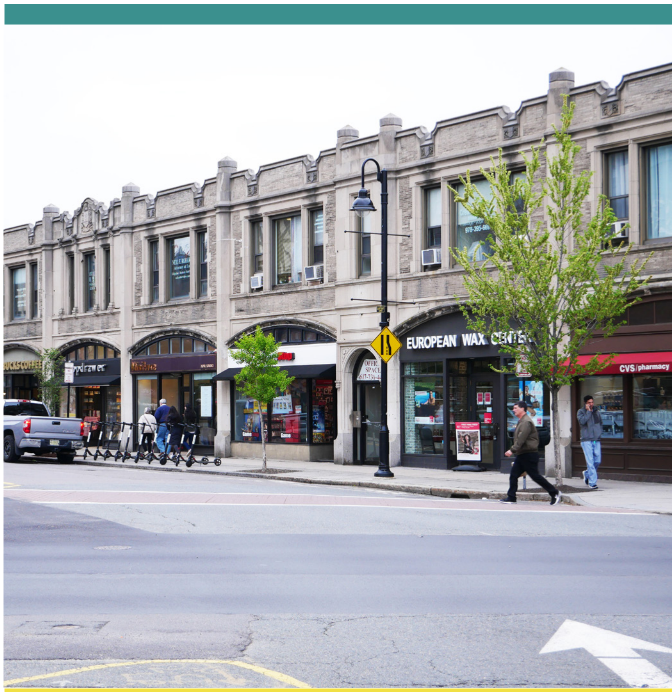
TOWN OF BROOKLINE, MASSACHUSETTS
CLIMATE RESILIENCE DESIGN GUIDANCE

CLIMATE RESILIENCE AND ADAPTATION DESIGN RECOMMENDATIONS FOR COMMERCIAL DEVELOPMENT, GOVERNMENT FACILITES AND SCHOOLS, PARKS AND OPEN SPACE, AND RESIDENTIAL DEVELOPMENT



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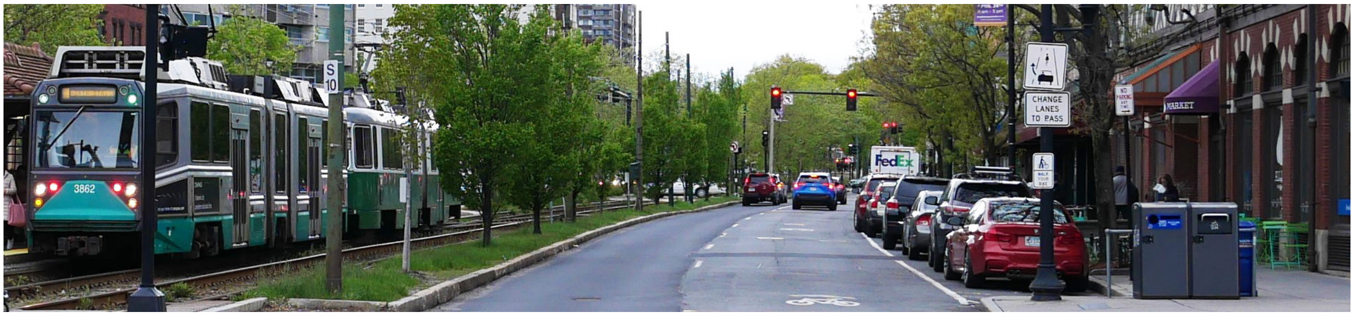
INTRODUCTION



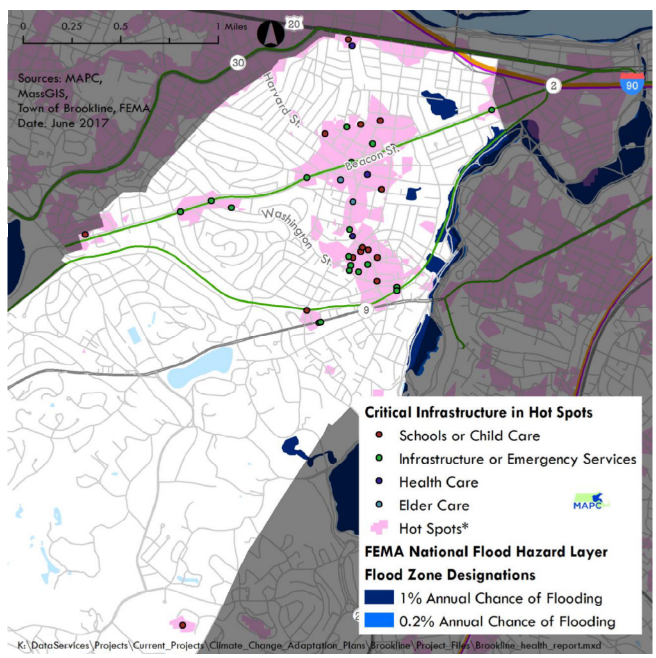
Climate change is occuring globally, but the Town of Brookline is already experiencing the impacts of climate change at the local level. Climate trends across the Commonwealth show an increase in the intensity and frequency of extreme weather. The observed increase temperatures and high intensity rainfall are expected to continue and worsen with time. The increased temperatures will be apparent as heat waves and days over 90 degrees Fahrenheit become more frequent. Heat is a particular concern in north Brookline, which is within the hottest 5% of the greater Boston area. Rising temperatures will impact natural systems and the built environment. Increased temperatures could result in an increase in invasive species and pests, infrastructure malfunctions due to overheating, and heat-related illnesses. Moreover, more intense rainfall may result in more frequent riverine flooding (out of banks) and stormwater flooding (when drainage infrastructure becomes overwhelmed. Stormwater from more intense or longer duration precipitation events can increase the amount of pollutants washed into water bodies. Although Brookline has no coastal shoreline, climate change projections indicate that storm surge could travel up the Muddy River from the Charles River and impact the Brookline shoreline by late century.

Read more about the
Brookline's Climate Vulnerability Assessment and Action Plan

The impact of climate change on the Town of Brookline will be dependent upon the local ability to adapt to changing conditions. Businesses, employees, residents, and the municipalities could experience service disruptions, property damage, and increased health risks related to climate change. The Town of Brookline is committed to minimizing the impacts of climate change and to ensure residents, businesses, infrastructure and the environment can recover quickly when impacts do occur. The Town encourages all development to contribute to the community's resilience and to consider climate impacts in planning, design, and construction. This guidance document provides information on how Low Impact Development (LID) tools and climate resilience designs can be used to increase the resilience of new development and redevelopment in Brookline.

LID techniques use or mimic natural processes and are considered a best management practice for adapting to increased temperatures, rainfall amounts, and flooding associated with climate change. Urban heat island effect, or increased heat in highly developed areas due to surfaces that absorb heat (like pavement), can also be reduced through LID design. Some LID strategies also mimic natural systems to manage stormwater, thus minimizing stormwater flooding, protecting habitat, and improving water quality. Many LID tactics addresses stormwater onsite using permeable surfaces and vegetation, which reduce the impact on the municipal storm drainage system. The use of LID stormwater management techniques presented in this document

Critical Facilities in Temperature Hot Spots



Hot spots and flood zones in north Brookline. Image credit: Town of Brookline Climate Vulnerability Assessment and Action Plan (2017) should always avoid causing impacts to adjacent or surrounding sites. Climate resilience best management techniques presented in this document have been proven successful both locally and nationally. The climate resilience best management practices (see below) are described on fact sheets and their application is shown on five example sites in Brookline. The numbers below correspond to the numbers on the fact sheets and the numbers on each example site plan. For example, climate resilience design for commercial properties (p.5) involved best management practices 1, 2, 3, 6, 7, and 11 listed below. In addition, all developments should consider steps they should take to protect soils (10) and improve build resilience. Buildings prone to flooding should also consider site grading (9), floodable spaces (5) and flood barriers as strategies to improve resilience (4).

CLIMATE RESILIENCE BEST MANAGEMENT PRACTICES

1. **Bioswale and Rain Garden**
2. **Building Planter Boxes**
3. **Exterior Window Shade**
4. **Flood Barriers**
5. **Floodable Spaces**
6. **Green Wall**
7. **Permeable Pavement and Cool Pavement**
8. **Rainwater Harvesting**
9. **Site Grading for Flood Management**
10. **Soil Protection**
11. **Sustainable Roofing Strategies**
12. **Tree Box Filters**
13. **Vegetation and Shade Trees**

RESILIENCE BENEFITS

- ✓ Manages Stormwater Onsite
- ✓ Filters Stormwater Pollutants
- ✓ Reduces Urban Heat Island Effect
- ✓ Provides Groundwater Recharge
- ✓ Improves Air Quality
- ✓ Improves Site Aesthetics
- ✓ Reduces Urban Heat Island Effect
- ✓ Reduce Heating and Cooling Costs
- ✓ Mitigates the Impact of Flooding
- ✓ Reduce Erosion and Sedimentation

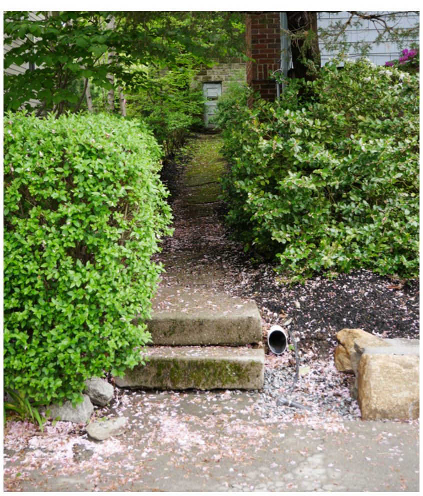
The following fact sheets provide a list of resilience benefits (presented to the left) that can be achieved with each best management practice in addition to the following:

COST

RESOURCES

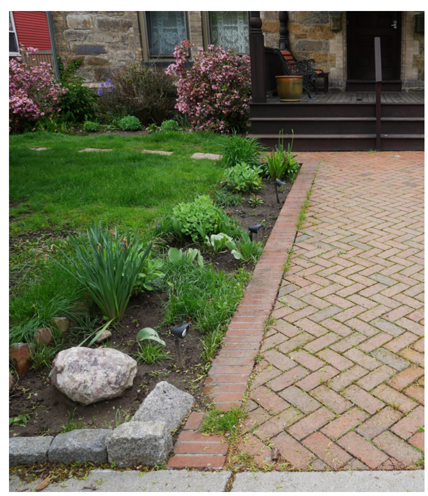
MAINTENANCE

DESIGN RECOMMENDATIONS



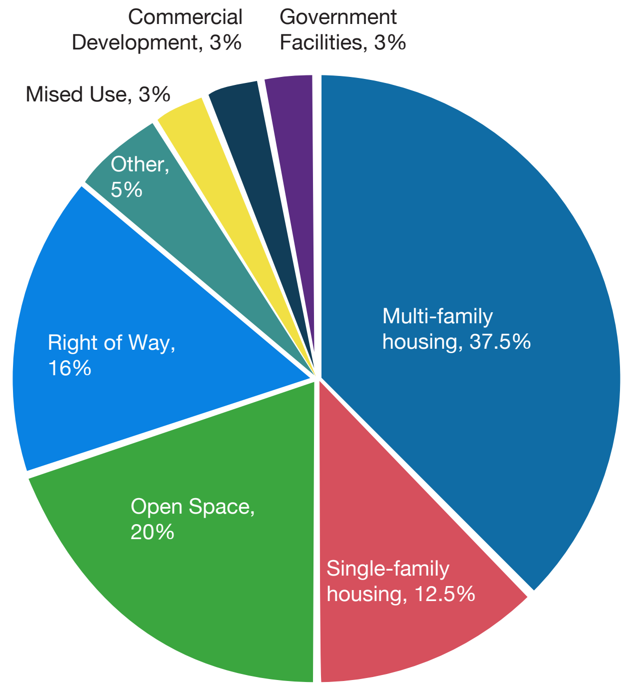
Roof runoff directed into permeable area.

Renewable energy and electric vehicle infrastructure are important climate mitigation efforts.



Permeable pavent allows water to soak into the soil.

Four land use types make up the majority of land in Brookline, which include commercial, government facilities and schools, parks and open space, and residential. The typical site descriptions for the different land use types are described below. Climate resilience practices were recommended for five actual sites in Brookline to demonstrate the applicability of potential resilience practices. Note, each type of land has one example except commercial development, which has two examples. The Brookline specific example sites demonstrate the applicability of climate resilience practices to in a local context. **Roadway and parking lot design** can be a component of any type of site and the proposed strategies proposed for the Kent Street Parking Lot in Brookline Village could be model for any parking lot design. Overall, Brookline is likely to see more redevelopment than new development, however, the techniques presented here can be applied to both.



Brookline Land Use Types (MAPC, 2017)

COMMERCIAL DEVELOPMENT

Commercial development comprises only 3% of Brookline and another 3% is mixed use (Town of Brookline's Climate Vulnerability Assessment and Action Plan, MAPC, 2017). Typical commercial development occurs in commercial centers Brookline's five largest commercial districts: Brookline Village, Coolidge Corner, Chestnut Hill, Washington Square, and along Route 9 (Brookline Housing Production Plan, RKG Associates, Inc. and et al., 2016). Commercial centers are highly developed with little open space and high amounts of impervious surface. More than half of Brookline's businesses lay within critical temperature hot spots, and a relatively small number of businesses are located in areas currently subject to flooding (MAPC, 2017). Coolidge Corner and the Kent Street parking lot in Brookline Village are provided as typical examples in this guidance document.

GOVERNMENT FACILITIES AND SCHOOLS

Three percent of Brookline's land use is categorized as government facilities. Government facilities and schools can be great locations to implement climate resilience measures for not only the benefits provided, but as venues for public education. The Town has already begun to make municipal buildings more resilient by retrofitting for energy efficiency, installing solar photo voltaic arrays and requiring new municipal facilities to be solar-ready, achieving LEED Silver certification for school expansions, and exploring net zero emissions for new school projects. Lincoln School (Kindergarten through 8th grade) is the example site presented in this document.

PARKS AND OPEN SPACE

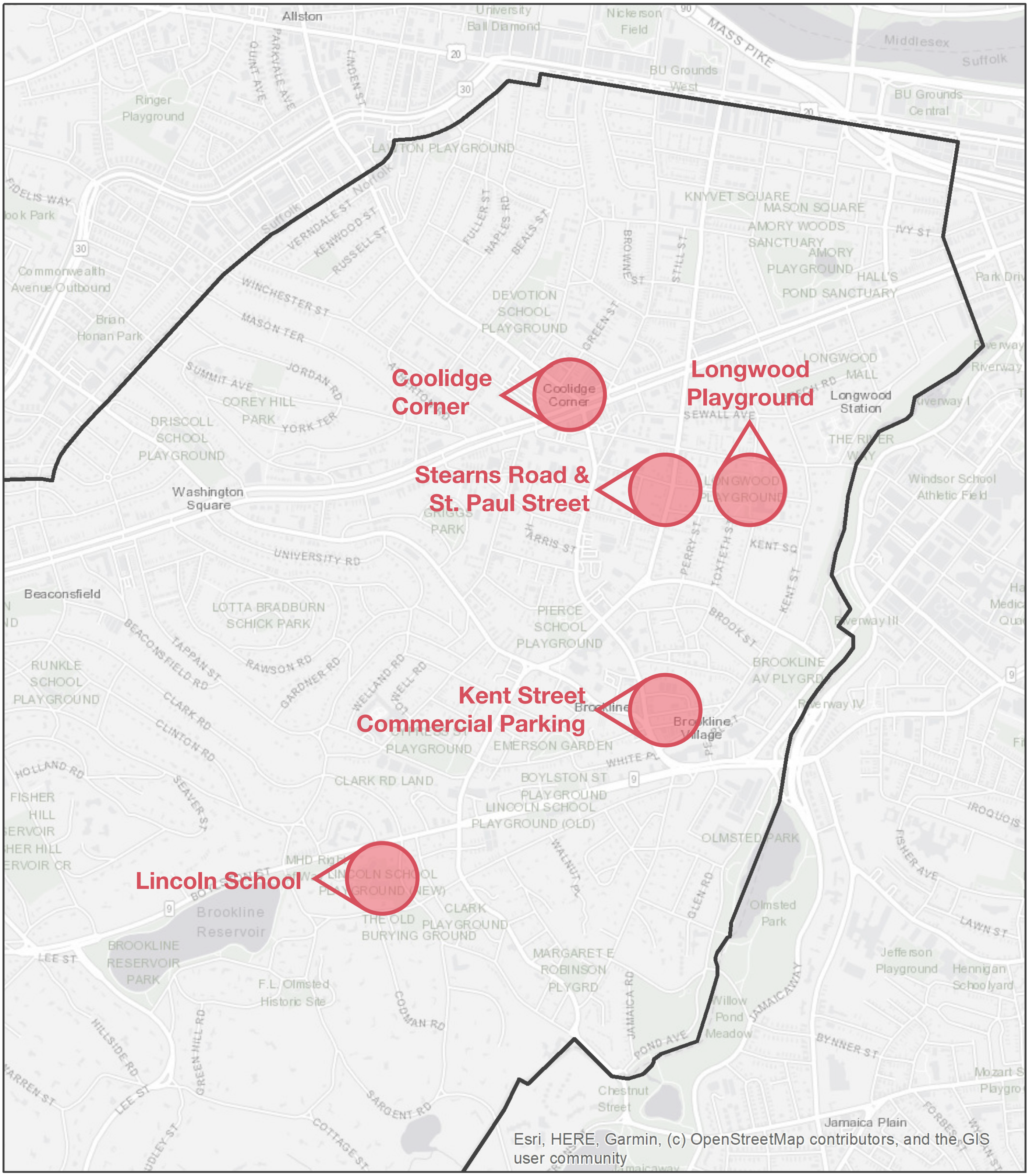
Brookline is fortunate to be have 20% of the total land as open space. Brookline's open space resources range in scale from grand historic parks and private estates to small pocket parks and public gathering places in commercial areas (RKG Associates, Inc. and et al., 2016). **Longwood Playground** is a mid-size park that was historically a deep marsh and is provided as a typical example in this guidance document.

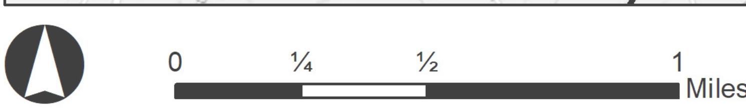
RESIDENTIAL DEVELOPMENT

Fifty percent of Brookline is residential (MAPC, 2017). Brookline's housing stock includes an estimated 28,013 units. Twenty-five percent of these units are detached single-family homes. Brookline's rate of multifamily housing (75%) is among the highest in Boston's inner-core communities. A third of Brookline's multifamily homes are in larger-scale buildings of 20 or more units. Another 15 percent of homes are in small buildings with 3-4 units and an additional 15 percent exist in buildings with 5-9 units. An intersection with a larger multifamily unit and a small detached single-family or small building of 3-4 units is provided as an example of a typical site in this guidance document. Statistics are from the **Town of Brookline's 2016 Housing Production Plan** (RKG Associates, Inc. and et al.).

Use the Climate Resilience Site Development Checklist in Appendix A to mitigate potential adverse climate change impacts on site.

The five Brookline-specific examples to show the opportunities that exist to implement climate resilience best management practices on four land use types: residential, commercial, schools, and parks.





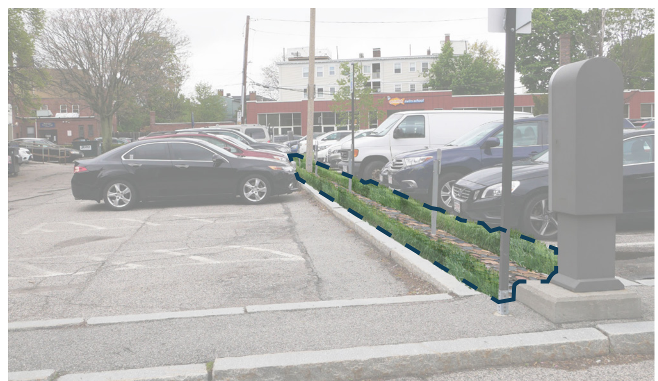
Location of the five Brookline-specific examples

CLIMATE RESILIENT DESIGN: COMMERCIAL
KENT STREET COMMERCIAL PARKING

2 **Building Planter Boxes** can be designed to filter stormwater and overflow into drainage systems.

11 **Sustainable Roofing Strategies** reduce urban heat island and utility costs by using vegetation or reflective materials on the roof. Vegetated roofs can also retain stormwater.

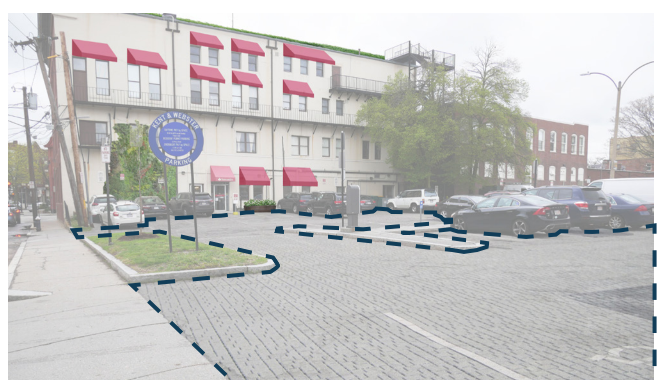
1 **Bioswales and Rain Gardens** along sidewalks and streets treat stormwater runoff and allow water to recharge groundwater.



1 **Bioswales and Rain Gardens** can be incorporated into parking median strips to reduce stormwater runoff.

6 **Green Walls** can help mitigate the urban heat island effect and soak up stormwater.

3 **Exterior Window Shade** provide reduce indoor air temperatures and cooling costs.



7 **Permeable Pavement and Cool Pavement** allow water to infiltrate into the soil through porous material.

CLIMATE RESILIENT DESIGN: COMMERCIAL
COOLIDGE CORNER

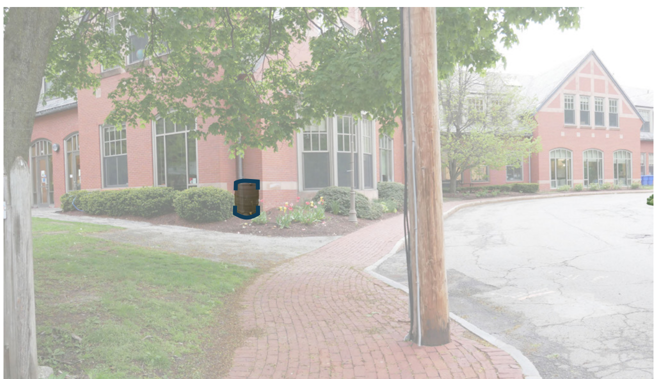
1 **Bioswales** can be incorporated into street medians to reduce stormwater runoff.

3 **Exterior Shading** reduces impacts of extreme heat.

11 **Sustainable Roofing Strategies** reduce urban heat island effect and utility costs. Vegetated roofs can also retain stormwater.

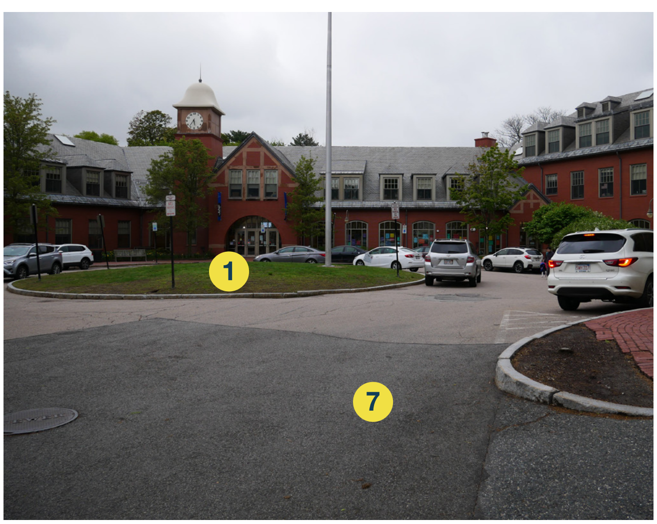
12 **Tree Box Filters** capture stormwater, which is then taken up by the tree or filtered into the soil.

CLIMATE RESILIENT DESIGN: GOVERNMENT FACILITIES AND SCHOOLS
LINCOLN SCHOOL



8 **Rainwatering Harvesting** or rain barrels collect stormwater from roof runoff for future use.

1 **Bioswales** reduce stormwater runoff by filtering water into soil and can be incorporated into cul-de-sacs.



1 **Bioswales** can be incorporated into curb bump outs.

7 **Permeable pavement:** Allow water to infiltrate into the soil through porous material.

CLIMATE RESILIENT DESIGN: PARKS AND OPEN SPACE

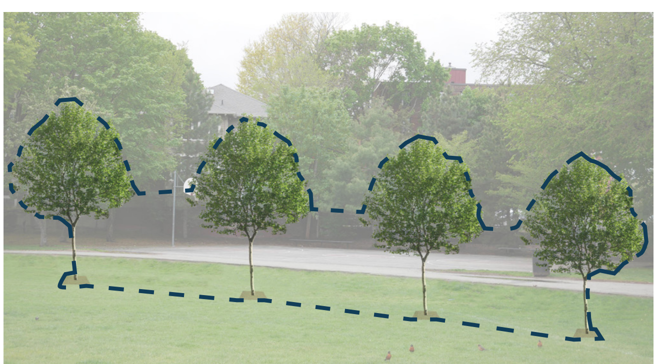
LONGWOOD PLAYGROUND

1 **Rain Gardens are small bioswales** that treat stormwater runoff and recharge groundwater.

7 **Permeable Pavement or Cool Pavement** allow water to infiltrate into the soil through porous material.

5 **Floodable spaces** can be natural spaces or urban water squares.

13 **Vegetation and Shade Trees** provide relief from urban heat and soak up rainwater.



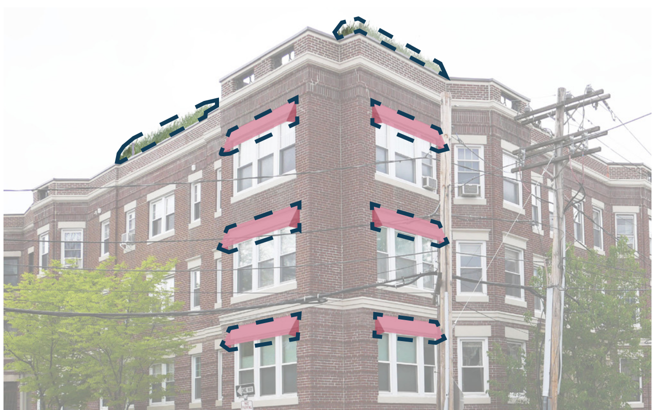
13 **Vegetation and Shade Trees**

10 **Soil Protection** reduces erosion from stormwater runoff.

10 **Soil Protection** reduces compaction, which reduces erosion and filters stormwater quickly.

5 **Floodable Spaces** are designed to flood and filter stormwater quickly.

CLIMATE RESILIENT DESIGN: RESIDENTIAL
STEARNS ROAD AND ST. PAUL STREET



11 **Sustainable Roofing Strategies** reduce urban heat island effect and utility costs. Vegetated roofs can retain stormwater.

3 **Exterior Window Shades** reduce the impacts of extreme heat.

1 **Bioswales** can be incorporated along sidewalks to reduce stormwater runoff

8 **Rainwater Harvesting** collect stormwater from roof runoff for future use.

1 **Bioswales** reduce stormwater runoff by filtering water into soil in curb bump outs.

12 **Tree Box Filters** capture stormwater, which is then taken up by the tree or filtered into the soil.

Did You Know? Brookline's tree canopy draws in stormwater helping the Town avoid 26.7 million gallons of stormwater runoff per year (MAPC, 2017 Climate Vulnerability Assessment and Action Plan).

1

BIOSWALE AND RAIN GARDEN

DESCRIPTION

Bioswales and rain gardens, also known as bioretention areas, filter stormwater runoff and allow water to recharge groundwater. Bioswales reduce the stormwater pollution by using soil, plants and microbes to filter stormwater before it is infiltrated or discharged. Bioswales can be used in a variety of spaces including parking and roadway median strips, along sidewalks and streets, in cul-de-sacs, and corner bump-outs. In residential development, rain gardens may be considered as an alternative if the available space for onsite stormwater retention is limited. Bioswales and rain gardens are good options for both new development and redevelopment.

RESILIENCE BENEFITS

✓ Manages Stormwater Onsite

✓ Filters Stormwater Pollutants

✓ Reduces Urban Heat Island Effect

✓ Provides Groundwater Recharge

✓ Improves Air Quality

✓ Improves Site Aesthetics

COST

$5 to **$30**
per square foot

estimated cost of a biorention area

(**Massachusetts Clean Water Handbook**)

MAINTENANCE

- Bi-annual evaluation of vegetation health and replace if necessary.
- Monthly inspection for erosion and removal of invasive species and trash
- Annually re-mulch void areas and prune vegetation

RESOURCES

Massachusetts Clean Water Toolkit:
- **Biorention Areas & Rain Gardens**
- **Water Quality Swales**

MAPC Fact Sheets:
- **Biorentention Areas**
- **Vegetated Swales**

University of New Hampshire:
- **Regular Inspection and Maintenance Guidance for Bioretention Systems and Inspection Checklist**

DESIGN RECOMMENDATIONS

Bioswales capture stormwater in depressions filled with sandy soil, topped with a thick layer of mulch, and planted with dense vegetation.

The design can incorporate components to increase drainage and prevent flooding.

Use native plant species to reduce the use of water and overall maintenance requirements.

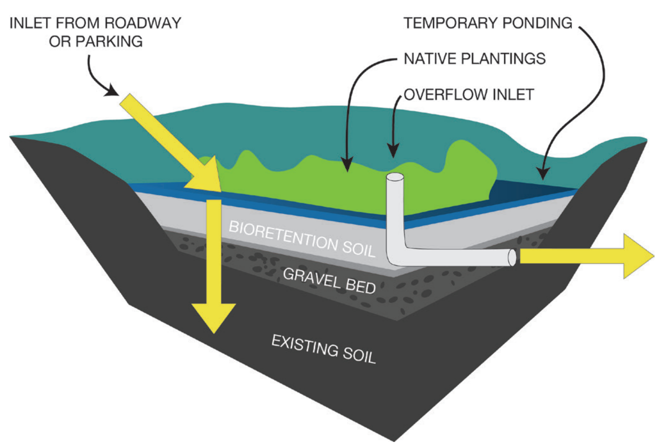


Image: Weston and Sampson based on Massachusetts Clean Water Handbook

2 BUILDING PLANTER BOXES

DESCRIPTION

Building planter boxes are a way to infiltrate roof runoff alongside a building. Planter boxes are impermeable structures with underdrains. As stormwater, typically roof runoff conveyed via a downspout, passes down through the planting soil, pollutants are filtered, adsorbed, and biodegraded by the soil and plants. Building planter boxes do not take up much room alongside building and reduce potential basement flooding.

RESILIENCE BENEFITS

- ✓ Filters Stormwater Pollutants
- ✓ Improves Air Quality
- ✓ Improves Site Aesthetics

COST

$24 to **$32**

estimated cost per square foot

(**Massachusetts Clean Water Toolkit**)

MAINTENANCE

Regular maintenance includes:

- Tending to the plants and cleaning out sediment.
- Inspecting for erosion and repairs.

RESOURCES

Massachusetts Clean Water Toolkit: **Planter Box**

DESIGN RECOMMENDATIONS

Building planter boxes can be designed with a direct connection to the drain to mitigate stormwater flooding if the system reaches capacity.

Plants should be selected carefully to minimize maintenance and maximize function. Native plant species are preferred.

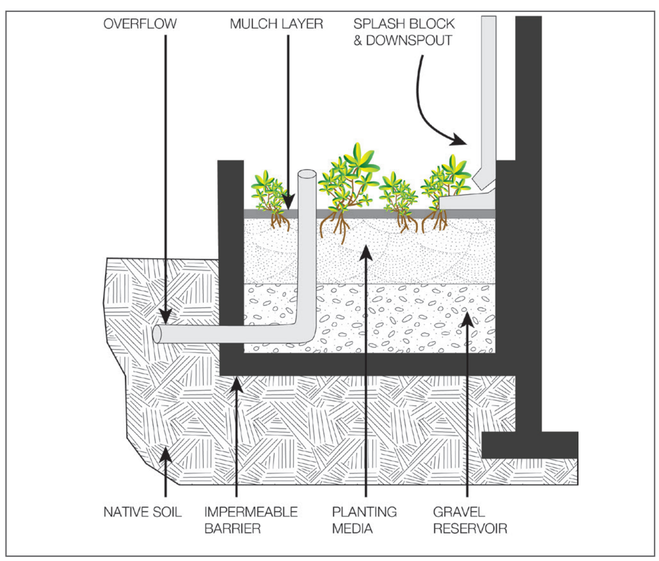


Image: Weston and Sampson adapted from the Bayou Land RC&D BMP Guidance Document (Geosyntec Consultants, 2010)

3 EXTERIOR WINDOW SHADE

DESCRIPTION

Building overhangs, canopies, and large trees can provide exterior shade. Exterior shade can create a microclimate with reduced temperatures in outdoor public spaces as well as help control the interior temperature of a building.

RESILIENCE BENEFITS

✓ Reduces Urban Heat Island Effect

COST

Exterior window shade will vary depending upon the site. The cost is typically lower compared to other resilience measures with monetary benefits being gained through reduced air conditioning costs.

MAINTENANCE

- Exterior shades will need to be replaced with normal wear and tear.

RESOURCES

Enterprise Green Communities: **Strategies for Multifamily Building Resilience (p.76)**

DESIGN RECOMMENDATIONS

Southern facing facades receive direct sunlight when the sun is at its highest. Overhangs are effective on the southern facing facades because of the sun's location throughout the day. The sun hits east- and west-facing windows lower. Awnings work well for blocking the sun on east-and west-facing facades.

Retractable overhangs and deciduous vegetation work well in climates with seasonal climates so the benefits of heat and sunlight can be optimized during colder temperatures. Deciduous vegetation blocks sunlight in the summer and sunlight is allowed through in the winter when the leaves have fallen. Greenery also provides important psychological and health benefits for residents. Falling snowpack and icicles from overhangs or awnings can also become public safety hazards. Therefore, overhang and awning placement should be limited or carefully located over walkways. Alternatively, facility managers should plan to reduce winter-related hazards.

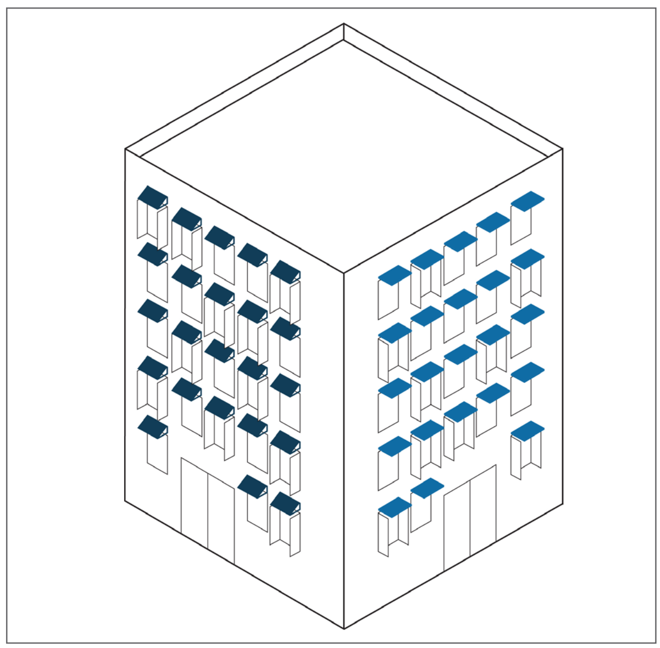


Image: Weston and Sampson based on Enterprise Green Communities: Strategies for Multifamily Building Resilience.

DID YOU KNOW?

A significant portion of north Brookline is within the hottest 5% of the land area in the metro-Boston area. Trees can help reduce land surface temperatures.

4 FLOOD BARRIERS

DESCRIPTION

Permanent or temporary physical barriers can prevent flooding. Property owners with older buildings may prefer to apply this technique because modifications to the building structure are not required. Temporary flood barriers could include sandbags, water-inflated tube systems, panels, or walls. Permanent barriers could include walls and berms. Berms are raised areas of land or compacted earthen structures that prevent water seepage and act as a natural flood barrier. All federal, state and local permits must be obtained prior to filling, including constructing, in a regulated floodplain.

RESILIENCE BENEFITS

✓ Mitigates the Impact of Flooding

COST

Costs are mid to high.

MAINTENANCE

- Inspect after flood for damage
- Clean periodically
- Train residents or staff on deployment

RESOURCES

Massachusetts Clean Water Toolkit: **Filter Berm**

Enterprise Green Communities: **Strategies for Multifamily Building Resilience (p.28)**

DESIGN RECOMMENDATIONS

Flood barriers can also keep water in, so make a plan to pump water out or giving floodwaters an outlet.

Ensure residents or emergency personnel can get in and out of structure.

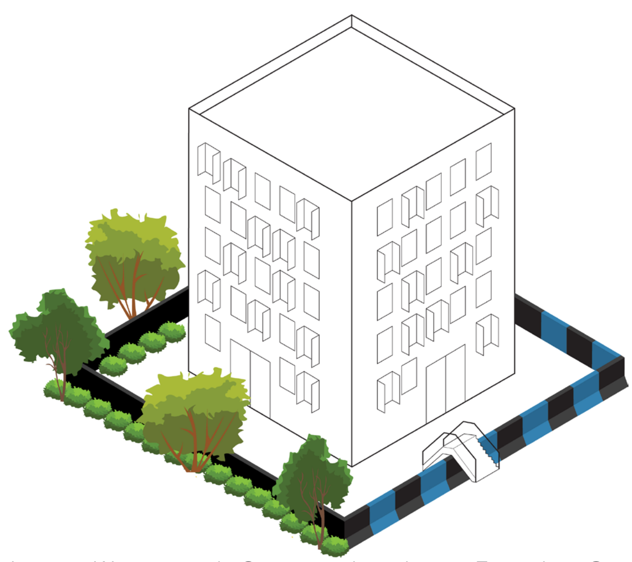


Image: Weston and Sampson based on Enterprise Green Communities: Strategies for Multifamily Building Resilience.

DESCRIPTION

Floodable spaces are designed for active uses during clear weather, but will become inundated during heavy rainfall events. These include spaces both onsite and in buildings that can be used to store water. In buildings, wet floodproofing is used for protection of uses to allow unoccupied spaces, like parking, to be flooded during a storm. A water square is an urban plaza designed to collect floodwater and increase stormwater detention or infiltration. In a more rural or suburban setting, techniques such as a subsurface infiltration bed provide temporary storage and infiltration of stormwater runoff by using below grade storage media to hold the water.

RESILIENCE BENEFITS

✓ Mitigates the Impact of Flooding

COST

Costs are mid to high. Costs vary considerably and are dependent upon the site-specific situation.

MAINTENANCE

- Create a plan for removal of unwanted items from the floodable area
- Professionally clean area after flooding to remove pollutants and reduce health risks

RESOURCES

Enterprise Green Communities: **Strategies for Multifamily Building Resilience (p.15)**

Linnean Solutions, The Built Environment Group, The Resilient Design Institute:
Building Resilience In Boston

Urban Green-Blue Grids:
Water Squares

DESIGN RECOMMENDATIONS

Relocate or protect equipment that should not be exposed to water. Provide floodwater entry and exit points. Use water-resistant building materials.

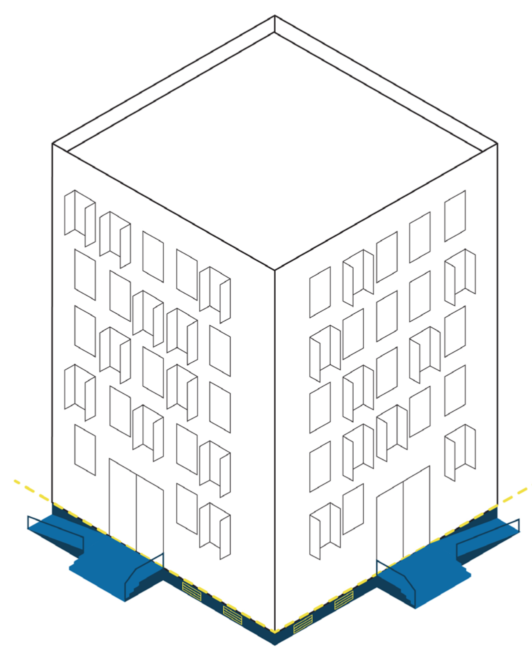


Image: Weston and Sampson based on Enterprise Green Communities: Strategies for Multifamily Building Resilience.

DESCRIPTION

A green wall uses a trellis of metal or wood or net system of cable or rope as a base on which plants can grow. Green walls can also be landscaped alongside berms or slopes serving as natural barriers. Green walls can be used as an additional layer of building insulation, privacy walls, or noise barriers. For example, the Brookline Zoning By-Law requires properties adjacent to parking lots are shielded from head light glare and green walls can be used in this instance. Green walls also improve air quality.

RESILIENCE BENEFITS

- ✓ Reduces Urban Heat Island Effect
- ✓ Improves Air Quality
- ✓ Improves Site Aesthetics

MAINTENANCE

- Plant maintenance will vary depending on plant type.
- The base trellis or net should be checked periodically to ensure the structure is secure and the tension is still supportive.

RESOURCES

Green Roofs for Health Cities: **Introduction to Green Walls Technology, Benefits & Design**

University of Maryland Extension: **Green Facades**

DESIGN RECOMMENDATIONS

Plant selection should consider vines or other vegetation that require little to no irrigation or nutrient supplements.

COST

Cost will vary depending on project size and system type.

For reference, a 300 square foot modular living wall in New York City cost $110 per square feet. Read about other case studies with higher costs from **Green Roofs for Health Cities.** However, **Architek** sells green façade systems and quotes the average the cost for installing a green facade system, complete with plants, is $25 - $30 per square foot.

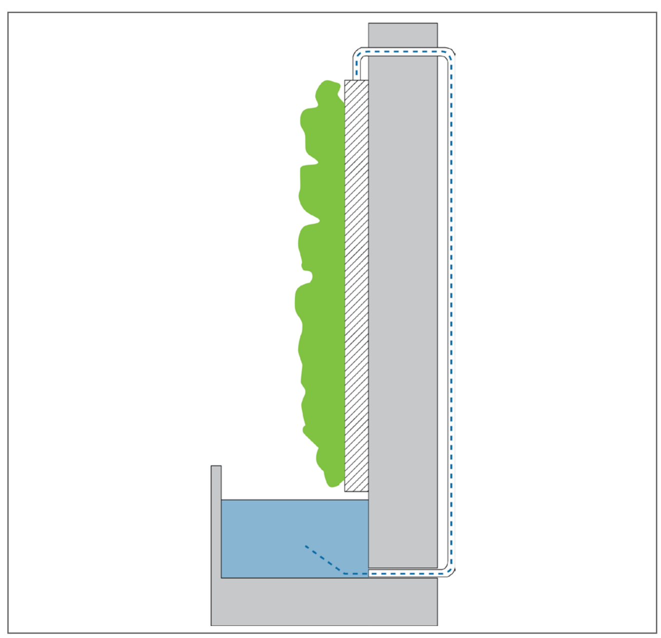


Image: Weston and Sampson based on Vertical Oxygen webpage.

7

PERMEABLE PAVING AND COOL PAVEMENT

DESCRIPTION

Permeable or porous pavement looks just like regular pavement and allows water to seep through and infiltrate into the ground. Permeable paving techniques include porous asphalt, pervious concrete, paving stones, permeable pavers, and manufactured "grass pavers" made of concrete or plastic. Cool pavements reflect sunlight, enhance evaporation, and stay cooler than conventional paving materials. Cool pavements help reduce urban heat island effect.

RESILIENCE BENEFITS

- ✓ Manages Stormwater Onsite
- ✓ Filters Stormwater Pollutants
- ✓ Reduces Urban Heat Island Effect
- ✓ Provides Groundwater Recharge

COST

Environmental Protection Agency **Cost Estimates** (p.25)

Porous asphalt and pervious concrete construction costs may be 50% more than conventional asphalt and concrete. Construction costs of paving stones and grass pavers varies considerably and will depend on the application (**Massachusetts Clean Water Toolkit**).

MAINTENANCE

- Clean debris at least twice a year. Periodic vacuuming and low-pressure washing increases the functional life.
- **Modular porous concrete** can improve ease of maintenance.

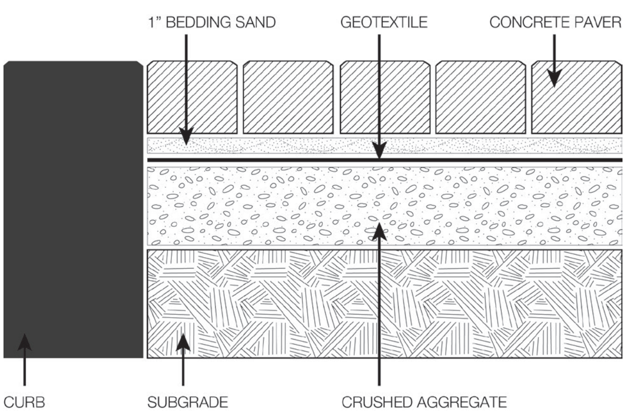


Image: Weston and Sampson based on the The Conway School, 2014

RESOURCES

Massachusetts Clean Water Toolkit: **Porous Pavement**

Metropolitan Area Planning Council: **Permeable Paving Fact Sheet**

Pioneer Valley Sustainability Toolkit: **Understanding Porous Asphalt**

University of New Hampshire: **Regular Inspection and Maintenance Guidance for Permeable Pavements and Inspection Checklist**

DESIGN RECOMMENDATIONS

Permeable pavement is particularly appropriate for pedestrian-only areas or areas with a low traffic volume or traffic speeds.
Porous pavement performs well in cold climates. Porous pavement can reduce runoff from snowmelt and avoid excessive water on the road during the snowmelt period.

The potential for frost heaving should be anticipated in cold climates. The storage bed specifications prepared by the **University of New Hampshire** address this concern.

Cool pavements can be achieved through the material or applying coating to traditional pavement types.

DESCRIPTION

Rainwater harvesting with rain barrels or cisterns can reduce water consumption and stormwater runoff. Harvested rainfall can be used to water plants among other outdoor uses. A simple rain barrel system can be set up to collect runoff from a down-spout (less than 100 gallons). Cisterns are larger systems (greater than 100 gallons) that collect water either above ground, on roofs, or underground. Some cistern systems will require pumps to move water to vegetation, which increases the costs and maintenance of rainwater harvesting.

RESILIENCE BENEFITS

✓ Manages Stormwater Onsite

✓ Provides Groundwater Recharge

MAINTENANCE

- Repair and replace components as necessary.
- Inspect twice a year.

COST

Commercially available rain barrels begin at approximately $60 for a 55-gallon barrel. Cisterns are more expensive and vary in in cost due to the larger size, complexity, and installation costs. For reference, a project with an 800 gallon two-tank system complete with pump and drywell structure in Massachusetts cost $3,000. A common cistern shared by multiple properties may reduce costs because there is only one excavation, one tank or set of tanks, and one pump (**Metropolian Area Planning Council**).

RESOURCES

Massachusetts Clean Water Toolkit:
Rain Barrels & Cisterns

Metropolitan Area Planning Council:
Cisterns and Rain Barrels Fact Sheet

Pioneer Valley Sustainability Toolkit:
Understanding Rainwater Harvesting

DESIGN RECOMMENDATIONS

Minimize leaves and debris in the storage tank by placing a screen at the top of the downspout.

Rain barrels should be childproof and secured against disturbance by people or animals. Any openings should be sealed with mosquito netting.

May need to be disconnected and drained in winter to avoid cracking of storage structure.

Before using rooftop runoff for vegetable gardens, investigate the quality of the runoff.

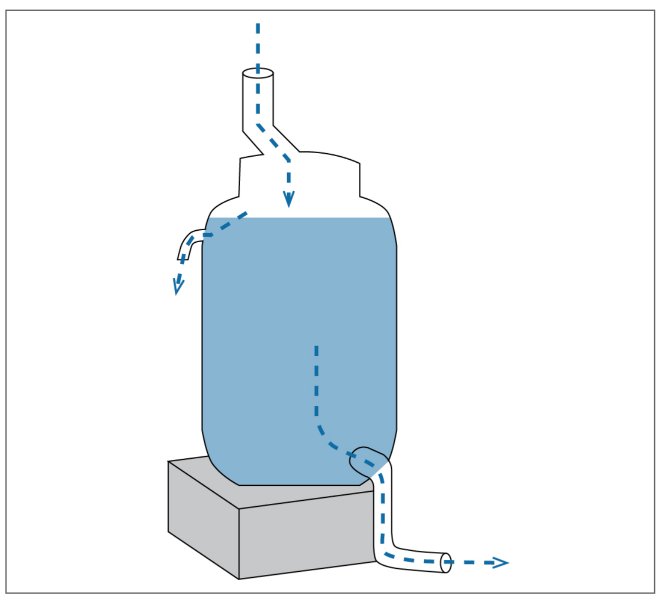


Image: Weston and Sampson based on City of Berkeley, CA Residential Rainwater Harvesting System Webpage.

DESCRIPTION

Site grading can be used as a tool to change topography so that it prevents, minimizes, redirects, or captures stormwater or riverine flooding onsite. Site grading can be used to elevate buildings and infrastructure or to create flood storage. Changes in topography can anticipate future floodplains, under climate change, to minimize future impacts from flooding. All federal, state and local permits must be obtained prior to filling, including constructing, in a regulated floodplain.

RESILIENCE BENEFITS

✓ Mitigates the Impact of Flooding

COST

If planned appropriately, elevation and storage areas can be constructed as part of site development at a relatively small cost.

MAINTENANCE

- Vegetation and armoring must be maintained in good condition.

RESOURCES

Missouri State Emergency Management Agency: **Floodplain Management in Missouri, Quick Guide**

Federal Emergency Management Agency: **Compensatory Storage**

DESIGN RECOMMENDATIONS

Elevating with Fill

Provide at least one foot of freeboard above current or projected base flood elevations.

If using fill to elevate an area or structure, the fill must be:

- Good quality and free of non-soil materials (large rocks, construction debris, stumps and roots, etc.)
- Machine compacted to 95 percent of maximum density and certified as such by a soil scientist or professional engineer.
- Graded to slopes no steeper than 2:1 and ideally of 3:1 or flatter.
- Reinforced against erosion and sloughing with well-established vegetation for lower velocity flows (no more than 1 foot per second) and armored for higher velocity flows.

Flood Storage

Seek to provide a volume of floodwater storage to minimize impacts elsewhere on- or off-site. Use modeling to simulate current and future flooding conditions under climate change.

DESCRIPTION

For the purposes of climate resilience, soil protection strategies preserve and use topsoil, when possible, and reduce compaction of *in situ* soils. The goal of soil protection is to maintain the amount of stable soils and grades onsite. When soil is compacted through the use of heavy machinery, its stormwater filter and infiltration properties are lost. There are a variety of strategies to protect soils including:

- Minimizing site disturbance
- Reducing clear cutting and maintaining natural areas
- Applying soil amendments, which include both soil conditioners and fertilizers
- Hydroseeding, sodding, seeding or stabilizing fine-graded disturbed areas by establishing permanent grass stands

RESILIENCE BENEFITS

✓ Reduce Erosion and Sedimentation

✓ Provides Groundwater Recharge

COST

Minimizing site disturbance and reduction of cutting typically save money. Soil amendments and sodding are moderately expensive.

MAINTENANCE

Periodically and after rainstorms, soil protection and retention measures should be inspected for erosion, damage, or other signs of deterioration.

RESOURCES

Massachusetts Clean Water Toolkit:

Land Grading and Stabilization
Topsoiling
Soil Retention
Sodding
Soil Amendments
Preserving Natural Vegetation

DESIGN RECOMMENDATIONS

Promote drought tolerant cover by choosing types of grass and plant species that require less water.

Ensure soil conditions are appropriate for sustaining low water use and healthy cover. Loam, soil with adequate organic material, of 6 inches will greatly reduce water needs by providing the ability to hold water and provide nutrients to the plants.

SUSTAINABLE ROOFING STRATEGES

DESCRIPTION

Roofs have great potential for stormwater management and urban cooling benefits. There are several ways to adapt a roof to provide benefits to the building owner, occupants, and community. Green roofs are vegetated and increase on-site stormwater retention. Cools roofs use materials that have a high solar reflectance. Solar reflectivity measures a material's ability to reflect sunlight and therefore reduce warming effects on buildings. Solar reflectivity is measured on a scale from 0 to 1 (or 0%-100%) with higher values representing cooler or high albedo material. Solar roofs are best for southern facing rooftops. Solar panels can provide shade and renewable energy onsite. Blue roofs are typically cool roofs that can also store rainwater. Blue roofs are designed to release the water slowly. Sustainable roofing strategies reduce urban heat island effect and reduce utility costs.

COST

Green roofs start at $5 per square foot in additional roofing costs. They generally cost more to install than conventional roofs but are financially competitive on a lifecycle basis because of longer life spans (up to 40 years), increased energy efficiency, and reduced stormwater runoff. If the application is a retrofit, structural upgrades may increase the cost. Blue roof cost less than green roofs. Cool roofing can be very affordable overall, especially after the payback from energy savings. Energy savings range from 7%-15% of total cooling costs.

MAINTENANCE

- Green roofs need to be inspected, specifically the roof membrane and drainage layer flow paths.
- In the first two years before vegetation is established, green roofs may require weeding, mulching, and additional plantings.

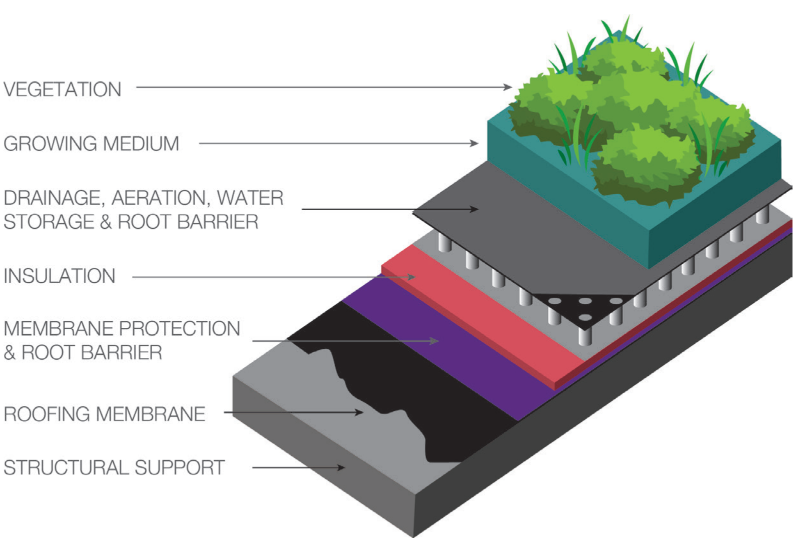


Image: Weston and Sampson based on American Wick Drain Corp.

RESILIENCE BENEFITS

- ✓ Reduce Heating and Cooling Costs
- ✓ Manages Stormwater Onsite
- ✓ Reduces Urban Heat Island Effect
- ✓ Improves Air Quality
- ✓ Improves Site Aesthetics

RESOURCES

Massachusetts Clean Water Toolkit:

- **Green Roofs**
- **Rooftop Detention**

Metropolitan Area Planning Council:
Green Roofs Fact Sheet

Pioneer River Valley Sustainability Toolkit:
Understanding Green Roofs

DESIGN RECOMMENDATIONS

Green roofs require structural components able to bear additional weight

Vegetation should be low growing, spreading perennial or self-sowing annuals that are drought tolerant.

DESCRIPTION

Tree box filters consist of an underground, open bottom concrete barrel filled with a porous soil media, an underdrain in crushed gravel, and a tree. The compact size of a tree box filter makes this technique applicable to many types of development and redevelopment because its location can be adapted to the site.

RESILIENCE BENEFITS

- ✓ Manages Stormwater Onsite
- ✓ Filters Stormwater Pollutants
- ✓ Reduces Urban Heat Island Effect
- ✓ Provides Groundwater Recharge
- ✓ Improves Air Quality
- ✓ Improves Site Aesthetics

COST

Estimated cost range of tree filters is $10,000 and $18,000. (**Massachusetts Clean Water Toolkit**)

There are a variety of costs described in the available literature on tree box filters, ranging from $1,500 to $10,000. Recent quotes from manufacturers of these systems provide perhaps a more realistic range: $7,000 to $12,000, depending on size and not including installation. For public projects, installations can be done by municipal public works department or they might be bid out as part of a larger construction project.

MAINTENANCE

- Removal of trash, debris, and sediment.
- Replenish mulch
- Care and replacement of plants.
- Rake media at least twice a year to maintain permeability
- Annual maintenance cost for an owner has been reported at approximately $100 per unit. Annual maintenance by the manufacturer is $500 per unit. (**Pioneer Valley Sustainability Toolkit)**

DESIGN RECOMMENDATIONS

Native plants or plants that can withstand alternating inundation and drought will be good choices for tree planter boxes

RESOURCES

Massachusetts Clean Water Toolkit:
Tree Box Filters

Pioneer Valley Sustainability Toolkit:
Understanding Tree Box Filters

University of New Hampshire: **Regular Inspection and Maintenance Guidance for Tree Filters and Inspection Checklist**

Contech: **Filterra Biorientation**

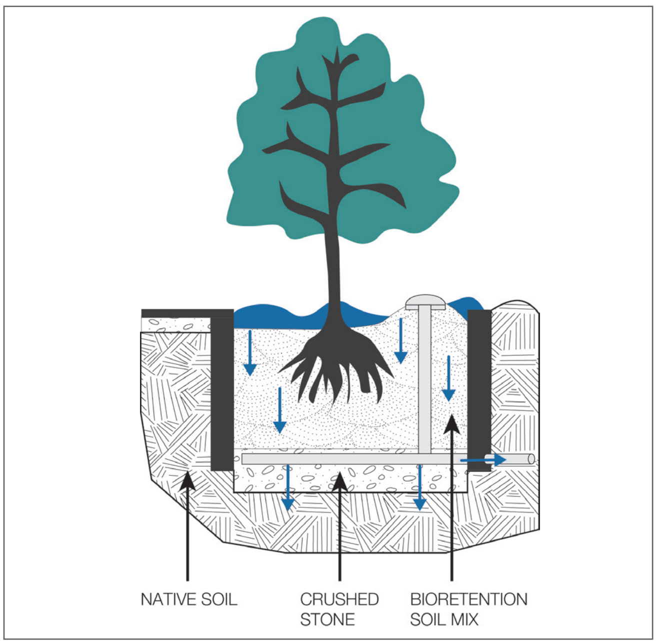


Image: Weston and Sampson based on University of New Hampshire Stormwater Center, 2009.

13 VEGETATION AND SHADE TREES

DESCRIPTION

Vegetation and trees can be utilized on almost any type of development. Vegetation helps lower temperatures through shade and evapotranspiration. Trees help lower temperature by providing shade. Both can also help with stormwater retention. Preserving natural vegetation on the site provides site stabilization and helps reduce erosion. Vegetation and trees provide habitat for wildlife.

RESILIENCE BENEFITS

- ✓ Manages Stormwater Onsite
- ✓ Filters Stormwater Pollutants
- ✓ Reduces Urban Heat Island Effect
- ✓ Provides Groundwater Recharge
- ✓ Improves Air Quality
- ✓ Improves Site Aesthetics

COST

Varies depending on plant species

MAINTENANCE

- Possible watering during dry periods, inspection and replacement when necessary

RESOURCES

Massachusetts Clean Water Toolkit:
- **Preserving Natural Vegetation**
- **Tree and Shrub Planting**

DESIGN RECOMMENDATIONS

Native species are preferred. When preserving trees and vegetation on site consider:
- **Location**: Ensure vegetation will not interfere with the installation and maintenance of utilities.
- **Health**: Examine vegetation and trees for broken tops, dead branches, or signs of insect infestation or disease
- **Age and Size:** Young small plants will take a while to develop and provide the benefits of a more mature tree. Old trees reaching the average lifespan of a tree species may have less vigor and decline rapidly. Established, mature trees (usually less than 40 years old) are the best fit for preservation.

DESCRIPTION

Buildings should consider climate resilience measures above and beyond those required by the Massachusetts State Building Code. Building interiors should be designed to elevate, protect and back up critical infrastructure, like the power system. The power system and backup power system may be equipped with a lower occupancy mode, which would include enough power for an elevator, water and wastewater systems, some LED lighting, refrigerators, and a conditioned community room. Sump pumps and dry flood proofing (or sealing building to keep water out) are typically paired strategies to protect the building from flood damage.

RESOURCES

Enterprise Green Communities: **Strategies for Multifamily Building Resilience (p.76)**

Linnean Solutions, The Built Environment Group, The Resilient Design Institute: **Building Resilience In Boston**

RESOURCES

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Appendix A
Climate Resilience Site Development Checklist

TOWN OF BROOKLINE
CLIMATE RESILIENCE SITE DEVELOPMENT CHECKLIST

The purpose of the Site Development Climate Resilience Checklist is to assist special permit applicants mitigate potential adverse climate change impacts over the design life of a project (normally at least 30 to 50 years). Climate change is expected to result in increased frequency and intensity of extreme temperatures, periods of drought, severe storms, and precipitation. Increased precipitation intensity may result in increased stormwater and riverine flooding. Climate change is also likely to alter ecological conditions, which could lead to habitat degradation and favorable conditions for invasive species.

All development must adhere to the Town of Brookline Zoning By-Law and other applicable federal, state, and local laws and regulations. Brookline has adopted the Massachusetts Stormwater Management Standards for development and redevelopment projects on a town wide basis, whether or not the site is regulated under the Wetlands Protection Act Regulations, 310 CMR 10.05(6)(k) or the Water Quality Certification Regulations, 314 CMR 9.06(6)(a). Projects that disturb 2,500 square feet or more, which result in an increased amount of stormwater runoff, must apply for a stormwater permit from the Town. Smaller projects are exempt from permit review should still comply with the Massachusetts Stormwater Management Standards. Developers are encouraged to use this checklist to produce resilient projects and to facilitate coordination with the Town of Brookline. Completing this checklist does not take the place of project permitting and does not, in any way, ensure or imply that a permit has or will be granted by the Town. A public emergency plan for the proposed project site describing the evacuation routes, emergency procedures, and the availability of power, water, and wastewater is also encouraged.

GENERAL PROJECT INFORMATION

Project Name: ____________________

Project Address: ____________________

Map: __________ Block: __________ Lot(s): __________

APPLICANT INFORMATION

Applicant: ____________________

Company/ Organization: ____________________

Mailing Address: ____________________

Phone Number: ____________________

Email Address: ____________________

OWNER INFORMATION

☐ The owner and applicant are the same.

Owner(s) Name: ____________________

Company/ Organization: ____________________

Mailing Address: ____________________

Phone Number: ____________________

Email Address: ____________________

POINT OF CONTACT INFORMATION

☐ Point of contact and owner are the same.
☐ Point of contact and applicant are the same.

Point of Contact Name: ______________________________

Company/ Organization: ______________________________

Mailing Address: ______________________________

Phone Number: ______________________________

Email Address: ______________________________

PROJECT INFORMATION

PROJECT TYPE

Please check all that apply.

☐ Nonresidential
☐ Residential
☐ New Construction
☐ Redevelopment

EXISTING

Total building footprint (ft^2): ______________________________

Area of impervious cover (ft^2): ______________________________

PROPOSED

Total building footprint (ft^2): ______________________________

Area of impervious cover (ft^2): ______________________________

Area of disturbance (ft^2): ______________________________

SITE LOCATION

☐ Project is within a known floodplain.
If the project is within a known floodplain, construction should conform to current floodplain regulations, including those established by FEMA and Section 4.11 Floodplain Overlay District in the Zoning By-Law. Projects should follow the most recent standards set by the American Society of Civil Engineers (ASCE) Flood Resistant Design and Construction, the Massachusetts Wetlands Protection Act, and Brookline Wetlands By-Law and Regulation.

☐ Project is within local hot spots as identified in the Climate Vulnerability Assessment and Action Plan.
☐ Project is within a Resource Area as defined by the Brookline Wetland Regulations.

SITE DESIGN ELEMENT: LANDSCAPING AND VEGETATION

Landscaping and vegetation reduce the impacts of climate change by providing shade and by storing precipitation. Plants identified as invasive, likely invasive, or potentially invasive by the **Massachusetts Invasive Plant Advisory Group*** (MIPAG) should be avoided because invasive plants threaten local native habitat and ecosystem services. Soil health is important to vegetation survival and erosion control and is included in this site design element. Please provide a narrative and landscape plan with the information in the table below.

Site Design Element Intent:

- Mitigate extreme temperatures
- Reduce urban heat island effect
- Build and maintain habitat for native species
- Reduce water usage
- Increase stormwater infiltration
- Ensure maintenance of plantings
- Protect and promote healthy soil

✓	Provide a narrative and landscape plan including:
	A planting list and landscape plan(s) showing new and existing vegetation and the following: ☐ Additional details for tree removal and plantings, including location, type, and caliper. ☐ A description for the removal of invasive species listed by the MIPAG and comparable native replacements. ☐ A description of salt tolerant species, where applicable.
	A plan to protect native or specimen trees with a process and method for enforcement to ensure existing trees on the site are preserved.
	A description of an increase or decrease in the tree canopy or vegetated shade.
	A description of proposed drought resistant/low-water consumption landscaping elements, including irrigation systems.
	A description of the maintenance schedule and activities.
	A plan to conserve and manage forested areas or environmentally sensitive areas.
	A description of open space in adjacent lots and plan for contiguity of open space across lots.
	A plan to limit site disturbance and reestablish vegetated areas.
	A plan to avoid soil compaction, erosion, and/or restore soils.

*Invasive Plant List *https://www.mass.gov/files/documents/2016/08/tm/invasive-plant-list.pdf*

SITE DESIGN ELEMENT: STORMWATER MANAGEMENT

Effective stormwater management protects water quality and ensures proper water quantity infiltration into surface and ground water for adequate streamflow and water supply. Stormwater is best managed by reducing impervious surfaces and promoting infiltration through Low Impact Development (LID). Please provide a site plan and narrative illustrating the details of the stormwater management system and efforts to reduce the amount of impervious surface (roads, parking lots, sidewalks).

Site Design Element Intent:

- Mitigate flooding
- Increase infiltration of pollutants into the environment
- Protect public safety
- Protect property

STORMWATER MANAGEMENT

✓	Provide a site plan and narrative about that stormwater management system, including;
	A description of how the stormwater best management practices have been applied for: ☐ Bioswale and Rain Garden ☐ Building Planter Boxes ☐ Exterior Window Shade ☐ Flood Barriers ☐ Floodable Spaces ☐ Green Wall ☐ Permeable Pavement/Cool Pavement ☐ Rainwater Harvesting ☐ Site Grading for Flood Management ☐ Soil Protection ☐ Sustainable Roofing Strategies ☐ Tree Box Filters ☐ Vegetation and Shade Trees ☐ Other:______________________
	A description of how best management practices have been applied in yards, the center of cul-de-sacs, rotaries, and vegetated strips along sidewalks.
	A description of how street edges allow side-of-road drainage into a vegetated open swale(s).
	A description of how climate change projections and impacts have been considered in the stormwater management design.
	A description of the operation and maintenance of the stormwater best management practices.

IMPERVIOUS SURFACES

✓	Provide a site plan and a narrative about impervious surface reduction efforts, including:
	A description of the impervious surfaces on site (like roads, sidewalks, parking areas) and how the total impervious surface area has been minimized.
	A description of how parking areas (pervious pavement cleaning and vegetation) will be maintained.
	A plan for shared parking and easements (if required) or multi-level parking for larger developments.
	A description of any vegetated walls or screens to protect adjacent properties from headlight glare.

SITE DESIGN ELEMENT: BUILDING RESILIENCE

Buildings should consider climate resilience measures above and beyond those required by the Massachusetts State Building Code. Building exteriors can reduce the impact of extreme temperature within and surrounding the building. Buildings can be designed to mitigate climate impacts like flooding and to maintain critical infrastructure during emergencies.

Site Design Element Intent:

- Reduce extreme temperature fluctuations
- Increase infiltration of pollutants into the environment
- Protect public safety
- Protect property

✓	Provide a site plan and description if any of the following are part of the proposed design:
	Green facades
	Sustainable roofing strategies (green, cool or blue rooftops)
	Drain leaders that are disconnected managed through infiltration and vegetated treatment
	Exterior building design uses heat reflective materials
	Designed to elevate, protect and back up critical infrastructure
	Power system and backup system includes a lower occupancy mode, which powers basic amenities
	Sump pumps, dry flood proofing, or other flood protection strategies