Urban Coastal Greenway Design Manual

For the Metro Bay Region

Cranston, East Providence, Pawtucket, and Providence

Photo © Save The Bay

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THE METRO BAY URBAN COASTAL GREENWAY

The Urban Coastal Greenway (UCG) Regulations for the Metro Bay Region are a new approach to coastal vegetative buffers for the urbanized environment of northern Narragansett Bay. The UCG policy allows redevelopment of the Metro Bay waterfront in a manner that integrates economic development with expanded public access along and to the shoreline, and provides for the management, protection, and restoration of valuable coastal habitats.

Permit applicants in the Metro Bay area have a choice between following the coastal buffer and setback regulations as set forth in the Rhode Island Coastal Resources Management Program (RICRMP) or using the UCG policy, which clarifies and streamlines the regulatory process for urban coastal development and allows greater flexibility in meeting the R.I. Coastal Resources Management Council (CRMC) requirements. The policy establishes standards regarding overall vegetation of the site, management of stormwater runoff using Low Impact Development (LID) techniques, and public access. Four UCG Zones, each with its own requirements, have been established within the planning boundary of the Metro Bay Special Area Management Plan (SAMP): Residential Zone, Area of Particular Concern Zone, Inner Harbor and River Zone, and Development Zone. The boundaries of these zones have been determined by the existing conditions of coastal habitat, public access infrastructure, single- and two-family residential areas, and current municipal plans for development and/or redevelopment. The requirements for each zone are described in UCG Sections 160 through 190. Applicants are encouraged to use the Metro Bay Internet Map Service (IMS) available online at: maps.provplan.org/sampmapper/ for more detailed maps and other information.

Definition

The UCG begins at the inland edge of the coastal feature, and its width is determined by its UCG Zone. With CRMC approval, applicants may utilize a buffer averaging method, where compensatory UCG width is provided in an area or areas in return for a necessary reduction in UCG width in other areas of the site, provided the total square footage of the UCG area remains the same.

Once the location of the UCG has been determined, a required construction setback of 25 feet is measured from the inland edge of the UCG. The setback may be reduced when the applicant can clearly demonstrate that the project and its subsequent use and maintenance will not result in the privatization of, or preclude public use of, the UCG. The CRMC executive director may require additional setback when site conditions warrant, especially for areas susceptible to high erosion, to protect coastal resources or public safety.

Compensation

Another novel component of the Urban Coastal Greenway policy is an option to reduce the UCG width through compensation. The compensation option generally allows an applicant to reduce the UCG from the standard width in return for site or coastal resource enhancements such as improved public access or habitat conservation and preservation. These options are described in Section 230 of the policy.

This manual

This design manual is intended to assist applicants in meeting UCG requirements. It is not a regulatory document.

100. INTRODUCTION

110. URBAN COASTAL GREENWAY PROGRAM

A. Vision

The Metro Bay region (Cranston, East Providence, Pawtucket, and Providence) is experiencing a major redevelopment boom, and is poised to become a nationally recognized destination for urban living. Given this, regulations specific to the urban shoreline of northern Narragansett Bay were developed for the Coastal Resources Management Program (Redbook). While the Redbook requires that buffer zones be undisturbed and allowed to grow naturally so as to maximize wildlife habitat and water quality benefits, an urban landscape requires greater flexibility in buffer design and maintenance. It is still desirable to achieve the maximum habitat and water quality benefits possible within urban areas, but the design of urban vegetative buffers must also acknowledge the simultaneous goals of redevelopment and allowing usable urban green space with increased public access to the shoreline. In addition, urban buffers require thoughtful design and maintenance if they are to achieve water quality goals in areas dominated by impervious cover.

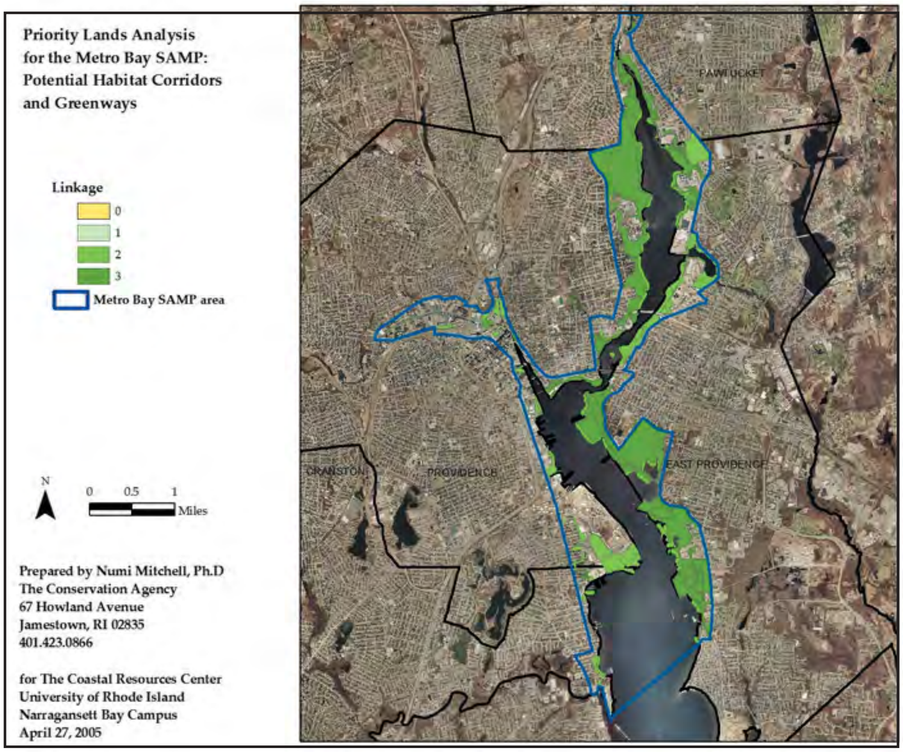
Northern Narragansett Bay

The ultimate vision of the Urban Coastal Greenway (UCG) Program is the creation of a continuous, sustainably landscaped, green corridor along upper Narragansett Bay. This green corridor, or greenway, will protect coastal resources and foster recognition of the natural aesthetic value as well as the economic value of the Metro Bay shoreline. It will also be a direct link to the water for residents and visitors and ensure a sustainable approach to shoreline development.

Save The Bay coastal greenway

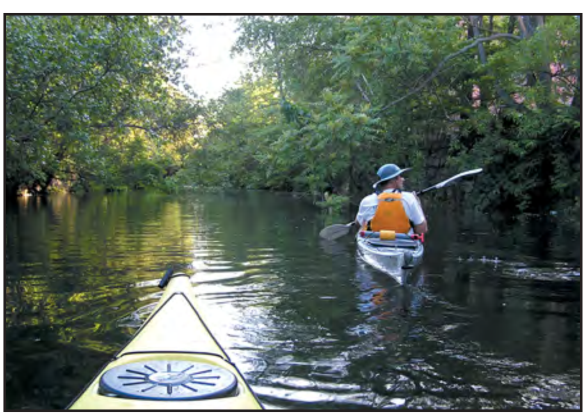
B. Goals

The UCG Program was designed to achieve three primary goals: increased public access to the coast, complete on-site stormwater management primarily through vegetative treatments, and the preservation and restoration of the aesthetic value of Rhode Island's



Potential greenway corridor for northern Narragansett Bay

urban shoreline through sustainable landscaping. Although the federal mandate governing CRMC's activities also calls for the consideration of additional coastal values and functions, CRMC recognizes that the use, size, and financial constraints of urban parcels require a more focused and flexible approach to coastal management. Therefore, the major requirements of this new approach toward urban coastal vegetative buffers are:



Woonasquatucket River

1. Sustainable landscaping:

(a) Greenways shall be entirely vegetated, with the exception of public access pathways. The greenway shall be planted with sustainable vegetation.

(b) Fifteen percent vegetation of the development. Each development site shall have vegetative coverage of at least 15 percent of the surface area within the site. The coverage shall consist of sustainable vegetation, and may be met by the greenway alone, or through a combination of the greenway and additional plantings elsewhere on the property, including rooftops.

2. One hundred percent on-site stormwater management:

One hundred percent of the stormwater shall be managed on site. One hundred percent stormwater management is defined in section

300.6 of the Redbook. (www.crmc.state.ri.us/regulations/programs/redbook.pdf). CRMC applicants must demonstrate that the proposed project will remove 80 percent of the total suspended solids (TSS) from the first one inch of runoff, which, per the most recent version of the Rhode Island Stormwater Design and Installation Standards Manual, can also be defined as 100 percent removal of TSS particles equal to or greater than 70 microns in diameter (www.dem.ri.gov/programs/benviron/water/permits/ripdes/stwater/index.htm). This shall be accomplished through low-impact-development (LID) treatments to the maximum extent practicable (e.g., swales, bioretention areas, and green roofs). The use of LID techniques is also in agreement with the policies of the Narragansett Bay Commission.

3. Continuous alongshore public access and periodic arterial access:

The greenway shall include a continuous alongshore (primary) public access pathway and at least one arterial (secondary) public access pathway per development site.

120. WHY THIS DESIGN MANUAL?

A. Design Goals

The UCG Program is intended to help achieve several design goals:

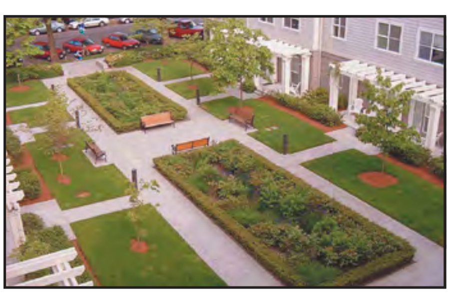
1. Adherence to an urban design aesthetic that showcases the views of Narragansett Bay and the Seekonk, Providence, Woonasquatucket, and Moshassuck rivers from the shoreline, as well as the view of the shoreline from the waterways.

2. Use of a diverse mix of sustainable, low-maintenance vegetation throughout each development site, and especially within the UCG. This will allow aesthetic appeal, will provide some of the water quality benefits of a natural vegetative buffer, and will protect some habitat value for wildlife such as migratory songbirds.

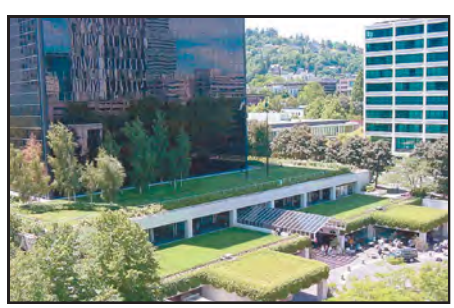
3. An infiltration approach to stormwater management through the use of LID techniques.

130. HOW TO USE THIS DESIGN MANUAL

The Urban Coastal Greenway Design Manual applies to all development proposals in the Metro Bay Special Area Management Plan boundary. This manual is intended to provide technical information, guidance, and additional references for accomplishing the UCG requirements. This manual is not a comprehensive source for design options within the UCG. CRMC and its staff may clarify, interpret, and apply the guidelines in this manual as appropriate.



Bioretention areas



Green roof on commercial building

Each section of the manual is organized according to the following outline:

100. Title of the chapter
This heading provides an introduction to the chapter subject, and a context for the UCG requirements.

110. UCG Requirements
This section contains a description of the specific requirements for the chapter subject in the UCG regulations. This section should not be used in place of the regulations document, but should be used as a brief summary of the major requirements regarding each subject.

120. Meeting UCG Requirements
This section details techniques and strategies to meet the UCG requirements, focusing on sustainable development technologies and methods.

130. Hypothetical Plans
The graphics in this section illustrate examples of appropriate design elements to accomplish specific requirements within the UCG. These hypothetical plans are not prescriptive.

Clockwise from upper left: Slater Mill, Pawtucket; Conley's Wharf, Providence; Stillhouse Cove, Cranston; Blackstone Park, Providence; Sabin Point Park, East Providence

200. SUSTAINABLE LANDSCAPING

210. UCG VEGETATION REQUIREMENTS

A. Sustainably vegetated greenway

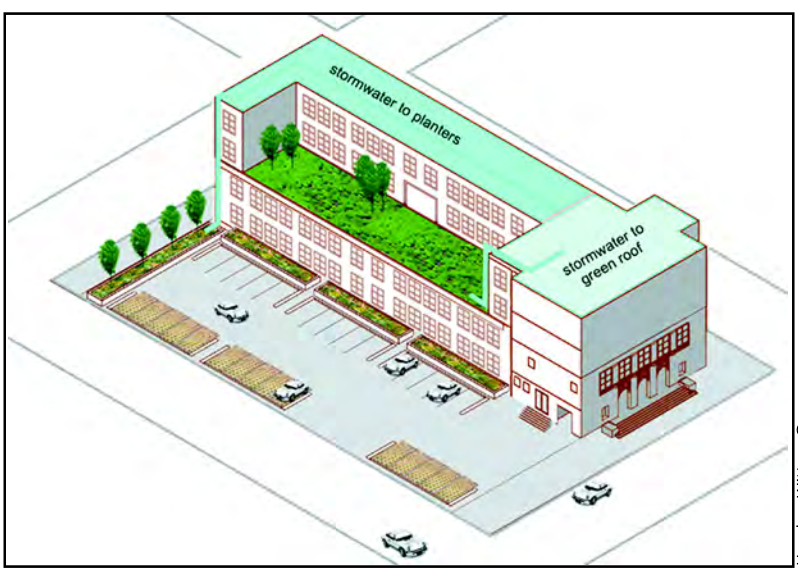
With the exception of certain low-impact development (LID) stormwater treatment facilities and approved public access pathways, urban coastal greenways shall be designed as native plant communities and/or sustainable landscapes using, whenever possible or appropriate, noninvasive native and/or sustainable species of vegetation. These species shall be chosen from the CRMC/University of Rhode Island (URI) Coastal Plant List (www.crmc.ri.gov/pubs/pdfs/uri_plantlist.pdf) or another appropriate list approved by CRMC. The plants on this list have been selected for their minimal maintenance requirements, habitat value, and ability to survive in coastal environments. Applicants should also refer to the Rhode Island Invasive Species Council's list of invasive plants (www.crmc.ri.gov/pubs/pdfs/RI_invasives.pdf). Plants on this list will not be allowed as part of a UCG landscape plan.

B. Fifteen percent vegetation of development site

Applicants must maintain sustainable vegetative coverage on at least 15 percent of the surface area within the development parcel. This vegetation requirement may be met by the greenway, or through a combination of the greenway and additional plantings elsewhere on the property. All planting plans shall be prepared by a licensed landscape architect (see R.I. Gen. Laws §5-51). When planning landscape features that also function as stormwater controls, be sure that the landscape architect has experience with creating planting plans for such practices, and keep in mind that the design of stormwater management practices must be done by a licensed engineer. It is ideal to have professionals from both fields working together early on in the

Horsley-Witten Group

Stormwater planters around buildings treat roof runoff.



Horsley-Witten Group

This illustration shows that 15 percent vegetation can be achieved using green roofs, stormwater planters, and permeable paving.

design process. The landscape plan shall use groundcovers, understory plantings, grasses, forbs, shrubs, and trees appropriately to achieve the goals of these regulations. These plantings may include landscaping elements or vegetated stormwater treatment practices such as green roofs and rain gardens. Within the greenway, the plantings should include a mix of trees, shrubs, and ground covers, with minimal use of high-maintenance lawn sods and grasses.

C. Preserve existing vegetation

Existing noninvasive vegetation (especially trees) shall be preserved in urban coastal greenways whenever possible.

D. Maintain the greenway

The property owner with a UCG is responsible for maintaining the UCG.

CRMC requires the property owner to submit a UCG landscape plan that includes the following:

- Delineation of UCG boundaries
- Photograph(s) of existing conditions
- Property lines, easements, and utilities
- Existing and proposed curbs, gutters, sidewalks or pavement edges
- Location, Latin and common names, and caliper of existing native trees and other native woody vegetation
- Location and Latin and common names of vegetation to be removed
- Latin and common names and caliper of plants to be installed, their planned locations and spacing (include on plan and as a separate list document)
- Planned grading or elevation changes
- Hardscaping and any other planned landscape features

Save The Bay chose a variety of species for their stormwater management properties, habitat value, and minimal maintenance requirements.

- Representative cross sections of landscaped areas
- Planned public amenities (parking areas, pathways, etc.)
- Planned LID stormwater management practices
- Location of UCG signage

In addition, property owners submitting landscape plans must include a maintenance plan that describes all landscape maintenance activities to be performed within the UCG. Activities addressed within the maintenance plan should include:

- Pruning and removal of dead material
- Leaf removal
- Weeding and removal of invasive species
- Mulching
- Irrigation
- Fertilization
- Pest management

For each activity, the maintenance plan should identify the party responsible for that activity, as well as a detailed schedule of when and the frequency with which the activity will occur. For maintenance of vegetated stormwater management practices, see the Stormwater Section (Section 300) of this manual. When creating a landscape management plan, keep in mind the following recommendations:

Fescues require little maintenance.

Pruning and weeding

- Whenever possible use mechanical methods of vegetation removal (e.g., mowing with tractor-type or push mowers, hand cutting with gas or electric powered weed trimmers) rather than applying herbicides. Use hand weeding where practical.
- Avoid loosening the soil when conducting mechanical or manual weed control, as this could lead to erosion. Use mulch or other erosion control measures when soils are exposed.
- Place temporarily stockpiled material away from watercourses, and berm or cover stockpiles to prevent material releases to storm drains.

Larry Gavin

Selecting a variety of plants provides visual interest while minimizing use of turf.

Waste management

- Leaves, sticks, or other collected vegetation should be disposed of by appropriate means as leaf and yard waste. Do not dispose of collected vegetation into waterways or storm drainage systems.
- Place temporarily stockpiled material away from water bodies and storm drain inlets, and berm or cover stockpiles to prevent material releases to the storm drain system or water bodies.
- Minimize the use of high nitrogen fertilizers that produce excess growth requiring more frequent mowing or trimming.
- Avoid landscape wastes in and around storm drain inlets by using bagging equipment or by manually picking up the material.

Irrigation

- Keep landscape irrigation needs to a minimum through proper plant selection and placement. Properly sited native or sustainable plants should require minimal irrigation once established.
- Whenever possible, utilize water collected in stormwater management practices such as rain barrels and cisterns for landscape irrigation.
- Where irrigation is necessary during plant establishment, utilize practices and equipment that promote water conservation, such as soaker hoses and moisture sensors. In addition, place plants in locations to which they are suited (e.g. shady or sunny areas). Simply grouping plants with similar water needs together will result in much more efficient water use. Refer

to the CRMC / URI Coastal Plant List for individual plant species characteristics and requirements.

Fertilizer and pesticides*

- Minimize fertilizer and pesticide use to the greatest extent possible through proper plant selection and placement. Properly sited native / sustainable plants should require minimal inputs of fertilizer and pesticides once established.
- Do not use fertilizers or pesticides if rain is expected within the following 24 hours. Apply fertilizers and pesticides only when wind speeds are low (less than 5 mph)
- Calibrate fertilizer and pesticide application equipment to avoid excessive application.
- Incorporate fertilizers into the soil where possible, rather than broadcasting onto the surface.
- After application, sweep fertilizer spilled on hard surfaces such as pavement back onto lawn surfaces (never hose it off). Do not sweep fertilizer into gutters or stormdrains. Use a fertilizer spreader with an "edgeguard" device. Alternatively, a buffer strip of plantings that won't require fertilizer should be used by driveways or sidewalks.

Portland Stormwater Management Manual

Green roof atop apartment building

- Periodically test soils to determine fertilizer needs.
- Utilize a comprehensive management system that incorporates integrated pest management (IPM) techniques (visit the Northeastern IPM Center's website at www.northeastipm.org for resources).
- Use pesticides only if there is an actual pest problem (not on a regular preventative schedule).
- Do not mix or prepare pesticides for application near storm drains or within 50 feet of the shoreline or edge of a surface water body.
- Prepare the minimum amount of pesticide needed for the job and use the lowest rate that will effectively control the pest.
- Employ techniques to minimize off-target application (e.g. spray drift) of pesticides, including consideration of alternative application techniques.
- Triple rinse containers, and use rinse water as product. Dispose of unused pesticide as hazardous waste.
- Dispose of empty pesticide containers according to the instructions on the container label.

**Follow all federal, state, and local laws and regulations governing the use, storage, and disposal of fertilizers and pesticides and training of applicators and pest control advisors.*

220. MEETING UCG VEGETATION REQUIREMENTS

A. Selection of greenway vegetation

1. Select sustainable plants

When selecting plant materials for the greenway, choose species listed in the URI

Urban forests, such as this one in the Metro Bay area, provide habitat for a variety of species.

Coastal Plant List (www.crmc.ri.gov/pubs/pdfs/uri_plantlist.pdf). These plants have been selected for their ability to thrive in coastal environments, their habitat value, and minimal maintenance requirements. A list of growers and suppliers can also be found on the CRMC website.

2. Minimize turf

While turf may seem preferable from a maintenance perspective, it can be problematic due to its potentially large fertilization and water requirements, as well as its limited wildlife habitat value. It is best to limit turf to areas reserved for picnicking or similar recreational activities that require lawn. When turf is used, select a low maintenance turf variety that is appropriate for the environment in which it is to be planted. The amount of use and level of care must be considered when selecting the correct grass mixture for the lawn, and cultivars should be selected that are disease, insect, and drought resistant. Avoid landscape designs that require long, narrow areas of turf, which are difficult to water efficiently, and instead specify native ground covers from the CRMC/URI Coastal Plant List for these areas.

Fertilizer and water use can be reduced by selecting the improved drought-resistant and low-fertilizer requirement varieties of fescues, or newer drought-tolerant hybrid varieties of Kentucky bluegrass. Fine fescues are a group of fescues including chewings, creeping red, and hard fescues. Fine leaf fescues perform well under low-maintenance situations and should be considered for use when looking for a low-maintenance lawn grass. Tall fescue is another lower maintenance grass but does not perform as well as the fine fescues under very low maintenance. A combination of turf-type, tall, and fine fescues is usually best. See the CRMC/URI Turf Protocol for Sensitive Areas for guidance in choosing the appropriate mix for your site.

3. Provide variety in landscape design

Variety can be achieved both through the selection of plants as well as in the design of the plantings.

- Focus UCG landscape design on creating plant communities rather than isolated specimen plantings. Place plants that are found growing together in natural settings in dense groupings.
- Visual interest can be created within the greenway by incorporating a variety of plant forms (trees, shrubs, groundcovers) into the landscape.
- Site plants properly so that, when mature, they complement rather than compete with each other. See CRMC's Buffer Zone Planting Guidelines for guidance on plant spacing and installation. To provide a greenway that draws interest throughout the year, choose evergreen trees, shrubs, vines, plants with colorful bark or fruit, and perennials that keep their foliage or flowers through the winter. Small plantings of

Benefits of incorporating trees within an Urban Coastal Greenway and adjacent lands. Modified from Ryan et al. (2002), McPherson et al. (2001), and Cappiella et al. (2005).

Design Component	Benefit
Shade east and west sides of the building.	***Energy savings*** Solar angle is lower and more direct on these sides. Limiting sun's exposure decreases cooling costs in summer.
Plant trees so as not to shade south-facing windows.	***Energy savings*** Unshaded southern facing windows decrease heating costs in winter months.
Plant trees upwind 25 to 50 feet from the building to create a windbreak. Evergreens provide better wind protection than deciduous trees.	***Energy savings*** Protect building from strong winter winds that increase heating costs.
Integration of multiple trees within the Greenway.	***Stormwater management*** Tree leaves and branches intercept and store rainwater, decreasing stormwater runoff (Xiao & McPherson, 2002). ***Recreation*** Shoppers make more frequent shopping trips in tree-lined commercial districts (Wolf, 1999). ***Increased property values*** Large trees are associated with increased sales prices for residential properties (Anderson & Cordell, 1988).
Plant/maintain trees of different ages and species.	***Habitat value*** A diverse urban forest promotes continuous canopy cover and provides greater habitat diversity.
Preserve existing trees on the development site.	***Reduced construction costs*** Preserving trees decreases cost per acre for clearing, grading, and installing erosion control best management practices.

annuals and bulbs can provide additional color during the growing season.

4. Cultivate wildlife habitat by selecting appropriate species

The careful selection of vegetation for the greenway can offer the concurrent benefit of providing wildlife habitat, especially for migratory birds. Consider the following guidelines for promoting bird habitat within the UCG.

- Examine existing and proposed landscaping in terms of promoting habitat, especially for migratory birds.
- Design landscaping with plant species that are bird friendly, i.e., provide shelter, nesting material, and food sources (See the URI Coastal Plant List for plant species with wildlife habitat value).
- Design multi-layered landscapes that include perennials and groundcovers, shrubs, under-story trees, and canopy trees.
- Design water edges with aquatic and riparian species and natural wetland and upland plantings.
- Design water supply for landscape maintenance and necessary sources of water for birds.
- Design new facilities to eliminate or minimize hazards to migratory and nesting birds.
- Use construction techniques and materials that avoid or mitigate bird-adverse interactions, such as erosion netting.

5. Cultivate Urban Forests

In addition to providing aesthetic value (Ryan et al., 2002), the careful preservation of existing trees and the cultivation of new trees within an urban greenway can increase shade (thereby decreasing the needs for mechanical cooling within adjacent buildings), create windbreaks (decreasing heating costs during cooler months), reduce erosion, retain/sustain shorelines and highly erosive areas, improve air quality, and intercept stormwater runoff. Urban forests have also been shown to present long-term benefits that are at least twice the value of their costs (McPherson et al., 1997).

Design considerations for urban forests:

- When choosing tree species, be careful to select trees whose water requirements match those of surrounding plants.
- Consider the maintenance needs of the tree species in regard to the overall greenway design. Trees that drop fruit should not be planted immediately adjacent to public access pathways, for example.
- Avoid planting shallow rooting species within three feet of paved areas to avoid tree root heaving.
- Provide sufficient soil volume to support the tree at maturity. According to Cappiella et al. (2005), it is generally appropriate to supply two cubic feet of usable soil for every square foot of mature canopy.
- Consider the spatial requirements of the tree at maturity, and choose the placement of each tree accordingly. See the URI Coastal Plant List for mature canopy diameters of approved tree species.

Existing trees are frequently inadvertently killed due to construction activities that cut, smother, or expose tree roots (Ryan et al., 2002). Soil compaction can prevent respiration by the tree, while changing the soil grade around a tree can lead to smothering or exposure of the tree's roots. Applicants should consult with professional arborists and landscape architects prior to construction activities to determine which trees can be preserved in the course of development. For more information, see Cornell University's *Recommended Urban Trees* (www.hort.cornell.edu/uhi/outreach/recurbtree/).

Site Assessment Checklist for Urban Tree Planting

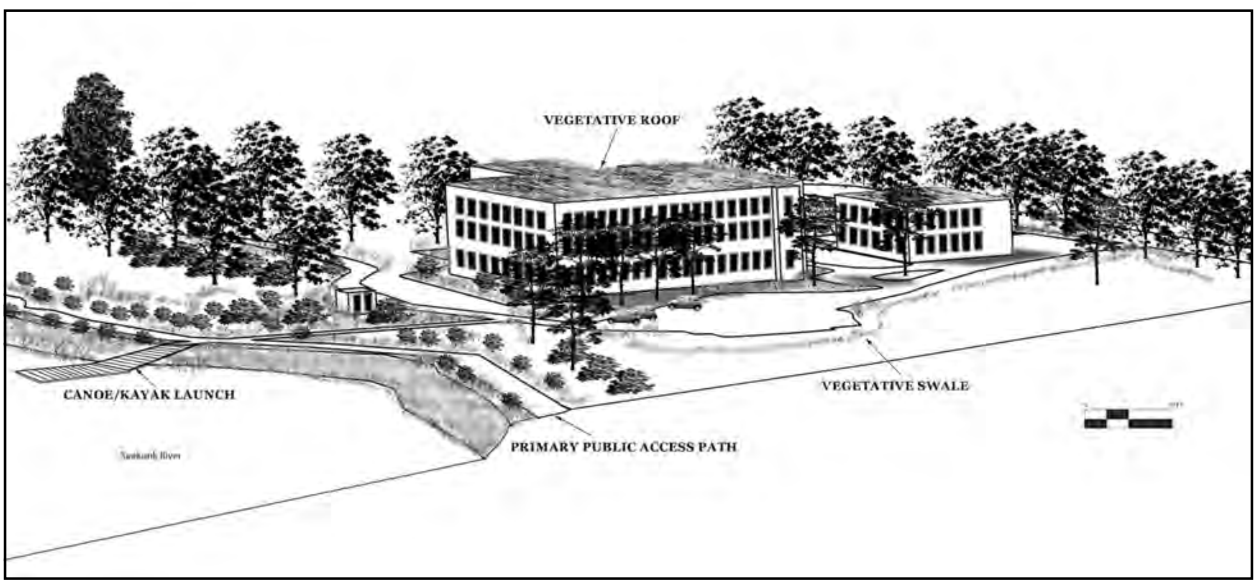
from Capiella et al., 2005

- Site location and description
- Climate
  - USDA Hardiness Zone
  - Microclimate factors
- Soil factors
  - Range of pH levels
  - Texture
  - Compaction levels
  - Drainage characteristics
- Structural factors
  - Limitations to above-ground space
- Sunlight and irrigation levels
- Other soil considerations

B. Meeting 15 percent vegetation requirements

Some development sites may meet the 15 percent vegetation requirement entirely within their greenway. However, other sites may need to incorporate additional vegetation throughout the development to satisfy the vegetation requirement. In the latter case, applicants should consider the use of green roofs, rain gardens, and stormwater planters to complement the greenway and any existing vegetation on the site. These alternative vegetative treatments are discussed further in Section 300.

230. HYPOTHETICAL LANDSCAPING PLAN



Source: M. Leighly and J. Martel, Rhode Island School of Design, 2006.

300. STORMWATER MANAGEMENT

As stormwater runoff passes over and through developed landscapes, it picks up and carries a variety of pollutants that affect water quality (including nutrients, sediments, organic materials, toxins, and pathogens). Impervious surfaces prevent infiltration of stormwater, thereby increasing the potential for flood damage and the amount of pollution that enters adjoining water bodies. The flow of urban stormwater through narrow channels or pipes also inhibits the natural hydrological cycle, concentrating and speeding up flows. This can cause changes in stream morphology, increase flooding and erosion, and prevent infiltration.

This section of the manual promotes a process and techniques that meet the Urban Coastal Greenway (UCG) stormwater management policy requirements, and that are also consistent with stormwater requirements described in section 300.6 of the Rhode Island's Coastal Resources Management Plan, known as the "Redbook," (www.crmc.state.ri.us/regulations/programs/redbook.pdf) and the Rhode Island Stormwater Design and Installation Standards Manual www.dem.ri.gov/programs/benviron/water/permits/ripdes/stwater/index.htm. The described process and techniques also assist the developer in complying with the Narragansett Bay Commission's (NBC) regulations that prohibit stormwater connections to any public sewer unless the NBC determines that a combined sewer is the only reasonable means available for disposal (www.narrabay.com/Documents/PDFs/NBC%20Rules%20&%20Regs.pdf).

310 UCG STORMWATER MANAGEMENT REQUIREMENTS

A. One hundred percent of stormwater management shall be on site

Stormwater management is defined in section 300.6 of the Redbook. (www.crmc.state.ri.us/regulations/programs/redbook.pdf). CRMC applicants must demonstrate that the proposed project will meet the stormwater management standards set forth in the UCG policy in Section 150.1(b). For purposes of the UCG requirements, this shall be accomplished through low-impact development (LID) practices (e.g., swales, bioretention areas, and green roofs) to the maximum extent practicable.

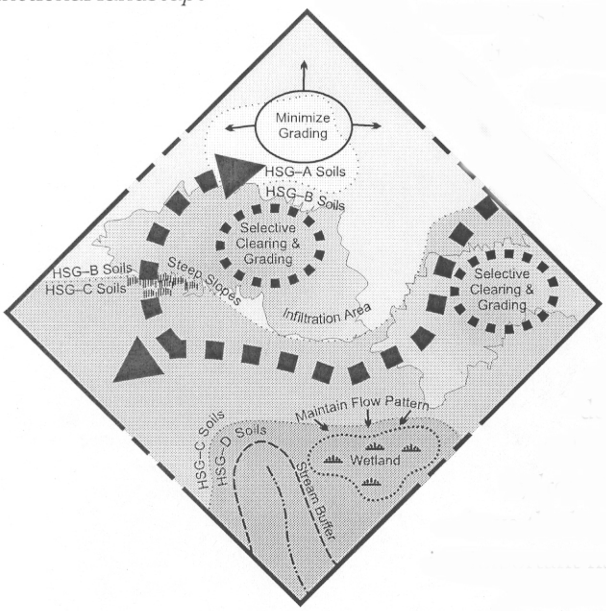
B. Stormwater treatment techniques constitute a hydrologically functional landscape amenity

Where possible, stormwater treatment practices should be vegetated, and designed as a landscape amenity. When site topography (or land shaping) requires hard structures as part of the stormwater treatment design, a textured surface and use of plant materials should be used to soften the appearance of the structure and provide additional onsite vegetation.

C. Consistency with state requirements and academic research

LID techniques have been shown to be highly effective in treating stormwater runoff while improving the hydrological functions (i.e., reducing runoff and promoting groundwater infiltration) of a site. The University of New Hampshire Stormwater Center (UNHSC)

Hydrologically functional landscape



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(www.unh.edu/erg/cstev) has extensively researched LID practices for their effectiveness and application to the New England climate. Many of the LID practices described in the following sections have been evaluated by the UNHSC. These LID methods will help applicants meet the requirements under R.I.G.L. § 45-61.2 whereby sites must maintain predevelopment groundwater recharge, control post-construction peak discharge rates to predevelopment levels, and use LID practices as the primary method of stormwater control. Using LID techniques is also in agreement with the requirements of the NBC, which state that "no person(s) shall make direct or indirect connections or shed stormwater from roof downspouts, foundation drains, areaway drains, or other sources of stormwater, which in turn are connected to any public sewer unless the NBC determines that a combined sewer is the only reasonable means available for disposal and such connection receives NBC approval." (NBC Rules and Regulations for Use of Wastewater Facilities Within the Narragansett Bay Commission District, Article 4.4).

D. Coordination with applicable agencies

Applicants shall coordinate their stormwater management strategy with CRMC, the R.I. Department of Environmental Management (RIDEM), the municipality of jurisdiction, and the NBC, where applicable.

E. Maintenance and monitoring of innovative technologies

Prior to installing any experimental stormwater treatment practice, the property owner must submit to CRMC, and receive approval on, a monitoring plan. For more information, see Section 250 of the UCG Policy, as well as CRMC's interim policy on innovative stormwater technologies (www.crmc.ri.gov/news/2007_0207_stormwater.html).

320 MEETING UCG STORMWATER MANAGEMENT REQUIREMENTS

This section provides information on meeting the UCG policy standards and other stormwater management requirements by integrating fundamental LID site planning concepts and techniques into the design process.

LID is an integrated approach to site development or redevelopment that focuses on replicating predevelopment hydrology through the distribution and management of stormwater across a development site. LID aims to provide the maximum absorption and treatment of stormwater pollutants and retention of stormwater prior to its loss as runoff. LID techniques capture rainwater onsite, reduce offsite runoff, infiltrate and recharge groundwater where appropriate, remove pollutants (i.e. excessive nutrients, sediments, toxins, pathogens), reduce reliance upon existing stormwater infrastructure and treatment facilities, and reduce infrastructure operation and maintenance costs.

Much of the information on LID site planning is from Low Impact Development Design Strategies: An Integrated Design Approach, prepared by the Prince George's County, Maryland, Department of Environmental Resources (www.epa.gov/owow/nps/lid/lidnatl.pdf), and much of the information on specific techniques is from RIDEM's The Urban Environmental Design Manual (www.dem.ri.gov/programs/bpoladm/suswshed/pdfs/udm3.pdf). Highlighting RIDEM-supported practices in this CRMC manual will assist applicants in coordinating their stormwater management strategies between the two agencies.

A. LID site-planning strategies to achieve the UCG stormwater management standards

Incorporating LID site-planning strategies and techniques facilitates the development of site plans that are adapted to natural topographic constraints such as those found in urban areas, allow for full development of the property while maintaining the essential site hydrologic functions, and provide for aesthetically pleasing, and often more effective, stormwater management controls.

It is important to consider LID approaches early in the planning stage, as careful design can enhance the goals and efficacy of LID. In addition, one of the attractive features of the LID approach is that it can incorporate smaller, inexpensive design features as well as larger ones. Because LID practices are distributed throughout a site and are often vegetated, it is important that landscape architects and engineers collaborate early on in the site design process.

Fundamental LID Site-Planning Concepts

Five fundamental concepts that define the essence of LID technology must be integrated into the site planning process to achieve a successful and workable plan.

Concept 1 - Using Hydrology as the Integrating Framework

Hydrology should be integrated into the site planning process from the beginning. Potential site development and layout schemes should be evaluated to identify potential sources of stormwater runoff (e.g., impervious surfaces such as roofs, driveways, and parking lots), and determine stormwater flow paths. Where possible, impervious surfaces should be reduced, minimized, and disconnected. Further analysis should then be conducted on the unavoidable impervious areas to disconnect them from each other and from existing stormwater drainage infrastructure. Stormwater flow should be redirected so that it is retained on site, treated and collected for reuse, or allowed to infiltrate where appropriate. Bioretention areas, infiltration devices, drainage swales, and many other practices identified in this document can be used to control runoff and disconnect impervious areas. The end result is an integrated and hydrologically functional site plan that mimics or improves the predevelopment hydrology while improving aesthetic values and providing recreational resources by adding landscape features.

Concept 2 - Thinking Micromanagement

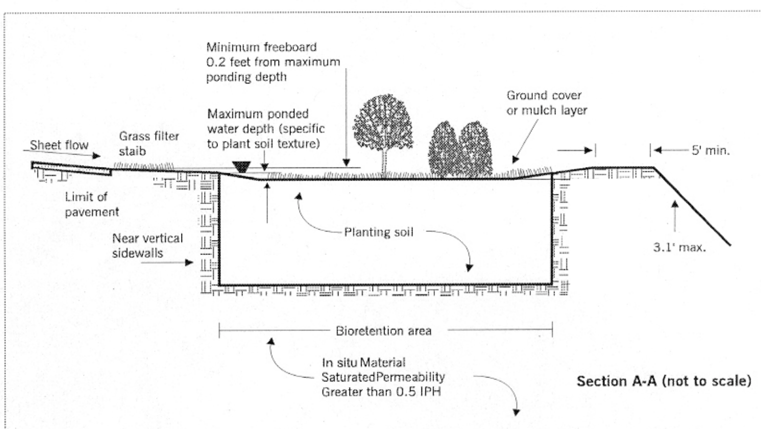
The key to making the LID concept work is to think small. This requires a change in perspective or approach with respect to the size of the area being controlled (e.g., microsubsheds), the size of the control practice (microtechniques), siting locations of controls, and the size and frequency of storms that are controlled. Micromanagement techniques implemented on small subcatchments as well as on common areas allow for a distributed control of stormwater throughout the entire site. This offers significant opportunities for maintaining the site's key hydrologic functions including infiltration where appropriate, depression storage, and interception, as well as a reduction in the time of concentration. These micromanagement techniques are referred to as integrated management practices. LID practices should be off-line controls, meaning that they should be designed to collect and treat runoff from small, frequent rainfall events and bypass larger stormwater volumes.

Concept 3 - Controlling Stormwater at the Source

The key to restoring or enhancing hydrologic functions is to first minimize and then mitigate the hydrologic impacts of land-use activities close to the source of generation. Compensation or restoration of hydrologic functions such as interception and infiltration should be implemented as close as possible to the point or source where the impact or disturbance is generated. This is referred to as a distributed, at-source control strategy and is accomplished using micromanagement techniques throughout the site.

The cost benefits of this approach can be substantial. Typically, the most economical and simple stormwater management strategies are achieved by controlling runoff at the source. Conveyance system and control or treatment structure costs increase with distance from the source and size of the drainage area.

Bioretention cell



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The bioretention cell in this illustration demonstrates a number of functions. First, the tree canopy provides interception and ecological, hydrologic, and habitat functions. The 6-inch storage area provides detention of runoff. The organic litter/mulch provides pollutant removal and water storage. The planting bed soil provides infiltration of runoff, removal of pollutants through numerous processes, groundwater recharge, and evapotranspiration through the plant material.

Concept 4 - Using Simple, Nonstructural Methods

The use of LID techniques can offer significant advantages over conventional engineered facilities such as ponds or concrete conveyances. Using materials such as native plants, soil, and gravel makes it easier to integrate these systems into the landscape, and gives them a more natural appearance than conventionally engineered systems. The natural characteristics may increase acceptance and willingness to adopt and maintain such systems.

Small, distributed, microcontrol systems also offer a major technical advantage: one or more of the systems can fail without undermining the overall integrity of the site-control strategy.

These smaller facilities tend to feature shallow basin depths and gentle side slopes, which also reduce safety concerns. The integration of these facilities into the landscape throughout the site offers more opportunities to mimic the site's predevelopment hydrologic functions and add aesthetic value.

Concept 5 - Creating a Multifunctional Landscape and Infrastructure

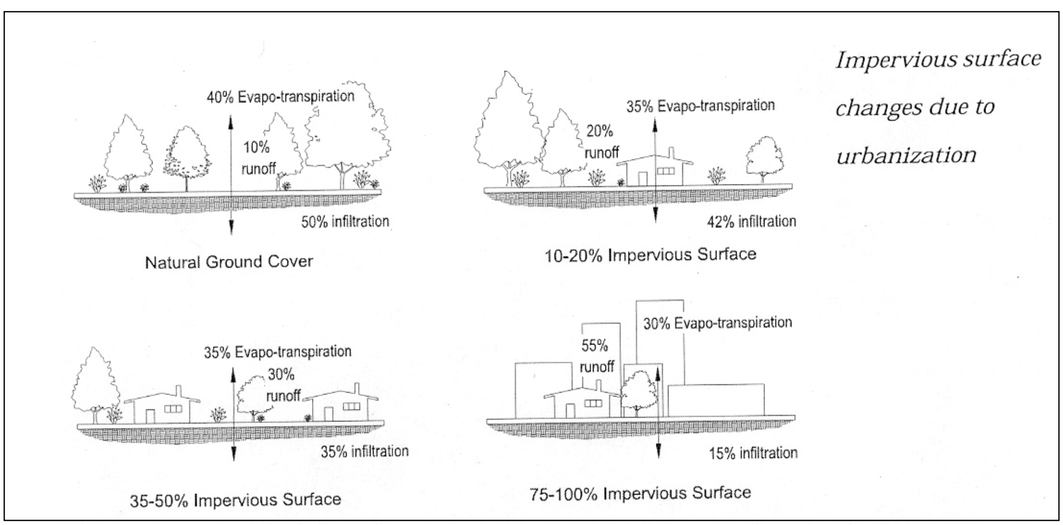
LID offers an innovative alternative approach to urban stormwater management that integrates stormwater controls into multifunctional landscape features. With LID, every urban landscape or infrastructure feature (roof, streets, parking, sidewalks, and green space) can be designed to be multifunctional, incorporating detention, retention, filtration, or runoff reuse.

The LID Site-Planning Process

The steps involved in integrating the LID technology into the conventional site-planning process are described below:

Step 1. Define Development Envelope and Protected or Contaminated Areas

In urban areas, the development envelope is likely to be a large percentage of the total lot



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This illustration shows how urbanization and increased impervious areas greatly alter the predevelopment hydrology.

area. However, certain site features should be identified early on in the site planning process. These include the location of greenway boundaries and setbacks, public access paths, parking and other public amenities, as well as existing vegetation that is to be preserved. In addition, areas of contamination should be identified in coordination with RIDEM's Office of Waste Management.

Step 2. Use Minimal Disturbance Techniques

Minimal disturbance techniques can be used to reduce hydrologic impacts. These techniques include the following:

- Reducing paving and compaction of soils, and restoring soils in planned vegetated or stormwater management areas where compaction is unavoidable
- Minimizing the size of construction easements and material storage areas, and siting stockpiles within the development envelope during the construction phase of a project
- Siting building layout and clearing and grading to avoid removal of existing trees where possible
- Minimizing imperviousness by reducing the total area of paved surfaces
- Disconnecting as much impervious area as possible to increase opportunities for infiltration or reuse where appropriate and reduce runoff volumes

Step 3. Use Drainage/Hydrology as a Design Element

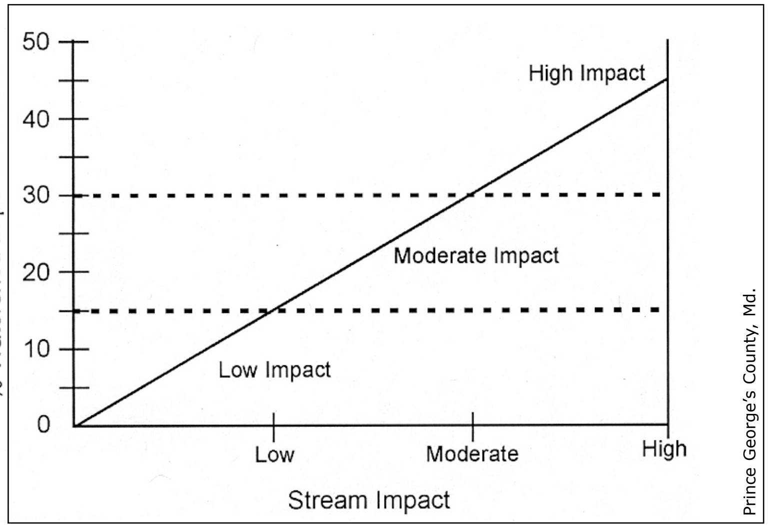
Site hydrology evaluation and understanding are required to create a hydrologically functional landscape. Urbanization and increased impervious areas greatly alter predevelopment hydrology (USEPA, 1993; Booth and Reinelt, 1993). This increase in impervious areas has been directly linked to increases in impacts on receiving streams by numerous investigators (including Booth and Reinelt, 1993; Horner et al., 1994; Klein, 1979; May, 1997; Steedman 1988). To reduce these impacts, LID site planning incorporates drainage/hydrology by carefully conducting hydrologic evaluations and reviewing spatial site layout options.

Hydrologic evaluation procedures can be used to minimize runoff potential and to maintain the predevelopment time of concentration (Tc). These procedures are incorporated into the LID site-planning process early on to understand and take advantage of site conditions.

Spatial organization of the site layout is also important. Unlike pipe conveyance systems that hide water beneath the surface and work independently of surface topography, an open drainage system for LID can work with natural landforms and land uses to become a major design element of a site plan. The LID stormwater management drainage system can suggest pathway alignment, optimum locations for park and play areas, and potential building sites. The drainage system helps to integrate urban forms, giving the development a more aesthetically pleasing relationship to the natural features of the site. The integrated site plan can also reduce development costs by minimizing earthwork and construction of expensive drainage structures.

Step 4. Reduce/Minimize Total Impervious Areas

After, or concurrent with, the mapping of the development envelope, the traffic pattern and road layout and preliminary lot layout are de-



The increase in impervious areas has been directly linked to increases in impacts on receiving streams.

veloped. The entire traffic distribution network (roadways, sidewalks, driveways, and parking areas) is the greatest source of site imperviousness. To reduce the total runoff volume from impervious surfaces:

- Reduce road width sections to minimize total site imperviousness as well as clearing and grading impacts.
- Place sidewalks on only one side of primary roads
- Develop greenroofs on rooftops
- Use permeable materials as surfaces for pathways and lower-traffic areas

Step 5. Develop an Integrated Preliminary Site Plan

Developing an integrated preliminary site plan will provide a base for conducting the hydrologic analysis to compare pre- and post-development site hydrology and to confirm that the site will be hydrologically functional. The procedures described below are aimed at disconnecting the unavoidable impervious areas, as well as modifying the drainage flow paths so that the post-development Tc of stormwater runoff will be as similar as possible to the predevelopment conditions.

Step 6. Minimize Directly Connected Impervious Areas

Strategies for disconnecting the unavoidable impervious areas include:

- Disconnecting roof drains and directing flows to stabilized vegetated areas or LID practices
- Directing flows from paved areas to stabilized vegetated areas or LID practices
- Grading to break up flow directions from large paved surfaces
- Encouraging sheet flow through vegetated areas wherever possible using filter strips, level spreaders and similar practices

Step 7. Modify/Increase Drainage Flow Paths

The Tc, in conjunction with the hydrologic site conditions, determines the peak discharge rate for a storm event. Site and infrastructure components that affect the time of concentration include:

- Travel distance (flow path)
- Slope of the ground surface and/or water surface
- Surface roughness
- Channel shape, pattern, and material components

Techniques that can affect and control the Tc can be incorporated into the LID concept by managing flow and conveyance systems within the development site:

a. Maximize overland sheet flow: Where possible, the site should be graded to maximize the overland sheet flow distance through vegetated areas along the post-development Tc flow path. This practice will increase runoff travel times (Tt) and thus the Tc. Consequently, the peak discharge rate (Q) will be decreased. Velocities in the range of two to five feet per second are generally recommended. Flows can be slowed by installing a level spreader along the upland ledge of the vegetated area or by creating a flat grassy area, or filter strip about 30 feet wide on the upland side of the vegetated area where runoff can spread out. This technique works best on large lots with wide greenways or large vegetated areas, and may not be viable on smaller lots or lots where the development envelope is a large percentage of the overall lot area.

b. Increase and lengthen flow paths: Increasing flow path of surface runoff increases infiltration and Tt. One of the goals of a LID site is to provide as much overland or sheet flow as possible to increase the time it takes for rooftop and driveway runoff to reach open swale drainage systems. To accomplish this, the designer can direct this runoff into strategically located bioretention facilities, infiltration trenches, dry wells, or cisterns prior to its reaching the lawn. In addition, strategic lot grading can increase both the surface roughness and the travel length of the surface runoff.

c. Lengthen and flatten site and lot slopes: Constructing roads across steeply sloped areas unnecessarily increases soil disturbance to a site. Good road layouts avoid placing roads on steep slopes by designing roads to follow grades and run along ridgelines. Steep site slopes often require increased cut and fill if roads are sited using conventional local road layout regulations. If incorporated into the initial layout process, slope can be an asset to the development.

d. Maximize use of open swale systems: Wherever possible, LID designs should use multifunctional open drainage systems in lieu of more conventional storm drain systems. To alleviate flooding problems and reduce the need for conventional storm drain systems, vegetated or grassed open drainage systems should be provided as the primary means of conveying surface runoff between lots and along roadways. Lots should be graded to minimize the quantity and velocity of surface runoff within the open drainage systems. Infiltration controls and terraces can be used to reduce the quantity and travel time of the surface runoff as the need arises.

e. Increase and augment site and lot vegetation: Revegetating graded areas, planting, or preserving existing vegetation can reduce the peak discharge rate by creating added surface roughness as well as provide for additional retention, reducing the surface water runoff volume, and increasing Tt. Developers and engineers should connect vegetated

Site constraints of LID techniques

	Bioretention	Dry Well	Filter/Buffer Strip	Swales: Grass, Infiltration, Wet	Rain Barrels	Cistern	Infiltration Trench
Space Required	Minimum surface area range: 50 to 200 ft² Minimum width: 5 to 10 ft Minimum length: 10 to 20 ft Minimum depth: 2 to 4 ft	Minimum surface area range: 8 to 20 ft² Minimum width: 2 to 4 ft Minimum length: 4 to 8 ft Minimum depth: 4 to 8 ft	Minimum length of 15 to 20 ft	Bottom width: 2 ft minimum, 6 ft maximum	Not a factor	Not a factor	Minimum surface area range: 8 to 20 ft² Minimum width: 2 to 4 ft Minimum length: 4 to 8 ft
Soils	Permeable soils with infiltration rates > 0.27 inches/hour are recommended. Soil limitations can be overcome with use of underdrains	Permeable soils with infiltration rates > 0.27 inches/hour are recommended	Permeable soils perform better, but soil is not a limitation	Permeable soils provide better hydrologic performance, but soil is not a limitation. Selection of type of swale, grassed, infiltration or wet is influenced by soils	Not a factor	Not a factor	Permeable soils with infiltration rates > 0.52 inches/hour are recommended
Slopes	Usually not a limitation, but a design consideration	Usually not a limitation, but a design consideration. Must locate downgradient of building and foundations	Usually not a limitation, but a design consideration	Swale side slopes: 3:1 or flatter Longitudinal slope: 1.0% minimum; maximum based on permissible velocities	Usually not a limitation, but a design consideration for location of barrel outfall	Not a factor	Usually not a limitation, but a design consideration. Must locate downgradient of buildings and foundations
Water Table/ Bedrock	2 to 4 ft clearance above water table/ bedrock recommended	2 to 4 ft clearance above water table/ bedrock recommended	Generally not a constraint	Generally not a constraint	Generally not a constraint		2 to 4 ft clearance
Proximity to build foundations	Minimum distance of 10 ft downgradient from buildings and foundations recommended	Minimum distance of 10 ft downgradient from buildings and foundations recommended	Minimum distance of 10 ft downgradient from buildings and foundations recommended	Minimum distance of 10 ft downgradient from buildings and foundations recommended	Not a factor		Minimum distance of 10 ft downgradient from buildings and foundations recommended
Maximum Depth	2 to 4 ft depth depending on soil type	6 to 10 ft depth depending on soil type	Not applicable	Not applicable	Not applicable		6 to 10 ft depth depending on soil type
Maintenance	Low requirement, property owner can include in normal site landscape maintenance	Low requirement	Low requirement, routine landscape maintenance	Low requirement, routine landscape maintenance	Low requirement		Moderate to high

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buffer or greenway areas with existing vegetation or forested areas. This technique has the added benefit of providing habitat corridors while enhancing community aesthetics.

Compare Pre- and Post-development Hydrology

Comparing the pre- and post-development hydrology of the site will quantify both the level of control that has been provided by the site planning process and the additional level of control required through the use of integrated management practices (IMPs).

Complete LID Site Plan

Completion of the LID site plan usually involves a number of iterative design steps. The hydrologic evaluation may identify additional stormwater control requirements for LID techniques distributed throughout the site. A trial-and-error iterative process is then used until all the stormwater management requirements are met. In the event the site requirements cannot be met with LID techniques alone, additional stormwater controls can be provided using conventional stormwater techniques. Mixed use of LID measures and conventional control is referred to as a hybrid system.

Hydrologic functions of LID techniques

	Preferred Management Practices (PMP)						
Hydrologic Functions	Bio Ret	Dry Well	Filter/Buffer	Swale Grass	Rain Barrel	Cistern	Infilt. Trench
Interception	H	N	H	M	N	N	N
Depression Storage	H	N	H	H	N	N	M
Infiltration	H	H	M	M	N	N	H
G.W. Recharge	H	H	M	M	N	N	H
Runoff Volume	H	H	M	M	L	M	H
Peak Discharge	M	L	L	M	M	M	M
Runoff Frequency	H	M	M	M	M	M	M
Water Quality	H	H	H	H	L	L	H
Base Flow	M	H	H	M	M	N	L
Stream Quality	H	H	H	M	N	L	H

H = High M = Moderate L = Low N = None

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Once the predevelopment hydrology objectives have been met, the designer can complete the site plan by incorporating the typical details, plan views, cross sections, profiles, and notes as required.

B. Procedures for Selection and Design of LID Techniques

The following steps guide the designer through the selection and design process. Again, because of the "multifunctional" nature of an LID project, it is essential that licensed professionals from both the landscape architecture and engineering fields collaborate early on in the planning and design process.

Step 1: Define Hydrologic Controls Required

Hydrologic functions such as infiltration, frequency and volume of discharges, and groundwater recharge become essential considerations when identifying and selecting LID techniques. The hydrologic functions can be quantified with respect to the various design parameters, which include runoff volume, peak discharge, frequency and duration of discharge, groundwater recharge, and water quality parameters. When these design parameters are quantified for predevelopment conditions, they define or quantify the hydrologic controls required for a specific site.

Step 2: Evaluate Site Opportunities and Constraints

The LID concept encourages innovation and creativity in the management of site impacts. The site should be evaluated for physical conditions such as available space, infiltration characteristics, possible soil contamination, and slopes.

Step 3: Screen for Candidate Practices

Management practices that are feasible and appropriate for the site should be chosen. Screening should consider both the site constraints and the hydrologic and water quality functions.

It is important to recognize that LID stormwater management is not simply a matter of selecting from a menu of available preferred practices. Rather, it is an integrated planning and design process. The preferred practices by themselves might not be sufficient to restore the hydrologic functions of a site without the accompanying site planning procedures described above.

Step 4: Evaluate Candidate LIDs in Various Configurations

After the candidate LID practices are identified, they are deployed as appropriate throughout the site and the hydrologic methods are applied to determine whether the mix of LID practices meets the hydrologic control objectives identified in Step 1. Typically, on the first design attempt the hydrologic control objectives are not met precisely but instead are overestimated or underestimated. An iterative process might be necessary, adjusting the number and size of LIDs until the hydrologic control objectives are optimized.

Step 5: Select Preferred Configuration and Design

The iterative design process typically identifies a number of potential configurations and mixes of LID practices such as bioretention structures, water storage and reuse systems, dry wells, infiltration trenches, vegetated swales, and other practices to provide the required level of hydrologic control at a reasonable cost. When configuring multiple LID practices, keep in mind that placing controls in series provides for maximum on-lot stormwater runoff control (i.e., the maximum mitigation of site development impacts on the natural hydrology). This type of design control is known as a hybrid and is effective in reducing both volume and peak flow rate.

Step 6: Design Conventional Controls if Necessary

If for any reason the hydrologic control requirements for a given site cannot be achieved using LID practices it might be necessary to add conventional controls to meet stormwater management requirements, particularly peak discharge control. Site constraints such as low-permeability soils, contamination, high water table, shallow bedrock, or space limitations can preclude the use of some LID practices. In these situations it is recommended that LIDs be used to the extent possible and then supplemented with conventional controls to meet the remaining hydrologic design objectives. Keep in mind that LID practices should be kept "off-line," and be designed to handle smaller, frequent rainfall events, while bypassing larger volumes. If peak control for larger storm events is required, conventional controls may also have to be used.

Suitability Criteria/ Factors for LID IMPs

The site designer should consider or evaluate the following factors when selecting LID IMPs.

Space/Real Estate Requirements. The amount of space required for stormwater management controls is always a consideration in the selection of the appropriate control. LID IMPSs, because they are integrated into and distributed throughout the site's landscape, typically do not require that a separate area be set aside and dedicated to stormwater management

Soils. Soils and subsoil conditions are very important consideration in every facet of LID technology, including the site planning process, the hydrologic considerations, and the selection of appropriate IMPs. The use of micromanagement practices, as well as the use of underdrains to provide positive subdrainage for bioretention practices, helps to overcome many of the traditional soil limitations for the selection and use of IMPs.

Slopes. Slope can be a limiting factor when the use of the larger traditional stormwater controls is considered. With the application of the distribution micromanagment IMPs however, slope is seldom a limiting factor; it simply becomes a design element that is incorporated into the hydrologically functional landscape plan.

Water Table. The presence of a high water table calls for special precautions in every aspect of site planning and stormwater management. The general criterion is to provide at least 2 to 4 feet of separation between the bottom of the IMP and the top of the seasonally high water table elevation. Also, the potential for contamination should be considered especially when urban landscape hotspots are involved.

Proximity to Foundations. Care must be taken not to locate infiltration IMPs too close to foundations of buildings and other structures. Considerations include distance, depth, and slope.

Maximum Depth. By their nature, the micromanagement practices that make up the LID IMPs do not require much depth, and thus this factor is no usually a major concern. Bioretention cells, for example, usually allow only 6 inches of ponding depth, and 2 to 4 feet of depth for the planting soil zones.

Maintenance Burden. Maintenance costs for traditional stormwater controls are significant and have become a considerable burden for local governments and communities. Maintenance costs can equal or exceed the initial construction cost. In comparison, many of the IMPs require little more than normal landscaping maintenance treatment. Additionally, this cost is typically the responsibility of the individual property owner rather than the general public. Communities are advised to retain the authority to maintain their sites if they fail to function as designed.

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C. LID Techniques

LID techniques are designed for on-lot use. This approach reduces or eliminates the need for large centralized parcels of land to control end-of-pipe runoff. LID techniques and site design strategies should be developed to provide quantity and quality control, including groundwater recharge through infiltration of runoff into the soil, retention or detention of runoff for permanent storage or for later release, and pollutant settling and entrapment by conveying runoff slowly through vegetated swales and buffer strips. In addition, LID can provide an added aesthetic value to the property since many LID practices are vegetated and may double as landscape amenities.

Examples of specific LID techniques are described below. They include:

- Bioretention filter
- Green rooftop systems
- Water storage and reuse systems
- Stormwater planters
- Tree box filters
- Permeable paving
- Open channels

Bioretention filter

Introduction

The bioretention filter (also referred to as a "rain garden" or a "biofilter") is a stormwater management practice to manage and treat stormwater runoff using a conditioned soil bed and planting materials to filter runoff stored within a shallow depression. The method combines physical filtering and adsorption with bio-geochemical processes to remove pollutants. The system consists of an inflow component, a pretreatment element, an overflow structure, a shallow ponding area (less than nine inches deep), a surface organic layer of mulch, a planting soil bed, plant materials, and may also include an underdrain system. Biortention facilities can be designed as "exfilter" systems, where the runoff that enters the system is allowed to percolate through the bioretention soil media and into the underlying soils, allowing for groundwater recharge. In situations where this is not advisable, such as on sites where the underlying soils may be contaminated, bioretention facilities can be lined to prevent infiltration of runoff to groundwater. In these systems, the runoff passes through the bioretention soil media and is conveyed via an underdrain system to the existing stormwater drainage system or other downstream facility.

Facility Application

The bioretention facility is one of the more versatile structural stormwater management measures. The practice can be applied to manage almost every land-use type from very dense urban areas to more rural residential applications. It is ideally adapted for ultraurban redevelopment projects. The bioretention system is intended to capture and manage relatively small volumes of water from relatively small drainage areas (generally less than five acres). Consequently, the system is rarely utilized on the watershed scale to manage large drainage areas. The system also is rarely used to manage large storms or to provide peak flow attenuation for the so-called "channel forming" storms (i.e, in the range of the one-year to 1.5-year frequency return interval) or flood control events (i.e., 10-year to 100-year frequency return intervals). As a general rule, it's recommended that bioretention areas be designed as off-line practices that capture only the water quality volume from a drainage area, and bypass larger storm runoff volumes through the use of a flow diversion structure or similar method.

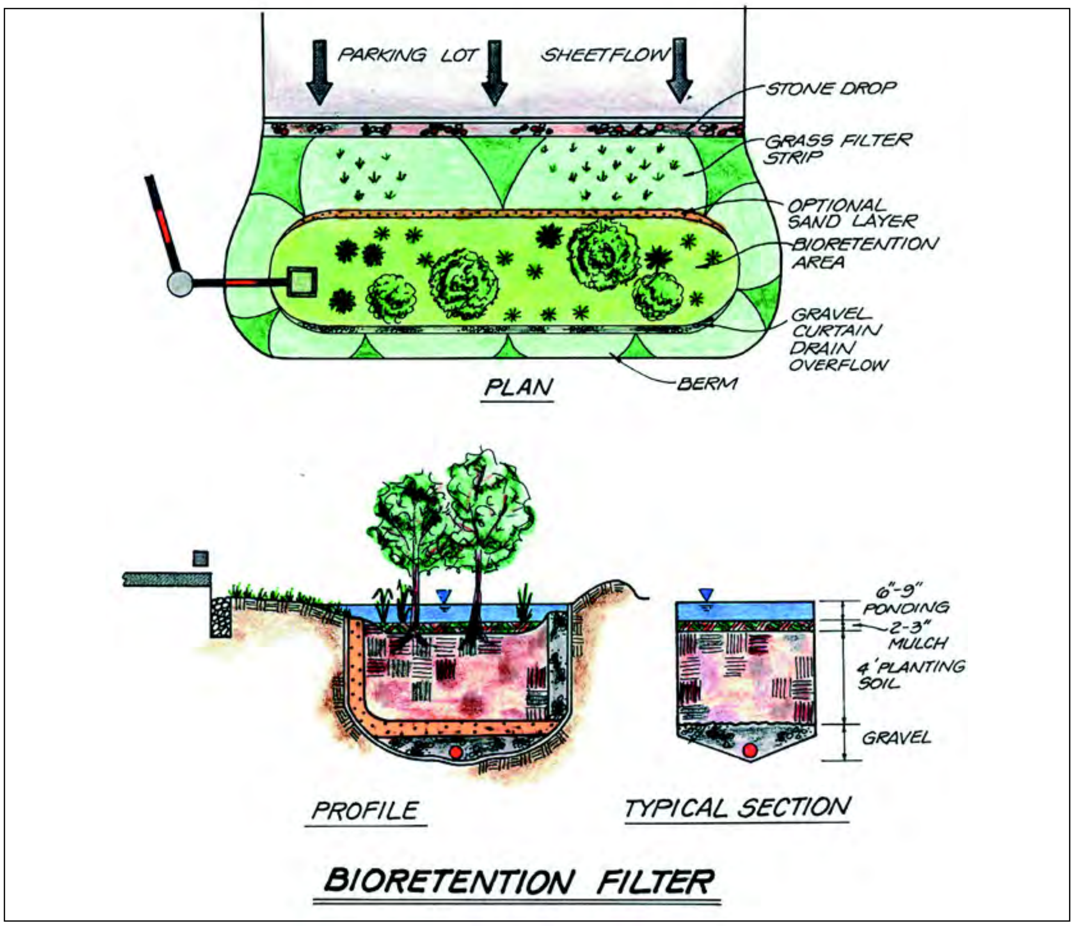
Benefits

Bioretention can have many benefits when applied to redevelopment and infill projects in urban centers. The most notable include:

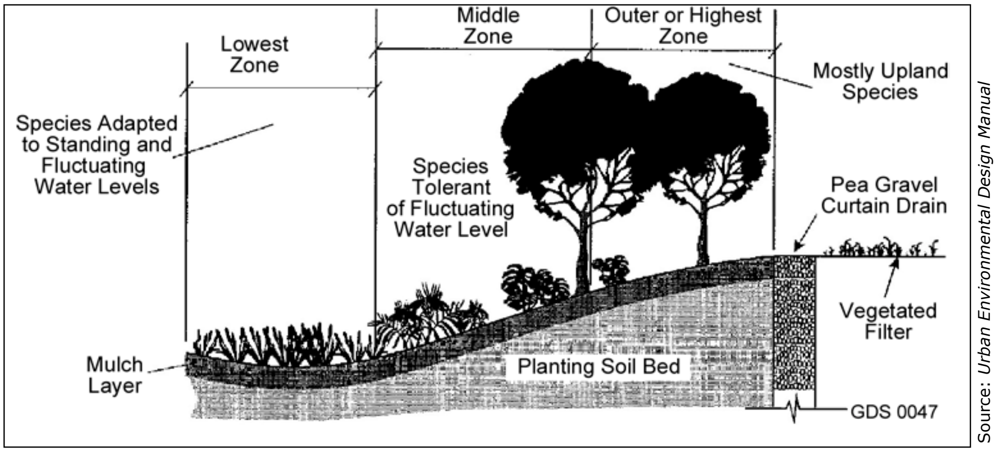
Horsley-Witten Group/Center for Watershed Protection

Bioretention filter

- Effective pollutant treatment for solids, metals, nutrients, and hydrocarbons
- Groundwater recharge augmentation (if designed as an exfilter, where soils, land uses, and groundwater elevations permit)
- Micro-scale habitat and reduction of urban "heat island" effects
- Aesthetic improvement to otherwise hard urban surfaces
- Ease of maintenance, coupling routine landscaping maintenance with effective stormwater management control



Claytor & Schueler, 1996



This profile of bioretention illustrates planting zones.

- Safety. The bioretention system is a very shallow depression that poses little risk to vehicles, children or the general public

Limitations

Bioretention facilities have some limitations that restrict their application. The most notable of these include:

- Steep slopes. Bioretention requires relatively flat slopes to be able to accommodate runoff filtering through the system.
- Direct entry of runoff at the surface of the facility. The bioretention system is designed to receive runoff from sheet flow from an impervious area or by entry by a roof drain downspout. Because the system works by filtration through a conditioned planting media, runoff must enter at the surface. If drainage is piped to the treatment area, runoff may enter the facility several feet below grade, thus requiring significant excavation.
- Minimum head requirements. Because the system is designed to filter runoff through the soil media, a minimum head is required. The bioretention soil must have an infiltration rate of 0.5 to 2.0 ft/day. Underlying soils should belong to hydrologic soil group (HSG) A. Some HSG B soils are appropriate.
- Bioretention facilities alone rarely meet all stormwater management objectives. If channel protection and/or flood controls are necessary for a given project, another practice is generally required.
- Bioretention requires a modest land area to effectively capture and treat runoff from storms up to approximately the 1-inch precipitation event (i.e., approximately 5 percent of the impervious area draining to the facility).
- Contamination of underlying soils. In areas where there are contaminated soils, such as brownfield sites, bioretention facilities should not be designed as exfilter system, but should be lined to prevent potential contamination of groundwater.

Sizing and Design Guidance

Bioretention facility surface areas are typically sized at a ratio of 5 percent of the impervious area draining to the facility to capture, manage, and treat runoff from the one-inch precipitation event (Claytor & Schueler, 1996). The basis for this guideline relies on the principles of Darcy's Law, where liquid is passed through porous media with a given head, a given hydraulic conductivity, over a given timeframe. The basic equation for sizing the required bioretention facility surface area is as follows:

$$Af = Vol*(df) / [k*(hf + df)(tf)]$$

where:

Af = the required surface area of the bioretention facility (ft^2)
Vol = the treatment volume (ft^3)
df = depth of the bioretention system (ft, usually set at 4 ft)
k = the hydraulic conductivity (in ft/day, usually set at 0.5 ft/day, but can be varied depending on the properties of the soil media, up to a maximum of 2 ft/day)
hf = average height of water above the bioretention bed (usually set at 3 inches

tf = the design time to filter the treatment volume through the filter media (usually set at 72 hours)

The 5 percent guideline can be modified by changing one or more of the above design variables. For instance, if a designer has a high water table, the depth might be reduced from the typical four feet to as low as 18 inches, or the media composition might be altered to allow for a higher hydraulic conductivity. In addition, there are several physical geometry recommendations that should be considered in the layout and design of bioretention facilities. The following design guidance is suggested:

- Minimum width: 10 feet
- Minimum length: 15 feet
- Length to width ratio: 2:1
- Maximum ponding depth: nine inches
- Planting soil depth: four feet, consisting of 50 percent sand, 20 percent leaf mulch, and 30 percent topsoil consisting of less than 10 percent clay content, and an organic or mulch layer (three inch maximum) or a herbaceous plant layer (70 percent to 80 percent coverage)
- Underdrain system: six-inch pipe in eight-inch gravel bed
- The minimum width allows for random spacing of trees and shrubs and also allows for the planting densities specified above, which help create a micro-environment where stresses from urban stormwater pollutants, drought, and exposure are lessened. For widths greater than 10 feet, a minimum length to width ratio along the stormwater flowpath of 2:1 is recommended. This longer flowpath allows for the settlement of particulates and maximizes the edge to interior ratio. The recommended maximum ponding depth of nine inches provides surface storage of stormwater runoff, but is not too deep to affect plant health, safety, or create an environment of stagnant conditions. The ponded water will also dissipate in less than 72 hours (and in most cases within a few hours), which maintains the flexibility in plant species selection. The bioretention system relies on a successful plant community to create the microenvironmental conditions necessary to replicate the functions of a forested ecosystem. To do that, plant species need to be selected that are adaptable to the wet/dry condi-

Native Plant Guide for Stormwater Bioretention Areas

Trees	Shrubs	Herbaceous Species and Grass-like Plants
Acer rubrum Red Maple	*Hamemelis virginiana* Witch Hazel	*Iris versicolor* Blue Flag
Juniperus virginiana Eastern Red Cedar	*Ilex verticillata* Winterberry	*Lobelia cardinalis* Cardinal Flower
Platanus occidentalis Sycamore	*Viburum dentatum* Arrowwood	*Rudbecka laciniata* Cutleaf Coneflower
Salix nigra Black Willow	*Alnus serrulata* Brook-side Alder	*Scirpus cyperinus* Woolgrass
Pinus rigida Pitch Pine	*Cornus stolonifera* Red Osier Dogwoood	*Scirpus pungens* Three Square Bulrush

Center for Watershed Protection, 2002

tions that will be present. A mix of upland and wetland trees, shrubs, and herbaceous plant materials are recommended that are arranged in a random and natural configuration starting from the more upland species at the outer most zone of the system to more wetland species at the inner most zone.

Cost

Bioretention facilities are cost-effective measures designed to help meet many of the management objectives of watershed protection. Because these facilities are typically sized as a percentage of the impervious area, the cost is relatively constant with drainage area. Unlike retention ponds and constructed stormwater wetlands, whose cost decreases with increasing drainage area, bioretention does not benefit from economies of scale. Typical capital construction costs are in the range of approximately $5 to $6 per cubic foot of storage. Another method of estimating cost is based on the impervious cover treated. Bioretention facilities range from approximately $18,000 to $20,000 per impervious acre (CWP, 1998). Annual maintenance cost is approximately 5 percent to 7 percent of capital construction costs or in the range of $900 to $1,000 per impervious acre treated.

Maintenance

Inspections are an integral part of system maintenance. During the first six months after construction, bioretention facilities should be inspected at least twice following precipitation events of at least 0.5 inch to ensure that the system is functioning properly. Thereafter, inspections should be conducted on an annual basis and after storm events of greater than or equal to the one-year precipitation event (approximately 2.6 inches in Rhode Island). Minor soil erosion gullies should be repaired when they occur. Pruning or replacement of woody vegetation should occur when dead or dying vegetation is observed. Division of herbaceous plants should occur when over-crowding is observed, or approximately once every three years. The mulch layer should also be replenished (to the original design depth) every other year as directed by inspection reports. The previous mulch layer would be removed, and properly disposed of, or roto-tilled into the soil surface. If at least 50 percent vegetation coverage is not established after two years, a reinforcement planting should be performed. If the surface of the bioretention system becomes clogged to the point that standing water is observed on the surface 48 hours after precipitation events, the surface should be roto-tilled or cultivated to breakup any hard-packed sediment and then revegetated.

Green rooftop systems

Introduction

A green roof is created by adding a layer of growing medium and plants on top of a traditional roof system. Green roofs are becoming more commonly used for stormwater management, and are suitable for urban retrofits as well as for new buildings. A green roof is different from a roof garden. A roof garden consists of freestanding containers and planters on a terrace or deck. Green roofs consist of the following components, starting from the top down:

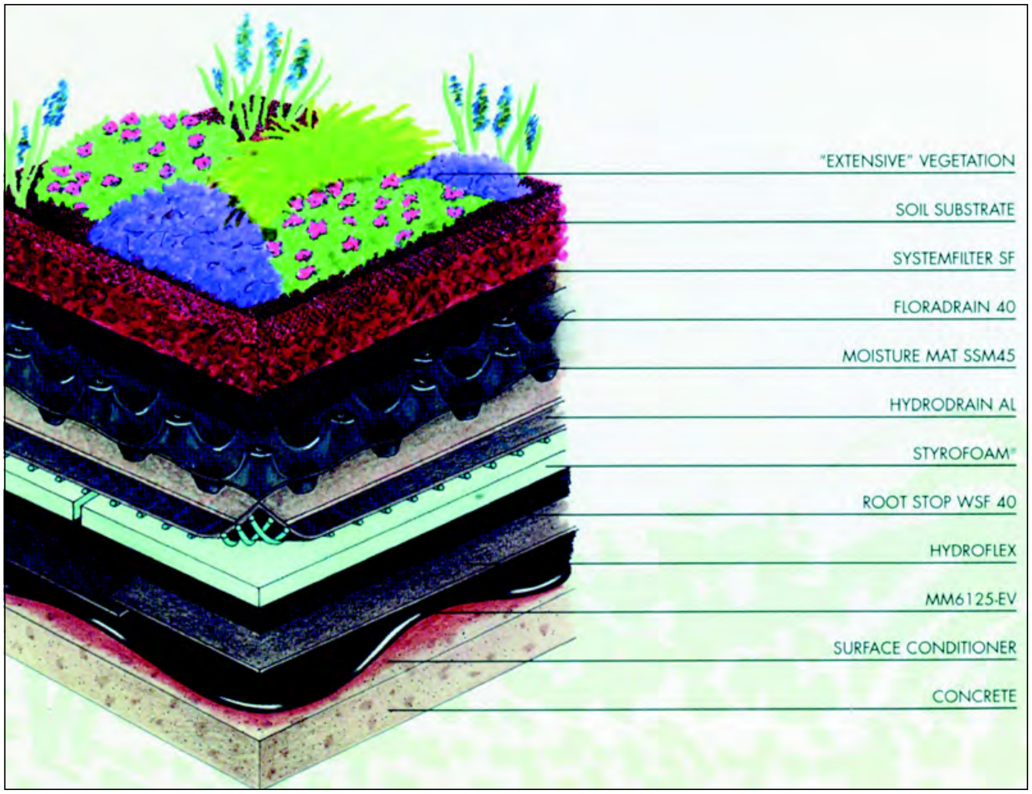
- Plants, often specially selected for particular application
- Engineered growing medium
- Landscape or filter cloth to contain the roots and the growing medium, while allowing for water to filtrate below the surface into the medium
- Drainage layer
- Waterproofing/roof membrane, with an integral root repellent
- Roof structure, with traditional insulation. Excess precipitation (beyond what is absorbed by the medium) filters through the growing medium and is collected in the drainage layer.

The drainage layer may contain a built-in water reservoir. The remaining stormwater is then drained into a conventional downspout. During large storm events there is an overflow drain to minimize ponding on the rooftop.

Facility Application

There are two different types of green roofs: extensive and intensive. Extensive green roofs are often not accessible and are generally characterized by low weight, low capital cost, low plant diversity, and minimal maintenance requirements. Intensive green roofs often have pedestrian access and are characterized by deeper soil and greater weight, higher capital cost, increased plant diversity, and more maintenance requirements.

Extensive roofs typically have a mineral base mixture of sand, gravel, crushed brick, leca, peat, organic matter and some soil as the growing medium. These are generally lighter than saturated soil. The growing medium depth ranges from two to six inches with a weight increase from a range of 16 to 36 lbs/sf when fully saturated. Due to the shallowness of the growing medium and the extreme desertlike condition on many roofs, the selected plants will need to be low and hardy. The figure above illustrates a cross section of a proprietary extensive roof. Intensive rooftops often have a soil-based growing medium, ranging from eight to 24 inches. This increases the loading weight from the saturated soil from a range of 60 to 200 pounds per square foot (lbs/sf) (Peck and Kuhn). With an intensive roof, plant selection is more diverse and can include trees and shrubs due to the deeper growing medium. This allows for the development of a more complex ecosystem but with this diversity a higher level of maintenance is required.



American Hydrotech, Inc.

Schematic cross section of an extensive green roof

Benefits

Green roofs provide many benefits both privately and publicly. Direct benefits to private owners may include:

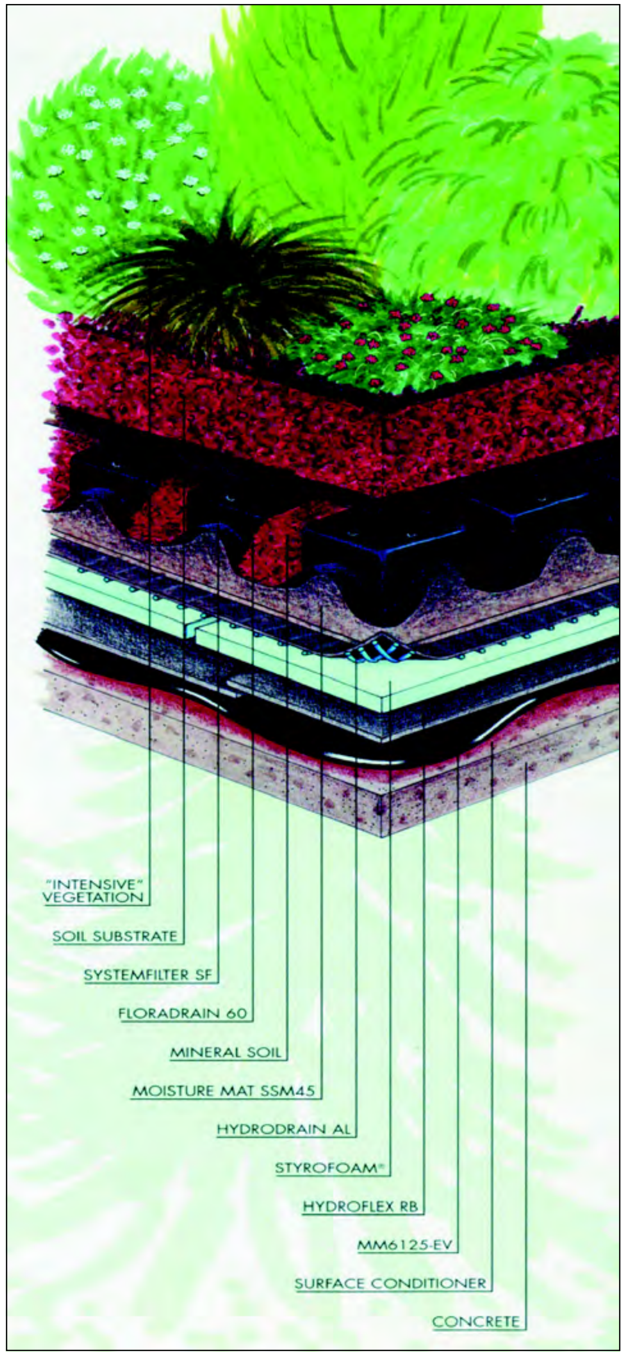
- Energy Savings - Green roofs provide insulation from the heat and the cold, reducing the amount of energy required to heat or cool the building.
- Extend Life of Roof - Green roofs protect roofing membranes from extreme temperature fluctuations and from the negative impacts of ultraviolet radiation.
- Sound Insulation - Green roofs can be designed to insulate against outside noises.
- Fire Resistance - When fully saturated, green roofs can help stop the spread of fire to and from building rooftops. The two major public benefits from green roofs are a reduction in urban heat island effects and stormwater retention capability. Urban heat island is the overheating of urban and suburban areas, due to increased paved, built-over, and hard surface areas. The urban heat island effect increases electricity and air conditioning costs. Green roof tops intercept and absorb solar radiation.

Green roofs can be designed as effective stormwater management controls. The growing medium on both intensive and extensive green roofs can act as a stormwater pretreatment system. The method combines physical filtering and adsorption with biogeochemical processes to remove pollutants. Green roofs can be designed for stormwater retention capability, therefore reducing the overall stormwater runoff volume from rooftops. Stormwater retention rates are determined by saturated filtration capacity, thickness of the growing medium, field capacity, porosity, under-drainage layer, water retention, flow, and relief drain spacing. A heavily vegetated green roof with eight to 16 inches of growing medium can hold four to six inches of water (Peck and Kuhn).

Limitations

Green roofs are best suited for new buildings, where structural considerations can be incorporated early in the design phase. Retrofits to existing buildings are possible. The limiting factor when dealing with retrofitting is soil weight. Soil weighs approximately 100 lbs/sf, while existing roofs are typically designed for a live load of 40 lbs/sf, which includes snow load. Since an extensive system can weigh 16 to 36 lbs/sf and an intensive system can weigh 60 to 200 lbs/sf, fully saturated, an existing roof may need considerable reinforcement before it can support the weight of a green roof. A landscape architect or horticulturist can advise on certain plants that do not require a deep soil layer, thereby reducing the weight on the roof. Other limiting factors are the initial costs and maintenance costs of a green rooftop. Installation costs for green rooftops are considerably higher (25 percent to 300 percent) than for conventional roofs. Maintenance costs can range from $1.25 to $2.00 per square foot annually, depending on the system.

Green roofs may not be suitable to heavy industrial areas. These areas are prone to high levels of dust and/or chemicals in the air that may cause damage to plants. Green roofs are also limited in their stormwater quantity control capability. Green roofs do not provide flood control or channel protection for any storm greater than one inch and do not provide recharge to groundwater unless a separate infiltration system is designed on site.



American Hydrotech, Inc.

Schematic cross section of an intensive green roof

Sizing and Design Considerations

To design and implement green rooftops, the following issues need to be considered:

- Condition of the existing roof is important. The most cost effective time to construct a green roof is when a roof needs to be replaced or newly constructed. A waterproof membrane and root resistance layer will need to be placed on all rooftops.
- Structural capacity of the roof will dictate the type of green roof that can be built.
- Access to the roof is an important consideration. Depending on the type of green roof, safe public access may be required. In addition, access to transport materials for construction and maintenance will be required.
- The weight of the green roof must not exceed the structural capacity of the roof.
- In addition to the cost for construction, materials, and permits, the costs for hiring specialists, such as structural engineers or horticulturists, as well as for making any needed structural and safety improvements, should be taken into consideration.

Components of a green roof can be bought and installed separately, or proprietary assembly can be purchased. In either case, the basic components starting from the roof up are the following:

- Insulation layer, a waterproof membrane to protect the building from leaks, and a root barrier to prevent roots from penetrating the waterproof membrane.
- Drainage layer, usually made of lightweight gravel, clay, or plastic. The drainage layer keeps the growing media aerated and can be designed to retain water for plant uptake at a later time.
- Geotextile or filter fabric that allows water to soak through but prevents erosion of fine soil particles.
- Growing media that helps with drainage while providing nutrients for plant uptake.
- Plants, typically for extensive green roofs, a mixture of grasses, mosses, sedums, sempervivums, festucas, irises, and wildflowers that are native to drylands, tundras, alvars, and alpine slopes. For intensive green roofs, with few exceptions, the choices are limitless. See Table 2 for an example of plant species used in the Chicago city hall green rooftop.
- A wind blanket, used to keep the growing media in place until the roots of the plant take hold.

Cost

All green roofs share common components; however there are no standard costs for implementation. In the United States, the cost range for extensive roof systems ranges from $15 to $20 per square foot (Scholz-Barth, 2001).

Maintenance

Maintenance of a green roof system requires plant maintenance as well as maintenance to the waterproof membrane. Depending on whether the green roof is an extensive or intensive system, the plant maintenance will range from two to three yearly inspections to check for weeds or damage, to weekly visits for irrigation, pruning and replanting.

Regular maintenance inspections should be scheduled, as for a standard roof inspection. Any leaks in the roof should be checked out immediately. Green roofs protects the waterproof membrane from puncture damage and solar radiation, however, leaks can occur at joints, penetrations and flashings, due more to installation than material failure. Drains should also be inspected for possible breach in filter cloth and cleaned on a regular basis.

Water storage and reuse systems

Rain barrels and cisterns are automatic water collection systems that store runoff from stormwater to be used later for activities such as lawn and garden watering or temporary storage of runoff for infiltration of storm runoff through a passive system into an "engineered" soil. Reuse of stormwater runoff is beneficial to the environment because the stored water would otherwise enter the storm sewer, increasing the volume of discharge into receiving waters. In older cities, such as many in Rhode Island with combined sewer systems, the addition of stormwater also contributes to sanitary sewer overflows. Rain barrels are small barrels (50 to 250 gallons) placed on the end of a downspout that store runoff for future irrigation use. A cistern is similar to a rain barrel, but it has much greater storage capacity and can be designed to collect and store runoff for watering lawns and gardens and/or for infiltration into the ground. The basic components of any rain barrel are relatively simple. Rain barrels consist of an actual barrel, often made of plastic, a sealed yet removable child- and animal-resistant top, connections to the downspout, a runoff pipe and a spigot. A number of accessories can be added, such as additional barrels for expanded storage volume, a water diversion soaker hose, an automatic overflow, or an automatic irrigation overflow and/or an infiltration system. Cisterns can be constructed of any impervious, water-retaining material. They can be located either above or below ground and can be constructed on-site or pre-manufactured and then placed on-site. The basic components of a cistern include a secure cover, a leaf/mosquito screen, a coarse inlet filter with clean-out valve, an overflow pipe, a manhole, a sump, a drain for cleaning, and an extraction system (tap or pump). Additional features might include a water-level indicator, a sediment trap, or an additional tank for more storage volume.

Facility Application

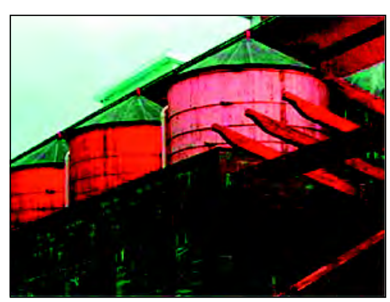
Rain barrels and cisterns can be used in most areas (residential, commercial, and industrial) due to their minimal site constraints relative to other stormwater management practices. The sizes of barrels or cisterns are directly proportional to their contributing drainage areas.

Benefits

Rain barrels and cisterns are low-cost water conservation devices that can reduce runoff volume from smaller storm events, and delay and reduce peak runoff flow rates. By storing and diverting runoff from impervious areas such as roofs, these devices reduce the undesirable impacts of runoff that would otherwise flow swiftly into receiving waters and contribute to flooding and erosion. Stored

www.drop.com

Rain barrel



Chesapeake Bay Foundation

Cisterns

water from rain barrels and cisterns can help reduce water consumption, thereby reducing water costs. Water reuse ultimately reduces the demand on municipal water systems and supplies, as well as reducing the amount of stormwater entering combined sewer systems (CSOs).

Limitations

Rain barrels and cisterns are physically limited by their size. Once the rain barrels or cisterns are full, additional stormwater will overflow onto surrounding areas and/or into the downstream drainage system. Rain barrels and cisterns are storage practices. They allow for reuse of stored rainwater, but do not allow for infiltration of stormwater runoff and groundwater recharge.

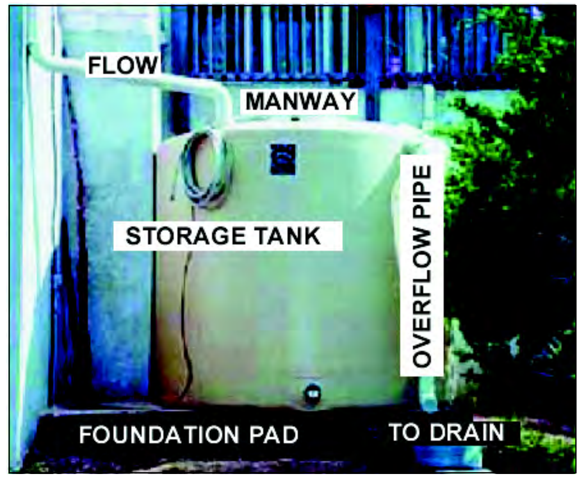
Sizing and Design Considerations

The sizing for rain barrels and cisterns is a function of the impervious area that drains to the device. The basic equation for sizing a rain barrel or a cistern is as follows:

Vol = A * R * 0.90 * 7.5 gals/ft3
where:

Vol = Volume of rain barrel or cistern (gallons)
A = Impervious surface area draining into barrel or cistern (ft2)
R = Rainfall (feet)
0.90 = Loss to system (unitless)
7.5 = Conversion factor (gallons per cubic foot

A cistern can be located beneath a single downspout or one large cistern can be located to collect stormwater from several sources. Due to the size of rooftops and the amount of contributing impervious area, increased



Source: *Portland Stormwater Management Manual*

Cistern

runoff volume and peak discharge rates for commercial and industrial sites may require large capacity cisterns. Cisterns can be located above or below ground, and can be constructed on site or pre-manufactured and then placed on site. Cistern sizes can vary from hundreds of gallons for residential uses to tens of thousands of gallons for commercial and/or industrial uses.

Cost

Rain barrels are relatively low cost, premanufactured systems averaging about $120, minus downspout and other accessories (UGRC). Basic supplies to construct a barrel can be as low as $20. The cost for a cistern can vary greatly depending on its size, material, and location (above or below ground).

Maintenance

Maintenance requirements for rain barrels and cisterns are minimal and consist of biannual inspections of the unit.

The average cost for a typical manually constructed cistern for residential use made of reinforced concrete (3,000 gallons), minus labor, would be approximately $1,000

Cost Guide – Pre-manufactured Cisterns (LID)		
Material	**Cost, Small System**	**Cost, Large System**
Galvanized Steel	$225 for 200 gallons	$950 for 2,000 gallons
Polyethelene	$160 for 165 gallons	$1,100 for 1,800 gallons
Fiberglass	$660 for 350 gallons	$10,000 for 10,000 gallons
Fiberglass/Steel Composite	$300 for 300 gallons	$10,000 for 5,000 gallons

Source: *Urban Environmental Design Manual*

Rain barrel and cistern maintenance

Source: *Urban Environmental Design Manual*

Rain Barrels	Cisterns
Roof Catchment – Ensure that no particulate matter or other parts of the roof are entering the gutter and downspout to the rain barrel	**Roof Catchment** – Ensure that no particulate matter or other parts of the roof are entering the gutter and downspout to the rain barrel
Gutters – Ensure that no leaks or obstructions are occurring	**Gutters** – Ensure that no leaks or obstructions are occurring
Downspouts – Ensure that no leaks or obstructions are occurring	**Downspouts** – Ensure that no leaks or obstructions are occurring
Entrance at Rain Barrel – Ensure that no leaks or obstructions are occurring	**Roof Washer and Cleanout Plug** – Inspection and replacement as needed
Rain Barrel – Check potential leaks, including barrel top and seal	**Cistern Screen** – Inspection and replacement as needed
Runoff/Overflow Pipe – Check that overflow is draining in non-erosive manner	**Cistern Cover** – Inspection and replacement as needed
Spigot – Ensure that it is functioning correctly	**Cistern** – Inspection and cleanout, should include inflow and outflow pipes
Accessories (such as rain diverter, soaker hose, or linking kit) – Inspection and replacement as needed	**Cistern Overflow Pipe** – Inspection and replacement as needed
	Accessories (such as sediment trap) – Inspection and replacement as needed

(Kessner, 2000).

Stormwater planters and tree box filters

Stormwater planters are small-scale stormwater treatment systems comprised of organic soil media and plants in a confined planter box. Stormwater planters are simply "bioretention in-a-box." Planters generally look like large vaulted plant boxes and can contain anything from basic wildflower communities to complex arrangements of trees and flowering shrubs. The method combines physical filtering and adsorption with biogeochemical processes to remove pollutants. There are three basic variations of the stormwater planters: the contained system, the infiltration system, and the flow-through system. Contained planters are typically large self-contained planters found on terraces, deck and sidewalks. Infiltration planter boxes are designed to allow runoff to filter through the planter soils and then infiltrate into the native soils. Flow-through planter boxes are designed with impervious bottoms or placed on impervious surfaces. This flow-through system consists of an inflow component (usually a downspout), a treatment element (soil medium), an overflow structure, plant materials, and an underdrain collection system to divert treated runoff back into the downstream drainage system.

Source: *City of Portland Stormwater Management Manual*

Infiltration planter

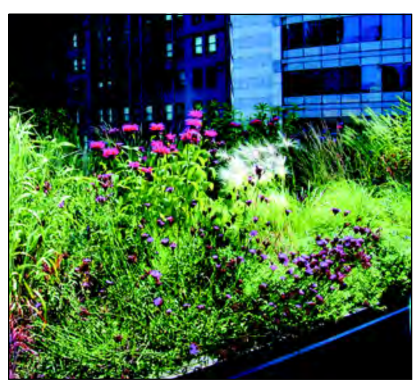
Tree planters or tree box filters are a specific type of stormwater planter. They are essentially the same type of self-contained device as a stormwater planter, but have the depth and size allowable for trees as opposed to smaller shrubs. Tree planters may also be located in areas similar to those used by stormwater planters, as long as the stormwater runoff is properly directed to the planter. The types of trees used must be able to survive in urban environments, in dry periods, and during periodic inundations of precipitation. A tree box filter, with its enclosed non-permeable concrete container, is ideal for situations where infiltration is undesirable or not possible. These situations include clay soils, karst topography, high groundwater conditions, and close proximity to buildings, steep slopes, contaminated soils, brownfields sites, highly contaminated runoff, maintenance facilities, and gas stations. For hot spots where chemical spills are likely, the underdrain system can be fitted with an emergency shut-off valve to quickly close the discharge drain pipe, isolating the spill in the concrete container for easy clean-up, removal, and replacement of the filter system.

Tree box filters are unique, since a major decision is to consider how to integrate their plants into landscape designs. They can be blended into the landscape scheme or they can be the centerpiece of the landscape design.

Tree planting pits in sidewalks are another option to integrate trees into an urban setting. Trees are planted individually, or soil is placed in a continuous channel under the pavement to connect several pits and allow for greater volumes of soil for root growth and water storage. If the pits are planted above the surface, supplemental fertilization and irrigation may be required. Pits located at surface level may require ground cover around the base of the tree to minimize foot traffic over the tree roots. A cover or grate around the base of the tree that allows for tree growth will be required if the pit soil level is two to eight inches below the pavement surface.

Facility Application

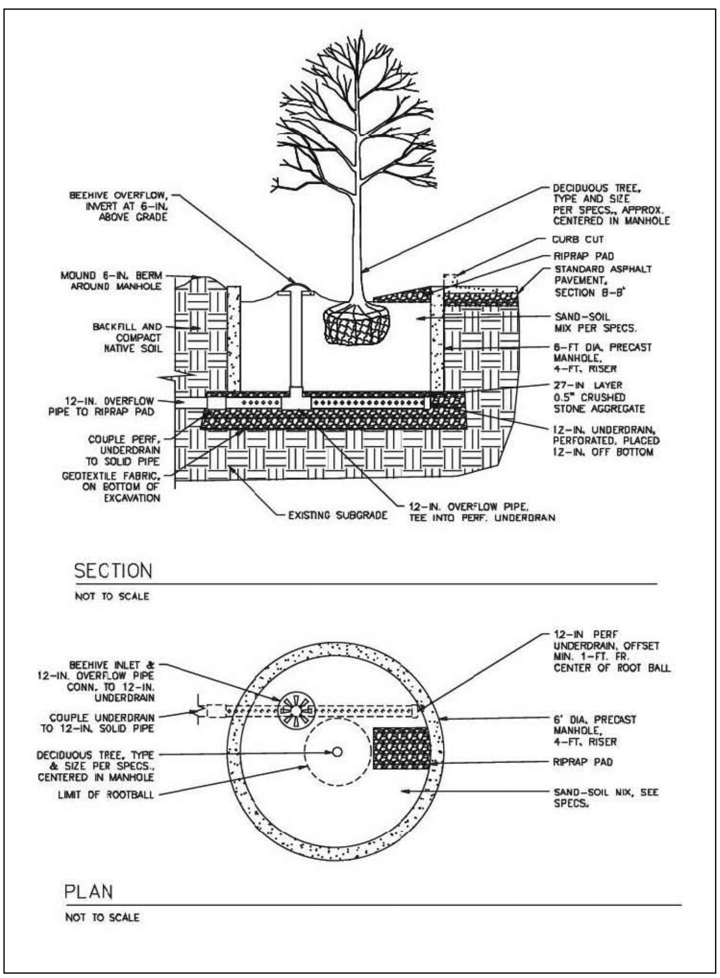
Stormwater planters are ideally adapted for



Chicago City Hall/
American Society of Landscape Architects

Contained planter

ultra-urban redevelopment projects. Roof runoff can be directed from the downspout directly into the planters. Runoff from rooftop areas contains nutrients carried in rainwater, sediments and dust from rooftops, and bacteria from bird droppings. These pollutants can all be attenuated to a significant degree during small rain events. Planters can be effective in reducing the velocity and volume of stormwater discharge from rooftop areas. Another benefit of stormwater planters is the relatively low cost. These are small self-contained units that can be easily constructed without heavy-duty excavation that accompanies other practices. Stormwater planters also add aesthetic elements by improving the surrounding streetscape. These systems are rarely used to manage large storms. Any storm greater than the infiltration capacity of the soil will flood the planters and will overflow onto the street or into an overflow pipe. Planters should be designed to attenuate water no more than three to four hours after an average storm. The topsoil (soil medium) should have an infiltration rate of two inches per hour. The drainage layer (sand or gravel) should have a minimum infiltration rate of five inches per hour. Infiltration planters are also known as "exfilters." An exfilter is a system designed to filter runoff through the soil media before infiltration into the underlying soil. If poor soils or high groundwater would prevent conventional infiltration, then a contained or a flow-through stormwater planter is recommended.



UNH Stormwater Center

Benefits

Stormwater planters can have many benefits when applied to redevelopment and infill projects in urban centers. The most notable benefits include:

- Effective pollutant treatment for solids, metals, nutrients, and hydrocarbons
- Groundwater recharge augmentation (if designed as an exfilter, where soils, land uses, and groundwater elevations permit)
- Micro-scale habitat
- Aesthetic improvement to otherwise hard urban surfaces
- Ease of maintenance, coupling routine landscaping maintenance with effective stormwater management control
- Low cost relative to other practices

Limitations

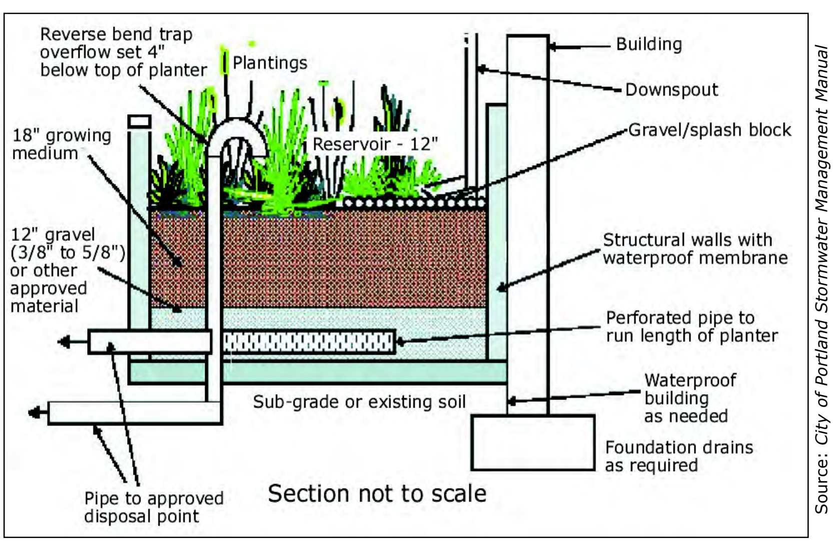
Stormwater planters are limited in the amount of runoff they can receive. Infiltration and flow-through planter boxes should receive drainage from no more than 15,000 square feet of impervious area. Any storm event greater than two inches per hour (topsoil infiltration rate) will start to pond in the planters and eventually overflow onto the street or into the underdrain system and therefore will not be treated for water quality.

Frequently soils under pavement are compacted to meet load-bearing requirements and engineering standards. This reduces the chances for a healthy root system to grow, which results in the premature death of the tree. Use of a new pavement substrate called "structural soil" can be compacted to meet engineering requirements as well as to allow trees to develop a productive root system.

Sizing and Design Considerations

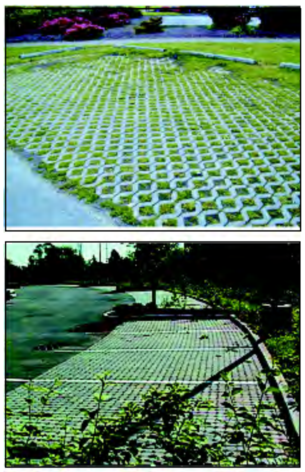
The basis for this guideline relies on the principles of Darcy's Law, where liquid is passed through porous media with a given head, a given hydraulic conductivity, over a given timeframe. The basic equation for sizing stormwater planters is as follows:

Af = Vol*(df) / [k*(hf +df)(tf)]
where:



Flow-through planter

Af = the required surface area (ft^2)
Vol = the treatment volume (ft^3)
D f = depth of the soil medium (ft)
k = the hydraulic conductivity (in ft/day, usually set at 4 ft/day, but can be varied depending on the properties of the soil media)
hf = average height of water above the planter bed (maximum 12 inches)
tf = the design time to filter the treatment volume through the filter media (usually set at three to four hours)


Source: City of Portland Stormwater Management Manual

Different types of permeable pavement

In addition, there are several physical geometry recommendations that should be considered in the layout and design of stormwater planters. The following design guidance is suggested:

- Minimum width: 1.5 feet (flow through planters) 2.5 feet (infiltration planters)
- Minimum length: none
- Maximum ponding depth: 12 inches
- Minimum building offset: 10 feet (applies to infiltration planters only)

Stormwater planters rely on successful plant communities to create the micro-environmental conditions necessary to replicate the functions of a forested ecosystem. To do that, plant species need to be selected that are adaptable to the wet/dry conditions that will be present.

CRMC encourages the development of unique and innovative designs for stormwater planters in urban areas, including designs that route stormwater runoff from outside into the building, and use it to water indoor planters that help to visually enhance common areas such as building lobbies.

Cost

Stormwater planters are cost-effective measures designed to help meet many of the management objectives of watershed protection. Since stormwater planters are intended only for roof runoff, they are much more cost effective than other roof treatment systems, such as green roofs. Although stormwater planters often function with the same processes as bioretention systems and rain gardens, they may be more cost effective in ultra-urban areas due to the ability to retrofit the planters directly adjacent to buildings or alongside sidewalks where space is limited. Planters may also have lower costs per area for smaller treatment areas as opposed to site-specific designs of other practices.

An example cost estimate for a proprietary flow-through system is approximately $24,000 per acre of impervious surface. Annual maintenance cost is approximately 2 percent to 8 percent of the system cost, or in the range of $200 to $2,000 per impervious acre treated.

Maintenance

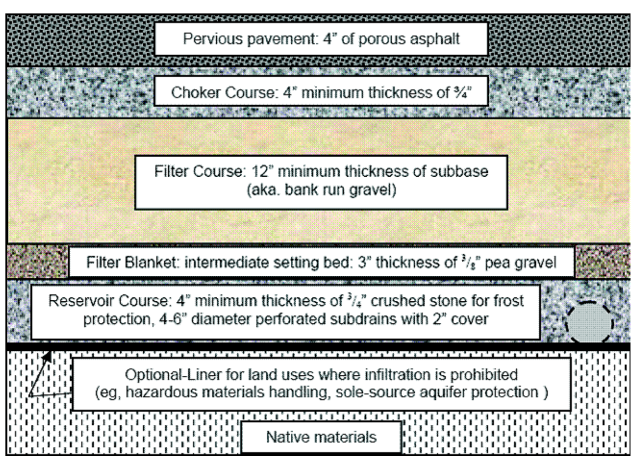
Inspections are an integral part of system maintenance. During the six months immediately after construction, and following precipitation events of at least 0.5 inches, planters should be inspected at least twice to ensure that the system is functioning properly. Thereafter, inspections should be conducted on an annual basis and after storm events of greater than or equal to the one-year precipitation event (approximately 2.6 inches in Rhode Island). Minor soil erosion gullies should be repaired when they occur. Pruning or replacement of woody vegetation should occur when dead or dying vegetation is observed. Herbaceous perennials should be divided when over-crowding is observed, or approximately once every three years.

Permeable paving and porous asphalt

Permeable paving is a broadly defined group of pervious types of pavements used for roads, parking, sidewalks, and plaza surfaces. Most of these consist of a permeable surface layer with enough structural integrity to support at least light vehicular use, and subgrade layer or layers of materials such as aggregate that provide a structural base and allow for storage and infiltration of stormwater. Permeable paving reduces impacts of impervious cover by allowing runoff to infiltrate, augmenting the recharge of groundwater, and enhancing pollutant uptake removal in the underlying soils. Permeable pavement can even result in reduced maintenance requirements by improving the drainage characteristics of an impervious area. There are many different types of permeable paving, including:

- Concrete grid pavers
- Lattice-style paving that includes grass in spaces in between lattice work
- Porous pavement that looks like regular pavement (asphalt or concrete) but is manufactured without fine (small particle-size) materials
- Cobblestone
- Brick
- Plastic modular blocks
- Crushed aggregate or gravel

Porous asphalt is similar to traditional asphalt, but is manufactured without fine materials to increase its porosity and allow water to pass through it. It is typically constructed over an aggregate base which allows runoff to infiltrate through it into the underlying soils. Its application in parking lots has been studied at the University of New Hampshire, where it has been shown to be a very effective stormwater management practice. For the results of these studies, as well as porous asphalt manufacturing and design specifications developed by UNH, see the UNH Stormwater Center's website at www.unh.edu/erg/cstev/ or on the CRMC website at www.crmc.ri.gov/samp/sampfiles/UNHSC_PA_Spec_July_07.pdf.



UNH Stormwater Center Design Specifications for Porous Asphalt Pavement and Infiltration Beds, 2007.

Typical cross-section of a pervious paving system

Facility Application

The ideal application for permeable paving is on low traffic roads, overflow parking areas, sidewalks, plazas, and courtyard areas. Permeable paving is intended to capture and manage small frequent rainfall events. These events can add up to as much as 30 percent to 50 percent of annual precipitation (Schueler, 1987).

Benefits

Permeable paving can have many benefits when applied to redevelopment and infill projects in urban centers. The most notable benefits include:

- Groundwater recharge augmentation
- Effective pollutant treatment for sediment, metals, nutrients, chemical oxygen demand and hydrocarbons (see pollutant removal performance table)
- Aesthetic improvement to otherwise hard urban surfaces (lattice pavers)
- Less ponding of water on surface, resulting in reduced need for salt and sand applications in the winter

Limitations

Proper site selection is an important criterion when selecting this practice.

Partial or total clogging of the paving or underlying materials (such as woven geotextile fabrics) with sediments or oil during construction or over the life of the pavement can cause system failure. The clogging problem can be overcome by proper design and maintenance. The following steps should be taken to prevent against system failure:

- Be sure that pavement does not receive runoff from areas that are likely to contribute large sediment loads and debris
- Do not install pavement adjacent to areas subject to significant wind erosion
- Protect pavement from sediment inputs during the construction phase
- Do not install pavement over highly compacted soils
- Do not install pavement in areas that receive high vehicular traffic volumes and regular use by heavy vehicles (leading to subsoil compaction and reducing infiltration capacity)
- Use pretreatment practices such as vegetated filter strips where possible
- Follow all design and manufacturing specifications for subgrade materials as well as surface materials

Requirements for maintaining infiltration capacity and effective pollutant removal include:

- Routine vacuum sweeping and high-pressure washing (with proper disposal of removed material)
- Drainage time of at least 24 hours
- Permeable soils
- Pretreatment of runoff from site
- Organic matter in subsoils
- Clean-washed aggregate

Sizing and Design Guidance

Potential permeable paving sites need to be evaluated for the following criteria:

- Underlying soil permeability should be between 0.5 and 3.0 inches per hour (up to 8.3 inches for sand).

Estimated Pollutant Removal Performance of Permeable Paving
(Porous Pavement) (EPA, 1999)

Long-Term Monitoring Conducted in Rockville, MD, and Prince William, VA	
Pollutant Parameter	**Percent Removal**
Total Phosphorous	65
Total Nitrogen	80-85
Total Suspended Solids	82-95

Cost Guides for Permeable Pavement System (LID)

Paver System	Cost per Square Foot (Installed)
Asphalt	$0.50 to $1
Porous Concrete	$2 to $6.50
Grass/Gravel Pavers	$1.50 to $5.75
Interlocking Concrete Paving Blocks	$5 to $10

Typical Maintenance Activities for Porous Pavement (WMI, 1997)

Activity	Schedule
Ensure that paving area is clean of debris	Monthly
Ensure that paving dewaters between storms	Monthly
Ensure that the area is clean of sediments	Monthly
Mow upland and adjacent areas and seed bare areas	As needed
Vacuum sweep frequently to keep surface free of sediments	As needed (typically 3 to 4 times per year)
Inspect the surface for deterioration or spalling	Annual

Source: *Urban Environmental Design Manual*

- The bottom of the stone reservoir should not exceed a slope of 5 percent. Ideally it should be completely flat so that the infiltrated runoff will be able to infiltrate through the entire surface.
- Permeable paving should be located at least two feet above the seasonally high groundwater table, and at least 100 feet away from drinking water wells.
- Permeable paving should be located in low traffic and overflow parking areas.
- The contributing drainage area should be less than 15 acres.
- Infiltration practices shall be designed to exfiltrate the water quality volume through the floor of each practice.

Calculate the surface are of the underlying infiltration area as:

Ap = Vw / (ndt + fT/12)
where:

Ap = surface area (f^2)
Vw = design volume (e.g., WQv) (ft^3)
n = porosity (assume 0.4)
dt = trench depth (maximum of seven feet, and separated by at least three feet from seasonally high groundwater) (ft)
fc = infiltration rate (in/hr)
T = time to fill trench or dry well (hours) (generally assumed to be less than two hours)

Cost

Costs for permeable paving can be significantly more than traditional pavement, depending upon the materials used. However, the overall project costs are reduced when taking into account savings from reduced traditional stormwater infrastructure costs. The estimated annual maintenance cost for a porous pavement parking lot is $200 per acre per year (EPA, 1999). This cost assumes four inspections each year with appropriate jet hosing and vacuum sweeping.

Maintenance

Depending on the type of permeable paving and the location of the site, the maintenance level ranges from high to low. Areas that receive high volume of sediment particles will clog more readily due to soil compaction. Concrete grid pavers and plastic modular blocks require less maintenance because they are not clogged by sediment as easily as porous asphalt pavement. However, regardless of the type of pavers used, the level of maintenance and ultimately the failure rate is dependent on the location of the site. Properly selected sites with permeable paving normally require regular vacuum sweeping or high pressure hosing two to three times per year to remove sediments.

Open channels

Open channels are concave, vegetated conveyance systems that slow down runoff flow and can improve water quality through infiltration and filtering. When designed properly, they can be used to retain and pre-treat stormwater runoff. There are four different categories of open channels used in stormwater management practices. These include grass channels, dry swales, and wet swales. Grass channels are modified drainage channels that provide water quality treatment for small, frequent storm events. Flow rate is the principle design criteria for grass channels. Dry swales have the same principle pre-treatment process as bioretention filters, which combine physical filtering and adsorption with bio-geochemical processes to remove pollutants. Dry swales are designed to rapidly move water through a highly permeable layer and then collect it by an underdrain pipe. Wet swales often incorporate check dams, and act as long, linear shallow wetland treatment systems. Wet swales occur when the water table is located very close to the surface. Wet swales are designed to treat or retain stormwater for a 24-hour period ("volume-based" systems). Proper vegetation selection is needed to ensure plant survival

Source: *Portland Stormwater Management Manual*

Open channel system

Claytor

Dry swales

and channel stability for both wet and dry swales.

Facility Application

Grass channels and dry/wet swales are rarely used to manage large storms or to provide peak flow attenuation for the so-called "channel forming" storms (i.e, in the range of the one-year to 1.5-year frequency return interval), or flood control events (i.e., 10-year to 100-year frequency return intervals). Grassed channels accent the natural landscape, break up impervious areas, and are appropriate alternatives to curb and gutter systems. They are best suited to treat runoff from rural or very low-density areas and major roadway and highway systems. They are often used in combination with other stormwater management practices to provide pre-treatment and attenuation, but can be used as stand-alone practices. The design objective for grass channels is to maintain a low flow rate in order to achieve a minimum residence time of 10 minutes. On-site soil characteristics determine whether a site is suitable for grass channels designed for infiltration. Grass channels have the same design considerations that are applied to infiltration basins and trenches: soil type, infiltration rate, and separation to groundwater and/or bedrock.

Dry swales are appropriate in areas where standing water is not desirable, such as residential, commercial, or industrial areas and highway medians. In dry swales, a prepared soil bed is designed to filter the runoff for water quality. Runoff is then collected in an underdrain system and is discharged to the downstream drainage system. The design objective for dry swales is to drain down between storm events within 24 hours. Wet swales are similar to stormwater wetlands in their use of wetland vegetation to treat stormwater runoff. The water quality treatment mechanism relies primarily on settling of suspended solids, adsorption, and uptake of pollutants by vegetative root systems (Claytor & Schueler, 1996). Wet swales are designed to retain runoff for 24 hours. The application of wet swales is limited due to standing water and the potential problems associated with it, such as safety hazards, odor, and mosquitoes. The feasibility of installing any open channel on a site depends on the local climate, the right soils to permit the establishment and maintenance of a dense vegetative cover, and available area. The contributing area, slope, and perviousness of the site will determine the dimension and slope of the open channels.

Benefits

The benefits of open-channel systems include minimized water balance disruptions through the reduction of peak flows, the filtering and adsorption of pollutants, and increased recharge. Other benefits include lower capital cost relative to more structural stormwater management practices, improved aesthetics because they accent the natural landscape and break up impervious areas, and a net benefit to the public in the reduction of urban heat island effect.

Limitations

Open channels used in stormwater management are typically ineffective for water-quality treatment and are vulnerable during large storm events. High velocity flows as a result of these large storm events can erode the vegetative cover, if the channels or swales are not designed properly. Other limitations include:

- Areas with very flat grades, steep topography, and wet or poorly drained soils
- Wet swales are potential drowning hazards, mosquito-breeding areas, and may emit odor
- The land space required for open channels ranges from 6.5 percent of total contributing impervious area for grass channels and 10 to 20 percent for dry and wet swales
- Pre-treatment is necessary to extend the channel's functional life, as well as to increase the pollutant removal capability. A shallow forebay at the initial inflow point is recommended as a pre-treatment component.

Sizing and Design Guidance

The general design of open channel systems should take into consideration the following criteria:

• Soils - for grass channels, the infiltrating capability is a factor in locating swales. Swale infiltration rates measured in the field should be between 0.5 and 5.0 inches per hour. Suitable soils include sand, sandy loam, loamy sand, loam, and silty loam. Highly permeable soils provide little treatment capability, and soils with low permeability do not provide adequate infiltration during the short retention time. The soil bed underneath the dry swale should consist of a moderately permeable soil material, with a high level of organic matter.

• Shape - Open channel systems are usually parabolic or trapezoidal in shape. Parabolic swales are natural and are less prone to meander under low flow conditions. Trapezoidal swales provide additional area for infil-

Design Equations for Open Channel Systems

Grass Channel		Dry Swales		Wet Swales	
Equation		**Equation**		**Equation**	
$V=(1.49/n)R^{2/3}S^{1/2}$ $R=A/P$		$A_f=Vol*(d_f)/[k*(h_f+d_f)(t_f)]$		Vol= A x L	
Variables		**Variables**		**Variables**	
V	Velocity should be less than 1 ft/sec	A_f	Required surface area of the dry swale (ft^2)	Vol	Retention volume (ft^3)
n	Roughness coefficient (tabulated values)	Vol	Treatment volume (ft)	A	Cross sectional area (ft^2)
R	Hydraulic radius (ft)	D_f	Depth of the filter medium (ft)	L	Length of Swale (ft)
A	Cross Sectional area (ft^2)	k	Hydraulic conductivity (ft/day)		
P	Wetted perimeter (ft)	h_f	Average height of water above the bottom of dry swale		
S	Longitudinal slope	t_f	Design time to filter the treatment volume through the filter media (usually set at 24 hrs)		

Source: *Urban Environmental Design Manual*

Filter Strip Design Considerations

Design Storm	Determined by state or local agency. Refer to guidance provided by the Prince George's County LID Design Manual (PGC, 1997) and the Maryland Stormwater Design Manual (MDE, 1998).
Drainage Area	Maximum drainage area to filter strips is limited by the overland flow limits of 150 feet for pervious surfaces and 75 feet for impervious surfaces
Slope	Minimum slope = 1 percent Maximum slope = determined by field conditions
Flow	Should be used to control overland sheet flow only. Discharge should not exceed 3.5 cubic feet per second range
Length and Size	The size of the filter strip is determined by the required treatment volume. A minimum length of 20 feet is recommended
Water Quality	See table on reported pollutant removal efficiency of LID techniques
Maintenance	Routine landscape maintenance required

Prince George's County, Md.

tration but may tend to meander at low flows and may revert to a parabolic form. Trapezoidal sections should be checked against the parabolic sizing equation as a long-term functional assessment.

• Dimension - for grass channels, the side slopes in the channel should be 3:1 or flatter. The longitudinal slope should be between 1 and 4 percent for grass channels and 1 and 2 percent for dry and wet swales. The minimum length of a grass channel to ensure water quality treatment is 600 feet. This is determined based on the maximum flow velocity of one foot per second (fps) for water quality treatment, multiplied by a minimum residence time of 10 minutes (600 seconds). The wet swale length, width, depth, and slope should be designed to temporarily accommodate the water quality volume through surface ponding. To achieve surface ponding, it is usually necessary to install check dams as part of a wet swale system. For a dry swale, all of the surface ponding should dissipate within a maximum 24-hour duration.

• Vegetative Cover - Dense vegetative cover slows the flow of water through the swale and increases treatment. Vegetation should be able to tolerate being wet for 24 hours. The velocities in the open channel systems should not exceed the erosive levels for the vegetative cover in the channel. Once runoff rates and volumes are calculated using an appropriate hydrologic model, the basic equation for sizing open channel systems is summarized below.

Cost

Open channel systems are cost-effective measures relative to curb and gutter systems and underground storm sewers. The base cost for grass channels is 25 cents per square foot (SWRPC, 1991). Designed swales, such as a dry swale with prepared soil and underdrain piping, have an estimated cost of $4.25 per cubic foot (SWRPC, 1991). Relative to other filtering system options, these costs are considered to be moderate to low. Most recent cost estimates have approximated $5 per linear feet for grass channels and $19 per linear feet for dry swales. The annual maintenance cost can range from 5 to 7 percent of the construction cost (SWRPC, 1991).

Maintenance

The life of an open channel system is directly proportional to its maintenance frequency. The maintenance objective for this practice includes keeping up the hydraulic and removal efficiency of the channel and maintaining a dense, healthy grass cover. The following activities are recommended on an annual basis or as needed:

- Mowing and litter and debris removal
- Stabilization of eroded side slopes and bottom
- Nutrient and pesticide use management
- De-thatching swale bottom and removal of thatching
- Discing or aeration of swale bottom
- Every five years, the channel bottom

Grassed Swale Design Considerations

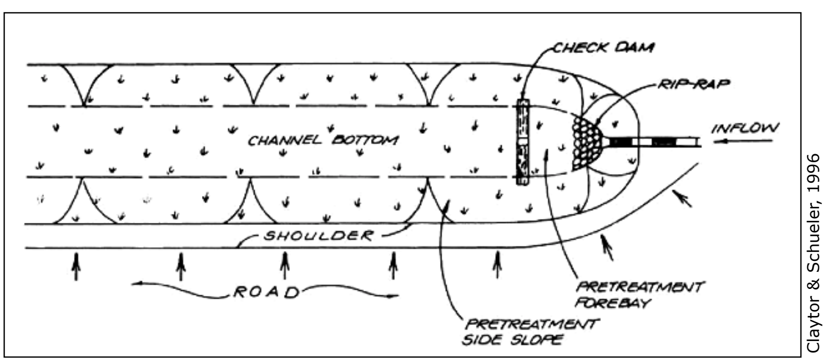
Design Storm	Determined by state or local agency. Refer to guidance provided by the Prince George's County LID Design Manual (PGC, 1997) and the Maryland Stormwater Design Manual (MDE, 1998). Local condition may necessitate adjustment of the recommendations in the guidance documents.
Channel Capacity	Swale must be sized to convey the peak discharge of the design storm
Soils	The permeability (infiltration rate) of the soils will determine whether a dry or wet swale can be used. It is recommended that soils used for dry swales have infiltration rates of 0.27 – 0.5 inches per hour.
Channel Shape	Trapezoidal or parabolic shape recommended
Bottom Width	2-foot minimum, 6-foot maximum
Side Slopes	3:1 or flatter
Channel Longitudinal Slope	1 percent minimum; 6 percent maximum
Flow Depth	4 inches for water-quality treatment
Manning's n value	0.15 for water-quality treatment (depth < 4") 0.15 – 0.03 for depths between 4" and 12" 0.03 minimum for depth 12"
Flow Velocity	1 fps for water-quality treatment; 5 fps for 2-year storm; 7 fps for 10-year storm
Length of Channel	Length necessary for 10-minute residence time
Water Quality	See table on reported pollutant removal efficiency of LID techniques
Maintenance	Routine landscape maintenance required

Prince George's County, Md.

may need reshaping and removal of sediment to restore original cross section and infiltration rate, and seeding or sodding to restore ground cover is recommended

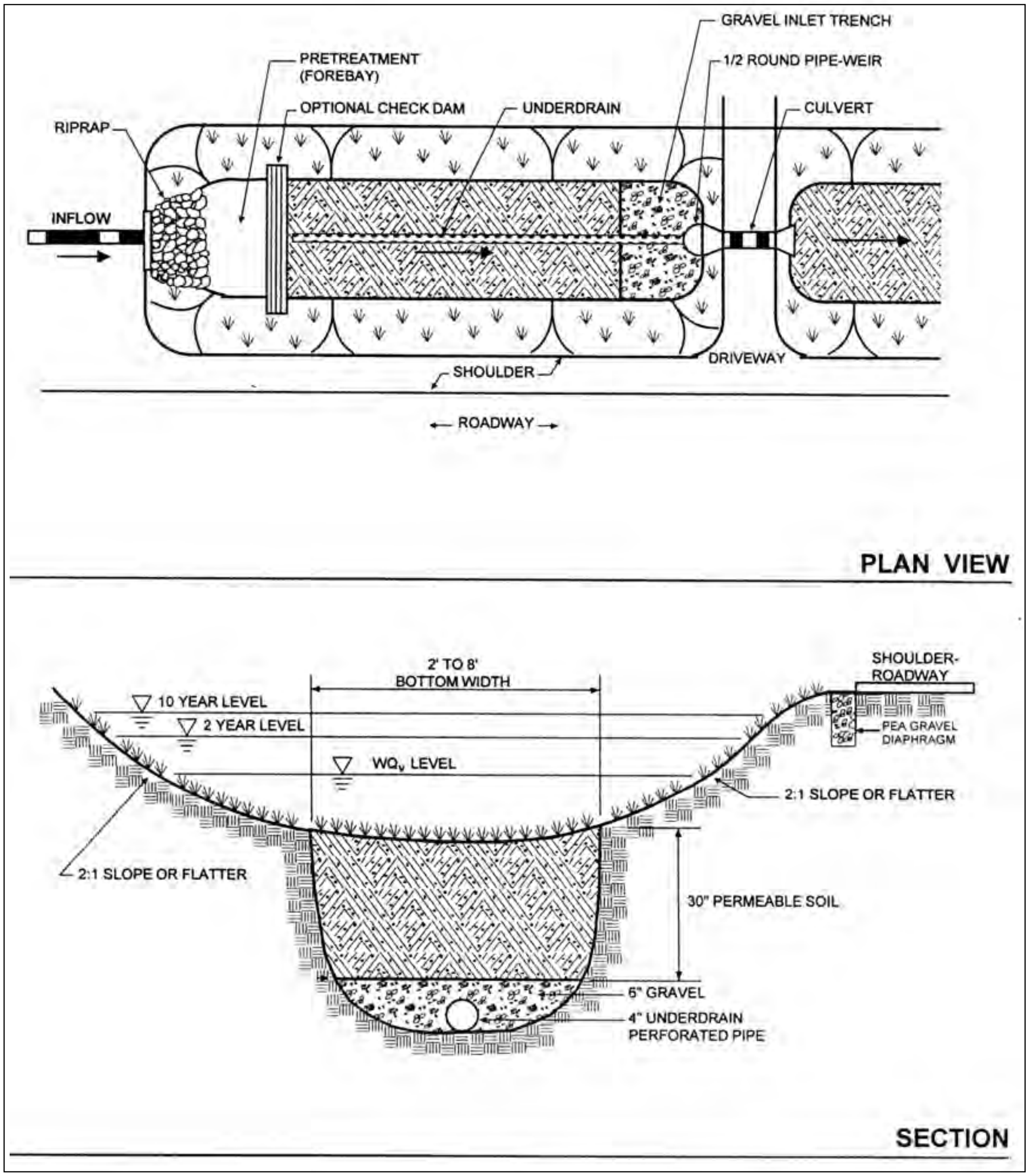
Maintenance for the grass channel consists of annual inspections and correction of erosion gullying and reseeding as necessary. When sediment accumulates to a depth of approximately three inches, it should be removed and the swale should be reconfigured to its original dimensions. The grass in the swale should be mowed at least four times during the growing season. The condition of the grass vegetation should be noted during inspection and repaired as necessary. Dry swales should be inspected on an annual basis and just after storms of greater than or equal to the one-year frequency storm. Both the structural and vegetative components should be inspected and repaired. When sediment accumulates to a depth of approximately three inches, it should be removed and the swale should be reconfigured to its original dimensions. The grass in the dry swale should be mowed at least four times during the growing season. If the surface of the dry swale becomes clogged to the point that standing water is observed in the surface 48 hours after precipitation events, the bottom should be roto-tilled or cultivated to break up any hard-packed sediment, and then reseeded. Trash and debris should be removed and properly disposed of.

Wet swales should be inspected annually and after storms of greater than or equal to 2.8 inches of precipitation. During inspection, the structural components of the pond, including trash racks, valves, pipes and spillway structures, should be checked for proper function. Any clogged openings should be cleaned out and repairs should be made where necessary. The embankments should be checked for stability and any burrowing animals should be removed. Vegetation along the embankments, access road, and benches should be mowed annually. Woody vegetation along those surfaces should be pruned where dead or dying branches are observed, and reinforcement plantings should be planted if less than 50 percent of the original vegetation establishes after two years. Sediment should be removed from the bottom of the swale.



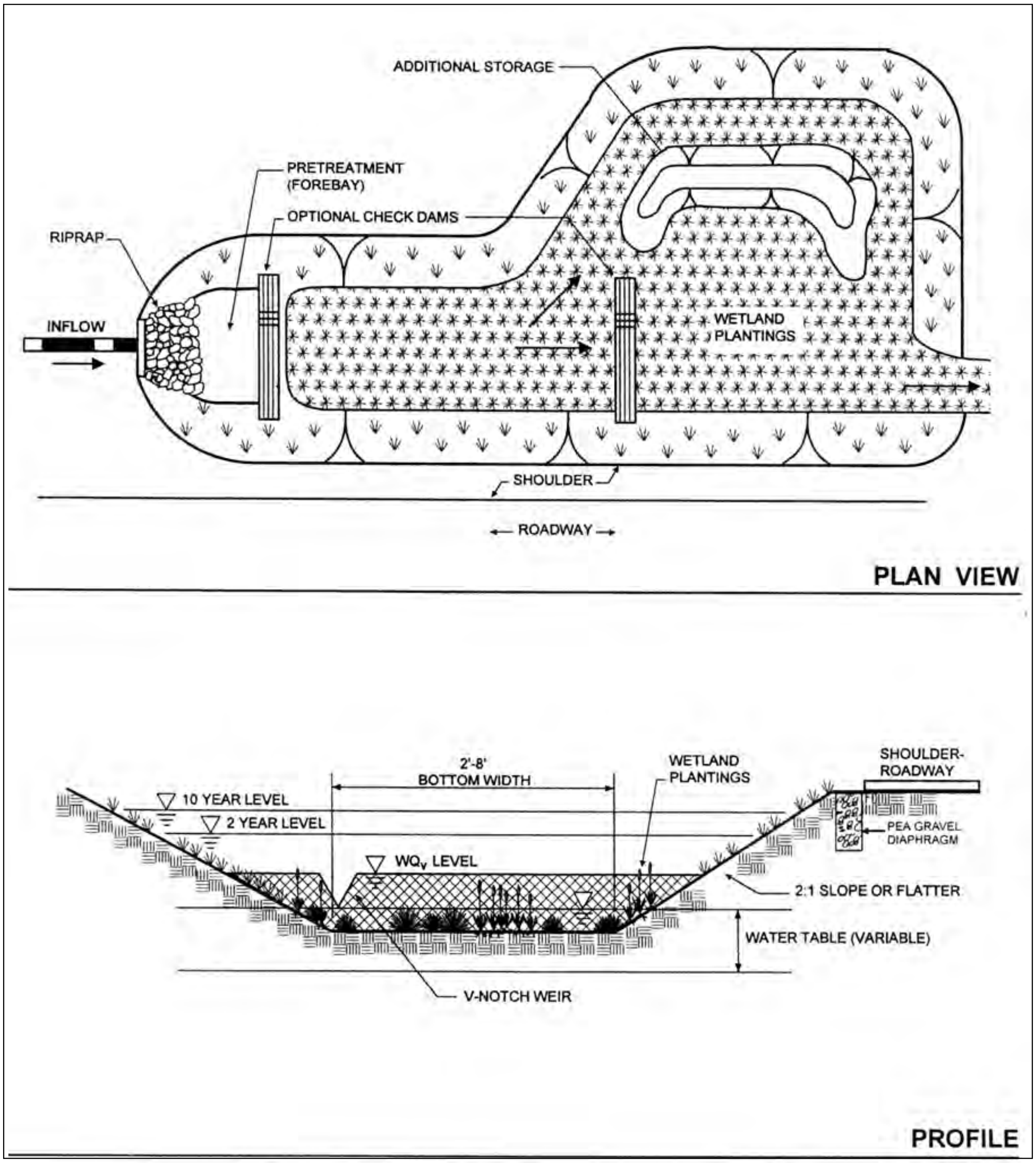
Schematic plan of a grass channel

Plan and section of a dry swale



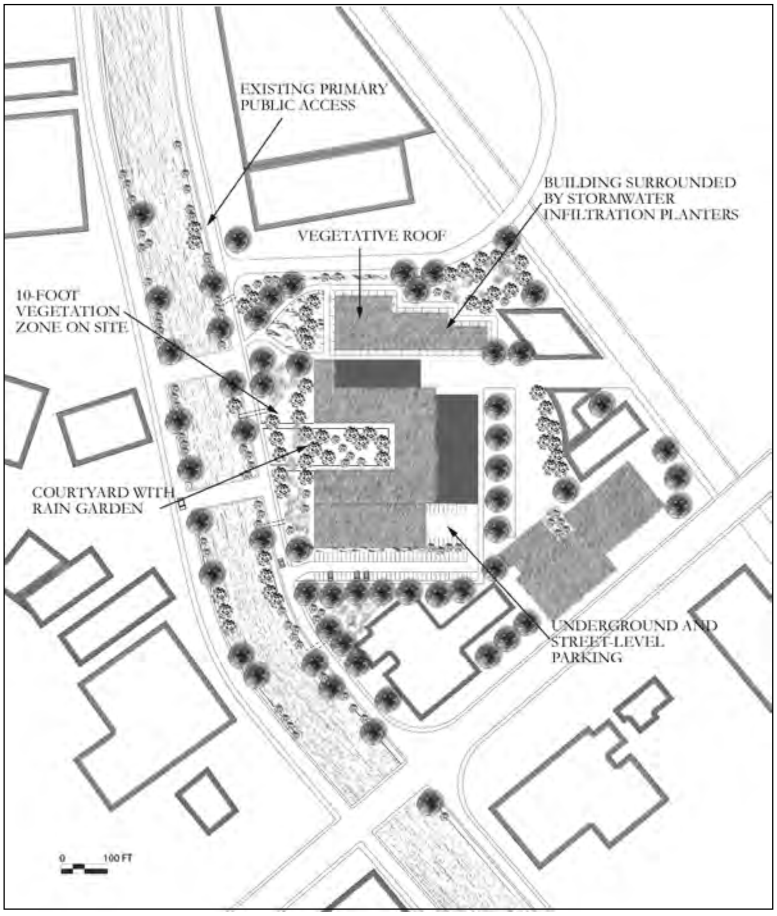
Horsley-Witten Group

Plan and section of a wet swale



Horsley-Witten Group

330. HYPOTHETICAL STORMWATER MANAGEMENT



Source: M. Leighly and J. Martel, Rhode Island School of Design, 2006.

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400. PUBLIC ACCESS IN THE URBAN COASTAL GREENWAY

410. UCG PUBLIC ACCESS REQUIREMENTS

To establish continuous public access along the Metro Bay shoreline is one of the overall objectives of the Urban Coastal Greenway (UCG) policy. Per the R.I. Coastal Resources Management Program (Section 335 of the Redbook), CRMC is responsible for ensuring that public access to the shore is protected, maintained and, where possible, enhanced for the benefit of all. The following points are the public access standards in the Metro Bay Urban Coastal Greenway policy for physical access along and to the waterfront, as well as visual access.

A. Primary (alongshore) public access

All new multi-residential, commercial, and mixed-use developments should provide public access along their portion of the UCG. In certain cases, the public access component may be allowed within the construction setback or another portion of the site. The primary path, however, should connect or be consistent with existing municipal or state pedestrian or bike path access paths and consider future pathway plans. Although CRMC will allow pathways of up to 20 feet in width when emergency vehicle access is necessary, primary public access pathways may be a minimum of 8 feet in width to accommodate pedestrian and bicycle access.

Pawtucket Town Landing provides physical and visual access to the Seekonk River.

Bold Point Park, East Providence, provides visual access to the Bay and to Providence.

B. Secondary (arterial or perpendicular) public access

Each design plan shall include at least one secondary access path that emanates from a public place and leads to the primary public access path per 500 linear feet of shoreline. The secondary access path shall connect sidewalk traffic with the alongshore UCG path, and may be a meandering path, as long as erosion is minimized. The access path should be a minimum of 8 feet in width to accommodate pedestrian traffic, but may be as wide as 20 feet when emergency vehicle access is necessary. CRMC may waive the 500-foot secondary pathway standard if the applicant provides 10 percent more public parking spaces than required and can demonstrate that there is adequate available secondary public access.

Benches at Pawtucket Town Landing are located on a pervious surface.

C. Permeable pathways

All public access pathways must be constructed of a pervious surface unless they will be used for activities such as cycling and/or emergency vehicles where the pathway may require a more permeable surface, or where consistency with existing adjacent impervious surface paths (e.g., Waterplace Park) is required. In these cases, paths shall be designed to ensure that runoff drains into vegetated stormwater treatments to so that water does not pool and then erode the path surface or adjacent soils. When paths are located directly adjacent to the coastal feature, they should be angled slightly to cause stormwater runoff to flow inland for vegetative treatment, rather than toward the coastal feature. Approved vegetative techniques are described in Chapter 3 of this manual.

D. Areas with existing public access

Where existing public access pathways and public roads occur between the coastal feature and the development parcel(s), the primary public access and construction setback requirements may be waived. In addition, where public roads are immediately adjacent to the sides of the development perpendicular to the coastal feature, these public roads may count toward the UCG secondary public access requirements. The road(s) must be usable for pedestrian and/or emergency vehicle access, as appropriate. This situation will occur mostly within the UCG Inner Harbor Zone. In addition, CRMC may waive the 500-foot secondary pathway standard if the applicant provides 10 percent more public parking spaces than required and can demonstrate that there is adequate available secondary public access.

E. Emergency vehicle access

Through the primary and secondary access pathways, each UCG design must include adequate provisions for emergency vehicle access paths from the nearest street to the shoreline (approximately every 500 feet), as determined in coordination with the municipality with jurisdiction. These vehicular paths shall be constructed of a permeable surface capable of supporting emergency vehicles.

Seaview Park, Cranston, provides amenities for enjoying the Bay.

F. Sharing public access among adjoining parcels

Adjoining parcels may share secondary pedestrian or vehicular access paths on their shared boundary, where applicable, as long as there is at least one secondary pathway per 500 feet of shoreline.

G. Public access parking

Each development shall include a minimum of two public parking spaces adjacent to an access point, and an additional space per 100 feet of linear shoreline (where "linear" refers to the shortest distance between lot boundaries) within the parcel. Adjacent on-street parking and off-street public parking may be considered by CRMC as satisfying the public parking requirements. The placement of the public parking spaces shall be decided in consultation with the CRMC and the municipality of jurisdiction. In cases where the project is directly adjacent to public parking, (defined as on-street parking and off-street parking available to the general public), such spaces may be included for purposes of satisfying the public parking requirements of this section, provided they are within 200 feet of the perpendicular public access path and have a reasonable vacancy rate.

H. Compliance with the Americans with Disabilities Act

Public access paths and associated elements must be compliant, where applicable, with the most recent version of the Americans with Disabilities Act (ADA) Standards for Accessible Design (www.usdoj.gov/crt/ada/stdspdf.htm).

This Bay shoreline is accessed from the parking lot at Richmond Square, Providence.

I. Public access enhancement as a possible compensation measure

An applicant may propose to increase opportunities for public recreational use of coastal waters on the development in place of compensation for a reduction in the required UCG width. This might include enhancement of the pathway through the placement of benches, lookout points, bicycle paths, fishing piers or platforms, public canoe or kayak racks, fish cleaning facilities, or interpretive signage. This option does not include construction of marinas.

420 MEETING UCG REQUIREMENTS

Both physical (pedestrian or bicycle) and visual access to the Bay should be considered during the initial stages of design. Although in most cases the physical public access should be located within the UCG, by considering building massing and viewscapes during project design, visual access may be achieved from distances beyond the scope of the UCG and can be accomplished through thoughtful site planning and design, including roadway layout, building siting and massing, and use of intrinsic opportunities at the site, such as natural grade changes and shoreline variations.

Site planning for public access

In order to determine the best and most appropriate locations for public access and to ensure that the public access areas relate to the scale and intensity of the proposed development, a site analysis should be prepared prior to developing schematic designs. This process encourages the developer to consider the inclusion of public access as one of the primary design elements, as opposed to it being an afterthought, and to ensure that it relates directly to the context of the site as well as to the region. Site analysis considerations should include the proposed use of the site, the topography of the site and the contour of the shoreline, if the site has any significant natural or cultural features, the surrounding built and natural environment, and the adjoining existing and proposed uses (e.g. industrial or neighborhood). The view of the water from the land, and toward the land from the water, should also be considered and cultivated when planning and designing public access areas.

Techniques for developing quality public access

The following additional information will assist the developer in creating public access that both meets the UCG public access objective as well as enhance that particular Metro Bay parcel. This information is based on the Shoreline Spaces: Public Access Design Guidelines for the San Francisco Bay (www.bcdc.ca.gov/pdf/planning/PADG.pdf) and modified to provide guidance for the Metro Bay region.

East Providence offers parking adjacent to the East Bay Bike Path.

A. Provide connections and continuity along the shoreline

Access areas are utilized most if they provide direct connections to public rights-of-way such as streets and sidewalks, are served by public transit and are connected to adjacent public access or recreation areas. This can be done by:

- Providing clear and continuous transitions to adjacent developments
- Connecting shoreline public access with the municipalities' park and open space systems, public buildings, shopping districts, and other public spaces
- Coordinating shoreline public access with state agencies and local municipalities to provide for connections to trail and public use areas that may be planned for the future. Some of these plans include the Rhode Island Greenspace and Greenways Plan, the Blackstone River Bikeway, the Woonasquatucket River Greenway, and the East Coast Greenway.
- Using local public street networks to inform shoreline site design and to extend the public realm to the Bay
- Providing connections perpendicular to the shoreline at regular intervals to maximize the opportunities for accessing and viewing the Bay
- Promoting safe pedestrian and bicycle access to the Bay by calibrating traffic lights at nearby intersections and providing safe, enhanced crosswalks

- Conveniently and directly connecting shoreline developments to transit sources such as water taxis, ferries, buses and rail systems

B. Make public access usable

The pubic access amenities offered should correspond with the suitable uses of the site. While some shoreline areas are best suited for quiet and contemplative public spaces, others lend themselves to be used for large public gatherings, such as festivals. . Existing site characteristics and opportunities, such as fishing, viewing, picnicking, or boating, should be capitalized on in designing public access spaces that are safe and secure. Other techniques to make public access usable include:

1. Gathering and seating areas

- Provide gathering places, such as plazas, that function as focal areas within larger public access areas.
- Provide plenty of seating choices- some of which are shaded- such as fixed benches and chairs, picnic tables, retaining walls, planter seats, grass berms, steps, and moveable chairs.
- Provide elevated places for viewing the Bay.

Corliss Landing, Providence, offers amenities for viewing the Bay at the hurricane barrier.

- Orient seating toward Bay views or vistas of opposite shores or landmarks, such as bridges or towers.
- Provide durable site furnishings to minimize maintenance requirements.
- Provide enough lighting to create a sense of safety, but design to control intensity, glare and spillover

2. Signage

Provide clear and understandable signs are posted in public access areas that: 1) inform the public where public access areas are located and how to reach them, including parking; 2) describe the recreational opportunities are available nearby: 3) describe how the public can use the area, consistent with rules governing appropriate behavior; 4) and provide the interpretation of natural, historic and cultural features in or near the public access areas. Some other considerations include:

- Install the CRMC UCG sign within the UCG public access areas
- For larger developments, a comprehensive sign program should be implemented
- Provide wayfinding signs to assist shoreline users in traveling to and along the Bay
- Provide management signs in wildlife areas that describe environmental sensitivity and/or any rules and restrictions associated with the management of the wildlife area
- Do not locate advertising signage in public access areas
- Use the same design in every application so that public access areas are easily identifiable by members of the public
- Select and install signs that are in scale with the environment

This path offers visual access to the Woonasquatucket River at Eagle Square, Providence

3. Shoreline edge treatments that provide closeness to the water

- Tidal stairs provide visitors with a simple means of getting close to the water. However, algae growth usually occurs below the Mean High Tide line, creating slippery conditions. Therefore, careful consideration should be given to facilities proposed lower than where algae normally occurs.
- Tidal ramps provide a means for access into the water, especially for windsurfers and persons with disabilities
- With careful placement of appropriately sized rock and stone, riprap can be designed to include seating elements, providing closeness to the Bay
- Sandy beaches provide simple and convenient access to the water for human-powered watercraft and swimmers
- Low-profile floats and docks provide safe launching and landing conditions for human-powered watercraft, such as canoes and kayaks; these should be appropriately sited to avoid traffic and water safety hazards
- Piers and overlooks provide closeness to the water by enabling users to get out over the water

4. Pedestrian and vehicular railings

- Design guardrails to allow maximum views, especially on bridges
- Design guardrails and handrails that relate to the architectural or landscape style of the public access area

5. Fishing facilities

- Design fishing facilities, such as piers and fish cleaning stations that accommodate people with disabilities
- Post public information about potential fishing hazards, such as boating conflicts or health considerations help to keep the public safe

6. Point access at port and water-related industrial areas

- Provide the public with opportunities to safely view port activities and the operations of water-related industry, such as oil terminals and marine construction facilities

7 Interpretive elements and public art

- Consider including interactive site elements or interpretive signs to allow people to more fully appreciate the natural, cultural, or historical assets of the site and the Bay
- Public art that complements the Bay

setting adds visual interest to the shoreline

C. Provide, maintain, and enhance visual access to the Bay and shoreline

Northern Narragansett Bay is a scenic resource that contributes to the enjoyment of daily life for many Rhode Islanders. CRMC, as described in section 330 in the Redbook, has a responsibility to preserve, protect, and, where possible, restore the scenic value of the coastal region to retain the visual diversity and unique visual character of the Rhode Island coast.

Probably the most widely enjoyed "use" of the Bay is simply viewing it and the activities taking place on it from the shoreline, from the water, or from a distant viewpoint. CRMC maintains that views to and across the water through yards, between buildings, and from roadways should be preserved and, where possible, created. Techniques to enhance visual access can be achieved by:

- Locating buildings, structures, parking lots, and landscaping of new shoreline projects such that they enhance and dramatize views of the Bay and the shoreline from public thoroughfares and other public spaces
- Organizing shoreline development to allow Bay views and access between buildings

D. Maintain and enhance the visual quality of the Bay, shoreline, and adjacent developments

Factors that contribute to the visual quality of the shoreline and adjacent developments include:

- Landscaping with native and drought-tolerant plants to provide texture and interest to the waterfront
- Improving existing degraded shoreline edges and substandard shoreline erosion protection
- Removing litter and debris that mars the appearance of the shoreline
- Providing visual interest and architectural variety in massing and height to new buildings along the shoreline, and setting back uses that do not complement the Bay so they do not impact the shoreline

Some techniques to achieve this include:

1. Shoreline planting

- Control landscaping to preserve and dramatize Bay views, especially in side yards, at street ends, in parking lots, and along public thoroughfares
- Provide a hierarchy of plant types and sizes within a project that relates to the shoreline, public spaces, and adjacent developments
- Use native plants that provide habitat for wildlife wherever possible and appropriate. For specific planting recommendations, refer to the most current edition of the CRMC/URI

Public access at the end of Narragansett Boulevard, Cranston, overlooks Stillhouse Cove, the Rhode Island Yacht Club, and the Providence River.

Coastal Plant list (www.crmc.ri.gov/pubs/pdfs/uri_plantlist.pdf)

2. Shoreline erosion control

Structural shoreline protection facilities are defined as structures that control the erosion of coastal features, according to Section 300.7 in the Redbook. Examples of these include revetments, bulkheads, seawalls, groins, breakwaters, and jetties. Non-structural methods for controlling erosion such as stabilization with vegetation and beach nourishment are strongly preferred by CRMC. Riprap revetments are favored to vertical steel, timber, or concrete seawalls and bulkheads except in ports and marinas. When structural shoreline protection is proposed, CRMC shall require that the owner exhaust all reasonable and practical alternatives including, but not limited to, the relocation of the structure and nonstructural shoreline protection methods. Refer to Section 300.7 of the Redbook for more guidance on this topic.

E. Take advantage of the Bay setting

Development along the shores of the Bay should take maximum advantage of the attractive setting that the Bay provides. Some ways to achieve this are by:

- Orienting the development to Bay views and providing physical connections to the Bay at every opportunity
- Orienting public access areas and improvements to take advantage of views of opposite shores, landmarks (such as islands and bridges) and adjacent maritime activities such as boat launching, gas docks, ferry landings, or other marine-related uses
- Utilizing the shoreline for Bay-related uses, and setting uses, such as parking lots, that do not complement the Bay or require a Bay setting, well back from the Bay and design and manage them so as to not impact the shoreline

Corliss Landing

F. Ensure that public access is compatible with wildlife through siting, design, and management strategies

In many locations around the Bay, the shoreline edge is a vital zone for wildlife. These areas are primarily located within the UCG zone called Area of Particular Concern. Access to some wildlife areas allows visitors to experience and appreciate the Bay's natural resources and can foster public support for resource protection. However, in some cases, public access may have adverse effects on wildlife, and may result in adverse long-term population and species effects. The type and severity of effects, if any, on wildlife depend on many factors, including site planning, the type and number of species present, and the intensity and nature of the human activity. Take into consideration these issues by preparing a site analysis to generate information on wildlife species and habitats existing at the site and the likely human use of the site and then employing appropriate siting, design, and management strategies (such as buffers or use restrictions) to reduce or prevent adverse human and wildlife interactions.

Other techniques include:

- Use design elements such as varying trail widths, paving materials, and site amenities to encourage or discourage specific types of human activities
- Use durable materials to reduce erosion impacts on adjacent habitats and to keep users from creating alternate access routes
- Provide spur trails to reduce informal access into and through more sensitive areas
- Locate parking and staging areas away from sensitive habitat areas
- Locate night lighting away from sensitive habitat areas
- Use physical design features to buffer wildlife from human use
- Manage type and location of public use to reduce adverse effects on wildlife
- Incorporate educational and interpretive elements

Managing public access

CRMC permits will require that public access areas will be used properly, managed for the public's safety and enjoyment, and reasonably maintained. The following are some common requirements for managing public access areas:

A. Responsibility for public access areas

Once a CRMC permit is issued, the permittee is typically responsible for ensuring that the public access area and associated improvements are installed, used, and maintained in accordance with the permit. Public access areas are often required to be dedicated to a public agency or otherwise permanently guaranteed, usually through a legal instrument, for the exclusive use by the public. In accordance with R.I.G.L. 32-6-5(c), limited liability applies when the CRMC stipulates public access as a permit condition and when the council designates a public right-of-way to the shore.

B. Uses within public access areas

Shoreline spaces that are dedicated as public access areas are typically made available exclusively to the public for unrestricted uses, such as walking, bicycling, sitting, viewing, fishing, picnicking, kayaking, and windsurfing. If someone wishes to use the public access area for uses other than those specified by the CRMC permit, prior written approval by or on behalf of CRMC is usually required.

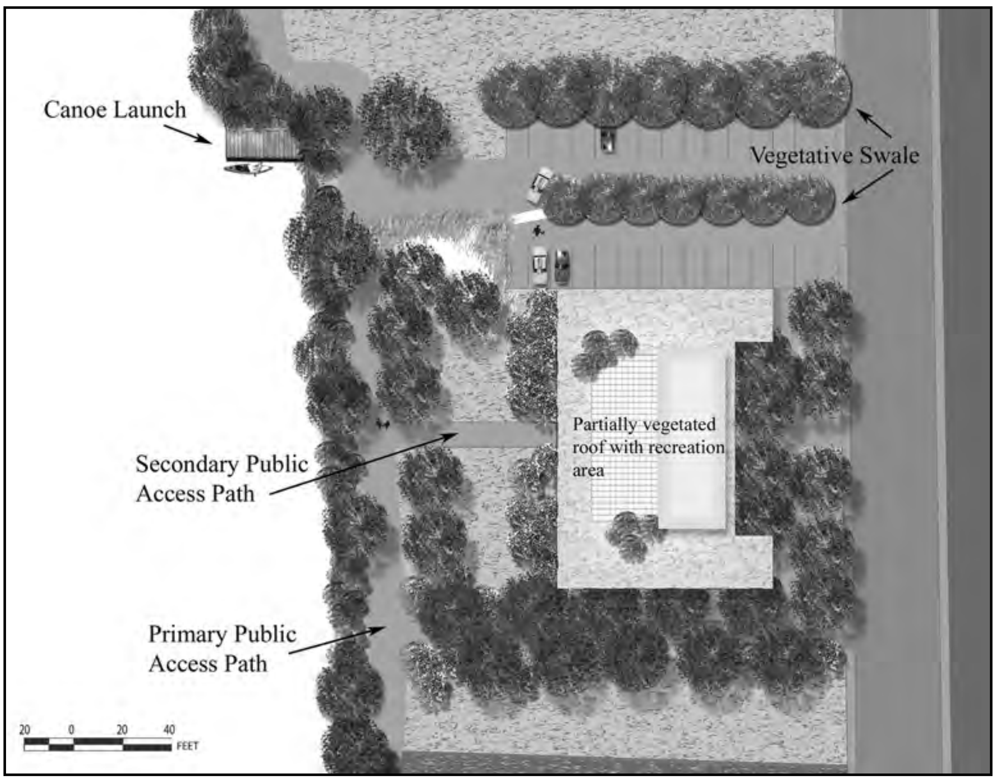
A path starting at Irving Avenue, Providence, leads to the Bay.

C. Maintenance of public access areas

CRMC may require a public access maintenance plan that describes the landowner's plans to repair all path surfaces; replacement of any landscaping that dies or becomes unkempt; repairs or replacement of any public access amenities such as seating areas, restrooms, drinking fountains, trash containers, and lights; periodic cleanup of litter and other materials deposited within the access areas; removal of any hazards in or encroachments into the access areas; and assuring that public access signage remains in place and is clearly visible. To reduce ongoing maintenance requirements, public access areas should be built with durable materials and using high-quality construction methods.

Pawtucket Town Landing

530. HYPOTHETICAL PATHWAY DESIGN



Source: M. Leighly and J. Martel, Rhode Island School of Design, 2006.

REFERENCES

Shoreline Spaces: Public Access Design Guidelines for the San Francisco Bay. (2005). San Francisco Bay Conservation and Development Commission.

J. LaClair, B. McCrea, and Hunt Design Associates. (2005). *Shoreline Signs: Public Access Signage Guidelines.* San Francisco Bay Conservation and Development Commission.

APPENDIX I. METRO BAY SHORELINE SIGNS

Much of the information in this section has been adapted from the San Francisco Bay Conservation and Development Commission's *Shoreline Signs: Public Access Signage Guidelines* (2005).

These guidelines on public access signage for development or redevelopment projects along the Metro Bay shoreline will assist CRMC permit holders in meeting the signage requirements specified in their permits.

URBAN COASTAL GREENWAY SIGNS

The Metro Bay Urban Coastal Greenway sign is intended to be used consistently in public access areas around the Metro Bay as a readily recognizable sign that informs visitors of teh location and access to the Urban Coastal Greenway.

How to get the signs

Artwork for the Metro Bay Urban Coastal Greenway sign is available from CRMC at (401) 783-3370. Signs may be fabricated by sign manufacturers. CRMC will provide some, but not all, required signs. See below section on use of the sign for more information.

Use of the Metro Bay Urban Coastal Greenway sign

It is important that the Metro Bay Urban Coastal Greenway sign appear the same way in every application so that public access areas are easily identifiable by the public.

- **Placement**

Primary Urban Coastal Greenway signs must be placed at each perpendicular point that allows the public to get to the greenway. Secondary Urban Coastal Greenway signs must be placed along the greenway to assist the public in staying on the path. Secondary signs must be placed at each property boundary that intersects the greenway, and at 200-foot intervals along the greenway. In the case of properties narrower than 200 feet, secondary signs must be placed at property boundaries with a minimum of one secondary sign in the middle of the greenway on that property. Property owners are responsible for obtaining primary Urban Coastal Greenway signs. CRMC will provide a minimum of one secondary sign per property.

- **Materials**

Signs may be made of any one of a variety of rigid, durable materials, including porcelain enamel, aluminum, acrylic, or phenolic resin.

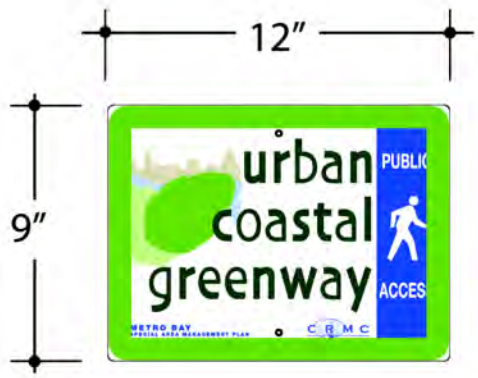
- **Graphic**

The graphic may be applied to the panel in any number of recognized signage techniques, including silk screening, digital printing, porcelain enamel image, or phenolic resin image. Do not hand paint or hand letter signs. Do not modify the proportions of the sign design. New sign types and designs should be developed in consultation with CRMC staff.

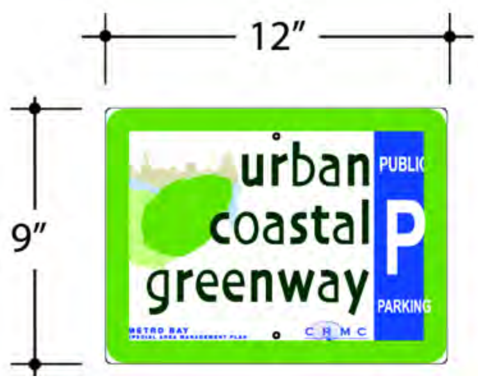
- **Mounting**

Signs may be firmly mounted on fences, walls, posts, or projected off surfaces (blade mounted). While it is preferred that the signs be mounted with concealed fasteners, bolting through the sign is acceptable. The size of visible bolt heads should be minimal. Do not bolt through lettering or symbols.

Primary UCG Sign



Secondary UCG Sign



Parking Sign

Sign artwork by Grady Peck.

Benjamin Morton

▪ **Specifications**
The primary greenway sign measures 18 inches by 24 inches horizontal. Secondary and parking signs measure 9 inches by 12 inches horizontal. Materials for sign faces should be of the highest quality available. Inks and screen paints should be fade resistant for a minimum of five years. Fasteners should be tamper-proof. Corners of sign panels should be eased to eliminate sharp edges. Wooden posts should be No. 2 foundation-grade redwood, pressure treated douglas-fir larch or better. Steel posts should be hot-dipped galvanized to conform to ASTM A 123.

INTERPRETIVE SIGNS

Description
Interpretive signage is permanently posted information about local history, natural features, or events that enhance the visitor experience. Developers and operators of publicly accessible shoreline properties are encouraged to create and implement such displays, thereby adding value to public shore visits.

Content Guidelines
The best interpretive displays are usually based on a series of simple but interrelated topics or stories. Each individual display should focus on a single topic; a series of closely located displays can illuminate various aspects of a subject. For example, two or three displays at a location can present related single topics such as the location's commercial history, social history, or environmental significance.

▪ **Text**
Appropriate and interesting text is important. Whenever possible, engage a professional writer to create short, compelling paragraphs.

Design Guidelines
Interpretive planners have found that illustrated panels, mounted on posts and parallel to pedestrian paths, are the most effective way of attracting usage. This "wayside" design approach is found in national parks and historic sites throughout the United States. Panels are mounted low and at an angle to allow viewing while not disturbing the scenic view.

▪ **Artwork**
Illustrations can vary from historic photographs to specially commissioned illustrations or diagrams. Color can be an effective tool for organizing information and attracting attention.

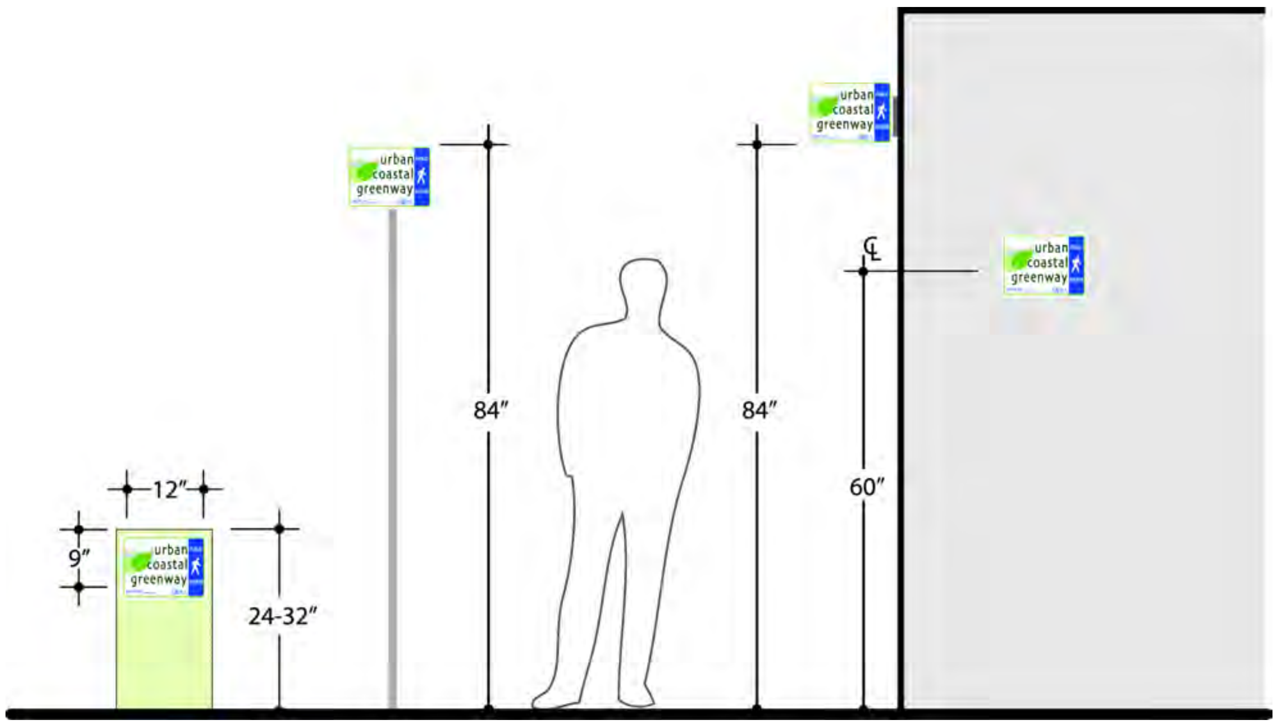
▪ **Layout**
Panel design and layout is best kept simple with a short topical headline or title placed at the top and illustrations or text arranged below, magazine style. Short captions for illustrations can enhance interest and engage the reader.

▪ **Accessibility**
Interpretive signs should be designed to ensure that people with disabilities or those speaking other languages, including Braille, can understand the message. For assistance in designing accessible signs, please see The Smithsonian Guidelines on Accessible Exhibition Design at www.si.edu.

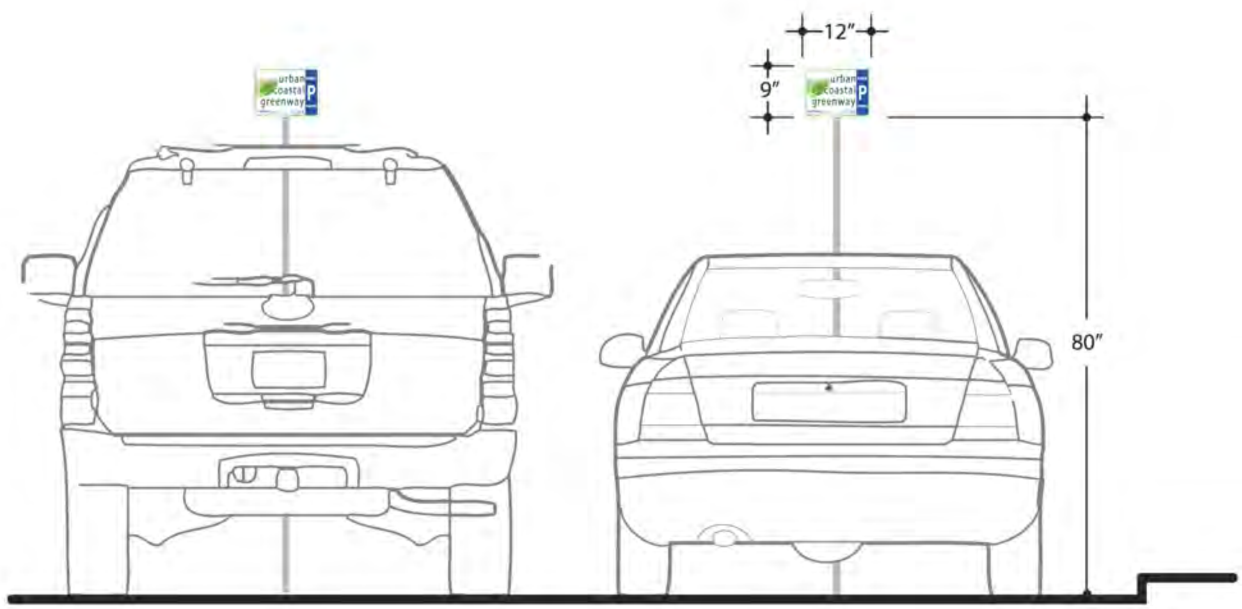
Representative design and topographic guidelines as well as good examples of interpretive signs are available from the National Park Service at www.nps.gov/hfc/products/waysides/contents.htm.

AREA MAPS

Purpose
Area maps help visitors find their way along the shoreline. Designed correctly, maps can enhance a public shoreline visit by presenting



Urban Coastal Greenway sign height and placement options for public access signs.



Urban Coatal Greenway public access parking signs.

Benjamin Morton

geographic context. All developers and operators of publicly accessible shoreline properties are encouraged to create and install area maps.

Content Guidelines
Area maps should be centered on the site where the map is located, should describe the shoreline and immediate inland areas within an approximately three- to five-mile radius of the site, should include points of interest that fall within the area of the map and a small key map or overview of the larger area, highlighting the areas shown on the main map. Maps should have a scale and provide information about walking times and distances between points of interest.

Design Guidelines
A simple, clear art style is best with bold lines for trails. Incorporate symbols or pictographs where possible to reinforce meaning.

Accessibility Guidelines
Lettering should be clear and large enough for reading by most people.

Placement Guidelines
Maps should be mounted low and at an angle to allow viewing while not disturbing the scenic view.

Representative design and typographic guidelines as well as good examples of maps are available from the National Park Service at www.nps.gov/hfc/products/waysides/contents.htm.

REFERENCES

Shoreline Spaces: Public Access Design Guidelines for the San Francisco Bay. (2005). San Francisco Bay Conservation and Development Commission.

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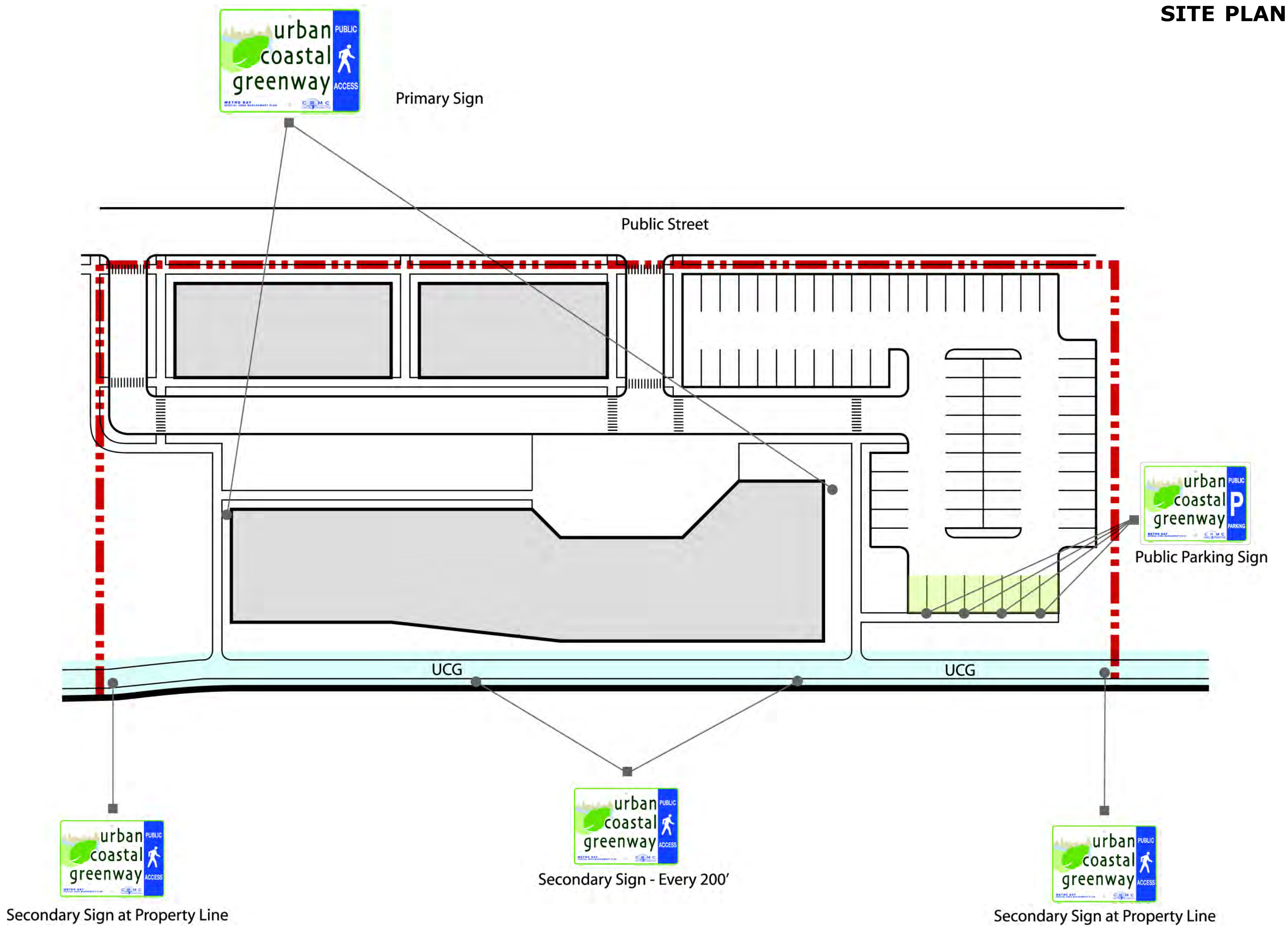
SITE PLAN



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