new canal system. The canals will provide new waterway connections to the Charles River through a system of locks and to Fort Point Channel by way of the naturally forming Mass Pike Canal.

Managing water assets and threats. Today, the Charles River Dam maintains a relatively constant fresh water elevation in the basin, providing quality recreational uses on and around the river. Its large pumps are used to reduce the basin's water elevation in preparation for heavy rains. As future sea levels rise beyond the control of the dam, other means to control water quantity and quality will be introduced to replace today's dam function. The current purpose of Storrow Drive is envisioned as becoming obsolete and changing from thoroughfare to a water-controlling canal. Constructed wetlands and bermed parklands will provide support through absorption capacity and vertical relief between the Storrow Canal and the Charles River Basin. Once the Charles River Dam no longer provides flood control, a more decentralized flood control system will be provided through canal inlets located along the Storrow Canal.



OPPOSITE PAGE Clarendon Canal.
Image credit: Michael Wang, Arlen Stawasz, and Dennis Carlberg

ABOVE Section looking East.
Image credit: Michael Wang, Arlen Stawasz, and Dennis Carlberg

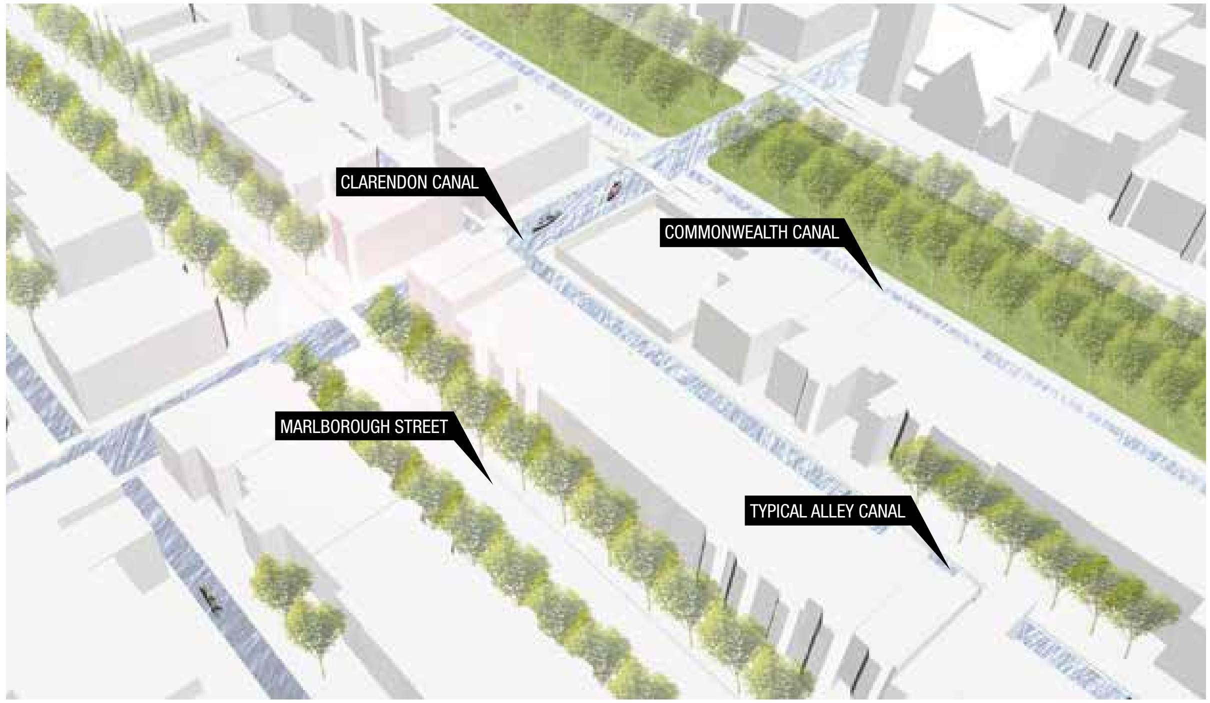
Enhance green infrastructure. Creation of multi-functional green spaces for retention, absorption, and distribution of floodwaters will be integrated to increase recreation opportunities.

Enhance modes of sustainable transportation. New modes of public transportation will be developed and the existing transportation infrastructure will be improved, while emphasizing walking and use of bicycles. A primary concern is to ensure continued connectivity between the Back Bay and the Greater Boston area.

Develop an incremental, phased approach. The Back Bay's old infrastructure poses several clear challenges in the face of sea level rise:

- The first step toward building resilient infrastructure is to reduce the demand for energy and water resources, and to reduce waste conveyance. The goal is to reduce the size of system infrastructures and therefore the costs associated with resilient upgrades. This has already begun and will continue well into the foreseeable future.
- The existing combined sewer and storm system poses a substantial health risk with rising floodwaters, whether from sea level rise or from heavy rain events. The first phase of implementation will include separation of these systems and relocating them to allow the construction of the canal system.
- Most of the existing electrical and communications infrastructure in the Back Bay is in underground conduits and equipment vaults. As these systems require replacement over time, they will be raised and relocated to safer elevations.

Preservation of historic buildings and character. Historic buildings will need to withstand daily flooding through use of appropriate materials. Strategies for adaptive reuse during remodeling will have to be developed and integrated into municipal and state policy. Research and education on preservation will inform future strategies for resilience in historic buildings. The definition of value and the meaning of preservation for future flooding scenarios will need to be explored and expanded. The preservation of the historic character of the neighborhood will be realized through the development of new typographies for the built environment.



ABOVE Back Bay Canal/Street System. The Clarendon Canal shows a typical north/south canal alternating with streets. *Image credit: Arlen Stawasz*

Minimizing financial risk and loss. Financial tools to generate revenue for building resilience will need to be developed. This could be as much an opportunity for economic development as it is an expense. New tools and new sources will need to be explored for municipal, state, and federal revenues simultaneously with the redistribution of existing funds. Because plans take time to implement, preparing and investing in resiliency measures is urgently needed. If begun now, costs would be distributed over time. Projections of sea level rise that will significantly affect the Back Bay allow an investment time frame of 50 years to budget for changes to open space, buildings, streets, and infrastructure.

Development of new public policy and public/private partnerships. Zoning will need to be modified to allow for the relocation of building systems above specified flood levels, whenever permits are issued for open space, building, street, or infrastructure renovations. Support of Boston's efforts to rethink energy legislation, and support of the Green Ribbon Commission will be needed from Boston's real estate community, from owners, to developers, to property managers, and end users. Adaptive reuse of existing and historic structures will take on an entirely new meaning, as such rethinking will be required in order to maintain a connection to the past. Zoning incentives for building and infrastructure modifications that reflect effective, long-term climate resilience will be needed. The zoning and code relief may need to allow upward expansion to offset the loss of the lower-level uses and revenue. Integration and concurrent adaptation of public policy and building codes must be ensured to keep up with the realities of a changing tideline and increased storm recurrence.

Obstacles and Barriers

Uncertainty of extent and timing of sea level rise. NOAA's tide gauge in Boston Harbor indicates sea level has risen nearly a foot in the last century, and projections range from one to six feet by the end of the century, a very significant range, when the whole concept of designing for change is new.

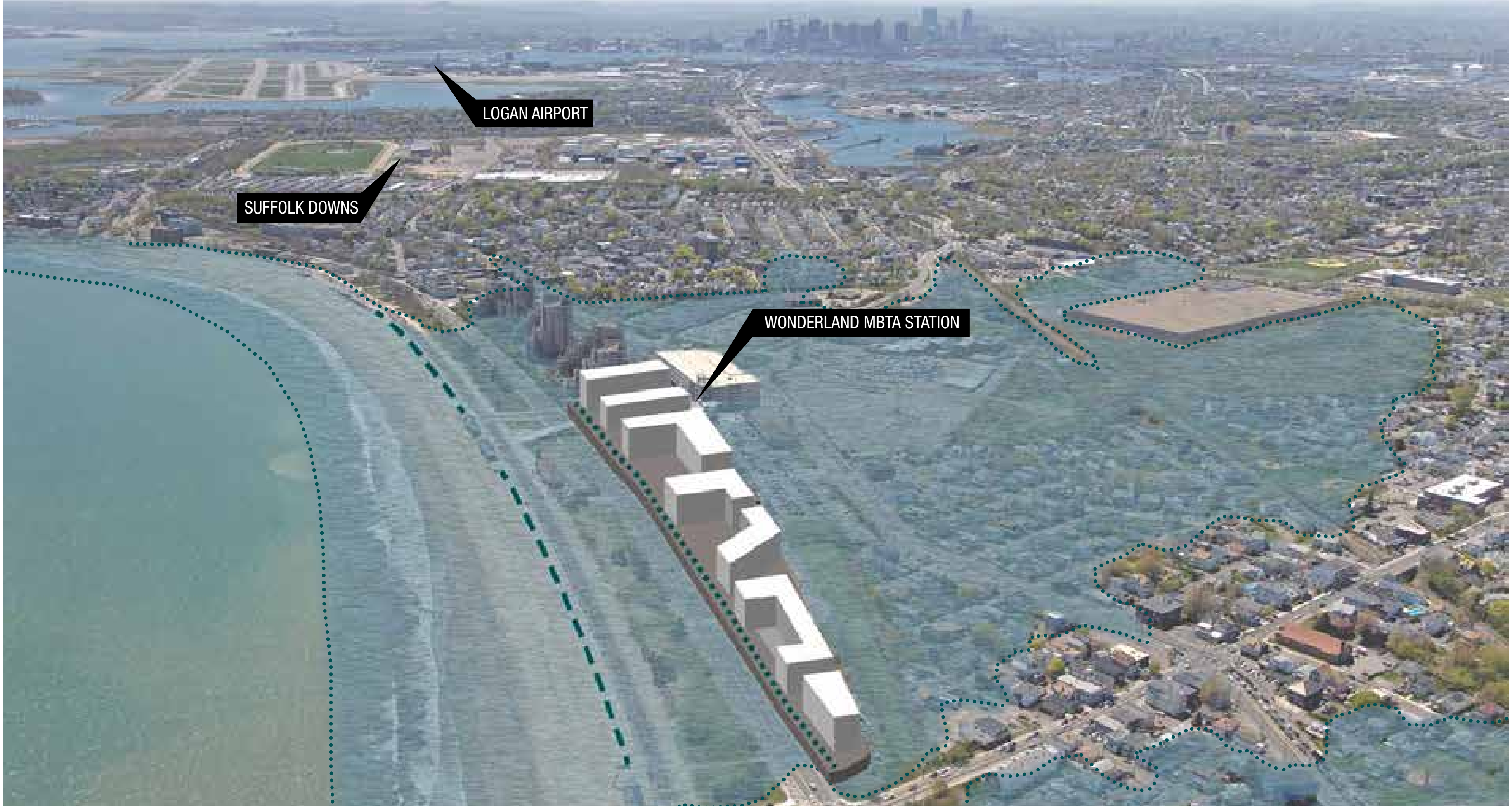
Property ownership. Property ownership in Boston's Back Bay is diverse, with thousands of individual stakeholders: owners, property managers, financiers, and inhabitants, each with a personal stake, and many with an institutional investment in the continued cultural, historic, and financial relevance of their real estate.

Interwoven ownerships and boundaries. Cities such as Boston are a complex mix of ownership among individual land owners, utilities, and jurisdictional boundaries, but water knows no bounds; so close collaboration among stakeholders will be needed to effectively prepare the community for the effects of sea level rise and climate change. A great need to address cultural, physical, and financial barriers and divergent stakeholder interests lies ahead.

Infrastructure investment. Separation of combined sewer and storm systems reflects a significant need for public investment as a first step in the development of resilient infrastructure. Additionally, implementation of strategies to create resilient electrical, gas, and water supplies is equally important in the provision of basic services to the resident and working population. Waterproofing of subway systems will require a diverse range of planning expertise to manage the safety of riders and crews in unexpected conditions, as well as the technical expertise to design and implement solutions. There is also a need to preserve values inherent to the built environment through investment in upgrades and adaptation of neighborhood transportation, utility infrastructure, historic and new buildings, and culturally significant places and open spaces.

Historic preservation. A roadmap is needed to develop a Cultural Resources Hazard Mitigation Plan for the Back Bay. It will be important for this plan to examine the impacts of climate resilience strategies on preservation restrictions and appropriate implementation strategies.

Investment as a first step in the development of resilient infrastructure. Additionally, implementation of strategies to create resilient electrical, gas, and water supplies is equally important in the provision of basic services to the resident and working population. Waterproofing of subway systems will require a diverse range of planning expertise to manage the safety of riders and crews in unexpected conditions, as well as the technical expertise to design and implement solutions. There is also a need to preserve and conserve values inherent to the built environment through investment in upgrades and adaptation of neighborhood transportation, utilities infrastructure, historic and new buildings, and culturally significant places and open spaces.



ABOVE Flood zone based on FEMA Flood Map for Revere Beach Boulevard (Zone AE: EL. 10 (NAVD 88)).
Image credit: Arrowstreet

OPPOSITE PAGE Proposed flood protection actions for Revere Beach Boulevard.
Image credit: Arrowstreet

REVERE BEACH

"The flood management systems that Revere Beach has relied on for years do not have the capacity to deal with more frequent and more intense storms."

A 10-acre site in the middle of a crescent-shaped beach just minutes from downtown Boston, Waterfront Square at Revere Beach is the last remaining large area of undeveloped property on the beach. Ironically, the site opportunity is a direct result of coastal flooding resulting from the Blizzard of '78, which destroyed a significant amount of property along the beach front, prompting the state and city to take the land to allow for more appropriate development and the creation of parkland.

STATISTICS

SITE AREA	10 acres
ELEV. RANGE (MHHW)	+1.0 – 3.0'

KEY CHALLENGES

- Costs of development vs. return for developers – creating viability for investment
- Impacts on adjacent established but vulnerable neighborhoods
- Existing inadequate infrastructure
- Creation of active pedestrian environment
- Multiple stakeholders (developers, MBTA, city, state)
- Transportation

KEY THEMES

- Economic sensitivity
- Minimize impacts
- Capitalize on public/private partnerships already fostered in the development of the area
- Utilization of the natural environment
- Flexibility for future adaptation

Engineered modifications to the beach have resulted in a more stable barrier to coastal flooding; however, the area is still directly impacted by inland flooding. A direct connection to subway and the city's desire for smart development has created a development opportunity for increased density which has the potential to transform the region.

Risk Profile

The area along Revere Beach faces risk related to both sea level rise and increased inland flooding from extreme weather events. Much of the site is in low-lying areas, directly adjacent to a man-made tributary utilized for area drainage. The "Eastern County Ditch" has historically connected low-lying areas to the Rumney Marsh for flood management but, with increasing storm intensity and volume, lacks sufficient capacity to adequately service the area. The Waterfront Square site in general is only 12 feet above current Mean High Water, and will increasingly rely on the beach and seawall as a barrier during coastal storm surges. Possible sea level rise of 2.5 feet or greater over the next 50 years directly impacts current development thinking related to the current site investment.

Key Strategies

Unlike the other, more urban, sites in the charrette, the Revere site is in a "gateway city" and more susceptible to market sensitivities. Development challenges and smaller development return opportunities have impacted site investment opportunities since the creation of the site in the late 1970s. For private development to be successful, construction and development costs must approximate the costs for other nearby non-impacted properties. The benefits and opportunities of the site (ocean views, transit access, proximity to downtown Boston) have recently been embraced by developers and investors; however, all of the strategies involved in building in resiliency must consider the potential dollars-and-cents impacts on the project. The city, state, and private developers all agree that a unique opportunity exists; however, the transformation from surface parking to vibrant, resilient community still requires economic sensitivity. Strategies outlined attempt to consider these realities.

Strategies to activate Ocean Avenue. The existing Ocean Avenue street grade, being lower than the existing berm adjacent to the beach, presents challenges and opportunities for building a relationship between the proposed development and the street. The City of Revere desires to activate Ocean Avenue with public uses for pedestrian enjoyment and access to Revere Beach from the development, the neighborhood, and nearby MBTA station. Past developments resolved the flooding issues by creating a separation at the sidewalk, which has resulted in an inactive streetscape that has stunted other development efforts. A flexible approach is required to address the varying conditions along the length of the long, linear site, much of which is located approximately four feet below FEMA flood elevations.

- **Raise the sidewalks and create a double sidewalk at Ocean Avenue.** Raising the sidewalk to an elevation above the floodplain allows for occupied/active uses at the new sidewalk. The transition between sidewalks could be landscaped to increase the permeability of the site.

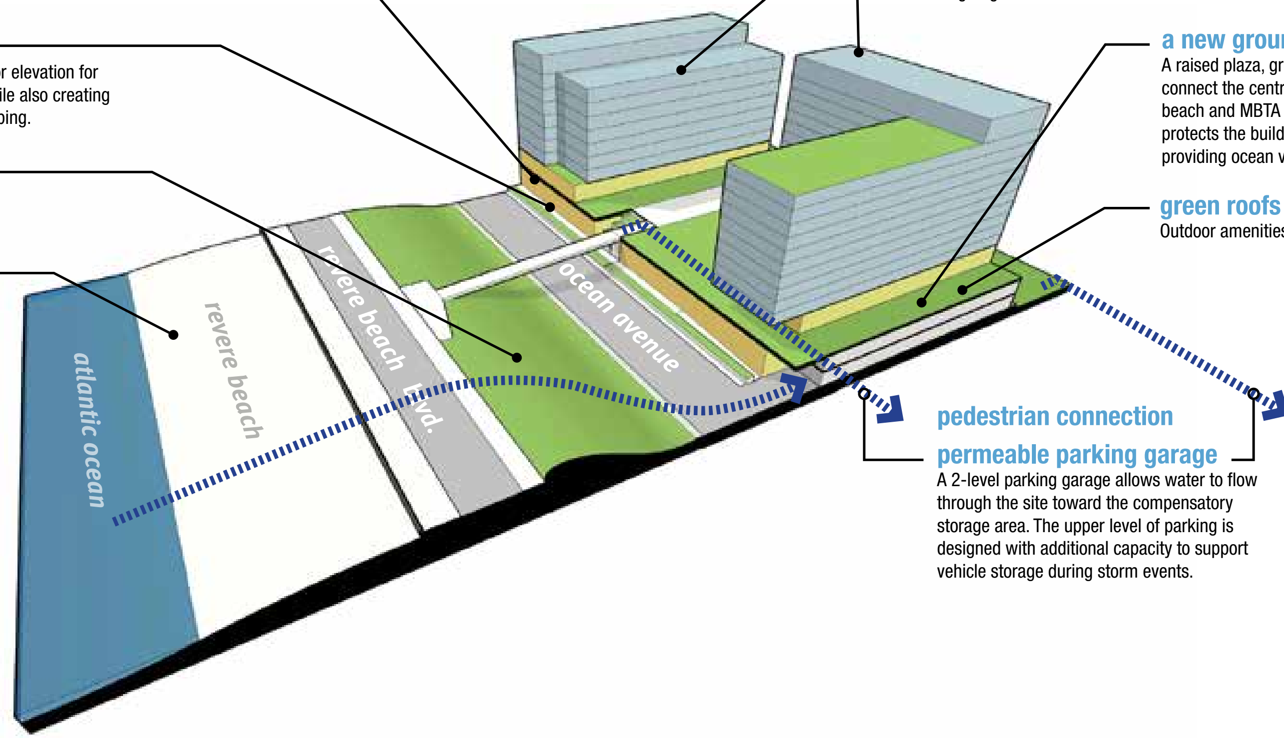
ABOVE Development section incorporating possible resilience features such as dune structures, landscaping, parking at lower floors, and the use of "pop-up" retail.
Image credit: Arrowstreet

- **Create seasonal "pop-up" retail** at street areas that cannot be raised due to site constraints or accessibility. Seasonal, non-critical uses could provide activity during peak summer site use, but be vacated easily during extreme weather and/or off-season.
- **Create a "new ground plane"** at the upper level above Ocean Avenue that is connected to Revere Beach with ocean views. Build a new plaza at the heart of the commercial portion of the development that is connected via pedestrian bridge to the beach.

Compensatory storage strategies. Any development within the floodplain requires compensatory storage (cubic feet of displaced flood storage requires equal amount of storage to be created somewhere within or offsite) to avoid negative impacts on surrounding neighborhoods. Without compensatory storage, flood waters currently "stored" onsite during periods of overburden on existing infrastructure would be diverted from the project site to surrounding neighborhoods, increasing impacts on existing buildings at the neighborhood scale. A strategy of minimized impacts along with improvements to the overall drainage approach to the area should be employed.

- **Minimize the footprint of construction** for new development. Make the majority of lower levels open parking structures at or slightly below the current site elevations. The open structure minimizes the impacts of displaced floodwaters.
- **Utilize and enhance flood storage capacity** in the existing drainage ditch. Re-grade and re-route the ditch to increase storage capacity. Remove invasive plant species currently in the ditch and replace them with new native plantings appropriate for the marsh/beach environment, to transform the drainage elements into a more attractive feature, enhancing the development. Improvements to the compensatory storage and drainage system have the potential for making positive impacts on low-lying adjacent neighborhoods.

Maintain the abilities for water to flow naturally. Avoid creating low areas that are below the surrounding properties that would trap water. Open parking structures at street grade allow the natural flow of water to be maintained.



ABOVE Waterfront Development Diagram showing resilient features that can also lead to development and emergency access enhancements.
Image credit: Arrowstreet

Consider adding other drainage connections from low-lying areas to Revere Beach. A channel cut from the drainage infrastructure could provide immediate outflow capacity to the ocean during peak periods. These strategies focus on adaptation and reducing future risk and vary in feasibility given the current environmental regulations.

Flood management and emergency access strategies. Flood management strategies should be addressed by both natural (landscape) and structured systems. A successful approach on this site should blend the environment with the man-made. Smart planning of the new buildings can protect and prepare the property for adaptation to future environmental changes without significantly increasing initial investment requirements. Through partnership with state and local government, modifications to the parkland can provide more resilient buffer zones that enhance the beach environment.

- **Create berms at adjacent parkland, temporary sea wall barriers, natural sandbar barriers, and bioswales** to buffer and minimize impacts of coastal flooding and storm intensity. Consider creating an elevated parkway that could act both as a dune and as an attraction for pedestrians and for retail in the area. There is potential to build on Revere Beach's designation as a National Historic Landmark for the benefit of both the development and the local neighborhood. This adaptive strategy is possible, but would likely need public investment, approval, support, and coordination with the development.

- **Design the upper parking level to structurally support excess car loads**, which would allow for the storage of vehicles that are moved from the lower to the upper level during flood events. These actions focus on addressing emergency preparedness and would require coordination between the developers, city, and local officials.

- **Ensure the continuous operation of mechanical/electrical systems** by locating them on the upper parking level, well above flood elevations. This strategy is a relatively straightforward adaptation, but may be more costly and require coordination with utility companies.

- **Implement an emergency evacuation plan** for residents and public safety officials to address site-specific concerns. Connect development phases at upper plaza levels to provide egress continuity to surrounding higher areas and include plans for community egress from lowest lying areas.

Additional potential strategies:

- In the future, as flooding events increase in frequency and elevation, the MBTA tracks will likely be impacted. The development, in coordination with local and state transportation officials, could **consider supplementing transportation options** in the event of track flooding with temporary busing or water taxis to connect with Boston and other areas.

- Consider strategies for **making power- and life-safety-related utilities more resilient and redundant**, such as elevating or flood proofing utilities, focusing on alternate energy sources (photovoltaic, wind, etc.), or using a microgrid. This may require changes to building and zoning codes, and a more flexible approach from public entities during review processes.

- **Engage insurance entities in a discussion** of how insurance availability and rates may be affected by resiliency improvements. Urban resiliency is clearly an imperative of the insurance industry as it reduces losses, promotes the maintenance of insurability, and presents opportunities for innovative risk transfer and insurance solutions to help manage climate risk. By building public/private partnerships, city leadership, and the insurance sector have the power to lead in building urban resiliency and protect the people and property within. Efforts to build climate resilience in cities have historically been led by public policy and planning approaches. However, the pace and scale of investment and behavior change required to ensure cities are prepared for future risks mean that the private sector has a crucial and catalytic role to play. Insurers, working with other partners, can use their strategic view of societal risk management to propel our thinking forward and focus us on what needs to be done to head off these risks.

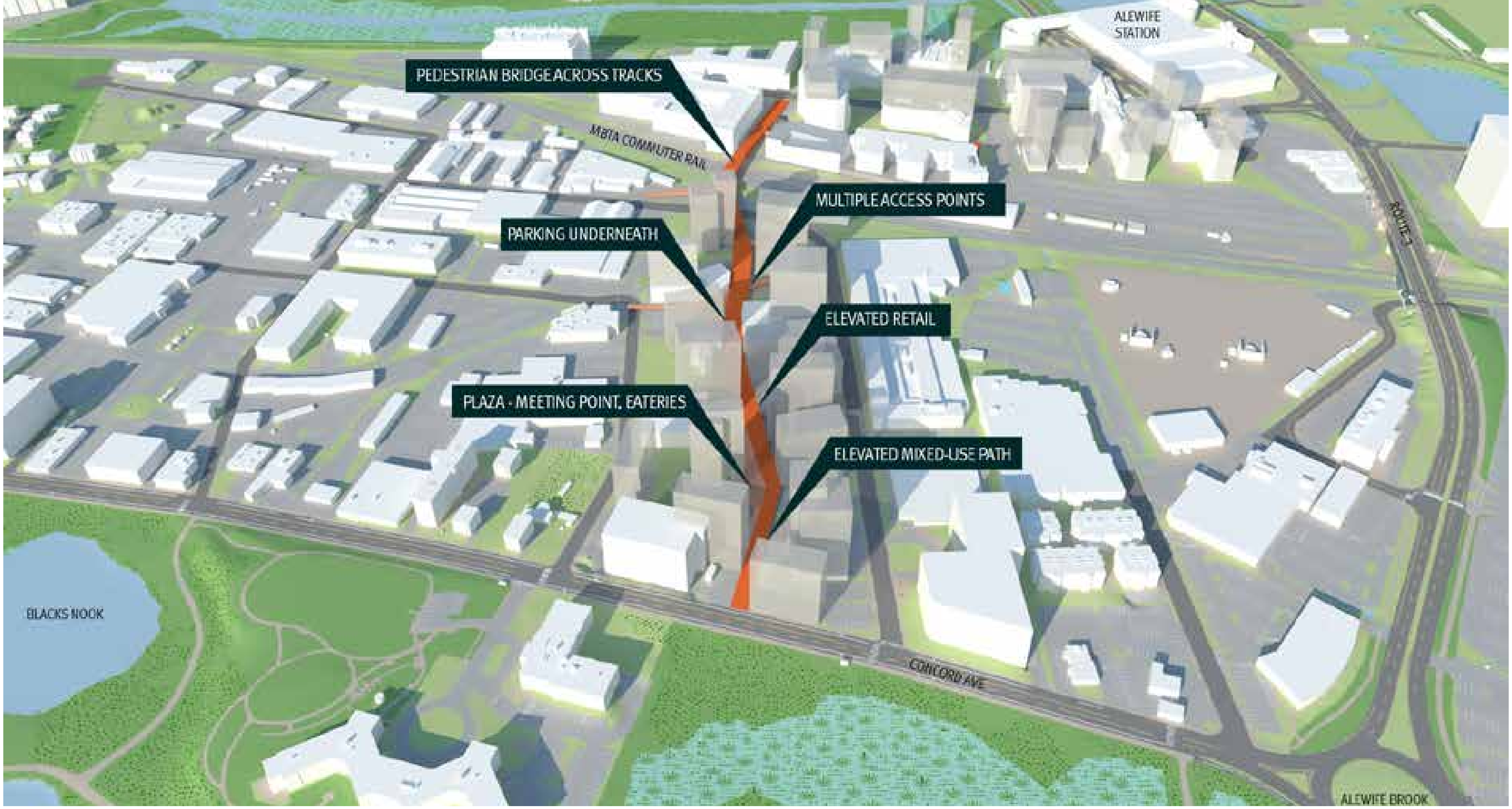
Obstacles and Barriers

Integrating the city's needs into the development and vice versa. Revere Beach is a National Historic Landmark and an integral part of the city. How can this attraction be enhanced while at the same time making both the new development and existing neighborhoods more resilient in the future? The success of both the development and neighborhoods are linked, but how can it be achieved by both?

Some key steps to making both succeed may involve coordination of key stakeholders (neighbors, developers, city, conservationists, state and federal agencies, insurance agencies) and an honest, long-term assessment of the area's functional components. What functions can be maintained and what may require significant overhaul? What is each party willing to contribute to the future success?

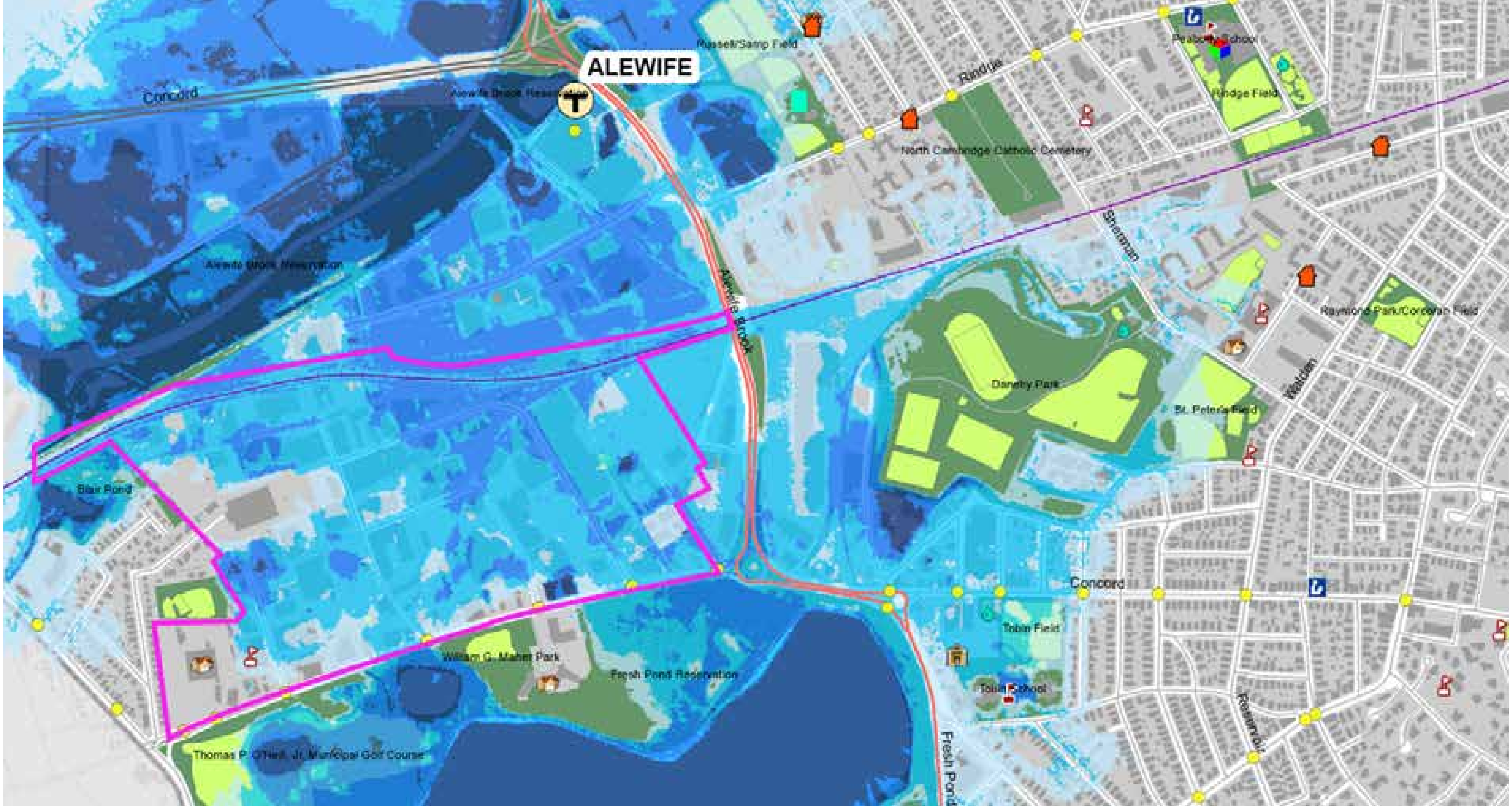
Transportation coordination. Revere Beach has a unique advantage given its location adjacent to the Wonderland MBTA station. However, several future developments may have impacts on the area's transportation needs. Sea level rise may impact continuity of train service and bus connections in the future. Given other potential developments in the area, what are some adaptations or supplemental transportation services that could be considered to address both sea level rise and ridership demand?

One approach to diversify transportation alternatives might be to consider ferry services to Revere Beach and add/increase pedestrian-friendly modes of transportation such as intercity cycling paths. After Hurricane Sandy hit New York City, one of the preferred methods of accessing the city was through the use of bicycles – a relatively resilient method of transport.



ABOVE Proposed conditions at Alewife Quadrangle, illustrating the raised commercial corridor connecting the Quadrangle to the Alewife MBTA Station.
Image credit: Arrowstreet
Base model was created using planimetric and terrain created by InfoTech and 3D building data created by CyberCities3D. Both based on 2009 aerial photography. All data are courtesy of City of Cambridge GIS. Model prepared by Paul B. Cote Geographic Information Services www.pbcgis.com Cultivating Spatial Intelligence.

OPPOSITE PAGE The map depicts flooding that could result from a worst-case Category 2 hurricane according the U.S. Army Corps of Engineers based on the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model, but without future sea level rise. The City of Cambridge is assessing the flood risks with the Advanced Circulation (ADCIRC) model, which is a dynamic and high resolution tool that will take into account the operations of the Amelia Earhart Dam on the Mystic River and sea level rise. Results from the ADCIRC analysis may differ from the SLOSH model.
Image credit: U.S. Army Corps of Engineers, Kleinfelder



ALEWIFE QUADRANGLE

"Depending on the degree to which the brook backs up and if it is accompanied by a high runoff event, the Alewife area could face major flooding."

The Alewife Quadrangle is a 130-acre area in the western part of Cambridge that historically has been the location of low-rise, light industrial, and commercial activities. Following the 2006 Concord-Alewife Planning Study and subsequent rezoning, the area has started to see new housing developments, but there is significant potential for additional new development and redevelopment. While most of the Quadrangle area is currently in the 500-year floodplain, the prospect of more frequent episodes

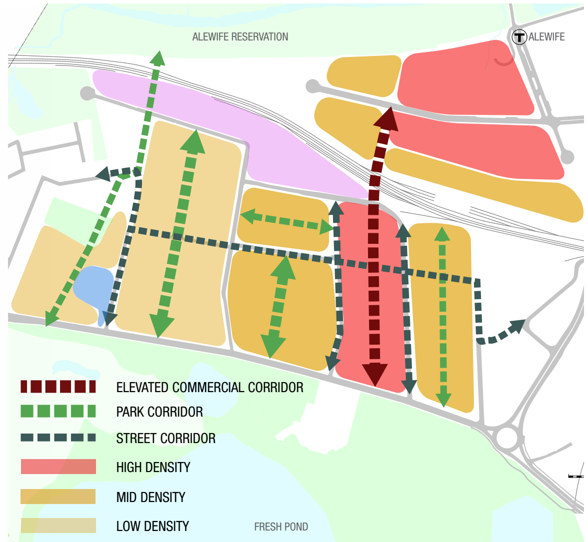
ABOVE This image is a representative view of the quadrangle and shows Fawcett Street as it exists today. The projected flood elevation illustrates the potential impact of climate change on the current street realm and building vulnerability.
Image credit: Activitas, Hanaa Rohman, City of Cambridge

OPPOSITE PAGE (LEFT) Watershed diagram.
Image credit: Mystic River Watershed Association

OPPOSITE PAGE (RIGHT) This diagram illustrates the planning concept for future development in the Alewife Quadrangle. Successful development in this area will depend on appropriate density and scale. The key corridor concepts are diagrammed to illustrate potential opportunities for implementation and successful synergies with development density.
Image credit: Ager Group The Boston Studio

of intense precipitation and the possibility of Alewife Brook backup up from storm surges affecting the Mystic River presents challenges. Yet there is much value to the community to have an area for the types of uses that have recently located there.

The key question for this session of the "The Urban Implications of Living with Water" charrette was: If the Concord-Alewife Plan were to be issued today with more frequent flooding patterns and tidal influences factored in, how might Cambridge approach planning the Quadrangle area in terms of zoning, urban design guidelines, and non-regulatory or behavioral change methods?



Risk Profile

The Alewife Quadrangle area faces different flooding risks than the three other charrette sites, which all face more direct risks from coastal storm surges. The Quadrangle is contiguous to the Alewife Brook system which is a tributary to the Mystic River. A coastal storm surge that breaches or flanks the Amelia Earhart Dam on the Mystic River would likely cause Alewife Brook to back up. As sea level rises, the probabilities will shift upwards. Depending on the degree to which the brook backs up and if it is accompanied by a storm with high runoff, the Alewife area could face major flooding.

The image on page 37, from the U.S. Army Corps of Engineers, shows flooding that might result from a worst-case hurricane event — a “perfect storm” — where the variables including tide, storm direction, and surge align in a very low probability event to cause major flooding. However, the Corps’ analysis is based on current sea levels and does not take future sea level rise into account. The City of Cambridge is currently engaged in a comprehensive analysis of flooding risks across the city, including the Alewife area, to better understand how flooding might occur from episodes of intense precipitation alone and coupled with storm surges under future climate conditions. Over the next century, the risk faced by the Alewife area is probably one of periodic floods and not permanent inundation.

While the potential floods may be of limited duration following the storm event, they will bring other challenges in addition to water. The receding waters will leave behind trash, debris, and biological and chemical pollutants that will require cleanup.

STATISTICS

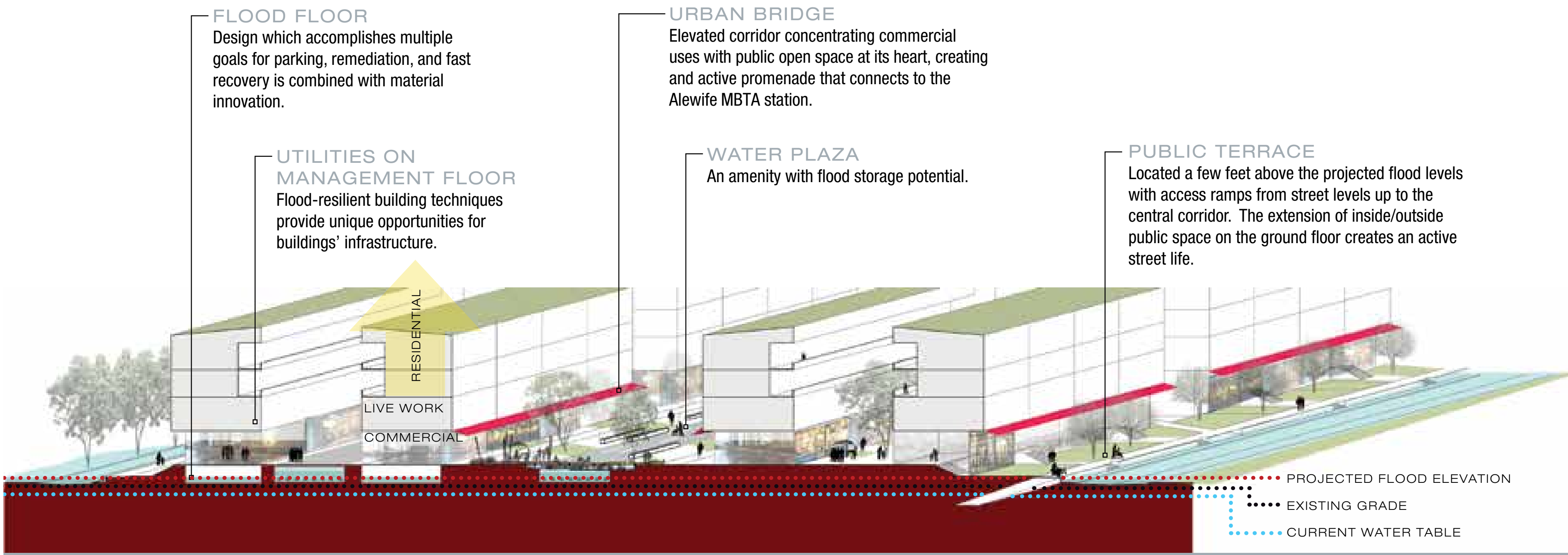
SITE AREA	130 acres
ELEV. RANGE (Mystic MHHW)	+3.0 – 4.0'

KEY CHALLENGES

- Limited ability to store/infiltrate/redirect flood water
- Cost of adaptation
- Existing regulatory frameworks developed without climate change
- Limited ability to coordinate development
- Uncertainty about climate change impacts
- Multiplicity of stakeholders
- Maintaining street-level activities
- Vulnerability of supporting infrastructure
- Transportation connectivity

KEY THEMES

- Street realm and buildings can be adapted
- Timing of climate change impacts allows phasing
- Integrated public/private policy and partnerships
- Stakeholder engagement



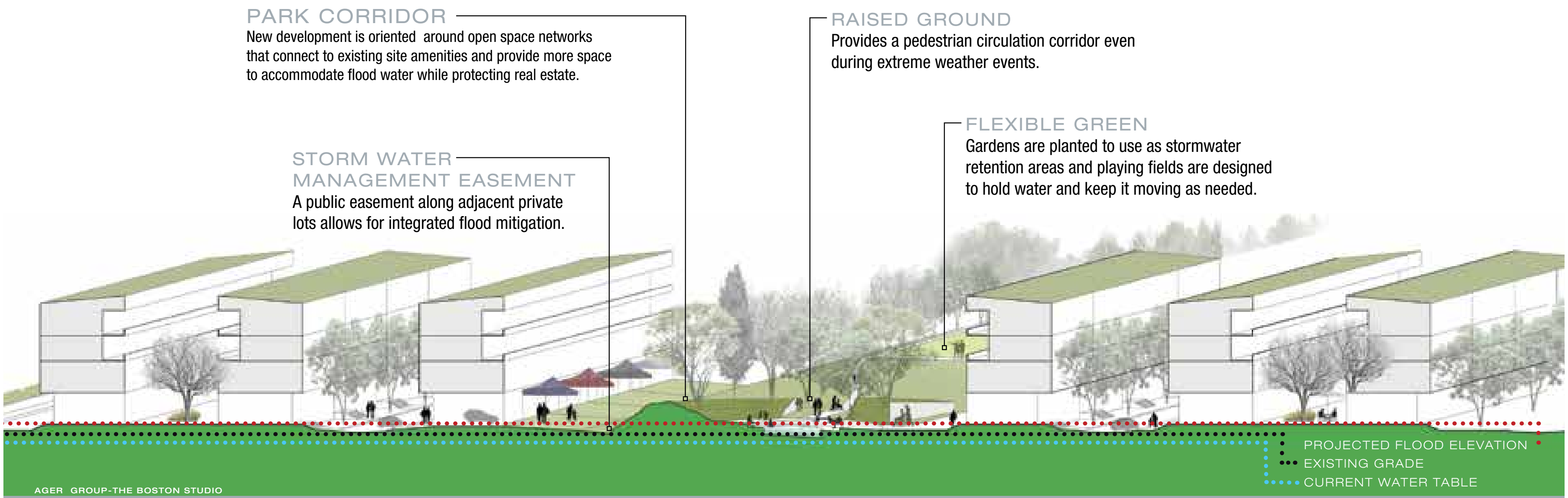
^ ELEVATED COMMERCIAL CORRIDOR

ABOVE The Elevated Commercial Corridor section depicts an infrastructure strategy that constructs an activated pedestrian route that increases in elevation to ultimately bridge across the MBTA commuter rail lines.
Image credit: Ager Group The Boston Studio

Key Strategies

Redistribute land uses to accommodate flooding. Through zoning, the City of Cambridge could redistribute development density and uses to facilitate concentration of key land uses, allow taller building heights, and create more contiguous open areas as amenities and flood storage. More open space would also provide additional areas to plant trees to use as a flood mitigation measure and to accommodate stormwater management features such as canals, swales, and ponds.

Concentrate and elevate key land uses. A goal of the City of Cambridge is to create areas with active street life, which usually involves street-level retail uses. Because it is difficult for brick-and-mortar retail establishments, such as restaurants or stores, to allow periodic flooding, a remaining strategy that maintains active street life could involve elevating the area above the flood level. Since for practical reasons the entire Quadrangle cannot be entirely filled, this strategy involves creating a central raised corridor for retail uses. For example, there are current plans to build a bridge over the adjacent commuter rail tracks to create a pedestrian connection from the Quadrangle to the Alewife subway station and a future commuter rail station. The raised corridor could be aligned with the bridge, creating a pedestrian friendly retail streetscape that becomes the heart of the emerging district. Shops, restaurants, and other commercial



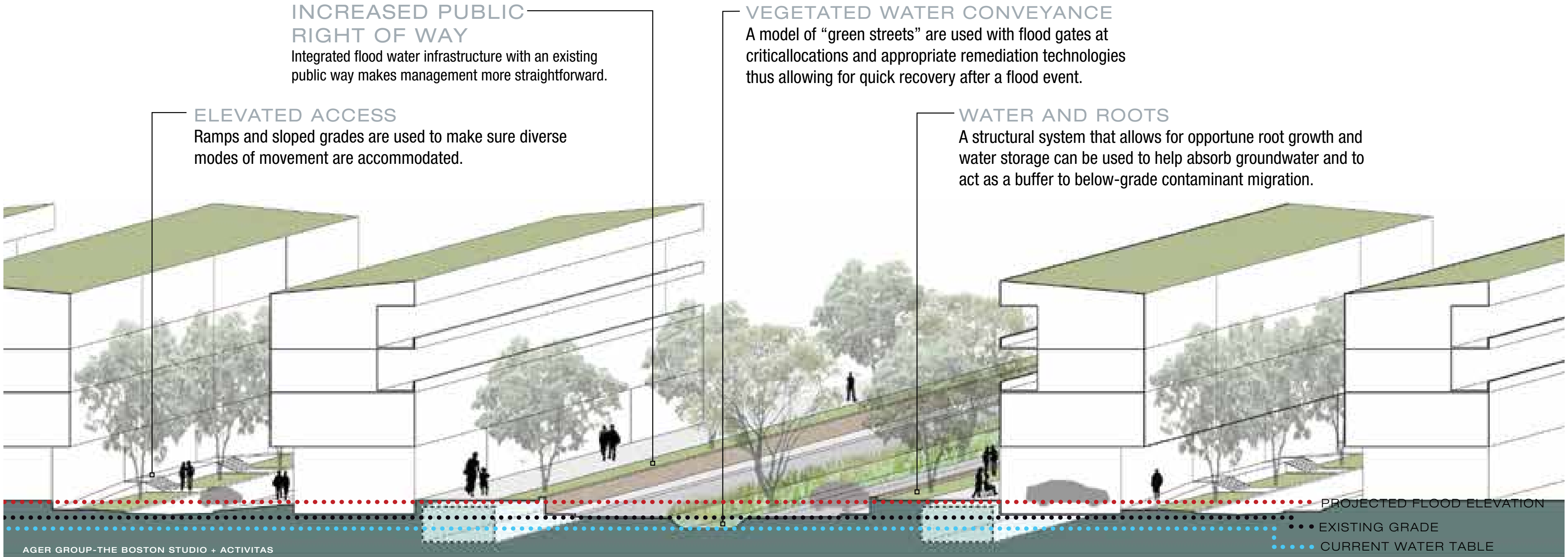
^ PARK CORRIDOR

ABOVE The Park Corridor section stems from the notion that a linear green space network will be a much more effective tool during storm events than a network of isolated open spaces. The park corridor would provide flexible greens that can accommodate a variety of public use and be effective stormwater management tools when needed.
Image credit: Ager Group The Boston Studio

activities along the raised corridor would enhance the pedestrian experience while creating a resilient connection between the district and the MBTA subway station. The use of the raised corridor could be coordinated with other resilience and land use strategies, such as garages or other flood-resilient ground-floor activities, allowing easy-to-recover uses at ground level, and providing adjoining open space as both an amenity and a flood storage strategy.

Utilize flood-resilient building techniques and materials. Some land uses, such as residential buildings, could be constructed in a manner that allows the ground level or sub-levels to flood periodically. Materials that are resistant to mold and that can be easily cleaned after a flood recedes (e.g., tile, sealed concrete) would enable a rapid return to normal activities. Underground parking garages could double as flood storage tanks, with adequate contingency plans to relocate vehicles in advance of an event.

New development can drive increased resilience. Since the majority of the Alewife Quadrangle remains available for redevelopment, it is possible to harness new development to make most of the building stock more resilient and to pay for improvements in resiliency. With changes in zoning, development can be redistributed to concentrate and protect key uses such as ground-level retail, and provide more space to accommodate floodwater and public easements for stormwater management.



^ STREET CORRIDOR

ABOVE The section depicts a coordinated street realm strategy for medium-density development. The main physical strategy is to create an elevated barrier free pedestrian network above the projected flood elevation. Increasing the public right of way would enhance the experience of the tiered spaces as well as provide an opportunity for a vegetated water conveyance zone.
Image credit: Activitas, Ager Group The Boston Studio

Take advantage of the incremental increase of flood risks. It is likely there is time to plan for and implement a strategy to make the Alewife Quadrangle climate-resilient. The exact timing of the increases in flood risk is not possible to predict, but trends are understood sufficiently to provide tentative planning horizons that can be modified based on monitoring of environmental conditions. It may be possible to schedule improvements to infrastructure and buildings based on their normal replacement periods and to use normal development cycles to implement resiliency strategies.

Coordinate infrastructure improvements to increase resiliency. Buildings are not islands. The occupants of the buildings rely on public and private infrastructure and services to be operable. While the City of Cambridge has certain authorities to manage development, the resulting buildings will still be vulnerable if energy systems, transportation, and emergency services are not also made resilient. Public/private partnerships will be key to ensuring that parallel improvements for resiliency are made to critical systems, such as creating open-space networks with adjacent storm-water management easements and increased street right-of-ways that provide public open space while doubling as flood mitigation infrastructure.

Obstacles and Barriers

Watershed is largely upstream of site and infiltration capacity is limited. The watershed that contributes to stream flows and floods in the Alewife area is largely upstream of Cambridge. This fact plus the high water table and low infiltration capacity of the soils in the Quadrangle severely limit the ability to store and infiltrate flood waters onsite.

Lack of climate-informed standards and criteria. Designers and developers need criteria on which to base building designs. Historically, the flood insurance rate maps, which are based on historical events and assume static conditions, have been used to guide designs; but climate change introduces uncertainty and dynamic conditions. FEMA is presently in the process of reviewing and updating all Flood Insurance Rate Maps (FIRMs) for coastal areas of the U.S., however the proposed FEMA maps still do not accurately represent flood risks for specific sites. Government and the insurance industry will need to provide integrated guidance and may also need to reconsider the return period (i.e., recurrence interval) that is appropriate, given that flood risks will increase discernibly over the life of a building. It may be prudent to design a building so that it is protected for a lower probability flood than currently required, given that it will become more likely in the future.

Today's regulations are not designed for climate change. Regulations such as those under federal and state wetlands and floodplain laws are based on historical flood occurrences and do not take into account the changing climate and the incremental increase in risks. Some areas that are presently outside regulated floodplains will fall within regulated zones in the future. Building code requirements are also not designed to protect buildings that are not currently in regulated flood zones and do not take into account increased frequency of flooding. Some zoning requirements, such as height limitations, may constrain the ability of buildings to adapt to changing conditions. Accessibility requirements under the Americans with Disabilities Act may be a challenge on sites where building entrances need to be raised from street level for resiliency reasons, so methods to ensure accessibility will need to be developed.

Cost of retrofits. While standards and codes can be used to encourage resilient building design for new construction, existing buildings will need to be retrofitted or repurposed for resiliency, such as raising floor levels or relocating key building systems above grade. Unfortunately, such retrofitting can be far more costly than integrating desired features into new construction. Building owners would need to plan for these investments or risk unplanned expenses to rebuild after a flood event. A longer planning horizon can alleviate this burden to a degree; however, providing financing options that encourage building owners to move forward with resiliency investments is a better approach.

Multiplicity of stakeholders. In an area like the Alewife Quadrangle, there are many disparate property owners who must be guided toward individual decisions to pursue redevelopment with resilient designs for new construction and retrofit of existing buildings. There are also private and public infrastructure owners, such as utilities and transportation agencies, which the municipal government has virtually no control over. In addition, the professional design community is not trained to deal with long-term and dynamic changes such as those posed by climate change. The challenge is to find a way to bring some order to the disparate interests to forge coordinated action, and strong leadership will be needed to unite the different parties toward a cohesive vision.

WHERE DO WE GO FROM HERE?

"The realities of climate change and associated sea level rise and natural hazards have become increasingly clear, and the city and private sector need to make sure that our current and future buildings and infrastructure are prepared."

— Brian Swett, CHIEF OF ENVIRONMENT AND ENERGY, CITY OF BOSTON[9]

The Economic Perspective

In August 2013, the World Bank commissioned a report entitled *Future Flood Losses in Major Coastal Cities* and evaluated 136 of the largest coastal cities in the world. This study predicted that global flood losses could exceed more than $1 trillion per year by 2050 without investment in resiliency measures. Of the 136 cities studied, Boston was ranked as the eighth most vulnerable city in the world in terms of overall cost of damage.[10] Clearly, an integrated plan is needed to reduce our future exposure.

Mayor Walsh and Governor Patrick, recognizing this need, have taken leadership roles to drive responsible development. Through modifications to the Article 80 process and the pursuit of a local wetlands ordinance for vulnerable property, the City of Boston is moving towards action. Though certain portions of Boston's private economic sector have begun to follow suit, it is difficult to envision such a widespread and interlinked issue moving towards full resolution without actions of the remainder of private enterprise. With an estimated $360 billion in projected 2014 GDP for the greater

Boston-Cambridge-Quincy areas[11], the power of private enterprise vastly outshines that which any locality or municipality can afford. We must consider not only the economic cost of extreme disruption at our regional and international business links such as Logan Airport and along the Boston Harbor Port economy, but also widespread property damage due to more frequent and damaging floodwaters. Though our city and state leadership have begun the conversation, it is time for the drivers of the economy to continue the pursuit. Assigning just one-thousandth of a percent of expected GDP, or 0.001%, could give $3.6 million in resiliency efforts and infrastructure investment annually.

New Paradigms for Development. Until we began to understand the magnitude of the challenge presented by climate change on our built environment, we were comfortable designing to static standards based on historical experience. Now development and design strategies need to be flexible and adaptable for an ever-changing condition, with uncertain impacts and time frames that fall within the life cycle of our current assets and communities.

Our challenge as a community is to create new paradigms for responsible development that consider bigger questions that we traditionally have not considered:

- Is this building worth saving? What is the cost of retreat? Can it fail safely?
- Are there efficiencies in regional protection? Can we afford to wait for the answer?
- What other initiatives will suffer at the expense of sea level rise adaptation?
- How do we prioritize improvements? What is more important? Less?
- What uses are acceptable in flood-prone areas? What materials are better? Worse?
- How can we modify our organizational models to create a coordinated effort for building resilient communities?

The Standard of Care is Evolving. Climate change is now an anticipated risk that we all need to design responsibly for. The rules are changing, codes are changing; and designing to meet the minimum code requirements is not enough. Our FEMA maps are based on data from past events that do not take into account sea level rise and increased frequency of flooding. The maps ignore the complexities of debris-filled water, surrounding watersheds, and changes to these watersheds; yet they are still relied on to determine base flood elevations for our buildings. In the absence of clear design standards, architects and engineers need to be able to make a professional judgment about what design flood elevations should be and evaluate these elevations in conjunction with other strategies of managing water. Cities and utility companies need to invest in infrastructure upgrades and increase storm system capacities or risk being sued.[12] Developers need to look beyond their typical development costs and evaluate how changing insurance premiums and increased flood risk over a much shorter time frame might influence the resiliency strategies they build into developments. And we all need to work together to develop the robust public/private partnerships, public policy changes, and strong governmental leadership that will ultimately result in more resilient communities and the region.

APPENDIX

[1] Multihazard Mitigation Council, Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities (Washington, DC: National Institute of Building Sciences, 2005), http://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/MMC/hms_vol1.pdf

[2] Hurricane Sandy was the 18th named tropical cyclone of the 2012 Atlantic hurricane season (June 1-November 30). Sandy formed in the central Caribbean on October 22 and intensified into a hurricane as it tracked north across Jamaica, eastern Cuba, and the Bahamas. Sandy moved northeast of the United States until turning west toward the mid-Atlantic coast on October 28. Sandy transitioned into a post-tropical cyclone just prior to moving onshore near Atlantic City, NJ. http://www.weather.gov/okx/HurricaneSandy

[3] Robert Repetto and Robert Easton, "Changing Climate, More Damaging Weather," *Issues in Sciences and Technology* (Winter 2010), http://issues.org/26-2/repetto-2/

[4] The rebound after ice from the last Glacial Maximum melted is still occurring in the Northeast region, causing the landmass to slowly subside, or sink.

[5] U.S. Government Accountability Office, "National Flood Insurance Program," *High-Risk Series: An Update* (Washington, DC: February 2013), http://www.gao.gov/highrisk/national_flood_insurance/why_did_study

[6] U.S. Government Accountability Office, "National Flood Insurance Program: Continued Attention Needed to Address Challenges" (Washington, DC: September 18, 2013), http://www.gao.gov/products/GAO-13-858T

[7] National Climate Assessment, http://nca2014.globalchange.gov/report/our-changing-climate/sea-level-rise

[8] Nancy D. Israel, *Inaction on Climate Change: The Cost to Taxpayers* (Boston, Massachusetts: Ceres, October 2013), http://www.ceres.org/resources/reports/inaction-on-climate-change-the-cost-to-taxpayers

[9] City of Boston Mayor's Office, "Mayor Menino Announces Comprehensive Actions to Better Prepare Boston for Storms like Sandy" (Boston, Massachusetts: February 5, 2013) http://www.cityofboston.gov/news/default.aspx?id=5959

[10] The World Bank, "Which Coastal Cities Are at Highest Risk of Damaging Floods? New Study Crunches the Numbers" (Washington, DC: August 19, 2013), http://www.worldbank.org/en/news/feature/2013/08/19/coastal-cities-at-highest-risk-floods

[11] The United States Conference of Mayors, *U.S. Metro Economies* (Washington, DC: IHS Global Insight, November 2013), http://www.usmayors.org/metroeconomies/2013/201311-report.pdf

[12] "Climate change: Get ready or get sued," *Washington Post*, May 19, 2014. In May 2014, Farmers Insurance Co. sued Chicago area municipalities and alleged that they knew their storm systems were undersized and failed to take reasonable action to prevent flooding, sewer overflows, and storm damage. The insurance companies also charged that the municipalities did not take the appropriate preventative measures in the days before the storm to minimize flooding. http://www.washingtonpost.com/news/morning-mix/wp/2014/05/19/climate-change-get-ready-or-get-sued/

For consistency with the previously published documents on sea level rise in Boston, and as a more intuitive measure, this report uses Mean Higher High Water (MHHW) as the primary reference elevation. Though MHHW varies from location to location, the relationship between the elevation of the site and the bordering water elevation is an important relationship to consider. We also use MHHW in describing more general future predictions. In addition, because available data references for landside elevations are typically presented using the North American Vertical Datum of 1988 (NAVD88), which is a more precise and the generally accepted vertical reference elevation (datum), this reference was also used throughout the report.

MHHW (Mean Higher High Water): The average level of the higher high water of each tidal day over the course of a 19-year reference period (the National Tidal Datum Epoch) based on available NOAA data. For all four sites in this report, NOAA's Boston Tide Gauge is used for the MHHW, as it is the best information available at this time.

NAVD 88 (North American Vertical Datum of 1988): A fixed vertical reference elevation. In 2012, Boston's Mean Higher High Water elevation is 4.8 feet relative to NAVD (4.8 ft. NAVD)

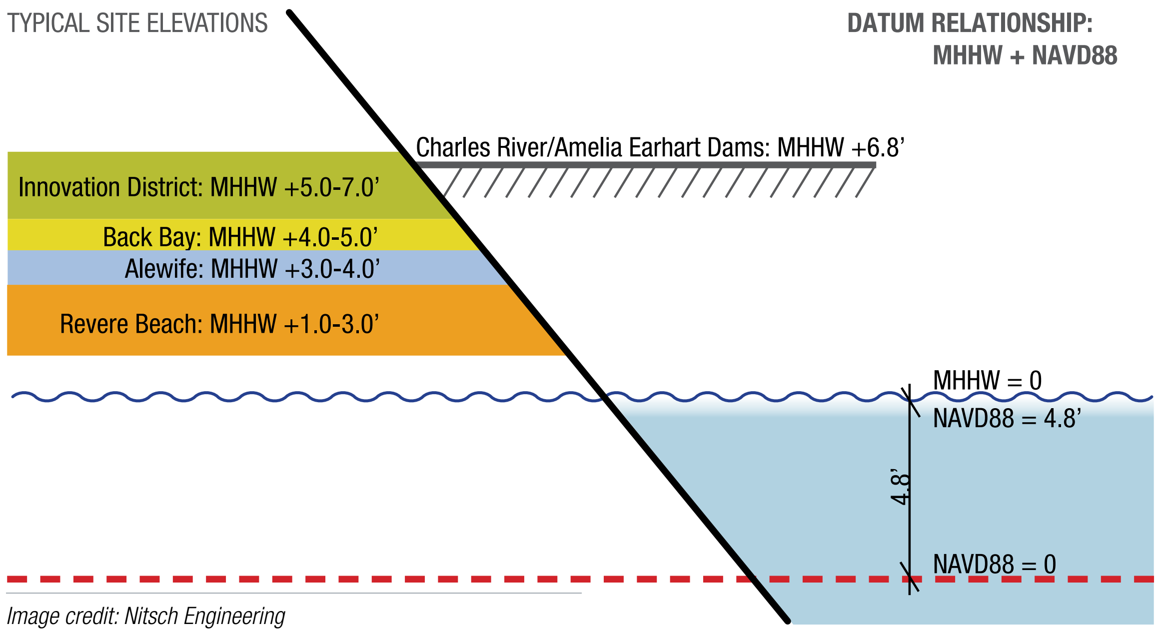


Image credit: Nitsch Engineering

RESOURCES

Preparing for the Rising Tide, The Boston Harbor Association, *After Sandy: Advancing Strategies for Long-Term Resilience and Adaptability*, Urban Land Institute, *Building Resilience in Boston*, Linnean Solutions, *The Built Environment Coalition and the Resilient Design Institute* (Green Ribbon Commission representing commercial and nonprofit interests)

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