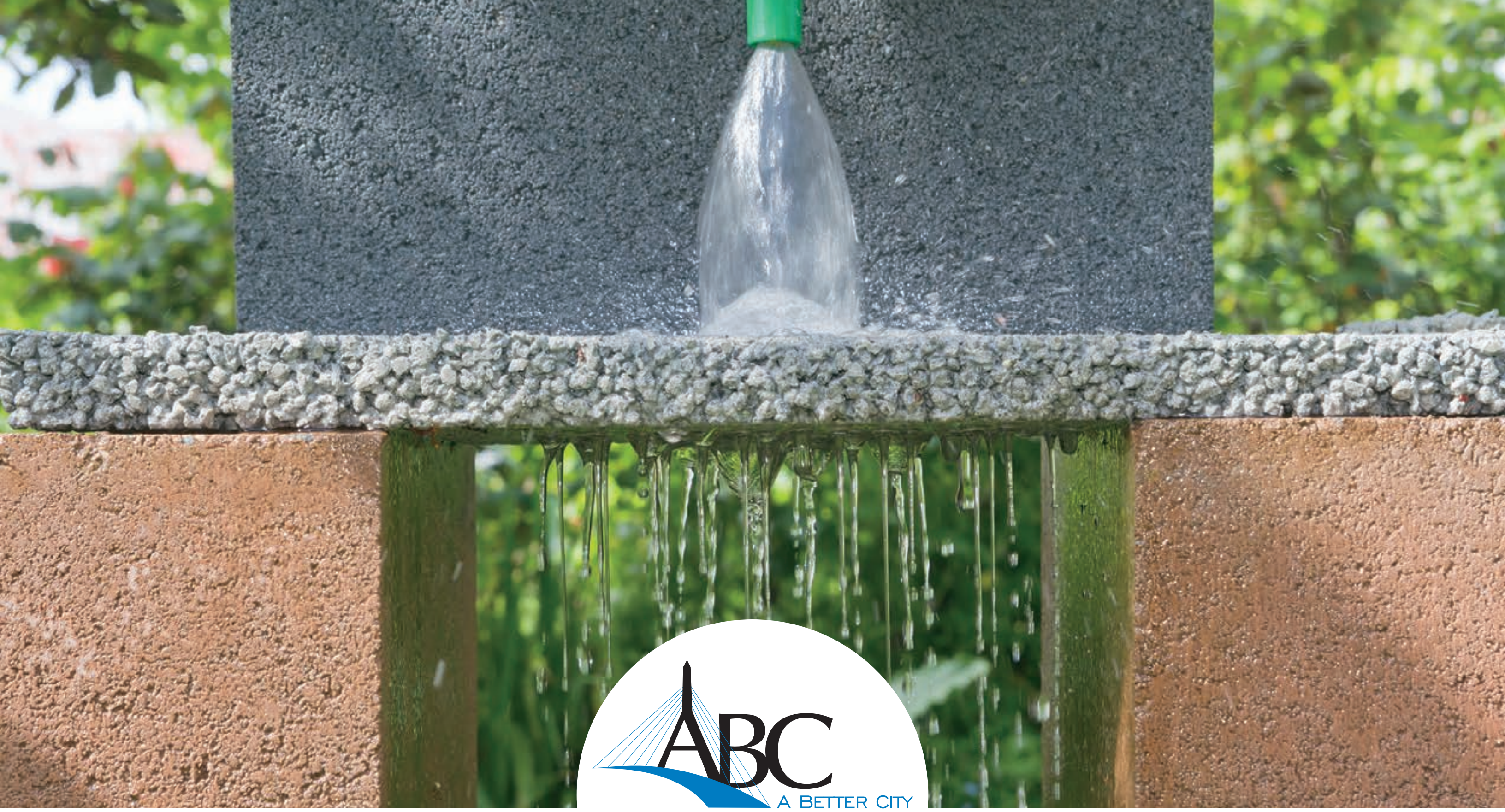

ABC
A BETTER CITY

Enhancing Resilience in Boston

A Guide for Large Buildings and Institutions

FEBRUARY 2015

Acknowledgements

A Better City (ABC) would like to thank the Barr Foundation, whose generous funding support helped to make this research possible.

ABC extends a thank you to David Lander (ABC intern) for his research and Vanessa Bighinatti (ABC intern) for her GIS support.

We would also like to thank Carl Spector and Bryan Glascock of the City of Boston for their insights, and the resilience technology providers for speaking with us.

A Better City improves the economic competitiveness and quality of life of the Boston region by advancing and providing leadership on significant transportation, land development, and environmental policies, projects, and initiatives related to the business and institutional community.

The Boston Green Ribbon Commission is a group of business, institutional and civic leaders in Boston working to develop shared strategies for fighting climate change in coordination with the city's Climate Action Plan.

ABC's Challenge for Sustainability engages Boston's commercial real estate sector and businesses to adopt best practices in sustainability and energy efficiency through a platform of benchmarking and a peer support network to reduce their carbon footprint.

For additional copies of this report please visit ABC's website at: *www.abettercity.org/about/publications.html*.

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(Bottom, clockwise from upper left)
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Contents

Written by

- Kathryn Wright
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Meister Consultants Group, Inc., on behalf of the Boston Green Ribbon Commission's Commercial Real Estate Working Group

Summary

Climate projections for Boston indicate that the City will experience rising temperatures, increased storm intensity and higher sea-levels. Boston's built infrastructure is at risk from these climate stressors, but there are a series of technologies currently available to help asset owners increase the adaptability of both existing and new buildings. This report and its associated online toolkit provide building owners with information on 32 available resilience actions and technologies. It also provides a preliminary assessment of potential regulatory touch points within the City and state for resilience actions and considers initial ideas for district-level resilience strategies for the Boston area. The private-sector can continue to be engaged on this topic through ongoing work by the City of Boston and the Boston Green Ribbon Commission in 2015 and beyond.

"There is no issue more urgent than climate action. When we work together, the steps we take do more than protect us: they can bring us closer together, they can create good jobs, they can improve our health, our public space, and our civic life."

— Mayor Martin J. Walsh

NOVEMBER 2014

Introduction

Photo: © User Rs1421 Wikimedia Commons

The City of Boston is vulnerable to a number of climate change impacts, including sea level rise, increased frequency of extreme storms, and a heightened urban heat island effect. Just missing severe damage from Hurricane Sandy in 2012, and consecutive summers of near record-breaking heat waves reminded residents that Boston is a coastal city with vulnerable building stock and infrastructure. Local vulnerability studies, analyses, and presentations from the City of Boston and external organizations have emphasized and reinforced the importance of integrating resilience into development decisions and planning.

A Better City (ABC) was recently tasked by the Boston Green Ribbon Commission's (GRC) Climate Preparedness Working Group to further study resilience options for private-sector buildings. This report builds on a previous GRC-commissioned study *Building Resilience in Boston* and illustrates the climate-related risk potential for commercial buildings, and presents available technologies and solutions for retrofits and new construction. These tools are grouped for buildings inside and outside projected floodplains. A database of 32 technologies and products available to building owners, including their costs, suppliers, and applications for addressing storm water management, flood-proofing, sea level rise, and the urban heat island effect is provided in the third section of this report and will be continually added to as new technologies and products are developed.

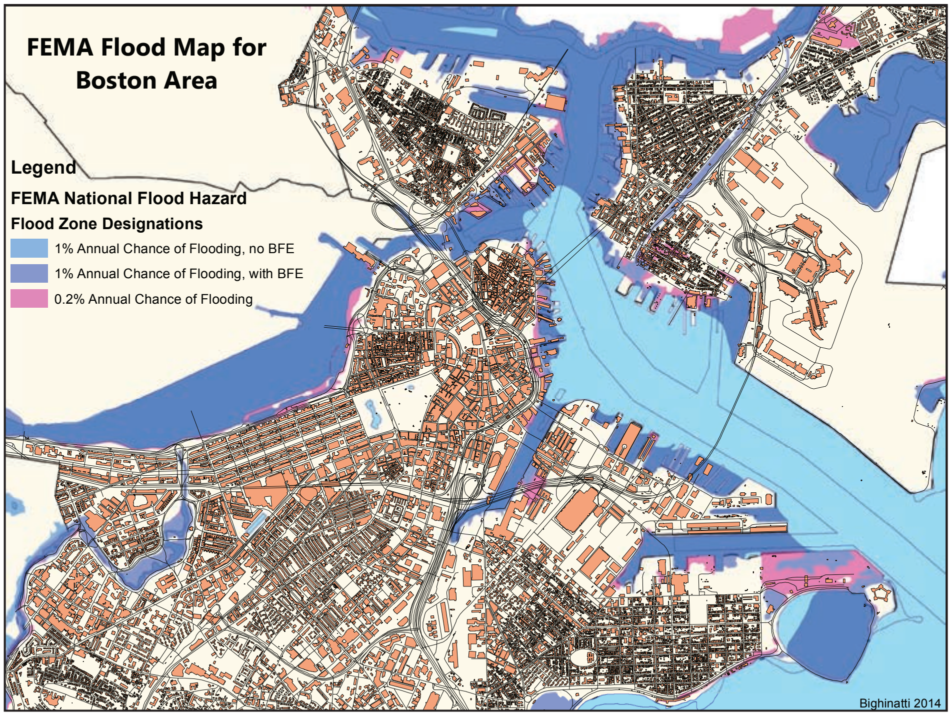
This report also includes case studies of ongoing and completed projects that enhance resilience in the built environment in the short-term, and lays the framework for longer-term solutions such as district-level coordination, and stakeholder engagement. Finally, included are a number of recommendations for addressing regulatory barriers to facilitate collaboration and investment in adaptation and resilience in the built environment.[1] It is hoped that these findings will encourage continued dialogue and collaboration to increase the resilience of the built environment in Boston, and integrate with ongoing initiatives such as the regional resilience initiative launched by Mayor Walsh, the Boston Green Ribbon Commission's financing roundtables, and the Living with Water design competition.

1 A web-based version of this report and toolkit is also available on A Better City's website.

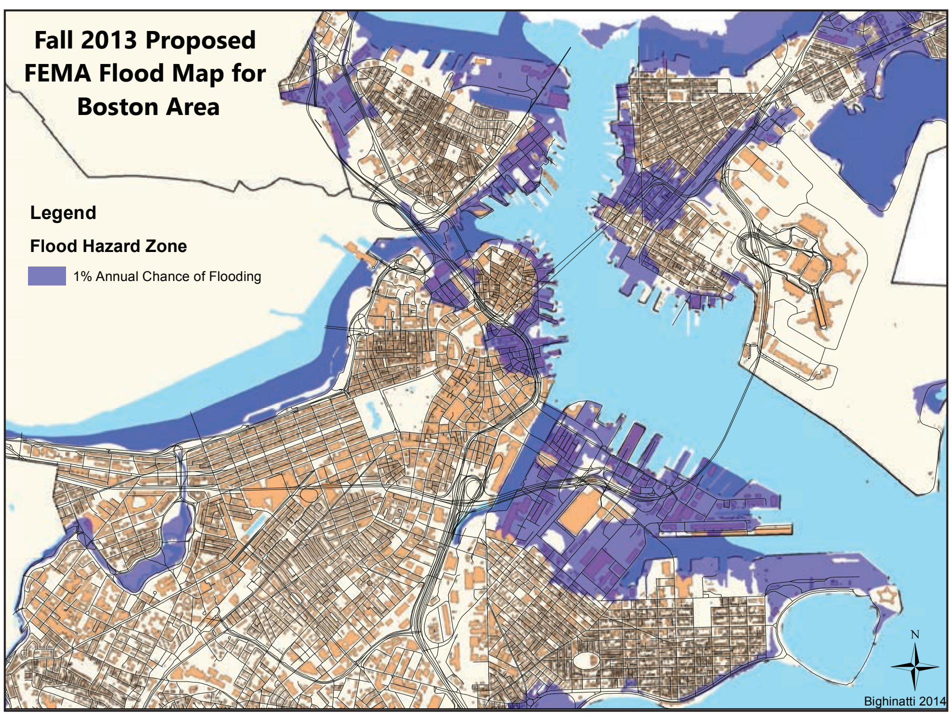
Climate Risks for Boston Buildings

Flood risks for Boston buildings have been characterized by a number of recent studies including proposed maps by the Federal Energy Management Agency (FEMA),[2] and future flood projections by Sasaki. Presented below are maps from both organizations. It is important to note that the FEMA maps rely on historical data, and include limited projections of climate change. ABC's membership is indicated with red pinpoints on the map.

Figure 1 and 2 **Existing and Proposed FEMA Maps for Boston**



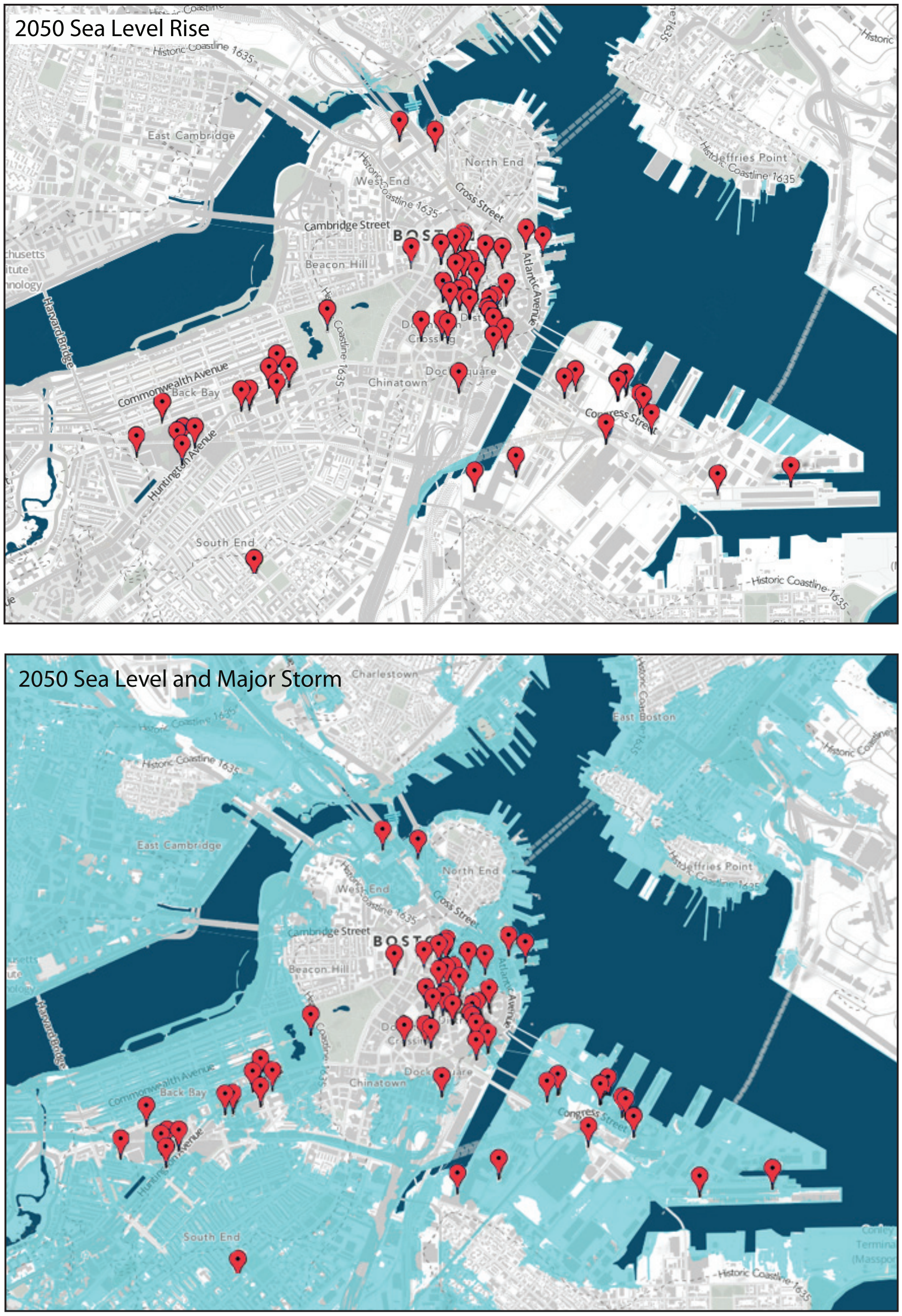
BFE = base flood elevation



2 These proposed maps are currently under appeal.

The maps from Sasaki project two feet of sea-level rise by 2050, placing significantly more buildings at risk of flooding. All buildings in Boston will be subject to further impacts from the urban heat island effect as the average global temperature rises,[3] and increased surface flooding risks from heightened vulnerability of existing infrastructure. Building owners will need to think about what strategies and measures are most appropriate for the near and long-term, and that their buildings remain economically viable.

Figure 3 and 4 **2050 Projections with Sea Level Rise and Storm Impacts**



3 Urban areas tend to have higher average temperatures than rural areas due to increased impervious surfaces, which maintain higher surface temperatures and reflect more heat than shaded or natural environments. For further details, please reference the EPA's website: *http://www.epa.gov/heatisland/about/index.htm*.

Even if only the proposed FEMA maps were used for evaluation, more buildings will enter into the floodplain, and thus new strategies and tools are required to increase resilience in the built environment. Whether a building is inside or outside of the floodplain depends on the timescale and projections used. Key questions to consider when evaluating these maps include:

- What is an acceptable level of risk and timescale for evaluating building assets inside and outside of the floodplain?
- What measures can be pursued at a building level to mitigate risk?
- What measures might be more appropriate to coordinate among interested neighboring buildings and institutions?
- What changes in regulations and federal and private property insurance would facilitate greater investment in resilience?

The following section explores these questions by presenting a series of building resilience measures organized for buildings inside and outside the floodplain.

Building Resilience Measures

The Challenge of Making Building Resilience Investments

When determining capital investments in an asset a building owner commonly looks at the potential return on investment (ROI) in determining the potential increase in value of the asset that can be achieved post investment. The higher the ROI the more feasible the investment is to make. This methodology works well in determining energy efficiency investments. The financial benefits of energy efficiency and renewable energy projects are generally easily quantified. Up-front investments are recouped over time as projects yield energy savings or generate revenue from excess electricity sales or reduced energy consumption. With adequate information, the simple payback or return on investment (ROI) of projects can be predicted in advance, giving decision-makers clear metrics with which to evaluate and select project opportunities.

Resilience measures, on the other hand, yield benefits which are less easily quantified. The standard metric for measuring the benefits of resilience is avoided cost.[4] Focusing on avoided costs recognizes that the primary benefit of resilience is that it reduces or avoids the financial impacts associated with extreme weather events and day-to-day climate change impacts.

Studies of disaster preparedness efforts suggest that avoided costs can significantly outweigh up-front costs, resulting in a substantial savings to organizations and communities. A widely cited study commissioned by FEMA suggests that every $1 invested in preparedness can yield as much as $4 in avoided costs.[5] Other studies suggest that ratio may be higher. Depending on the type of project and ability to leverage existing infrastructure, benefit-cost ratios can range as high as 64:1.[6]

However, the future costs avoided by a specific initiative can be difficult to accurately quantify—both at the point of implementation and even after successful deployment. Uncertainty regarding the extent of climate change and the magnitude and frequency of future extreme weather events makes it difficult to quantify the benefits of resilience measures in advance. Even after a completed project begins to yield benefits, avoided losses cannot be quantified without making numerous assumptions about hypothetical impacts that would have occurred in the project's absence. Finally, many resilience projects yield significant intangible benefits whose value may be difficult to quantify in financial terms. These could include, for example, public health, workforce productivity and retention, community and stakeholder engagement, risk mitigation/reduction, business continuity, and air quality or other environmental benefits.

Uncertainty and lack of quantifiable data can make resilience planning challenging, particularly in organizations that rely on project evaluation metrics like lowest-initial-cost, simple payback, or ROI. These metrics can significantly understate the true value of resilience measures, if they can be calculated at all. Instead, comprehensive benefit-cost analysis is recommended using best available data about the magnitude and likelihood of future climate impacts and the scope of their financial impact under a do-nothing scenario. This will provide organizations with a more complete picture of the true benefits of resilience investments.

4 The IPCC AR4 (2007) defines adaptation costs as "the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs," and defines benefits as "the avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures." See *http://unfccc.int/resource/docs/publications/pub_nwp_costs_benefits_adaptation.pdf*.

5 The Multihazard Mitigation Council of the National Institute of Building Sciences. 2005. Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities. Volume 1. Commissioned by the Federal Emergency Management Agency. Washington, D.C. Available at *http://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/MMC/hms_vol1.pdf*.

6 Kelman, Ilan. 2013. Disaster Mitigation is Cost Effective. World Bank, Washington, DC. *https://openknowledge.worldbank.org/handle/10986/16341*

Resilience Measures and Practices

The catalog of potential building resilience measures presented here was developed through an extensive research process that involved review of published resources on national and international climate preparedness best practices, direct outreach to resilience measure vendors, and discussions with local government officials in a number of international jurisdictions. This research focused on the leading threats facing Boston building owners as identified by previous vulnerability assessments produced by the City of Boston and the Resilient Design Institute, the Built Environment Coalition and Linnean Solutions. The field of building resilience is rapidly evolving and the catalog of measures presented in this section, while extensive, is likely not comprehensive. Given this, ABC has created a web-based version of this building resilience measures database which will be regularly updated as new measures and strategies are identified and more precise cost data becomes available.

Building location and the length of the long-term planning cycle are important factors building owners consider when investing in resilience measures. For instance, buildings that are not in the currently delineated flood plain should consider their future flooding risk given expected sea level rise and the potential for sever storms. Given the high difference in risk between buildings inside and outside the floodplain, buildings have been divided into two groups (inside and outside the floodplain) with potential resilience actions listed under each category. In some instances, buildings outside the floodplain may determine that it is in their buildings interest to invest in resiliency measures to improve market positioning, a history of water related issues not directly related to sea level rise, cross-benefits with issues of stormwater management and urban heat island impacts. Ultimately, it is the building owner's decision based on their plans for the asset to determine the acceptable amount of risk and ROI for each measure.

To assist in the decision-making process, individual factsheets have been prepared for each technology, including background information, case studies, cost information, technology providers and policy implications. The links below navigate to the appropriate page for each technology. These measures are also available in a web-based format on A Better City's Challenge for Sustainability website.

Photo: © Labeled for reuse by NJmonthly.com

Table 1 **Building Resiliency Toolkit Profiles Index**

Measure	Inside the Floodplain	Outside of Floodplain	Flooding/ Sea Level Rise	Stormwater Management	Urban Heat Island
Permeable Pavement					
Porous Asphalt	●	●	●	●	
Pervious Concrete	●	●	●	●	●
Permeable Interlocking Concrete Pavers	●	●	●	●	●
Permeable Clay Brick Pavers	●	●	●	●	●
Plastic Grid	●	●	●	●	●
Resin-Bound Paving	●	●	●	●	●
Bound Recycled Glass Porous Pavement	●	●	●	●	●
Rain Garden / Bioretention Cell	●	●		●	●
Bioswale	●	●		●	●

Table 1 **Building Resiliency Toolkit Profiles Index** (CONTINUED)

Measure	Inside the Floodplain	Outside of Floodplain	Flooding/ Sea Level Rise	Stormwater Management	Urban Heat Island
Dry Floodproofing					
Sealants and Impermeable Membranes	●		●		
Flood Shields	●		●		
Temporary Flood Barriers	●		●		
Permanent Flood Barriers					
Retractable Barriers	●		●		
Levees And Floodwalls	●		●		
Backflow Preventer	●		●	●	
Sump Pump/Internal Drainage System	●	●	●	●	
Polished Concrete Floor	●		●		
Wet Floodproofing	●		●		
Fuel Tank Anchoring	●		●		
Elevation of Mechanical/Electrical Equipment	●		●		
Elevation of Building on Fill	●		●		
Elevation of Building on Piles	●		●		
Floating Buildings	●		●		
CHP Generator	●	●	●	●	
Operable Windows	●	●			●
Green Roofing	●	●		●	●
Cool Roofing	●	●			●
Cross Ventilation	●	●			●
Passive Stack Ventilation	●	●			●
Ceiling Fans	●	●			●
Energy Efficient Building Envelope	●	●			●
Rainwater Harvesting	●	●		●	

District-level Coordination

Building-level strategies can provide protection of individual assets, but can offer little protection for a building's surrounding environment and infrastructure. Coordinated resilience investment efforts between neighboring buildings may result in reduced resilience measure investment costs and reduced building down-time in the event of a major storm or extreme weather event. Group purchasing efforts and co-ownership of assets such as temporary flood barriers have the potential to rapidly increase district scale climate resilience while lowering overall investment costs. Similarly, city policies could be implemented to promote district-level resilience. There are several potential pathways for such efforts; these are discussed below.

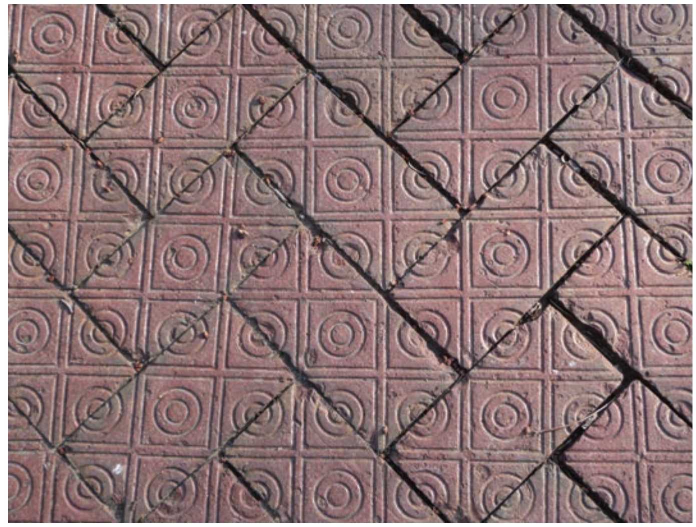


Photo: © User Werewombat on Wikimedia Commons

- ***Municipal Harbor Plans:*** The Municipal Harbor Plan process is established in Massachusetts regulations under 301 CMR 23.00. Cities and towns can voluntarily submit plans for waterfront areas to the state's Office of Energy and Environmental Affairs. The state then uses the plans to guide agency decisions and policies for the impacted areas. Plans can outline alternative requirements to those described in state Waterways regulations, including increased building heights. For example, the Municipal Harbor Plan for the Fort Point District was re-approved in February 2013, which allowed additional building height to shield a ventilation tower associated with the Central Artery/Tunnel.[7] Municipal Harbor Plans might similarly include provisions for buildings to elevate above a building height in exchange for relocating critical equipment from ground floors, or for use of district wide deployable flood barriers.

- ***Business Improvement Districts or Resilience Zones:*** Business improvement districts or special improvement districts have been used to pool resources from a variety of entities to fund projects within a specific geographic area. The same principles could be applied to resilience investments. Funds could be used to purchase flood barriers, develop bioswales, or pursue other climate adaptation projects which would benefit buildings and institutions within the district. Ceres, The Next Practice and the University of Cambridge have begun initial research on this topic, and refer to this type of improvement district as a resilience zone. Key components of a successful zone include developing mechanisms to support individual action, understanding localized risks, implementing projects and communicating success and impact.[8]

Helsinki 2030: The Kalastama District

In the major port and capitol of Finland, the city of Helsinki is working to redevelop an area historically dedicated to industrial and harbor operations into a thriving city district. The district development has a firm commitment to transit-oriented development and smart grid deployment. However green design is not the sole concern of the development—they have also identified their major climate threat is sea level rise. Thus, the current building of Kalasatama is keeping future rising sea levels and increased extreme weather events in mind. The city spearheaded its response to these threats by planning to build the new development to, at its lowest point, 2.6 meters (~8.5 ft.) above sea level, along with the lowest levels of buildings sitting at least 3.5 meters (~11.5) above sea level. They have also begun a pilot project featuring 40 floating houses through the city's utilization of a competition amongst developers to plan and build a floating district.

The growth and development of the Kalastama District can serve as a discussion point and parallel to the ongoing development in the Seaport District, and an opportunity for Boston to lead on a national scale in incorporating resilience into design.

http://www.hel.fi/hel2/ksv/julkaisut/kirjat/myotatuulessa_en.pdf

Legitimate adaptive flood risk governance beyond the dikes: the cases of Hamburg, Helsinki and Rotterdam, Heleen L. P. Mees • Peter P. J. Driessen • Hens A. C. Runhaar

7 Executive Office of Energy and Environmental Affairs. (February 2013). Decision on the City of Boston's Request for the Renewal of the Fort Point Downtown Waterfront Phase 1 Municipal Harbor Plan Pursuant to 301 CMR 23.00. Online.

8 Ceres, The Next Practice, and the University of Cambridge. (November 2013). Building Resilient Cities: From Risk Assessment to Redevelopment. Online.

- ***Tax Increment Financing and Value Capture:*** Tax increment financing allows future increases in tax revenue above existing levels to provide financing for current improvement projects for a particular area. Tax increment financing and other value capture strategies could be leveraged to finance resilience infrastructure projects to support Boston's existing and future built environment. Tax increment financing is currently being considered in Miami to help fund stormwater management improvements in response to more frequent floods,[9] and has also been successfully leveraged by other cities around the country post-recession.[10] The Metropolitan Area Planning Council (MAPC), which serves the metro Boston area, has recently completed a detailed study of additional value capture financing scenarios for transportation which may also be appropriate for resilience.[11] Existing state-level value capture programs include business improvement districts, district increment financing, I-CUBED and the local infrastructure development program.

- ***Resilience Building Rating Schemes:*** LEED certification and Article 37 have incentivized building owners to voluntarily invest in green building measures to increase the attractiveness of their properties. As of yet, a similar recognition program for resilience does not exist, but a local recognition program could incentivize building owners to pursue higher levels of resiliency. Early work on rating the resilience of homes and residential building materials to inundation from flooding and storms has been completed by the Insurance Council of Australia. Their Building Resilience Rating Tool 2.0 is being beta-tested by stakeholders and provides a rating of house design and materials to climate-induced threats. A public release is expected in the near term.[12] The Australian Resilience Taskforce hopes to continue work on the framework to include more hazards (cyclones, wildfire, and extreme heat) and commercial construction.[13] The U.S. Green Building Council has also completed work to link climate sensitivity and adaptation to its existing LEED rating schemes. The LEED Climate Resilience Screening Tool lists potential LEED points which may provide both green building and resilience benefits, or which may be impacted by future climate projections. This tool allows users to select their climate zone and one of four LEED rating schemes.[14] Further efforts would be needed to push forward recognition programs in the U.S. or a locally specific version. Boston currently utilizes a Preparedness Checklist through the Boston Redevelopment Authority's Article 80 development review process, which could be combined with existing research for a pilot recognition program.

- ***Public Space Planning:*** Public spaces can also be used to increase the adaptive capacity of districts and neighborhoods. Parks and open space not only have carbon sequestration benefits, but they can also reduce the urban heat island effect, and potentially provide flood protection. For example, the Bethemplein Plaza in Rotterdam was recently redesigned to function as public basketball court and skate park during dry periods, and a water collection area during precipitation events.[15]

- ***Municipal Incentives:*** The City can also play a role in incentivizing and supporting the deployment of resilience technology by offering financial incentives or allowing building resilience actions to count towards compliance with existing requirements. Toronto has developed incentive programs for commercial, industrial and residential buildings to upgrade to green or cool roofs during roof replacement. Toronto also has created a sump pump and backflow valve incentive program for residences to support its stormwater management efforts.[16] Programs like these could be tailored for the Boston context for technologies which would benefit the wider Boston community.

- ***Insurance Incentives:*** Initiatives such as R!SE are focusing on integrating risks and resilience into insurance and risk management practices. By valuing resilience measures through premiums and rates, building owners will have further incentives to reduce their vulnerability to climate change.

More research and outreach around these ideas and other issues related to larger-scale adaptation projects will need to be pursued in the near-term.

9 Vock, Daniel. (September 2014). *Governing.com*. Facing Climate Change Cities Embrace Resiliency. Online.

10 The Urban Land Institute. (June 9, 2014). *Urbanland*. Tax Increment Financing: Tweaking TIF for the 21st Century. Online.

11 Metropolitan Area Planning Council. (March 2013). Understanding Value Capture as a Transportation Finance Strategy in Massachusetts. Online.

12 Melbourne Insurance Brokers. (2014). How Building Standards Can Reduce Insurance Premiums. Online.

13 Australian Resilience Task Force. (2013). Building Resilience Rating Tool. Online.

14 U.S. Green Building Council. (2013). LEED Climate Resilience Screening Tool. Online.

15 Rotterdam Climate Initiative. (2013). Bethemplein: the first full-scale water square. Online.

16 Toronto Environment Office. (April 2011). Toronto's Adaptation Actions. Online.

Regulatory Considerations

Photo: © City of New York – Department of Sanitation, Public Domain

Adoption of many of the building resilience technologies listed above may require approval or oversight from a range of city or state agencies. This section discusses some of the key considerations related to regulatory oversight of the resilience technologies listed previously.

After Hurricane Sandy, New York City made efforts to streamline approval processes for flood protection technologies. These local legislative changes could serve as a model for city or state action regarding building resilience. Some New York City's revisions to local laws included:

- ***Local Law 83***, which mandated the installation of backflow valves for buildings located in the flood zone, and required the anchoring of storage tanks and elevation of plumbing systems above design flood elevation in its building code.[17]
- ***Local Law 109***, which approved the use of temporary flood barriers and stairs during storm events. It also permitted and allowed the use of anchors on sidewalks for periods leading up to and after the storm. The law also established protocols for any barriers which must be manually deployed.[18]
- ***Local Law 99***, which removed barriers to elevating cables and other wiring equipment above base flood elevation in flood zones. It also regulated the height and quantity of fuel that could be stored in buildings subject to flooding.[19]

It is important to note that New York City controls its own building code, while Boston utilizes state codes. Despite this difference, reforms with similar impacts may be implementable through other regulatory pathways.

Other jurisdictions, such as Toronto, have made green building standards for new construction, which include climate adaptation considerations. Developers who go beyond the minimum requirements are eligible for a refund of city fees.[20] In a similar vein, in the short-term climate adaptive building strategies can be encouraged through the existing Boston standards. Some actions, such as installing back flow valves and sump pumps, may help buildings achieve compliance with existing City regulations.

17 The New York City Law Department. (October 2013). Local Law 83. Online.
18 The New York City Law Department. (December 2013). Local Law 109. Online.
19 The New York City Law Department. (November 2013). Local Law 99. Online.
20 City of Toronto. (2014). Toronto Green Standard. Online.

The Boston Context

During October 2014, researchers conducted interviews with the Environment Department and the Boston Redevelopment Authority to review local and state regulations that building owners should consider when installing resilience technologies. The summary chart below is meant for discussion and consideration, and is not necessarily comprehensive. Details can also be found in the individual technology profiles.

There is an opportunity for the City of Boston to streamline its permitting and approval processes to facilitate the easy integration of resilience actions, some of which may become more common in the future. Some of the reforms and programs seen in New York, Toronto and other leading jurisdictions may serve as case studies for streamlining permitting resilience technologies. In New York City, a Building Resiliency Task Force led by the Urban Green Council developed regulatory recommendations for the Mayor's Office. A similar focus group may be an appropriate action-step for the Boston-area.

Table 2 **Regulatory Summary for Resilience Measures**

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	Dept. of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/Boston Landmarks Commission
Permeable Pavements	●		●	●	●						●	●	●	●
Water Storage/ Bioretention	●		●					●	●					
Barriers		●				●				●				
Pump Systems	●		●		●									
Building Insulation/ Internal Materials						●	●			●				
Elevation						●				●				
Floodproofing						●								
Green Roofs/Cool Roofs						●				●				
Generators						●				●				
Ventilation										●				

Next Steps

This document will foster continued dialogue on private-sector adaptation strategies, and activate property managers, building owners and tenants to prepare resilience strategies, and begin implementation of the preparedness recommendations from the latest Climate Action Plan update. Creating a climate ready Boston will require effort and planning from many key stakeholders in the public and private sector over the coming years and decades. It will also require collaboration between state, city and regional leaders to keep flood information up to date to inform long-term investment decisions. Climate preparedness will require both long-term planning and medium and near-term actions. The private sector must continue to be engaged and included in the development of strategies impacting both individual buildings and neighborhoods through on-going workshops, dialogues and events hosted by the City of Boston and members of the Green Ribbon Commission in the coming months, including a series of finance roundtables, implemented recommendations from the Climate Action Plan update and an insurer convening.

Photo: © User TonyTheTiger Wikimedia Commons

Building Resilience Toolkit

The Building Resilience Toolkit was developed to accompany A Better City's research paper on climate adaptation in buildings for the Boston Green Ribbon Commission to support the City of Boston's Climate Action Plan. It is designed to give Challenge participants, commercial building owners, and the public guidance on potential structural interventions for increasing the resilience of commercial buildings to climate change.

The Toolkit provides a short description of each potential action, and is grouped by climate impact: sea level rise and flooding; stormwater management; and urban heat island. The toolkit also notes if the action is targeted for buildings inside or outside the floodplain. Information is provided for potential costs, regulatory touchpoints, financing and incentives, and local vendors and case studies, where available. The full Toolkit follows and is also available at: *http://challengeforsustainability.org/resiliency-toolkit*.

Building adaptation is a rapidly evolving field. Ongoing feedback and contributions to the Toolkit can be sent to *challenge@abettercity.org*. The Toolkit is a living document and will continue to be updated by A Better City staff.

The Toolkit provides a short description of each potential action, and is grouped by climate impact: sea level rise and flooding; stormwater management; and urban heat island.

Building Resilience Toolkit Contents

DRY FLOODPROOFING: BACKFLOW PREVENTERS

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: Subject to existing plumbing configuration and installation difficulty, Cost estimates (NYC DEP):

- **Small/mid-size buildings (e.g. laundromats, small manufacturers):** $3,000–$5,000
- **Mid-size buildings (e.g. office complexes, dept. stores):** $7,500–$13,000
- **Large buildings (e.g. high rises, hospitals):** $14,000–$34,000

Applications: Can be retrofitted, but much cheaper in new construction

Service Life: Long, but requires regular preemptive maintenance

WHAT IS IT?

Backflow preventers (also known as backwater orbackflow valves and backflow prevention devices) are installed on sewage pipes to prevent contaminated water from flowing back into a building's systems or into public drinking water systems during sewage overflow events. Backflow events often occur from flooding or heavy rainfall, but can occur from any sudden fluctuations in water pressure in the public water system, including water main breaks and fire-fighting.

The Uniform State Plumbing Code of Massachusetts mandates backwater preventers for all buildings containing plumbing fixtures located below the manhole cover serving the building. Property owners are responsible for installing and maintaining backflow valves. Annual and semiannual tests and inspections by MassDEP-certified backflow testers are required. There are a number of types of backflow valves approved by the state for different building sizes and types, most of which utilize spring-loaded check valves, as well as other relief and shutoff valves to prevent back pressure backflow and back siphonage. All water lines to the building must have backflow valves, greatly increasing the cost for large commercial buildings.

BENEFITS

- Protects potable water and building systems from backflow contamination during flooding events

DRAWBACKS

- Extensive regular inspection and maintenance required by law to ensure long service life and functionality
- Costly to install in larger commercial buildings

REGULATORY IMPACTS AND REQUIREMENTS

- MA Uniform State Plumbing Code 248 CMR Section 2.09(4) – All existing or new building drains from plumbing fixtures liable to backflow (all plumbing fixtures located at an elevation below the top of the manhole on the DPW sewer serving the fixture) are required to have backwater valves installed at the owner's expense

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Backflow valves are mandatory if a building is deemed to be at risk of contaminating building or public water supplies during stormwater overflow events.

Photo: © User Verifiedbackflow (Own work) via Wikimedia Commons

DRY FLOODPROOFING: BACKFLOW PREVENTERS
CONTINUED

ADDITIONAL RESOURCES

SAMPLE OF SUPPLIERS

- Wide range of plumbing supply manufacturers, including Watts and Zurn Wilkins

SOURCES

- http://www.bwsc.org/REGULATIONS/WaterRegulations.pdf
- http://www.bwsc.org/REGULATIONS/SewerRegulations.pdf
- http://www.nyc.gov/html/dep/html/forms_and_permits/backflow_faq.shtml#a8
- https://www.lincoln.ne.gov/city/pworks/water/backflow/faq.htm
- http://www.mass.gov/eea/docs/dep/water/drinking/alpha/a-thru-h/cccpman.doc

BIOSWALE

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: $58 per linear ft.; $20–30 per sq. ft.

Applications: Parking lots, road/sidewalk drainage, residential/commercial buildings. Can be used in combination with other stormwater best management practices. Easily built into existing sites, though new construction can more easily take advantage of natural terrain and design for directing stormwater flows

Service Life: Extensive, depending on continued maintenance

WHAT IS IT?

Bioswales are similar to bioretention cells and rain gardens but instead channel stormwater into a trough filled with vegetation, compost or mulch, and rubble to reduce runoff, increase infiltration, and remove pollutants. Bioswales are often positioned alongside roads and parking lots to capture runoff. The swale's side slopes should not exceed 33%, and longitudinal slope should not exceed 4% unless check dams are used to reduce flow velocity. Bioswales typically cost less than traditional curb and gutter systems, though their efficacy is dependent on proper siting, design, and construction, as well as continued maintenance. Moreover, bioswales can be ineffective during and become damaged by large storms, as high velocity flows can overwhelm the swale and erode vegetation. Vegetation used in bioswales should be flood tolerant, erosion resistant, salt tolerant, and native when possible. Bioswales can be used in combination with other stormwater best management practices to manage high stormwater flows.

Regular maintenance is required to ensure continued effectiveness and system longevity, including regular mowing and reseeding, as well as inspections for erosion, weed control, and trash removal. Proper snow and sand removal are necessary to ensure that bioswales continue functioning after winters in cold areas.

BENEFITS

- Uses natural processes to reduce stormwater runoff volume, rate, and pollutants and increase soil and groundwater infiltration
- Green spaces can improve urban air quality, contribute to lower urban air temperatures, and be aesthetically pleasing
- Can be easily retrofitted during any landscape modification or parking lot/street resurfacing
- Construction and maintenance costs of bioswales are often lower than those of conventional stormwater management systems

DRAWBACKS

- Not suitable for heavy stormwater flows. Swales can be overwhelmed by large storms, and vegetation can be eroded by high velocity flows
- Careful landscaping and maintenance required; poor landscaping and maintenance can result in ineffective drainage and could attract pests

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.

Photo: The image is part of the public domain and available on Wikimedia Commons

BIOSWALE
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Water Storage/Bioretention	●		●					●	●					

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Municipal stormwater abatement service fees—Municipal-level
- Coastal Pollutant Remediation (CPR) Grant Program—MA State
- Clean Water State Revolving Fund (SRF)—MA State
- Section 319 Nonpoint Source Competitive Grant—Funding provided under federal Clean Water Act
- 604b Water Quality Management Planning Grant—Funding provided under federal Clean Water Act
- Drinking Water Supply Protection Grant Program—MA State

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Chagrin River Watershed Partners Case Study, OH
- East Washington Street in Syracuse, NY
- NYC Green Infrastructure Neighborhood Demonstration Area, NY
- The Steel Yard, RI

SAMPLE OF SUPPLIERS

- Landscape designers/contractors (e.g. Klopfer Martin Design Group, A Yard & A Half Landscaping)
- A list of plants native to Massachusetts coastal environments is available here
- A list of species appropriate for use in bioretention is available here

SOURCES

- http://epa.ohio.gov/Portals/41/storm_workshop/lid/CRWP_LID_Cost%20Study.pdf
- http://ma-northampton.civicplus.com/DocumentCenter/View/2489
- http://www.lakesuperiorstreams.org/stormwater/toolkit/swales.html
- http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_vegswale.pdf
- http://www.galeassociates.org/wp-content/uploads/2014/03/FMJ_Nov-Dec_2013_Low_Investment.pdf
- http://water.epa.gov/infrastructure/greeninfrastructure/upload/Franklin_Report.pdf
- http://www.ct.gov/deep/lib/deep/p2/raingardens/bioretention_manual_2009_version.pdf

BOUND RECYCLED GLASS POROUS PAVEMENT

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: $8.50–$18.00 per sq. ft. (FilterPave)

Applications: Parking lots, pathways, sidewalks, plazas, driveways, public spaces, tree pits, light vehicular traffic. Higher stone aggregate mixes can handle somewhat heavier vehicular loads (up to 2.7 tons)

Service Life: 15+ years

WHAT IS IT?

Bound recycled glass porous pavement is similar to resin-bound paving except that a mixture of recycled glass and stone is used for the aggregate. The mixture can range from 100% recycled glass to 20% glass and 80% stone for heavier vehicular loads and longer service life. Bound recycled glass pavement is extremely porous, with void space of 39–47% (more than double that of porous asphalt and pervious concrete), reducing the rate of clogging and the need for maintenance. When clogged with sediment, infiltration rates were still measured at over six inches per hour, exceeding multiple stormwater standards.

As with other permeable pavements, periodic vacuuming will help maintain infiltration rates, though many installed systems have maintained normal functionality after five years without vacuuming. In addition, higher glass-content mixtures (50%+) will require a topcoat every two to three years depending on traffic load to prevent shedding. Recycled glass pavement will also contribute to LEED credits: the pavement is comprised of regionally-sourced, recycled materials, has a solar reflective index of 29 to 62, and permeability and filtration rates meet LEED standards.

BENEFITS

- Enhances groundwater infiltration while reducing stormwater runoff volume, rate, and pollutants.
- Recycled glass and aggregate reduce urban heat island through increased reflectivity and evaporative cooling
- Wide range of glass colors can help preserve urban aesthetics
- Recycled content: approximately 90 glass beverage bottles used in every square foot of paving
- Highest porosity of other porous pavements, reducing clogging and need for vacuuming
- Resistant to freeze-thaw cycles and extreme heat—binding agent expands and contracts easily
- Reduces occurrence of black ice/freezing puddles in cold climates; requires less applied deicers

DRAWBACKS

- Pollutants and deicing salts can infiltrate groundwater—should not be installed in areas where hazardous material spills are possible
- Higher glass mixtures require additional maintenance (topcoat every two to three years)
- More expensive than other types of permeable pavement
- Snow removal can be more difficult than with other types of paving. Plows must use polycarbonate type-cutting blades

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.

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BOUND RECYCLED GLASS POROUS PAVEMENT
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Permeable Pavements	●		●	●	●						●	●	●	●

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Municipal stormwater abatement service fees—Municipal-level
- Coastal Pollutant Remediation (CPR) Grant Program—MA State
- Clean Water State Revolving Fund (SRF)—MA State
- Section 319 Nonpoint Source Competitive Grant—Funding provided under federal Clean Water Act
- 604b Water Quality Management Planning Grant—Funding provided under federal Clean Water Act
- Drinking Water Supply Protection Grant Program—MA State

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Western Oregon University, OR
- International Crane Foundation Headquarters, WI

SAMPLE OF SUPPLIERS

- FilterPave

SOURCES

- http://filterpave.com/resources

CEILING FAN

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: Standard commercial-grade fans for smaller rooms (~400 sq. ft.) range from—$65–$180 (not including installation). Larger fans for rooms of up to 5,000 sq. ft. with larger cooling effect cost up to $4,000

Applications: Can be installed in retrofits or in new construction

Service Life: 7–18 years (avg. 13)

WHAT IS IT?

A ceiling fan circulates air throughout a room through a set of rotating fan blades suspended from the ceiling. Contrary to belief, ceiling fans do not cool the rooms they are used in; ceiling fans make the building's occupants feel cooler because air moves more quickly across skin and accelerates the evaporation of perspiration—much like a breeze provides relief on a hot summer day. In buildings where no air conditioning is available, ceiling fans provide an effective low-cost alternative to installing air conditioning: central air conditioning can cost over 30 times more than running a comparable number of ceiling fans. However, in many large buildings, central air conditioning is already installed or its use is otherwise unavoidable, and the installation of ceiling fans will serve to supplement rather than replace central air conditioning systems.

Realizing energy savings from ceiling fans in these circumstances can be difficult. When temperatures are not excessively hot, ceiling fans can be used in place of central air conditioning with significant energy savings. If fans and air conditioning are used simultaneously, the use of ceiling fans will result in energy savings only if their use is matched by a corresponding increase in the building's thermostat and if they are only used when occupants are in the room. While the use of ceiling fans allows for a higher end range of comfortable temperatures (typically around 3°F), their use is often not accompanied by a reduction in air conditioning use, resulting in additional overall energy use rather than energy savings. Depending on the existing HVAC system, its energy efficiency, and the degree of control occupants have over temperatures and fans, installation of ceiling fans may or may not be a cost-effective investment for every building.

BENEFITS

- Ceiling fans provide a cooling effect to building occupants. When ceiling fans are used in place of air conditioning, significant energy savings can be realized. When ceiling fans are used simultaneously with air conditioning, they can allow for an increase in comfortable building temperature, resulting in energy savings.
- Constant air circulation can increase occupant comfort.

DRAWBACKS

- Ceiling fans do not lower indoor building temperatures.
- Ceiling fans increase overall building energy use when used simultaneously with air conditioning if the thermostat is not raised.
- Ceiling fans are inefficient if left on when building occupants are not in the room.

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.

Photo: © User Macroairtec via Wikimedia Commons

CEILING FAN
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	Boston Landmarks Commission/ MA Historical Commission
Ventilation										●				

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Not applicable

ADDITIONAL RESOURCES

SAMPLE OF SUPPLIERS

- Wide range of suppliers of standard ceiling fans (see Home Depot or Airdistributor Company)
- Suppliers of fans for larger spaces and commercial/industrial application include Big Ass Fans.

SOURCES

- http://www.facilitiesnet.com/energyefficiency/article/Operable-Windows-Can-Save-Energy--10284#
- http://www.greenbuildingadvisor.com/blogs/dept/musings/using-ceiling-fans-keep-cool-without-ac
- http://www.energy.ca.gov/appliances/2003rulemaking/documents/case_studies/CASE_Ceiling_Fan.pdf
- https://securedb.fsec.ucf.edu/pub/pub_show_abstract?v_pub_id=4080
- http://www.hansenwholesale.com/ceilingfans/reviews/ceilingfansenergysavings.asp

COMBINED HEAT AND POWER GENERATOR

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: Reciprocating engine: $1400–$1800/kW

- Gas Turbine: $1300–$1900/kW
- Microturbine: $2500/kW
- Fuel cell: $5600–$7500/kW
- Backup controls/switchgear add approx. ~$175/kW

Applications: Can be installed in retrofits or new construction. Only a cost-effective investment if heat is properly utilized

Service Life: Approx. 20 years

WHAT IS IT?

A combined heat and power (CHP) generator simultaneously creates heat and electricity from a single fuel source. CHP systems are highly efficient and cost-effective if the heat generated from power production is utilized on-site, as the use of on-site power reduces the loss of electricity through transmission. Overall efficiency can reach 80–85%, compared to the 35–40% electric efficiency in central power plants (including transmission and distribution). Other benefits of using CHP include increased reliability, reduced greenhouse gas emissions, and, if installed, backup capability to ensure continuous functionality during blackouts. Backup requirements include a battery powered startup system, a synchronous generator, and switchgear. With automatic/seamless backup controls installed, a CHP system can respond to a blackout in seconds.

A number of technologies can be utilized for CHP, including reciprocating engines (the cheapest), gas turbines, microturbines, and fuel cells (the most expensive). Regardless of the technology used, the upfront costs for CHP are high and it will only be a cost-effective investment if the heat generated is properly utilized. CHP is ideal for large commercial, institutional, and industrial buildings and can be used in some multifamily residential applications. CHP can be cost-effective, and payback periods range from 5.2 to 6.8 years. Payback periods will be reduced, depending on annual power outage time.

BENEFITS

- High efficiency and reliability. Can operate as backup power during extended power outages
- Reduced energy costs and emissions

DRAWBACKS

- High upfront costs. Can be mitigated by using available incentives.
- In flood-prone areas, CHP generator and attached systems must be floodproofed or located above the flood zone, increasing capital costs.

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.

Photo: © User SuSanA Secretariat via Wikimedia Commons

COMBINED HEAT AND POWER GENERATOR
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utiilties	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Generators						●				●				

FINANCING OPTIONS, INCENTIVES, AND REBATES

CHP is eligible for a number of federal and Massachusetts incentives. A database of federal and state CHP initiatives is available here. Some of these incentives include:

- MassSAVE Utility Energy Efficiency Program—Retrofitted CHP projects that pass a Benefit Cost Ratio test are eligible for an incentive of anywhere from $750 to $1200 per kW for systems of up to 150 kW, depending on the conditions met for each tier. CHP used in new construction is eligible for the first tier ($750/kW)
- Business Energy Investment Tax Credit—Fuel cells, microturbines, and CHP are eligible for tax credits of 10%–30% of expenditures.
- Accelerated MARC Depreciation—Qualifying CHP equipment can be depreciated using the 5–year modified accelerated recovery system.
- Massachusetts Alternative Energy Portfolio Standard – CHP is an eligible technology for the Massachusetts Altenerative Energy Portfolio standard. Tradeable AEC credits for generation can be sold and traded.

ADDITIONAL RESOURCES

SAMPLE OF SUPPLIERS

- Aegis Energy Services, Inc.
- Veolia Energy

SOURCES

- http://www.epa.gov/chp/documents/catalog_chptech_full.pdf
- http://www.epa.gov/chp/basic/
- http://www.meede.org/wp-content/uploads/Commercial-and-Industrial-CHP-Technology-Cost-and-Performance-Data-Analysis-for-EIA_June-2010.pdf
- http://www.masssave.com/~/media/Files/Business/Applications-and-Rebate-Forms/A-Guide-to-Submitting-CHP-Applications-for-Incentives-in-Massachusetts.pdf

COOL ROOFING

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: Low slope: Coating—$0.75–$1.50 per sq. ft.; Membrane—$1.50–$3.00 per sq. ft.

- **Steep slope:** Metal – $1.80–$3.75 per sq. ft.; Tiles – $0.60–$6.00 per sq. ft.

Applications: Can be installed in retrofits or in new construction.

Service Life: Extensive (30 years to lifetime). Can extend roof life due to lower temperatures

WHAT IS IT?

Cool roofs are constructed with highly reflective and emissive materials, usually in the form of membranes, coatings, and tiles. Cool roofing materials can have solar reflectance of over 65%, compared to 5%–15% for traditional roofing materials. As a result, cool roofs tend to stay within 10°–20°F of ambient air temperatures in the summer, while conventional roofs can be 55°–85°F hotter than ambient air temperatures. A simulation of New York City found that use of cool roofing on 50% of available roof surfaces would reduce city-wide temperatures by 0.3°F.

Cool roofs are typically categorized as low slope or steep slope, which use different roofing materials. Low slope cool roofs are defined as having no more than a 2:12 pitch. Low slope cool roofs use single-ply membranes or cementitious and elastomeric coatings to increase solar reflectance and thermal emittance. Cool roof retrofits are often considered when existing roofs near the end of their service life. Cool roof coatings have typically been applied to existing roofs that only need moderate repairs, while membranes are often used for roofs needing more extensive repairs. Steep slope cool roofs typically use specially colored tiles with higher solar reflectance or metal roofing to reduce solar heat gain.

While cool roofs reduce cooling energy use in the summer, they can also reduce the amount of solar heat in the winter that could be used to warm the building. As a result, summer energy savings may be partially offset by increased heating costs. In most climates, this offset does not typically exceed the summer energy savings. Building owners should consult tools like the Oak Ridge National Laboratory's Roof Savings Calculator to determine if cool roofing is a viable investment.

BENEFITS

- Reduces building summer cooling costs through increased solar reflectance.
- Reduced peak temperatures from cool roofing will increase the service life of the roof and reduce lifetime maintenance costs.
- Cheaper than green roofs while providing similar cooling benefits.

DRAWBACKS

- Reduced solar reflectance results in increased heating costs in winter. Ultimate net benefit will vary based on geographic region.

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.

Photo: © Wal-mart, CC by 2.0 Flickr

COOL ROOFING
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Green Roofs/Cool Roofs						●				●				

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Green and cool roofing are part of the City of Boston's Climate Action Plan, and policies and programs to support cool roofing may appear in Boston in the near to medium term

ADDITIONAL RESOURCES

SAMPLE OF SUPPLIERS

- CertainTEED
- Cool Flat Roof

SOURCES

- http://www.epa.gov/heatisland/resources/pdf/CoolRoofsCompendium.pdf
- http://energy.gov/sites/prod/files/guide_to_cool_roofs.pdf

CROSS VENTILATION

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: Cost of retrofit depends on state of current building, cross ventilation can be easily built into new building design at minimal additional cost

Applications: Can be installed in retrofits or in new construction. Not appropriate for all buildings—building siting and structure must permit effective cross-ventilation

Service Life: Not applicable

WHAT IS IT?

Cross ventilation relies on wind for cooling. When wind blows on a building, a pressure difference is created between the windward (wind-facing) and leeward walls. Openings (i.e. windows) placed on opposite sides of a building will allow the cooler external air to enter the building while warmer internal air is sucked out from the leeward side openings. The degree of passive cooling is determined by the size and placement of the building and ventilation openings, as well as the regularity of wind. As a result, while cross ventilation can provide effective cooling, it can also be unreliable when naturally occurring wind is not available. As a result, larger buildings will typically require mechanical ventilation systems or passive stack ventilation in order to ensure ventilation continues in the winter and when wind is unavailable.

For cross ventilation to be effective, the building must be in a location with regular summer winds. The windward wall should ideally be oriented to be perpendicular to typical summer wind; perpendicular orientation may not always be possible in existing buildings. The building itself should ideally be relatively narrow to ensure fresh air is distributed throughout the building. Extensive internal partitions will inhibit air flow and render cross ventilation impractical. Assuming a building's location and orientation allow for cross ventilation, operable windows/openings are required to ensure effective ventilation. Given the extensive building conditions required, it is typically more practical to design a new building for cross ventilation rather than retrofit an existing building. However, if the building conditions are met, retrofitting for cross ventilation can be a cost-effective, energy efficient passive cooling strategy.

BENEFITS

- Allows for building cooling and ventilation with minimal maintenance and no operating costs. Particularly for new buildings, cross ventilation can be built into the building design at minimal cost.
- Cross ventilation is fully passive and requires no energy. Cross ventilation can be combined with active mechanical ventilation or passive stack ventilation to minimize building energy costs while ensuring more regular ventilation and cooling.

DRAWBACKS

- Must be combined with another form of ventilation (e.g. mechanical or stack) in order to ensure ventilation continues when wind is unavailable and in cold months when windows will be shut.
- Existing internal space may result in uneven cooling in different places in the building.
- Building occupants may shut operable windows (due to comfort, noise, etc.), reducing the effectiveness of cross ventilation.
- Cross ventilation cannot reduce indoor temperature significantly below outdoor temperature. As a result, in extreme heat events, air conditioning will still be required to keep indoor air temperature at comfortable levels.
- Open windows in urban environments can increase exposure to external noise.

CROSS VENTILATION
CONTINUED

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table below.

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Ventilation										●				

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Building Research Establishment Environment Building, UK
- Art Stable, WA

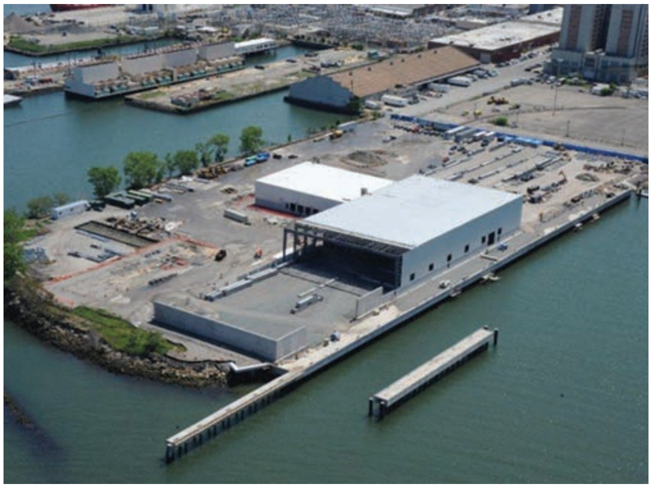
SAMPLE OF SUPPLIERS

- Building contractors/consultants (e.g. Building Science Corporation)

SOURCES

- http://www.architecture.com/RIBA/Aboutus/SustainabilityHub/Designstrategies/Air/1-2-1-2-Naturalventilation-stackventilation.aspx
- http://gbtech.emsd.gov.hk/english/utilize/natural.html
- http://www.mass.gov/eohhs/docs/dph/environmental/iaq/comfort-non-ac-school.doc

ELEVATION OF BUILDING ON FILL
INSIDE THE FLOODPLAIN



Cost: Expensive and site-dependent. 5% to 25% additional cost for new construction. The fill itself is a major additional cost associated with this measure. Additional site landscaping costs can be built into design of new buildings. Building accessibility issues from elevation in urban areas may also add additional costs. A retaining wall may also be necessary. Costs may be offset by reductions in insurance rate.

Applications: Due to extensive site modification, much more suitable for new construction.

WHAT IS IT?

Elevating a building above base flood elevation (BFE) is an effective way to provide protection from storm-related flooding, as well as flooding from high tide due to sea level rise. A building can be raised above base flood elevation by usingfill to elevate the building or to reshape the entire building site's topography. Due to the significant modifications needed to bring the building site above BFE, elevating a building on fill is much more difficult for retrofits. Proper elevation of a site may provide reductions in flood insurance premiums—or even entirely remove the site from the flood zone by obtaining a letter of map revision.

While elevating a building site above BFE will provide protection from some flooding, it will not protect the site from wave action, which may scour the fill. As a result, FEMA does not permit the use of structural fill in V zones.* Elevation of sites over three feet is not recommended, as channelization can occur and flooding of adjacent, lower areas could be exacerbated. Proper assessment and mitigation of potential negative effects on the surrounding area as a result of site elevation should be considered. If the building site is not completely elevated over BFE, additional floodproofing measures can be utilized to maximize flood protection. A significant portion of the additional cost of elevating a building on fill stems from the fill itself. Use of recycled materials in the fill can help to reduce costs.

BENEFITS

- Protects a building from flooding by raising it above base flood elevation.
- Site elevation may reduce flood insurance premiums. Site may even potentially be removed from flood zone. Elevation of large residential/non-residential with basement/enclosure/crawlspace from base flood elevation to 3 feet above base flood elevation may reduce annual insurance rates by over 70%.
- If entire building is raised above flood elevation, building area can be preserved.

DRAWBACKS

- Drainage and implications of site elevation on adjacent sites may prevent elevation of the site on fill. Additional costs related to assessing drainage and impacts on adjacent sites will be necessary.
- Elevation of the building site in urban areas can create accessibility issues and have negative impacts on the streetscape and adjacent sidewalks.
- The use of a fill and potential need for retaining wall will add significant costs to a new construction project.

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.
- FEMA does not permit elevation of building sites on fills in V zones.

* Indicates Boston-area supplier

Photo: © City of New York – Department of Sanitation, Public Domain

ELEVATION OF BUILDING ON FILL
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Elevation						●				●				

FINANCING OPTIONS, INCENTIVES, AND REBATES

- FEMA Hazard Mitigation Assistance—FEMA provides funding for flood and disaster mitigation through three grant programs: Hazard Mitigation Grant Program, Pre-Disaster Mitigation, and Flood Mitigation Assistance. Additional information and application instructions are available here through the Massachusetts Emergency Management Agency. Only non-residential dry floodproofing projects are eligible.
- Hazard Mitigation Funding Under Section 406 of the Stafford Act—Local, state, tribal, and some non-profit facilities damaged by disasters may use Section 406 funding to restore damaged facilities, as well as undertake preventative measures for future flood mitigation.

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Sunset Park Material Recovery Facility, NY (pg. 42)

SAMPLE OF SUPPLIERS

- General building contractors

SOURCES

- http://www.nyc.gov/html/dcp/pdf/sustainable_communities/urban_waterfront_print.pdf
- http://www.emd.wa.gov/hazards/documents/Flood_BuildingYourHome_FactSheet.pdf

ELEVATION OF BUILDING ON PILES

INSIDE THE FLOODPLAIN

Cost: Expensive and site-dependent—5% to 25% additional cost for new construction. Elevating a detached 1–2 family home can range from $45,000 to $200,000. Costs stem from pile-driving/new foundation, wet floodproofing measures, relocation of mechanical/electrical systems, and addressing potential accessibility issues from elevation in urban areas. Elevating existing buildings may require addressing other building code issues prior to elevation. Costs may be offset by reductions in insurance rate

Applications: Existing buildings can be elevated, though at greater cost than building into new construction. May not be practical or cost-effective for large commercial buildings.

WHAT IS IT?

Elevating a building on fill cannot protect a building from wave forces and cannot be used in V zones. Elevating a building on piles provides wave force protection and is mandatory in V zones for all new construction and in retrofits for bringing the building into compliance with FEMA standards. It is a strategy best pursued for new construction. Elevating a building on piles will allow floodwaters to pass underneath the building without causing structural damage. The space underneath the building cannot be occupied except for use as parking, storage, or building access. This space may be open or closed but should be wet floodproofed if enclosed and breakaway walls or lattice walls should be used for the enclosure. Vents can be installed into breakaway walls to allow for pressure equalization to prevent the walls from failing until the water is deep enough for significant wave action. As with elevating a building on fill, elevating a building on piles can significantly reduce flood insurance premiums.

While elevating a building on piles above flood elevation provides effective protection for buildings, it is costly and infeasible for larger buildings. Piles must be driven into the ground, and the building must be separated from its foundation while piles or a new foundation are constructed below. As many existing buildings in the Northeast are old, addressing asbestos, lead paint, and structural issues related to elevating heavy mechanical/electrical systems may increase costs significantly. Larger buildings with subgrade basements will face significant difficulties in elevating. Accessibility issues from elevation may increase costs. In A zones, it will likely be more cost-effective for many non-residential buildings to use dry floodproofing, though in V zones, the lowest occupied floor will need to be above base flood elevation.

BENEFITS

- Protects a building from high-velocity flooding and wave action.
- Site elevation may reduce flood insurance premiums. Site may even potentially be removed from flood zone. Elevation of large residential/non-residential with basement/enclosure/crawlspace from base flood elevation to 3 feet above base flood elevation may reduce annual insurance rates by over 70%.

1 Defined by FEMA as areas along coasts subject to inundation by the 1-percent-annual-chance flood event with additional hazards associated with storm-induced waves.

2 Defined by FEMA as an area subject to inundation by the 1-percent-annual-chance flood event.

Photo: © FEMA, Picture is part of the Public Domain

ELEVATION OF BUILDING ON PILES
CONTINUED

DRAWBACKS

- Creates additional space below the elevated structure that can be used for storage and parking. Elevation of existing buildings may maintain building floor area.
- Elevation of the building site in urban areas can create accessibility issues and have negative impacts on the streetscape and adjacent sidewalks.
- Very expensive to retrofit.
- Infeasible for larger buildings.
- Elevation may disrupt urban aesthetic without additional measures.

REGULATORY IMPACTS AND REQUIREMENTS

- Mandatory for all new construction in V zones. Elevating a building on piles is the only retrofit option that will bring an existing residential structure into compliance with FEMA standards in V zones.

FINANCING OPTIONS, INCENTIVES, AND REBATES

- FEMA Hazard Mitigation Assistance—FEMA provides funding for flood and disaster mitigation through three grant programs: Hazard Mitigation Grant Program, Pre-Disaster Mitigation, and Flood Mitigation Assistance. Additional information and application instructions are available here through the Massachusetts Emergency Management Agency. Only non-residential dry floodproofing projects are eligible.
- Hazard Mitigation Funding Under Section 406 of the Stafford Act—Local, state, tribal, and some non-profit facilities damaged by disasters may use Section 406 funding to restore damaged facilities, as well as undertake preventative measures for future flood mitigation.

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Harris Home—Home elevated post-Katrina resulting in reduced flood insurance premiums

SAMPLE OF SUPPLIERS

- General building contractors

SOURCES

- http://www.nyc.gov/html/dcp/pdf/sustainable_communities/urban_waterfront_print.pdf
- http://www.emd.wa.gov/hazards/documents/Flood_BuildingYourHome_FactSheet.pdf
- http://www.nyc.gov/html/sirr/downloads/pdf/final_report/Ch4_Buildings_FINAL_singles.pdf

ELEVATION OF MECHANICAL AND ELECTRICAL EQUIPMENT
INSIDE THE FLOODPLAIN

Cost: $1–$20 million for elevating equipment in commercial buildings (NYC)

- Elevating building systems in isolation will not influence FEMA premiums—must be paired with other measures

Applications: Retrofits and new construction, with lower costs for new construction projects

WHAT IS IT?

Critical equipment, which includes mechanical systems such as HVAC units, and electrical equipment including telecommunications services are essential to building operations. During Hurricane Sandy, many buildings lost access to their mechanical and electrical systems due to flooding.

If tenants are required to shelter in place, the ability to access communications networks and keep occupants comfortable during severe conditions is essential. Elevating or protecting equipment can avoid major replacement or repair costs from structural damage. To increase resilience of building systems, owners can choose to elevate critical equipment above base flood elevation or apply dry floodproofing techniques to create protective barriers around critical services. Buildings or campuses of buildings can also build redundancies into their IT infrastructure and mechanical systems in the event a set of equipment suffers an outage.

BENEFITS

- Protects critical infrastructure during flooding events
- Lowers the risk of equipment failure—the probability of elevating critical equipment failing as a resilience measure is <1% (American Association of Climate Change Officers)

DRAWBACKS

- Current regulations may inadvertently prohibit the elevation of telecommunications equipment by regulating maximum cable length. New York City encountered a similar barrier, and amended its building code
- Equipment elevation may interact with fire code
- Retrofits for large commercial buildings may require roof or floor reinforcements to accommodate heavy mechanical equipment

FINANCING OPTIONS, INCENTIVES, AND REBATES

- FEMA Section 406 Funding—This FEMA program provides funding to restore and enhance damaged sections of facilities which have experienced presidentially-declared disasters. This funding can be paired with Section 404 funding, which applies to undamaged portions of facilities in declared disaster areas.
- Business Physical Disaster Loans—The Small Business Association provides loans to restore and repair damages to facilities which are not fully funded by insurance.

Photo: © credit here credit here credit here

ELEVATION OF MECHANICAL AND ELECTRICAL EQUIPMENT
CONTINUED

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Flickinger Glassworks and Linda Tool Headquarters, NY
- NYU Langone Medical Center, NY

SAMPLE OF SUPPLIERS

- Most general contractors would be able to complete this work.

SOURCES

- http://www.fema.gov/media-library-data/1386072313670-21f4b31c1ebd7c79cc28664649fc90bb/Sandy_MAT_AppC_508post2.pdf
- http://www.nyc.gov/html/dcp/pdf/sustainable_communities/urban_waterfront_print.pdf
- http://urbangreencouncil.org/sites/default/files/brtf_4-_remove_barriers_to_elevating_buildings.pdf
- http://www.risingseassummit.org/presentations/ACCO-RisingSeas-2014-Slides-Showcase-Luck_Cohn.pdf

ENERGY EFFICIENT BUILDING ENVELOPE

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: In retrofits, ranges greatly depending on state of existing building envelope and scope of work. Cheaper to integrate energy efficient building envelope into new design.

Applications: Can be installed in retrofits or in new construction.

Service Life: Ranges depending on technologies used.

WHAT IS IT?

The building envelope, the boundary between the interior and exterior of a building, performs a number of tasks including exterior protection (e.g. protection from the elements) and preservation of internal space requirements (e.g. thermal, light, and acoustic comfort, humidity conditions). The use of a range of building technologies to create an energy efficient building envelope reduces both the thermal energy lost to the building's surroundings and the amount of energy needed to heat and cool the building. Heating, cooling, and ventilation are responsible for around a third of primary energy use in the commercial and residential sectors, and energy represents approximately 30% of the typical office building's costs. The technologies deployed can address a number of sources of energy loss such as air leakage, wet insulation, and thermal bridging. Installation options include:

- Building insulation
- Fenestration (i.e. windows, doors, skylights)
- High efficiency glazing
- Air sealing
- Cool/green roofing
- Advanced building facades

The amount of energy saved depends on the building and the technologies used, though ENERGY STAR buildings have been shown to reduce operating costs for corporate real estate owners by up to $25,000 per year for every 10,000 square feet of office space. Insulation and air sealing through effective air barrier systems can reduce non-residential building electricity consumption by more than 25%. Building owners interested in making energy efficiency improvements to their buildings should conduct energy audits to determine the most cost-effective methods to improve the efficiency of the building envelope.

BENEFITS

- Significant reductions to building energy use for both heating and cooling.
- In the event of blackouts, buildings can remain hospitable for greater periods of time.

DRAWBACKS

- Significant upfront costs result in long payback for energy efficient technologies.
- Highly insulated buildings carry higher risk of moisture-related damage.
- Split incentive between tenant and property owner creates a significant barrier to major energy efficiency investment.

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.

Photo: © User Edge Hill University Wikimedia Commons

ENERGY EFFICIENT BUILDING ENVELOPE
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Efficient Envelope						●	●							

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Utility energy efficiency programs—Utilities such as National Grid and NSTAR provide incentives and rebates for a wide range of energy efficiency technologies and upgrades for retrofits and new construction.
- MassSave—MassSave provides both incentives to commercial/industrial/institutional customers as well as interest-free loans of up to $500,000 for energy efficiency projects.

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Atlantic Wharf, MA—Designed to use 42% less energy than comparable office buildings
- Castle Square Apartments, MA—Deep energy retrofit of a 1960s-era, 192 apartment building yielded a 72% reduction in energy usage at a cost of $42,593 per apartment.

SAMPLE OF SUPPLIERS

- Wide range of suppliers for each technology mentioned above.

SOURCES

- http://www.facilitiesnet.com/energyefficiency/article/Building-Envelope-How-to-Avoid-Energy-Loss--9428
- http://www.buildingscience.com/documents/reports/rr-0406-face-sealed-drainable-eifs/at_download/file
- https://www.wbdg.org/pdfs/usace_buildingenvelope.pdf
- http://www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergyEfficientBuildingEnvelopes.pdf

FLOATING BUIDLINGS
INSIDE THE FLOODPLAIN

Cost: An additional $60 per sq. ft. in construction costs (International Marine Flotation Systems, Inc.)

Applications: New construction

WHAT IS IT?

Floating buildings are buildings which are able to rise and fall in response to rising water levels. Buildings are constructed on floating barges, which are then anchored to piles. This design allows for the building to move vertically. While deployment of floating buildings on the East Coast is rare, there have been successful commercial and residential floating structures in Oregon, British Columbia and California, as well as internationally in the Netherlands. Floating must have flexible utility connections to enable building movement. Unlike houseboats, floating buildings have do not have steering controls. Deployment in Boston may be subject to local wetlands ordinances as well as the state-level municipal harbor planning process.

In contrast, amphibious buildings are built on the ground, but can float if water inundates the surrounding area. Such structures are technically feasible, but have not been tested beyond single-family construction. Currently, FEMA does not recognize floating or amphibious buildings in its standards for flood resilience.

BENEFITS

- Can contribute to further waterfront development and activation
- Responds dynamically to rising sea-levels and tidal action
- Buildings can withstand storm surge events

DRAWBACKS

- Siting floating buildings will be a complex process and likely subject to a series of building and environmental regulations
- Vulnerable to wave impacts without additional structural supports
- Not recognized by FEMA as a flood standard, and likely not to have an impact on insurance premiums
- Limited expertise on developing floating buildings on the East Coast

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- University of British Columbia Boathouses, Vancouver
- The Citadel, Netherlands
- The Krystall Hotel, Norway

SAMPLE OF SUPPLIERS

- International Marine Flotation Systems, Inc. (Vancouver)
- Waterstudio.NL (Netherlands)
- Dutch Docklands (International)

SOURCES

- http://www.nyc.gov/html/dcp/pdf/sustainable_communities/urban_waterfront_print.pdf
- http://tbha.org/sites/tbha.org/files/documents/prt2_designing_with_water_full.pdf
- http://www.floatingstructures.com/product/commercial-structures/

Photo: © User Rs1421 Wikimedia Commons

DRY FLOODPROOFING: FLOOD SHIELDS
INSIDE THE FLOODPLAIN

Cost: $180–$250 per ft. (by width). Price increases for taller shields

Applications: Designed to be easily added onto any existing building

Service Life: Indefinite, with regular inspection/ replacement of seals

WHAT IS IT?

Dry floodproofing techniques can be used to make a structure watertight below flood elevation. Flood shields are temporary, watertight barriers erected in front of building openings (e.g. doors, windows, garages) prior to flood events. Flood shields are constructed of aluminum, stainless steel, or plastic and use neoprene rubber or similar materials to seal the barrier. Flood shield mounts are typically installed around all building openings externally, though inside mounts are possible. The shields are then put in place in preparation for potential flooding or after flood warnings are issued. Installation time varies between models. Most flood shields are able to effectively protect buildings from floods of 1–2 feet.

BENEFITS

- Cheaper than passive flood barriers and easily installed on existing buildings
- Applied to the building itself and does not require additional land (for floodwalls or levees)
- Easily combined with other dry floodproofing measures for maximum protection

DRAWBACKS

- Deployment of flood shields requires human intervention and sufficient installation time for larger buildings. Without adequate warning, flooding can occur before shields can be put in place
- Flood shields do not protect structures from high-velocity flood flows and wave action. Most models do not provide protection for floods deeper than 2 feet
- Dry floodproofing measures cannot alone be used to bring substantially damaged or substantially improved residential structures into compliance with floodplain management ordinances and laws

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.
- Flood shields installed over all entrances and exits to a building may cause concern over building egress from the fire or inspectional services departments.

DRY FLOODPROOFING: FLOOD SHIELDS
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Barriers		●				●				●				

FINANCING OPTIONS, INCENTIVES, AND REBATES

- FEMA Hazard Mitigation Assistance—FEMA provides funding for flood and disaster mitigation through three grant programs: Hazard Mitigation Grant Program, Pre-Disaster Mitigation, and Flood Mitigation Assistance. Additional information and application instructions are available here through the Massachusetts Emergency Management Agency. Only non-residential dry floodproofing projects are eligible.
- Hazard Mitigation Funding Under Section 406 of the Stafford Act—Local, state, tribal, and some non-profit facilities damaged by disasters may use Section 406 funding to restore damaged facilities, as well as undertake preventative measures for future flood mitigation.

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Vero Beach Power Plant, FL
- New England Youth Theater, VT

SAMPLE OF SUPPLIERS

- Flood Panel
- Flood Barrier Shield by Zero International
- Flood Shield

SOURCES

- http://www.fema.gov/media-library-data/20130726-1608-20490-9182/fema_551_ch_07.pdf
- http://www.climatetechwiki.org/content/flood-proofing

FUEL TANK ANCHORING
INSIDE THE FLOODPLAIN

Cost: \$300–\$500 to anchor a 1,000 gallon tank to a concrete base. Cost will be lower for smaller tanks and for tanks anchored to the ground

Application: Indoor or outdoor oil and propane tanks

WHAT IS IT?

In flooding events, fuel tanks can be swept up in flood waters. Outdoor fuel tanks can be driven into building walls or swept downstream, while indoor fuel tanks can tear free from flexible connections and contaminate basements with oil. Anchoring of fuel tanks to the ground or to concrete slabs will prevent them from moving during a flood. Indoor and outdoor oil tanks can be anchored to concrete slabs that have sufficient weight to resist flood waters. Horizontal propane and oil tanks can be secured by attaching metal straps from ground anchors on opposite sides of the tank to the collar around the top of the tank. Rooms containing indoor fuel tanks can also be dry flood-proofed. For outdoor oil tanks, it is crucial to extend all filling and ventilation tubes above the 100-year flood level to ensure flood waters do not enter the tank.

BENEFITS

- Prevents damage and spills from fuel tank movement in flooding events.

DRAWBACKS

- None

REGULATORY IMPACTS AND REQUIREMENTS

- None

FINANCING OPTIONS, INCENTIVES, AND REBATES

- None

ADDITIONAL RESOURCES

SAMPLE OF SUPPLIERS

- Minute Man Products
- CommTank
- ENPRO Services
- Other storage tank service companies

SOURCES

- http://www.fema.gov/media-library-data/20130726-1627-20490-6014/how2005_fuel_tanks_4_11.pdf

GREEN ROOFING

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: Extensive: \$5–25 per sq. ft.; Intensive: \$25–\$40 per sq. ft.

- Annual maintenance costs range from \$0.75–\$1.50 per sq. ft.

Applications: Can be installed in retrofits or in new construction. Intensive green roofs can only be installed on flat rooftops that can support the additional weight. Extensive green roofs can be used on sloped rooftops.

Service Life: Extensive (>50 years with maintenance). Can extend life of conventional roofs by 40–60 years.

WHAT IS IT?

Green roofs consist of a vegetative layer grown on part or most of a rooftop. Green roofs shade the roof surface and help remove heat in the air through evapotranspiration. Whereas conventional rooftops absorb heat and can be up to 90 degrees hotter than ambient air temperature, green rooftops can often be cooler and can reduce building cooling costs. Widespread use of green roofs in urban environments can reduce urban heat island effect: a study of Toronto suggested that use of green roofs on 50% of rooftop surfaces in downtown could lead to cooling the entire city by up to 1.4°F. In winter, green roofing provides an insulating effect, reducing building heat loss and heating costs. Green roofs can also enhance stormwater management, capturing over 50% of rainfall and reducing runoff to storm drains. Careful selection of vegetation can allow green roofs to also capture pollutants from stormwater, including phosphorous, nitrogen, and heavy metals. Green roofs can reduce temperature variations and ultra-violet ray exposure on roofing materials, potentially extending the roof's life by 40–60 years.

There are two types of green roofs. Intensive green roofs are over 6" deep and allow for a wide range of vegetation to be grown on the roof, including shrubs and potentially trees. Intensive green roofs can provide social and recreational uses, but are typically more costly to install and require more regular maintenance and potentially, irrigation. Intensive green roofs can only be installed on flat rooftops that can support the additional weight, potentially limiting their application in retrofits. Extensive green roofs are shallower, lighter weight systems that typically have lower upfront and maintenance costs than intensive green roofs. Extensive green roofs have been successfully grown on roofs with slopes of greater than 30°, and tend to be more cost-effective in retrofits.

BENEFITS

- Reduces building heating and cooling costs. In summer, green roofs reduce building and ambient air temperatures. In winter, green roofs reduce building heat loss.
- Enhanced urban stormwater and pollutant management.
- Reduced sound transmission and reflection.
- Improved air quality, carbon sequestration, and building aesthetics.

DRAWBACKS

- Green roofs (particularly intensive green roofs) add additional weight to the building roof. Additional structural reinforcement may be necessary for installation.
- Green roofs require extensive rooftop waterproofing, as water becomes retained on the roof during storms. Roots may penetrate waterproof membranes, leading to structural damage.
- Higher upfront costs than traditional roofing.

GREEN ROOFING
CONTINUED

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table below.

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	Boston Landmarks Commission/ MA Historical Commission
Green Roofs/Cool Roofs						●				●				

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Boston University Student Services Center, MA
- John W. McCormack Federal Building, MA
- Harvard University Business School Shad Hall, MA

SAMPLE OF SUPPLIERS

- A number of green roofing companies sponsor www.greenroofs.com. A list is available here.

SOURCES

- http://www.nycgovparks.org/pagefiles/53/Citywide-Services-Green-Roof_2.pdf
- http://www.epa.gov/heatisland/resources/pdf/GreenRoofsCompendium.pdf

PERMANENT FLOOD BARRIERS: LEVEES AND FLOODWALLS

INSIDE THE FLOODPLAIN

Cost: Varies by height above ground.

- **Levees/berms:** 2 feet: $60/linear foot; 4 feet: $106/linear foot; 6 feet: $170/linear foot
- **Floodwalls:** 2 feet: $92/linear foot; 4 feet: $140/linear foot; 6 feet: $195/linear foot

Application: Levees are most practical for new construction as they require excavation and a large amount of space. Floodwalls can be more easily retrofitted to existing sites.

Service Life: Extensive (up to 50 years). Regular maintenance required.

WHAT IS IT?

Vulnerable building sites can be protected from floods through the use of levees and floodwalls. Levees and berms are structures constructed of compacted earthen materials with interior cores of impermable soil (i.e. clay). Construction typically begins with excavation to ensure subsurface soil conditions are taken into account in design. Floodwalls are typically engineered structures made of reinforced concrete. Floodwalls can be built up to 20 feet in height and can be designed to be aesthetically pleasing architectural and landscape features. Floodwalls are typically more expensive to construct than levees, but require less space and landscaping and are more resistant to erosion. Construction of all floodwalls and levees should be undertaken by licensed engineers.

Due to the large amount of space needed for construction, the use of levees andfloodwalls may be difficult and cost-prohibitive in urban environments and may only be suitable for integration into new construction. In particular, levees and berms require a large quantity of earthen fill, and a lack of readily available, nearby fill may cause transportation costs to be prohibitive. Higher levees and floodwalls require significantly more support to withstand the greater water pressure exerted on the barrier. Stregthening levees and floodwalls requires increases and size, which may exceed the amount of space available on a building site and become impractical. Levees are typically limited to 6 feet in height and floodwalls to 4 feet to maintain cost-effectiveness. Sites with expected flood depths that exceed practical barrier heights should consider using alternate methods instead of or in addition to permanent flood barriers (e.g. elevation or floodproofing). Barriers must be located a sufficient distance away from structures with basements to prevent damage to basement walls from the additional pressure from saturated soils. Regular maintenance is crucial to maintain service life.

BENEFITS

- Floodwalls and levees will protect a building site from floodwater damage. As a result, protected structures will not need additional modifications for flood protection.
- Site aesthetics can be preserved or enhanced. Floodwalls can utilize decorated bricks or be built into garden areas.

DRAWBACKS

- Levees and floodwalls cannot be used alone to bring substantially damaged or substantially improved structures into compliance with floodplain management ordinances and laws.
- The amount of excavation and space required for levees may make them impractical for existing sites and most building sites in urban areas. Floodwalls may be applicable in these sites, but are more expensive to construct.
- The use of levees and in some cases floodwalls may affect drainage in the area, potentially worsening flood damage in adjacent sites.

Photo: Public Domain via Wikimedia Commons

PERMANENT FLOOD BARRIERS: LEVEES AND FLOODWALLS
CONTINUED

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table below.

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Barriers		●				●				●				

FINANCING OPTIONS, INCENTIVES, AND REBATES

- FEMA Hazard Mitigation Assistance—FEMA provides funding for flood and disaster mitigation through three grant programs: Hazard Mitigation Grant Program, Pre-Disaster Mitigation, and Flood Mitigation Assistance. Additional information and application instructions are available here through the Massachusetts Emergency Management Agency. Only non-residential dry floodproofing projects are eligible.
- Hazard Mitigation Funding Under Section 406 of the Stafford Act – Local, state, tribal, and some non-profit facilities damaged by disasters may use Section 406 funding to restore damaged facilities, as well as undertake preventative measures for future flood mitigation.

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Lourdes Hospital, NY—11 FloodBreak passive floodgates combined with 11-foot floodwall at a cost of approx. $7 million
- New Orleans, LA—After the infamous design failure of the levee and floodwall system in 2005 during Hurricane Katrina, a $14.5 billion civil works design
- Haverhill Floodwall, MA – $5.4 million in repairs to a 30 feet floodwall along the Merrimack River.

SAMPLE OF SUPPLIERS

- Building/landscaping contractors

SOURCES

- http://www.fema.gov/media-library-data/20130726-1608-20490-6445/fema551_ch_05.pdf

OPERABLE WINDOWS

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: Site, size, and project specific. Operable windows will typically cost 50%–75% more than fixed windows

Applications: Can be installed in retrofits or in new construction.

Service Life: 30–35 years

WHAT IS IT?

The installation of operable windows can give building occupants greater control over building temperature. During cooler summer days where outdoor air temperature is comfortable, building windows can be opened to allow for natural ventilation. In buildings with mechanical ventilation systems, the need for cooling and its associated energy costs will be reduced. Operable windows are essential in buildings that utilize passive ventilation strategies for cooling (i.e. cross ventilation and stack ventilation). Operable windows can also provide backup ventilation in the event of power outages or during other times when ventilation systems are inactive. A wide variety of operable windows are available depending on building needs and location.

Operable windows will have a larger capital cost compared to fixed windows, though the additional cost can be offset by reduced energy use for cooling and increased worker comfort and productivity. Not all windows in a commercial building need be operable; 15 to 20% operable windows positioned to allow for cross ventilation can be a cost-effective investment for a building owner. Ultimately, the cost-effectiveness of operable windows will often depend on occupant behavior. While building occupants will typically be more satisfied with having greater control over some workspace/living conditions, building energy use may increase if occupants do not properly close or open windows during the winter.

BENEFITS

- Operable windows allow for greater control over building temperature. This can result in increased building occupant satisfaction and productivity.
- Building energy use can be reduced if less mechanical cooling is required when windows are opened.
- Operable windows can be washed from the inside, potentially reducing cleaning/maintenance costs.
- Operable windows will provide continued ventilation during power outages or other HVAC downtime.

DRAWBACKS

- Operable windows are significantly more expensive than fixed windows.
- If windows are left open or improperly closed, a building ventilation system can experience excessive heating or cooling loads, increasing energy costs.
- Benefits of operable windows require buildings to utilize multiple HVAC zones so that the system can be switched off when windows are opened. These ventilation systems are more expensive and place space configuration limitations on realizing the benefits of operable windows. Failing to shut off HVAC systems when windows are opened can increase energy use for that area by as much as 30%.
- Operable windows may be impractical on the upper floors of high rise buildings. Wind levels may be too high due to the stack effect or higher outdoor wind speeds.

Photo: © National Parks Service, Image is part of the Public Domain

OPERABLE WINDOWS
CONTINUED

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table below.

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Ventilation						●								

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Spaulding Rehabilitation Hospital, MA
- Green on the Grand Office Building, ON

SAMPLE OF SUPPLIERS

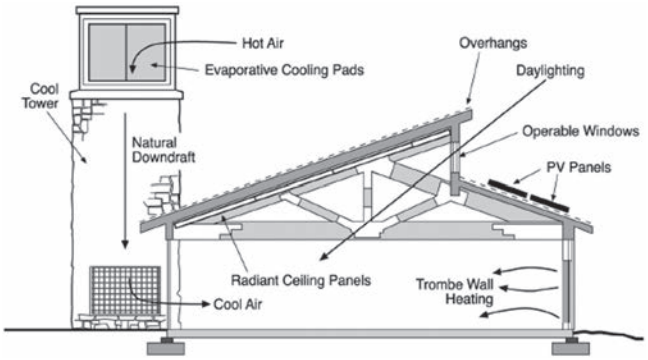
- Wide range of window suppliers, including Wojan Window & Door Corporation, Intus Windows, and Yaro Windows + Doors

SOURCES

- http://www.facilitiesnet.com/energyefficiency/article/Operable-Windows-Can-Save-Energy--10284#
- http://www.greenglobes.com/advancedbuildings/_frames/fr_t_building_operable_windows.htm
- http://ddc-resiliencedatabase.wikispaces.com/Operable+Windows

PASSIVE STACK VENTILATION

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN



Cost: Cost of retrofit depends on state of current building; cheaper in new construction than equivalent mechanical ventilation

Applications: Can be installed in retrofits or in new construction

Service Life: Extensive (25+ years)

WHAT IS IT?

The stack effect describes the passive movement of air through a building resulting from differences in vertical pressure developed by thermal buoyancy. When air inside a building is warmer than the outside air, the warmer, the less dense air will rise. Stack ventilation takes advantage of this effect by constructing openings in the building envelope high at a substantial height, allowing the warm air to escape. The negative pressure at the top of the building draws in colder, denser outside air through openings low in the building. Naturally, this effect is fairly weak, but it can be concentrated through the use of a stack. Longer stacks will typically increase airflow. Controlled stack ventilation can allow for passive cooling in the summer with some benefits over mechanical ventilation including low maintenance and operating cost, minimal or no energy costs, and typically lower construction costs in new buildings, as passive stack ventilation is designed similarly to mechanical ventilation without the mechanical components. Passive stack ventilation is generally rare in the United States, but is fairly popular in buildings in Europe.

While stack ventilation can have cooling benefits in the summer, it can be problematic during cold winters, as the high temperature difference between the building interior and exterior can result in overventilation and unwanted building heat loss. Conversely, underventilation can occur even with large ventilation openings when temperature differences are low. Even when temperature differences are sufficient to facilitate adequate stack ventilation, upper floors in larger buildings can be underventilated. Ventilation stacks, particularly in larger buildings, should be designed with some method of flow control, such as self-regulating vents, pressure sensitive ventilators, or fans (including solar powered fans). Some systems may need backup mechanical ventilation as well.

BENEFITS

- Allows for building cooling and ventilation with lower maintenance and operating costs than mechanical systems. Minimal operational noise.
- Fully passive systems require no additional energy. Stacks supplemented by active flow control use less energy than equivalent mechanical systems.
- Reduces building cooling energy needs. Can be combined with passive cross-ventilation to maximize ventilation.

DRAWBACKS

- Due to reliance on natural forces, overventilation and underventilation can occur frequently. Proper design and flow control are necessary to maintain adequate ventilation rates.
- Ventilation can be inadequate on upper floors of larger buildings, trapping heat and reducing air quality. Installation of operable windows may be necessary to facilitate ventilation.
- In winter, the high difference in temperature between the building's interior and exterior can result in overventilation and heat loss without adequate flow control.

PASSIVE STACK VENTILATION
CONTINUED

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table below.

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Ventilation										●				

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Building Research Establishment Environment Building, UK

SAMPLE OF SUPPLIERS

- Building contractors/consultants (e.g. Building Science Corporation)

SOURCES

- http://www.buildingscience.com/documents/guides-and-manuals/gm-review-residential-ventilation-technologies
- http://www.architecture.com/RIBA/Aboutus/SustainabilityHub/Designstrategies/Air/1-2-1-2-Naturalventilation-stackventilation.aspx
- http://gbtech.emsd.gov.hk/english/utilize/natural.html
- http://www.nrel.gov/docs/fy13osti/56253.pdf

PERMEABLE CLAY BRICK PAVERS

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: \$10.00–\$12.00 per sq. ft.

Applications: Parking lots, pathways, sidewalks, plazas, driveways, public spaces. Can be used in high weight but low volume/speed roads (industrial or residential)

Service Life: 20–40 years

WHAT IS IT?

Permeable clay brick pavers are very similar to permeable interlocking concrete pavers (PICPs). With the exception of the construction material (clay brick vs concrete), brick and concrete pavers share many technical specifications, maintenance needs, and applications. Relative to interlocking concrete pavers, permeable clay brick pavers have wider joints between bricks that allow for water infiltration. These open-graded aggregate-filled joints can allow for theoretical permeability of hundreds of inches per hour. In practice, infiltration rates will depend on the permeability of the subgrade soil. Replacement of aggregate fill should occur as needed. Periodic vacuuming will help maintain infiltration rates, and frequency should be determined by exposure to sediments (e.g. pavers not frequently exposed to mud and winter sanding may not need to be vacuumed for many years). Like PICPs, permeable clay brick pavers have very high load bearing strength and can be used in industrial applications, with the exception of areas that handle hazardous materials.

BENEFITS

- Enhances groundwater infiltration while reducing stormwater runoff volume, rate, and pollutants
- Bricks can reduce urban heat island through increased reflectivity and evaporative cooling
- Colors and shapes help preserve urban aesthetic
- Very high load bearing strength
- Easy to repair – units can be easily removed and reset
- Reduces occurrence of black ice/freezing puddles in cold climates; requires less applied deicers

DRAWBACKS

- Pollutants and deicing salts can infiltrate groundwater—should not be installed in areas where hazardous material spills are possible
- More expensive than other permeable pavements

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.

PERMEABLE CLAY BRICK PAVERS
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Permeable Pavements	●		●	●	●						●	●	●	●

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Municipal stormwater abatement service fees—Municipal-level
- Coastal Pollutant Remediation (CPR) Grant Program—MA State
- Clean Water State Revolving Fund (SRF)—MA State
- Section 319 Nonpoint Source Competitive Grant—Funding provided under federal Clean Water Act
- 604b Water Quality Management Planning Grant—Funding provided under federal Clean Water Act
- Drinking Water Supply Protection Grant Program—MA State

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Third Street, New Albany, OH
- Gotts Court, MD

SAMPLE OF SUPPLIERS

- Pine Hall Brick
- Whitacre Greer Company
- Belden Brick Company

SOURCES

- http://www.coastal.ca.gov/nps/lid/PermeablePavement-What'sitDoingonMyStreet.pdf
- http://www.gobrick.com/Portals/25/docs/Technical%20Notes/TN14D.pdf
- http://www.wastormwatercenter.org/files/library/x100percentbooktest3meta-textremovedreduced.pdf

PERMEABLE INTERLOCKING CONCRETE PAVERS

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: $2.50–$10.00 per sq. ft.

Applications: Parking lots, pathways, sidewalks, plazas, driveways, public spaces. Can be used in high weight but low volume/speed roads (industrial or residential)

Service Life: 20–40 years

WHAT IS IT?

Permeable interlocking concrete pavers (PICPs) leave open void spaces filled with gravel between pavers to allow for water infiltration. These filled joints can allow for infiltration rates of up to 50 inches per hour with regular maintenance (e.g. street sweeping/vacuuming and refilling of displaced gravel) and 3-4 inches per hour without, though in practice, infiltration rates will depend on the permeability of the sub-grade soil. PICPs meet U.S. EPA stormwater best management practice criteria for parking, road, and pedestrian surfaces.

PICPs have very high load bearing strength, often exceeding 1 million lbs per sq. ft., more than double the compression strength of concrete slabs. PICPs come in a wide variety of shapes, sizes, and colors, allowing for a diverse range of applications while preserving the surrounding aesthetic. The maximum slope of PICPs is higher than that of other permeable pavements, allowing for a slope of up to 12% while maintaining infiltration.

BENEFITS

- Enhances groundwater infiltration while reducing stormwater runoff volume, rate, and pollutants.
- Light colored PICPs can reduce urban heat island through increased reflectivity and evaporative cooling
- Available in wide range of colors and shapes to preserve urban aesthetic
- Very high load bearing strength
- Easy to repair—units can be easily removed and reset
- Reduces occurrence of black ice/freezing puddles in cold climates; requires less applied deicers

DRAWBACKS

- Pollutants and deicing salt can infiltrate groundwater—should not be installed in areas where hazardous material spills are possible
- Can be more expensive than other permeable pavements

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.

Photo: Image is part of the public domain

PERMEABLE INTERLOCKING CONCRETE PAVERS
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Permeable Pavements	●		●	●	●						●	●	●	●

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Municipal stormwater abatement service fees—Municipal-level
- Coastal Pollutant Remediation (CPR) Grant Program—MA State
- Clean Water State Revolving Fund (SRF)—MA State
- Section 319 Nonpoint Source Competitive Grant—Funding provided under federal Clean Water Act
- 604b Water Quality Management Planning Grant—Funding provided under federal Clean Water Act
- Drinking Water Supply Protection Grant Program—MA State

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Jordan Cove Watershed, CT
- Morton Arboretum, IL

SAMPLE OF SUPPLIERS

The Interlocking Concrete Pavement Institute provides technical information for PICP best practices and maintains a database of PICP manufacturers and contractors. Access the manufacturer database here and the contractor database here.

SOURCES

- http://www.coastal.ca.gov/nps/lid/PermeablePavement-What'sitDoingonMyStreet.pdf
- http://www.epa.gov/heatisland/resources/pdf/CoolPavesCompendium.pdf
- http://www.co.thurston.wa.us/planning/climate/docs/yl.Permeable-Pavement-Comparison-(Seattle).pdf
- https://www.icpi.org/sites/default/files/picp_fact_sheet_dp-april_2012.pdf
- http://www.wastormwatercenter.org/files/library/x100percentbooktest3meta-textremovedreduced.pdf

PERVIOUS CONCRETE

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: $2.00–$6.50 per sq. ft., typically 15% more expensive than conventional concrete and four times more expensive than porous asphalt

Applications: All applications as alternative to conventional concrete, including parking lots, low speed/volume streets, pathways, and other pedestrian applications

Service Life: 15–30 years

WHAT IS IT?

Pervious concrete is concrete mixed with less sand and fine particles than conventional asphalt. The concrete is then laid above a crushed stone aggregate base to allow for water infiltration. Water is able to permeate the concrete due to void spaces of 18%–20%, which also reduces the weight of pervious concrete by 20%–30% compared to conventional concrete. Rigid pavements like concrete typically do not require aggregate bases for structural stability, though deep aggregate bases are recommended for cold climates like the northeast. Suppliers are easy to find, as pervious concrete can be mixed and applied using the same equipment and methods as impervious concrete, though the lack of fine particles gives pervious concrete a coarser look than conventional concrete.

As with other pervious pavements, proper maintenance (primarily vacuum sweeping) is necessary to maintain high rates of infiltration. Infiltration rates are also highly dependent on the subgrade soil. Sandy soils have highest infiltration capacity and increased load bearing capacity, but lower treatment capacity. Potholes and cracks can be fixed with patching mixes unless >10% of the surface needs replacement. The maximum slope of pervious concrete exceeds porous asphalt, allowing for a slope of up to 12% while maintaining infiltration.

BENEFITS

- Enhances groundwater infiltration while reducing stormwater runoff volume, rate, and pollutants
- Can contribute to lower urban air temperatures when moist due to higher reflectivity and evaporative cooling
- Reduces occurrence of black ice/freezing puddles in cold climates; requires less applied deicers

DRAWBACKS

- Pollutants can infiltrate groundwater—should not be installed in areas where hazardous material spills are possible
- Plowed snow piles and improper deicing treatment can clog void spaces and reduce infiltration rate (sand should not be used); snow plow blades can damage surface
- More expensive than porous asphalt
- Coarse appearance can be aesthetically displeasing (relative to conventional concrete)

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.

Photo: © User PerviousConcrete on Wikimedia Commons

PERVIOUS CONCRETE
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Permeable Pavements	●		●	●	●						●	●	●	●

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Municipal stormwater abatement service fees—Municipal-level
- Coastal Pollutant Remediation (CPR) Grant Program—MA State
- Clean Water State Revolving Fund (SRF)—MA State
- Section 319 Nonpoint Source Competitive Grant—Funding provided under federal Clean Water Act
- 604b Water Quality Management Planning Grant—Funding provided under federal Clean Water Act
- Drinking Water Supply Protection Grant Program—MA State

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- List of projects in NJ/DE/PA involving PCA-Northeast

SAMPLE OF SUPPLIERS

- Cape Cod Ready Mix
- Boston Sand and Gravel
- Massachusetts Concrete & Aggregate Producers Association provides a directory of concrete mix producers, many of whom supply pervious concrete. Browse through the directory here.
- National Ready Mixed Concrete Association maintains a database of certified concrete installers. Search for pervious concrete installers and concrete sustainability experts by state here.

SOURCES

- http://www.epa.gov/heatisland/resources/pdf/CoolPavesCompendium.pdf
- http://environment.fhwa.dot.gov/ecosystems/ultraurb/3fs15.asp
- http://www.coastal.ca.gov/nps/lid/PermeablePavement-What'sitDoingonMyStreet.pdf
- https://extension.umd.edu/sites/default/files/_docs/programs/master-gardeners/Howardcounty/Baywise/PermeablePavingHowardCountyMasterGardeners10_5_11%20Final.pdf
- http://www.wastormwatercenter.org/files/library/x100percentbooktest3meta-textremovedreduced.pdf

PLASTIC GRID

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: $1.50–$5.75 per sq. ft.

Applications: Low speed vehicular traffic (e.g. parking lots, driveways, alleys, access roads), trails, pathways, bike paths. Can be used in retrofits or new construction

Service Life: 10–20+ years

WHAT IS IT?

Plastic grids are an alternative pavement, consisting of a durable interlocking plastic grid filled with gravel, earth, or seeded with grass. The grid is very porous, allowing for high rates of infiltration (up to 3 ft./hr.), and the modular plastic cells can reduce erosion and wear on gravel and grass pathways. Due to the flexibility of the grid components, plastic grids can be used on sites with uneven terrain, though maximum slope ranges from 6%–12% due to traction limitations.

Regular maintenance is typically low. Vegetated grids will need to be mowed and may need irrigation and occasional reseeding, while non-vegetated grids may need to be refilled with gravel or crushed rock. Vacuuming may be necessary to maintain high permeability. Plastic grids can be easily added onto existing paving, though care should be taken to ensure that high volumes of runoff are not directly routed from adjacent impervious areas onto the grid, as sediment can quickly clog the void spaces. Plastic grids are often made from recycled materials. Load bearing capacities range from 24,000 lb/sq. ft. to 823,680 lbs/sq. ft.

BENEFITS

- Enhances groundwater infiltration while reducing stormwater runoff volume, rate, and pollutants. Additional drainage facilities are not required
- Vegetated grids can lower urban air temperatures when moist due to evaporative cooling
- Quick installation time
- Reduces occurrence of black ice/freezing puddles in cold climates; requires less applied deicers

DRAWBACKS

- Pollutants and deicing salts can infiltrate groundwater—should not be installed in areas where hazardous material spills are possible
- Poorly placed grids can become clogged due to excess runoff from impervious areas
- Load bearing strength and durability generally lower than permeable pavers/asphalt/concrete
- Vegetated pavers require regular maintenance and may require additional irrigation during daytime

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.

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PLASTIC GRID
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Permeable Pavements	●		●	●	●						●	●	●	●

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Municipal stormwater abatement service fees—Municipal-level
- Coastal Pollutant Remediation (CPR) Grant Program—MA State
- Clean Water State Revolving Fund (SRF)—MA State
- Section 319 Nonpoint Source Competitive Grant—Funding provided under federal Clean Water Act
- 604b Water Quality Management Planning Grant—Funding provided under federal Clean Water Act
- Drinking Water Supply Protection Grant Program—MA State

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- City of Vancouver Sustainable Streets and Country Lanes, BC
- Thorndike Fields Parking Area, MA

SAMPLE OF SUPPLIERS

- Invisible Structures, Inc.
- TYPAR Geosynthetics
- Purus Plastics

SOURCES

- http://www.coastal.ca.gov/nps/lid/PermeablePavement-What'sitDoingonMyStreet.pdf
- http://www.epa.gov/heatisland/resources/pdf/CoolPavesCompendium.pdf
- http://www.co.thurston.wa.us/planning/climate/docs/yl.Permeable-Pavement-Comparison-(Seattle).pdf
- http://www.wastormwatercenter.org/files/library/x100percentbooktest3meta-textremovedreduced.pdf

DRY FLOODPROOFING: POLISHED CONCRETE FLOOR

INSIDE THE FLOODPLAIN

Cost: $3.00–$7.00 per sq. ft.

Applications: Can be installed in retrofits or new construction. Existing concrete floors can be polished.

Service Life: 30+ years. Re-polish needed every 7 to 10 years

WHAT IS IT?

Dry floodproofing techniques can be used to make a structure watertight below flood elevation. In the event that barriers and other dry floodproofing techniques fail and water enters the building, installing polished concrete flooring in the basement will help to minimize repair costs. Polished concrete is impermeable and if installed properly, will not need replacement after flooding. While polished concrete upfront costs can be higher than for other types of flooring (particularly vinyl, linoleum, and unpolished concrete), maintenance costs can be lower over time, as polished concrete is more resistant to foot traffic, has a longer service life, and does not require waxing or coating. Daily mopping or scrubbing with non-abrasive materials will remove dust particles which act as an abrasive and grind away the finish.

BENEFITS

- Polished concrete is impermeable and if properly maintained, will survive flooding with no damage to structural integrity.
- Typically lower maintenance costs and longer service life than other types of flooring

DRAWBACKS

- Can be colder, louder, and more expensive than other types of flooring.
- Improper installation and poor maintenance can result in flooring becoming susceptible to moisture.

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.

Photo: This picture was released to the public domain, Wikimedia Commons

DRY FLOODPROOFING: POLISHED CONCRETE FLOOR
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Building Insulation/ Internal Materials						●	●			●				

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Sample gallery of projects: Installations located in commercial and residential spaces in New England

SAMPLE OF SUPPLIERS

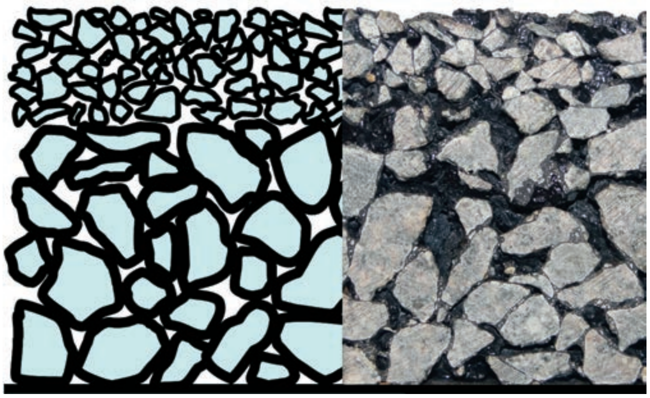
- Madstone Aesthetic Concrete
- Polished Concrete of New England
- Find other polished concrete contractors serving the greater Boston area through The Concrete Network here.

SOURCES

- http://moderncrete.com/polished-concrete-floor-maintenance-tips/
- http://www.concretenetwork.com/concrete/polishing/benefits.html
- http://www.concretenetwork.com/concrete/polishing/comparison-chart.html
- http://www.concretenetwork.com/concrete/polishing/maintenance.html

POROUS ASPHALT

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN



Cost: \$0.50–\$2.50 per sq. ft. (EPA), typically 10%–15% more expensive than conventional asphalt (FHWA)

Applications: All applications as alternative to conventional asphalt, including highways, parking lots, and streets.

Service Life: 7–20 years

WHAT IS IT?

Porous asphalt is open-graded asphalt mixed with less sand and fine particles than conventional asphalt and is laid above crushed stone aggregate layer to allow for water infiltration. Water is able to permeate the asphalt due to increased void space of (approx. 16% compared to 2%–3% for conventional asphalt). In order to maintain infiltration, porous asphalt should not be used on slopes of greater than 5%.

The infiltration rate ranges from hundreds of inches per hour when freshly paved to more than one inch per hour when the void spaces are clogged (EPA). Proper maintenance (primarily vacuum sweeping) is necessary to maintain high rates of infiltration. Potholes and cracks can be fixed with patching mixes unless >10% of the surface needs replacement. Infiltration rates are also highly dependent on the subgrade soil. Sandy soils have higher infiltration rates, but lower treatment capacity. Conversely, clay soils capture more pollutants, but have lower infiltration rates. In case of low permeability subgrade soils (<0.25 in/hr), installing under drains or combining pavement with infiltration trenches or bioswales can improve drainage.

BENEFITS

- Enhances groundwater infiltration while reducing stormwater runoff volume, rate, and pollutants
- Can contribute to lower urban air temperatures when moist due to evaporative cooling
- Reduces occurrence of black ice/freezing puddles in cold climates; requires less applied deicers
- Higher frictional resistance allows for better traction than conventional asphalt in cold climates

DRAWBACKS

- Pollutants and deicing salts can infiltrate groundwater—should not be installed in areas where hazardous material spills are possible
- Plowed snow piles and improper deicing treatment can clog void spaces and reduce infiltration rate (sand should not be used); snow plow blades can damage surface
- Can contribute to higher urban daytime temperatures due to lower reflectivity

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.
- Nearby buildings: When installing permeable pavement, it is critical to conduct subsurface investigation. There are many old vaults with direct access to building basements underneath Boston sidewalks that could potentially leak water into the building if permeable pavement is installed at the surface. Many of these vaults are unmapped and there are legal issues around who owns the vault and the sidewalk/sub-base above it. In addition, rubble foundations and other old building foundations nearby may begin to leak from increased hydrostatic pressure.
- Groundwater Trust: Installation of permeable pavements in the Groundwater Conservation Overlay District (GCOD) may require consultation with the Groundwater Trust. In particular, permeable pavements cannot be installed over polluted sites within GCOD.

Photo: © VBW-Asfalt on Wikimedia Commons

POROUS ASPHALT
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Permeable Pavements	●		●	●	●						●	●	●	●

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Municipal stormwater abatement service fees—Municipal-level
- Coastal Pollutant Remediation (CPR) Grant Program—MA State
- Clean Water State Revolving Fund (SRF)—MA State
- Section 319 Nonpoint Source Competitive Grant—Funding provided under federal Clean Water Act
- 604b Water Quality Management Planning Grant—Funding provided under federal Clean Water Act
- Drinking Water Supply Protection Grant Program—MA State

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- South End Alley 543, MA
- BP Whiting Refinery, IN
- Mystic River Watershed Initiative, MA

SAMPLE OF SUPPLIERS

- Whittier Paving*
- GSC Paving*

SOURCES

- http://water.epa.gov/polwaste/npdes/swbmp/Porous-Asphalt-Pavement.cfm
- http://www.epa.gov/heatisland/resources/pdf/CoolPavesCompendium.pdf
- http://www.dauphincd.org/swm/BMPfactsheets/Porous%20Asphalt%20fact%20sheet.pdf
- http://environment.fhwa.dot.gov/ecosystems/ultraurb/3fs15.asp
- http://www.asphaltpavement.org/index.php?option=com_content&view=article&id=517&Itemid=1149
- https://extension.umd.edu/sites/default/files/_docs/programs/master-gardeners/Howardcounty/Baywise/PermeablePavingHowardCountyMasterGardeners10_5_11%20Final.pdf
- http://www.wastormwatercenter.org/files/library/x100percentbooktest3meta-textremovedreduced.pdf

* Indicates Boston-area supplier

RAIN GARDEN/BIO-RETENTION CELL

INSIDE THE FLOODPLAIN

Cost: Estimates vary greatly based on site

- **Rain gardens:** \$3.00–\$40.00 per sq. ft.
- **Bioretention:** \$2.22–\$30.00 per sq. ft.

  See Appendix B of the Prince George's County, Maryland Dept. of Environmental Resources *Bioretention Manual* for project cost estimates

Applications: Parking lots, road/sidewalk drainage, residential/commercial buildings. Can be used in combination with other stormwater best management practices. Easily built into existing sites, though new construction can more easily take advantage of natural terrain and design for directing stormwater flows

Service Life: Extensive, depending on continued maintenance

WHAT IS IT?

Rain gardens and bio-retention cells use flowering plants and grasses to treat and reduce stormwater runoff and increase soil infiltration. Natural biological and chemical processes can significantly reduce suspended solids and pollutants like nitrogen, phosphorous, and metals by 30%–90%. Rain gardens are typically smaller and positioned alongside roads and buildings while bioretention cells are often used in larger drainage areas. Multiple gardens and cells can be used for large drainage areas, though proper siting is extremely important to maximize effectiveness.

Rain gardens should be located in sloped areas of up to 10% at least 10 feet away from building foundations and approximately one-third the size of the area providing the runoff. Bioretention cells should be located in landscaped or natural depressions not exceeding 6% slope and should be sized at approximately 5% of the drainage area, which should not exceed five acres. In addition to proper siting and sizing, sunlight requirements of the plant species used should be taken into consideration to maximize effectiveness and reduce maintenance.

Resilient native species that can survive in soaked soils should be used wherever possible. Salt-tolerant plants should also be used for drainage areas that are salted in winter. Design adjustments and combination with other stormwater best management practices and proper snow removal are necessary to ensure that bio-retention cells continue functioning during cold winters. Regular maintenance is required to ensure continued effectiveness and system longevity, including annual mulching, fertilizing, pruning, and removal of dead vegetation, as well as regular trash removal, weeding, and mowing. Costs range significantly depending on plants used, landscaping required, and use of underdrains, liners, and outlet structures. In calculating cost savings from utilizing bioretention, it is important to take into account the reduction of conveyance and other conventional stormwater management systems and reduced maintenance, design, and liability costs: a medical office building in Maryland saved \$24,000 through using bioretention in place of 570 additional feet of storm drain pipe.

BENEFITS

- Uses natural processes to reduce stormwater runoff volume, rate, and pollutants and increase soil and groundwater infiltration
- Green spaces used in rain gardens and bioretention can improve urban air quality, contribute to lower urban air temperatures, and be aesthetically pleasing
- Can be easily retrofitted during any landscape modification or parking lot/street resurfacing
- Maintenance costs of bioretention are lower than those of conventional stormwater management systems

Photo: © User DASonnenfeld on Wikimedia Commons and the U.S. EPA

RAIN GARDEN/BIO-RETENTION CELL
CONTINUED

DRAWBACKS

- Not suitable for large drainage areas
- Bioretention cells can take up significant land area; use in parking lots can reduce available parking
- Can sometimes be more expensive than traditional stormwater management practices; adjustments needed to facilitate winter operation will increase installation costs
- Careful landscaping and maintenance required; poor landscaping and maintenance can result in ineffective drainage and could attract pests

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table below.

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Water Storage/ Bioretention	●		●					●	●					

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Municipal stormwater abatement service fees—Municipal-level
- Coastal Pollutant Remediation (CPR) Grant Program—MA State
- Clean Water State Revolving Fund (SRF)—MA State
- Section 319 Nonpoint Source Competitive Grant—Funding provided under federal Clean Water Act
- 604b Water Quality Management Planning Grant—Funding provided under federal Clean Water Act
- Drinking Water Supply Protection Grant Program—MA State

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Chagrin River Watershed Partners Case Study, OH
- Seattle Street Edge Alternatives Project, WA
- Boston Dewey Demonstration Gardens, MA (video)

RAIN GARDEN/BIO-RETENTION CELL
CONTINUED

SAMPLE OF SUPPLIERS

- Landscape designers/contractors (e.g. Land Escapes)
- A list of plants native to Massachusetts coastal environments is available here
- A list of species appropriate for use in bioretention is available here

SOURCES

- http://epa.ohio.gov/Portals/41/storm_workshop/lid/CRWP_LID_Cost%20Study.pdf
- http://ma-northampton.civicplus.com/DocumentCenter/View/2489
- http://www.lakesuperiorstreams.org/stormwater/toolkit/raingarden.html
- http://www.lakesuperiorstreams.org/stormwater/toolkit/bioretention.html
- http://www.mass.gov/eea/docs/eea/water/raingarden.pdf
- http://www.lid-stormwater.net/bio_costs.htm
- http://www.wpi.edu/Pubs/E-project/Available/E-project-042313-151150/unrestricted/PPM1231_Final_MQP_Report.pdf
- http://www.ct.gov/deep/lib/deep/p2/raingardens/bioretention_manual_2009_version.pdf

RAINWATER HARVESTING
INSIDE THE FLOODPLAIN

Cost: Dependent on size and material

- Galvanized steel: $950 for 2,000 gal.
- Polyethylene: $1,100 for 1,800 gal.
- Fiberglass: $10,000 for 10,000 gal.
- Fiberglass/steel composite: $10,000 for 5,000 gal.

(Costs for system only, does not include installation/ other associated costs)

Applications: Can be installed in retrofits or in new construction

Service Life: Extensive (20–50 years)

WHAT IS IT?

A 1,000 square foot roof receives approximately 600 gallons of water from 1 inch of rainfall. Rainwater harvesting allows for some of this rainwater to be captured and reused in non-potable applications. Rainwater is captured in barrels (approx. 55 gallon capacity) and cisterns (10,000 gallons or more), which reduces the quantity of stormwater runoff and non-point source pollution. Rainwater storage tanks can be located above ground, underground, or inside building basements. Rainwater that exceeds a harvesting system's capacity can be diverted to a storm drain as needed. Annual cleaning is necessary to remove biological contaminants that collect in the storage tank. Downspout seals, installed to prevent mosquito breeding in the standing water, should also be inspected periodically.

Rainwater captured in cisterns has limited use. Rainwater can be used for irrigation, though rainwater is slightly acidic (pH 5.6–5.7) and should be used on appropriate vegetation. Rainwater can be used in buildings for toilet flushing or for HVAC processes (e.g. boilers, air conditioning). However, care must be taken to ensure that potable and non-potable water sources are separated and that all plumbing within the building is properly labeled. Successfully reused water can significantly reduce building water use: Atlantic Wharf installed a rainwater harvesting system utilizing a 40,000-gallon storage tank that has, in conjunction with other water conservation efforts, yielded a 63.1% reduction in irrigation-related water use and 15% reduction in process water use compared to similar buildings.

BENEFITS

- Rainwater capture reduces stormwater runoff and non-point source pollution during storm events.
- Reuse of rainwater can reduce building water use and associated costs.
- Captured rainwater used for irrigation preserves the hydrological cycle by allowing for groundwater recharge.

DRAWBACKS

- High capital cost; due to initial infrastructure investment, operations and maintenance, and pumping costs, life cycle cost and net present value benefits assessments have shown that rainwater harvesting is not economically viable given present conditions.
- Cisterns placed above ground must be winterized in cold climates, increasing capital cost. Cisterns placed below ground may require excavation, increasing costs.

Photo: © User Pengo, CC by 2.5 Wikimedia Commons

RAINWATER HARVESTING
CONTINUED

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table below.

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Storage/Bioretention	●		●					●	●					

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Atlantic Wharf, MA
- One Beacon Street, MA
- Multiple project profiles by Contech Engineered Solutions available here (pg. 9–11)

SAMPLE OF SUPPLIERS

- RainHarvest Systems
- Contech Engineered Solutions
- Park USA
- Conservation Technology

SOURCES

http://www.conteches.com/knowledge-center/pdh-article-series/cistern-designs-large-rainwater-harvesting-systems.aspx

http://www.tahoebmp.org/Documents/BMPHandbook/Chapter%204/4.1/e_RainBar.pdf

http://www.lid-stormwater.net/raincist_specs.htm

http://buildgreen.ufl.edu/Fact_%20sheet_Cisterns_Rain_Barrels.pdf

http://forsyth.ces.ncsu.edu/files/library/34/rainwater.pdf

http://www.iwaponline.com/ws/01203/ws012030309.htm

RESIN-BOUND/BONDED PAVING

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: $3.00–$12.00 per sq. ft.

Applications: Parking lots, pathways, sidewalks, plazas, driveways, public spaces, tree pits. Only use in low volume, low-speed roads

Service Life: 5–10 years (vehicular traffic); 10–15 years (pedestrian traffic)

WHAT IS IT?

Resin-bound and -bonded paving uses a clear resin to bind gravel and other aggregates together. In resin-bound systems, the aggregate is mixed with the resin before application, while in resin-bonded systems, resin is applied to the surface and loose aggregates are scattered onto the surface before the resin sets. Plastic grids are occasionally used to reinforce the aggregate and increase load support. The aggregate layers are often quite thin compared to other types of paving with no more than an inch of bound/bonded aggregates laid on top of a subgrade.

The porous nature of resin-bound/bonded paving gives it high permeability, subject to the permeability of the subgrade. As with other permeable pavements, periodic vacuuming will help maintain infiltration rates with frequency determined by the amount of sediment the system is exposed to. Without vacuuming, permeable systems typically become completely clogged within 5–7 years. Snow should only be removed using rubber or plastic shovels, as metal shovels and snow plows can damage the aggregate layers. Salt can also be used, but sand should be avoided.

BENEFITS

- Enhances groundwater infiltration while reducing stormwater runoff volume, rate, and pollutants.
- Aggregates can reduce urban heat island through increased reflectivity and evaporative cooling
- Variety of colors and shapes of aggregate can help preserve urban aesthetic
- Resin application prevents most aggregate displacement from heavy use
- Reduces occurrence of black ice/freezing puddles in cold climates; requires less applied deicers

DRAWBACKS

- Pollutants can infiltrate groundwater—should not be installed in areas where hazardous material spills are possible
- Lower load strength than other types of permeable paving
- Damaged surfaces must be repaired by cutting out the affected section and re-laying the aggregate
- Snow removal can be more difficult than with other types of paving
- Frequent freeze-thaw cycles may require that expansion joints be cut into the paving

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.

Photo: © Labeled for reuse by geograph.org.uk

RESIN-BOUND/BONDED PAVING
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Permeable Pavements	●		●	●	●						●	●	●	●

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Municipal stormwater abatement service fees—Municipal-level
- Coastal Pollutant Remediation (CPR) Grant Program—MA State
- Clean Water State Revolving Fund (SRF)—MA State
- Section 319 Nonpoint Source Competitive Grant—Funding provided under federal Clean Water Act
- 604b Water Quality Management Planning Grant—Funding provided under federal Clean Water Act
- Drinking Water Supply Protection Grant Program—MA State

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Four Freedoms Park, NY
- Various pedestrian projects

SAMPLE OF SUPPLIERS

- Cell-Tek Geosynthetics
- Chameleon Ways
- Atlanta CoreSystems

SOURCES

- http://www.resinbondedaggregates.com/resin-bonded-questions-and-answers.php

PERMANENT FLOOD BARRIER: RETRACTABLE BARRIERS

INSIDE THE FLOODPLAIN

Cost: Dependent on building site. See project examples below for project costs.

Application: Can be retrofitted to existing sites. Costs will likely be lower for new construction, as siting considerations can be built into design costs

Service Life: Barriers themselves have extensive service life (~50+ years). Seals may require replacement every 10 years, depending on model

WHAT IS IT?

Temporary flood barriers are effective, but require time and labor to deploy. Depending on site conditions and frequency of flooding, it may be more cost effective in the long-term to install a permanent, in-situ flood barrier. There are many permanent flood barrier options that are passive, recessed into a site, and require no deployment. In some cases, hydrostatic pressure from rising floodwaters causes flood barriers to rise from a recessed location until the barrier is fully upright and automatically sealed. Some products (e.g. Aquafragma) will issue warnings before deployment occurs. Other permanent barriers require human intervention, but often have shorter deployment times than temporary barriers. Permanent barriers will easily deploy and retract until end of service life with less setup and cleanup required than temporary barriers. Retractable permanent barriers can be combined with other permanent flood barriers (e.g. flood walls). The retractable barriers can be installed in gaps and entrances in the flood walls to allow for building access and mobility until rising floodwaters necessitate deployment of the retractable barrier.

Regular maintenance will be necessary to ensure the barrier is ready for deployment when a flood occurs, though maintenance will vary depending on the type of barrier installed. As permanent retractable barriers are often recessed into the ground until deployment, installation in existing sites will require construction and excavation. Non-passive barriers will typically require shallower foundations, lowering excavation costs. Consulting an engineer to determine optimal siting and certify structural integrity should also be considered; some suppliers (i.e. FloodBreak) include engineer certification in every purchase.

BENEFITS

- Passive barriers minimize human intervention in many areas, including deployment, demounting, and storage, as well as needs for training personnel. Permanent barriers that are not passive often still have lower deployment times and human intervention needs to deploy.
- Passive barriers do not use electricity, allowing for constant flood protection.
- Passive barriers do not need to be deployed ahead of a flood event. This provides protection against flash floods while also allowing site access until flood waters reach the building site.
- Passive barriers are installed onsite and are typically custom-sized for the site's needs.
- Recessed permanent barriers can be modified to minimize disruption to building aesthetics.
- Passive barriers are preferred by FEMA as a best management practice for flood mitigation.

PERMANENT FLOOD BARRIER: RETRACTABLE BARRIERS
CONTINUED

DRAWBACKS

- Onsite construction and excavation are usually needed to install permanent barriers.
- Upfront costs, especially for barriers requiring on-site construction, will be significantly higher than temporary barriers and flood shields.
- Due to higher costs, passive barriers usually need to be combined with other site protection (e.g. flood walls) to maximize effectiveness for larger sites.

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table below.

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Barriers		●				●				●				

FINANCING OPTIONS, INCENTIVES, AND REBATES

- FEMA Hazard Mitigation Assistance – FEMA provides funding for flood and disaster mitigation through three grant programs: Hazard Mitigation Grant Program, Pre-Disaster Mitigation, and Flood Mitigation Assistance. Additional information and application instructions are available here through the Massachusetts Emergency Management Agency. Only non-residential dry floodproofing projects are eligible.
- Hazard Mitigation Funding Under Section 406 of the Stafford Act – Local, state, tribal, and some non-profit facilities damaged by disasters may use Section 406 funding to restore damaged facilities, as well as undertake preventative measures for future flood mitigation.

PERMANENT FLOOD BARRIER: RETRACTABLE BARRIERS
CONTINUED

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Lourdes Hospital, NY: 11 FloodBreak passive floodgates combined with 11-foot floodwall at a cost of approx. $7 million
- Vulcan House Iron in Sheffield, UK: 96m of Tilt-Dam installed. Included surface finishing to match existing aesthetics.
- Route 22 Honda, NJ: Single FloodBreak passive floodgate installed in front of underground garage showroom entrance. Successful deployment and protection in two flood events resulted in reduction of insurance deductible from $100,000 to $10,000.

SAMPLE OF SUPPLIERS

- FloodBreak (passive)
- Aquafragma (passive)
- Tilt Dam/Spring Dams

SOURCES

- http://www.fema.gov/media-library-data/2c435971150193efc6a6ba08f2403863/P-936_sec4_508.pdf

DRY FLOODPROOFING: SEALANTS AND IMPERMEABLE MEMBRANES

INSIDE THE FLOODPLAIN

Cost: Sealants: $2.50 per linear ft.; Membranes: $3.50 per sq. ft.; $5.70 per linear ft. (Estimates based on floodproofing for floods of approx. 3 feet)

Applications: Easily integrated into retrofits and new construction (overall costs will be lower for new construction)

Service Life: 10 years minimum (most warranties are 10 years to lifetime)

WHAT IS IT?

Dry floodproofing techniques can be used to make a structure watertight below flood elevation. Impermeable membranes and sealants can be used to seal walls to reduce or prevent the penetration of floodwater through walls. Membranes and sealants are typically applied to exterior wall faces, making them cost-effective options for retrofitting existing buildings. Tests using sealed and sheet membranes used over concrete walls have yielded ¼ to 4 inches of leakage after over 24 hours of exposure to 3 feet of flooding. Particularly in structures with basements, walls and floors must be specifically designed to resist hydrostatic pressure. If design loads in dry floodproofed buildings are exceeded, buoyancy forces can actually cause more damage to a building than would have occurred if the building were simply allowed to flood. The success of interior floodproofing in protecting a building from flood damage will depend on the depth, duration, and velocity of the flood. For buildings in the most vulnerable flood zones, dry floodproofing will be most effective when multiple measures are combined. Wall sealing should be combined with other measures like flood shields for maximum protection. Internal drainage systems (e.g. sump pumps) may also be employed, as sealed walls can still leak in longer, deeper flood events. Sealants and membranes should be inspected regularly for cracks and potential leaks.

BENEFITS

- Cheaper than other retrofitting methods for floodproofing
- Applied to the building itself and does not require additional land (for floodwalls or levees)
- Easily combined with other dry floodproofing measures (e.g. flood shields/barriers, sump pumps) for maximum protection
- Does not require human intervention during a flood event for protection

DRAWBACKS

- Membranes and sealants do not protect structures from high-velocity flood flows and wave action
- Dry floodproofing measures cannot be used to bring substantially damaged or substantially improved residential structures into compliance with floodplain management ordinances and laws
- Regular inspection and maintenance required to ensure continued functionality

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table on the following page.

DRY FLOODPROOFING: SEALANTS AND IMPERMEABLE MEMBRANES
CONTINUED

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Floodproofing						●								

FINANCING OPTIONS, INCENTIVES, AND REBATES

- FEMA Hazard Mitigation Assistance—FEMA provides funding for flood and disaster mitigation through three grant programs: Hazard Mitigation Grant Program, Pre-Disaster Mitigation, and Flood Mitigation Assistance. Additional information and application instructions are available here through the Massachusetts Emergency Management Agency. Only non-residential dry floodproofing projects are eligible.
- Hazard Mitigation Funding Under Section 406 of the Stafford Act—Local, state, tribal, and some non-profit facilities damaged by disasters may use Section 406 funding to restore damaged facilities, as well as undertake preventative measures for future flood mitigation.

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- Flood Simulations 1 and 2 conducted by the Gulf Coast Community Design Studio
- University of Northern Iowa McLeod Center Plaza, IA

SAMPLE OF SUPPLIERS

- Sika Corporation
- Tremco Commercial Sealants & Waterproofing

SOURCES

- http://www.fema.gov/media-library-data/20130726-1608-20490-9182/fema_551_ch_07.pdf
- http://gccds.org/research/floodproofconstruction/
- http://www.climatetechwiki.org/content/flood-proofing

SUMP PUMP/INTERNAL DRAINAGE SYSTEM

INSIDE THE FLOODPLAIN | OUTSIDE THE FLOODPLAIN

Cost: Wide range depending on quality and pumping rate. Pump cost ranges from $282.50 for 75 gallons/min to $2,970 for 160 gallons/min

Applications: Can be retrofitted or used in new construction

Service Life: 5–10 years

WHAT IS IT?

Even with the use of dry floodproofing techniques, water may enter a building during flooding events—and from general basement leakage. Sump pumps discharge water collected in a small pit that extends through the building foundation from the basement out of the building and directly into a sewer. Internal drainage systems can supplement sump pumps by helping to capture wall and floor seepage. Sump pumps are powered by electricity, and backup generation or battery-operated backup may be necessary in the event of power outages during extreme storms. It is crucial to ensure that the sump pump has a properly sealed lid. Otherwise, moisture and other pollutants such as radon can enter the building's basement and crawl spaces, leading to potential health problems and mold growth. Maintenance may be necessary to remove sediment and debris from the sump pit to prevent clogging.

Excessive inflow from sump pumps to sanitary sewer systems can increase the risk of sewer overflow in heavy rain events, which may result in sewage backflowing into the basement. As a result, Massachusetts has banned the discharge of sump pumps into the sanitary sewer system. A number of cities and towns around the state, including Waltham, Revere, and Braintree are currently providing free sump pump reconnections to single family homeowners.

BENEFITS

- Easily combined with other dry floodproofing measures (e.g. flood shields/barriers, sealants) for maximum protection from flooding
- Provides drainage for increased water leakage resulting from sea level rise

DRAWBACKS

- Basic models require electricity to run. Power outages from storms could compromise building drainage without backup generation. Battery-operated backup pumps can be installed alongside sump pumps at greater cost.
- Heavy flooding can overwhelm pumping capacity. Multiple backup pumps may be needed to handle additional capacity from flooding.

SUMP PUMP/INTERNAL DRAINAGE SYSTEM
CONTINUED

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table below.
- 360 CMR: Massachusetts Water Resources Authority: All inflow from sump pumps must be discharged into storm drains and not into sanitary sewer systems. Discharge may be permitted into areas only served by combined sewer systems. Note that the City of Boston uses a combined system to transport both sanitary and stormwater flow, and the BWSC has additional regulations for inflow.
- Regulations governing the use of sanitary and combined sewers and storm drains of the Boston Water and Sewer Commission: Excessive inflow to sewer systems from sump pump may result in the Commission requiring the building owner to eliminate the source of inflow at owner's expense.

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Pump Systems	●		●		●									

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Sump Pump Amnesty Programs – In many cities and towns around Massachusetts (including jurisdictions in Greater Boston), homeowners with sump pumps that discharge illegally into the sanitary sewer system can have their pumps disconnected at no cost.

ADDITIONAL RESOURCES

SAMPLE OF SUPPLIERS

- Wide selection of pump and drainage system manufacturers, including Basement Systems and Zoeller

SOURCES

- https://basc.pnnl.gov/resource-guides/gasketedsealed-sump-pump-covers
- http://www.motherearthnews.com/diy/is-your-basement-sump-pump-ready-for-the-next-storm.aspx
- http://www.bwsc.org/REGULATIONS/SewerRegulations.pdf
- http://www.mwra.state.ma.us/03sewer/pdf/360cmr10r0903.pdf
- http://www.city.waltham.ma.us/sites/walthamma/files/file/file/sump_pump_faq_130606.pdf
- http://www.town.billerica.ma.us/DocumentCenter/View/295
- http://www.braintreema.gov/water/documents/WaterSewernoticeJune2014.pdf
- http://www.seepage.com/services/problem/sump-pump

TEMPORARY FLOOD BARRIER
INSIDE THE FLOODPLAIN

Cost, Deployment Time, and Service Life for Select Products

Tigerdam (inflatable)—$80/linear ft. for 50 ft.-long and 19-inch-diameter tube. Replaces 500 sandbags at a fraction of setup time and similar cost and can be interconnected indefinitely. One tube can be filled in 90 seconds with a hydrant and 3 minutes with a standard pump. 17-year service life.

Eco-Dam (inflatable)—Price varies by size (for 10m sections: $133/linear ft. for 5 ft. high, $63/linear ft. for 2 ft. high, cheaper for longer sections). 1 tube can be deployed in under 10 minutes. 15-year service life.

Rapidam (membrane)—$145/linear ft. for 1m high x 120m long barrier (significant cost reductions for larger orders). Multiple sections can be joined together. Each 120m section can be deployed by 3 people in 30 minutes. 15-year service life.

Aquafence (modular)—~$300/ft. for 4 ft. high, ~$750/ft. for 8 ft. high. 8–10 people can assemble 150 linear ft. of 4ft-high panels in <1 hour. 50 year service life, can be reused over a dozen times.

WHAT IS IT?

Flood shields and other permanent flood barriers can be expensive to install and aesthetically displeasing. A wide range of temporary flood barriers are available as alternatives to traditional sandbags for building owners to set up quickly in preparation for a potential flooding event. A selection of the types of temporary flood barriers include:

- Inflatable flood barriers: Inflatable flood barriers are set up prior to a potential flood event and use incoming flood waters to inflate automatically and create a barrier to divert water.
- Membrane barriers: Membrane flood barriers use flood-water to seal and stabilize the groundsheet and backwall.
- Modular barriers: Modular barriers can be constructed of a wide range of materials and use floodwaters to deploy.

Compared to sandbags, most temporary flood barriers can be reused and easily deconstructed and redeployed for multiple flood events. In selecting a temporary flood barrier, it is important to consider the amount of setup time and labor needed to prepare the barrier in addition to factors like cost and protection. Some barriers can be set up by a few people in a short period of time (e.g. Floodstop), while others will require teams of 12 or more workers and several hours to set up (e.g. Aquafence). Depending on flood frequency and site conditions, it may be more cost effective in the long-term to install a permanent, in-situ flood barrier (see "Permanent Flood Barrier"). In addition, some of these permanent flood barriers do not require human intervention to setup and will automatically deploy.

BENEFITS

- Temporary barriers are reusable, easier to deploy and clean up, and often cheaper than sandbags
- Temporary barriers do not require building or site modifications that may be costly or aesthetically displeasing

DRAWBACKS

- Models range in deployment time. Deployment requires human intervention and sufficient installation time for larger buildings. Without adequate warning, flooding can occur before shields can be put in place
- Most temporary barriers do not protect structures from high-velocity flooding and wave action.
- Can obstruct building access when deployed.

TEMPORARY FLOOD BARRIER
CONTINUED

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table below.

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Barriers					●				●			●		

ADDITIONAL RESOURCES

PROJECT EXAMPLES

- 2 Water Street, Manhattan, NY
- Grand Isle, LA (in response to Deepwater Horizon Oil Spill)

SAMPLE OF SUPPLIERS

- See above. Additional inflatable barriers include Water-Gate and FloodSax Sandless Sandbags.

SOURCES

- http://www.andovertown.co.uk/news/stop-flood-water-with-the-eco-dam/

WET FLOODPROOFING
INSIDE THE FLOODPLAIN

Costs: Dependent on building size and site requirements, modifications that reduce flood insurance premiums should be considered

- Cost estimates for wet floodproofing retrofits range from approx. $100,000 for a detached 1–2 family house to $1.5 million for a high-rise residential or commercial building.
- Costs of elevating a building's mechanical and electrical systems above BFE range from approx. $85,000 for a detached 1–2 family house to anywhere from $1 million to $20 million for a high rise commercial building, depending on whether additional retrofits are needed to reinforce floors or roofs for additional weight or meeting fire codes

Application: Retrofits and new construction, cheaper when integrated into new construction design

WHAT IS IT?

Compared to dry floodproofing, which makes building and site modifications to prevent water from entering a flooding event, wet floodproofing involves making a series of modifications to a structure to allow an enclosed area below the base flood elevation (BFE) to flood through use of openings (e.g. vents) or breakaway walls, which are designed to break free from the building when subjected to flood forces. Allowing the building to flood will reduce internal and external hydrostatic pressure, reducing loads on walls and floors and lowering the risk of damage to the structure.

Wet floodproofing has several advantages over dry floodproofing. Wet floodproofing measures are usually cheaper than dry floodproofing measures in both new construction and retrofits. When design loads are exceeded in dry floodproofed buildings, severe structural damage may occur that could potentially cause greater damage than if the building were allowed to flood. However, wet floodproofed buildings may require extensive cleanup after a flooding event. Building contaimination can occur if floodwaters carry sewage, chemicals, or other pollutants into the building. In addition, wet floodproofing has more limited applications and is usually only effective for buildings in A zones.[1] Furthermore, wet floodproofing will not lower flood insurance premiums for any buildings, while some dry floodproofing measures will lower premiums for non-residential buildings.

Installation of flood openings must be combined with other wet floodproofing measures to minimize damage. Approved flood damage-resistant materials should be used in the floodable space (see NFIP Technical Bulletin 2 for material requirements), and building electrical and mechanical systems should be protected or elevated to upper floors above the base flood elevation (BFE). Pumps can be installed to push water out of flooded areas, though this should not occur until after floodwaters have receded, as the hydrostatic pressure differential could cause basement walls to collapse.

BENEFITS

- Lowers risk of structural damage due to hydrostatic pressures being reduced by building flooding
- Cheaper than dry floodproofing in both retrofits and new construction.
- In retrofits, building exterior appearance will not be significantly altered compared to dry floodproofing, helping to preserve building aesthetics.

1 Defined by FEMA as an area subject to inundation by the 1-percent-annual-chance flood event generally determined using approximate methodologies.

Photo: FEMA, Public Domain

WET FLOODPROOFING
CONTINUED

DRAWBACKS

- Wet floodproofing is only practical in some applications. Buildings in A Zones can benefit from wet floodproofing, but is not recommended for buildings in V Zones.[2]
  Wet floodproofing can protect buildings from structural damage in floods but not the contents of the flooded area.
- Conversion of a ground floor enclosure and basement into approved floodable spaces and elevation of building mechanical/electrical systems reduce the amount of building space available.
- In retrofits, subgrade basements may need to be filled in to bring the building into compliance with FEMA standards.
- Does not significantly reduce potential damage from high-velocity flooding and wave action.
- Funds for flood mitigation generally cannot be used for wet floodproofing measures.
- Wet floodproofing does not reduce insurance premium rates for residential or non-residential structures.

REGULATORY IMPACTS AND REQUIREMENTS

- A summary of potential regulatory touchpoints is shown in the table below.
- Breakaway walls *must* be used in any enclosure below BFE in V zones to meet FEMA standards.
- Wet floodproofing can only be used to bring a substantially damaged or improved structure into compliance with floodplain management ordinances and laws if enclosed areas below base flood elevation are above grade on one side and are solely used for parking, storage, or building access.
- Wet floodproofing is not approved by FEMA for new construction or substantial reconstruction for structures in V zones. While breakaway enclosures can be used in V zones, flood insurance premiums will be higher.

POTENTIAL REGULATORY TOUCHPOINTS

City/State Regulatory Touchpoints	Boston Groundwater Trust	Inspectional Service Department	Boston Water and Sewer Commission	Local Utilities	Boston Public Works Department	Building Code/Permit	Stretch Energy Code	MA Department of Environmental Protection	Conservation Commission	Fire Department	Public Improvement Commission	Zoning Board of Appeals	Architectural Access Board	MA Historical Commission/ Boston Landmarks Commission
Floodproofing						●								

2 Defined by FEMA as an area along the coast subject to inundation by the 1-percent-annual-chance flood event with additional hazards associated with storm-induced waves.

WET FLOODPROOFING
CONTINUED

FINANCING OPTIONS, INCENTIVES, AND REBATES

- Hazard Mitigation Funding Under Section 406 of the Stafford Act—Local, state, tribal, and some non-profit facilities damaged by disasters may use Section 406 funding to restore damaged facilities, as well as undertake preventative measures for future flood mitigation.
- Small Business Administration Disaster Loan—Businesses of any size and most private non-profit organizations can apply for Business Physical Disaster Loans to cover disaster losses not fully covered by insurance. Improvements to mitigate future damage (i.e. wet floodproofing) may allow for a loan amount increase.

ADDITIONAL RESOURCES

SAMPLE OF SUPPLIERS

- Many general building and mechanical systems contractors can provide wet floodproofing services. Coastal building contractors may have more experience with wet floodproofing projects.
- Openings/Breakaway Walls
- Smart Vent—Foundation flood vents

SOURCES

- http://www.fema.gov/media-library-data/20130726-1627-20490-6014/how2005_fuel_tanks_4_11.pdf
- https://www.lsuagcenter.com/NR/rdonlyres/31169885-A678-43A2-A5DD-5B02EFFD84A3/86843/pub2771wetfloodproofingHIGHRES.pdf
- http://www.fema.gov/media-library-data/1381842520166-4d0b88314cfaa2b7e114391ce6ff2d73/508_FINAL_Guidance_09112013.pdf
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