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EPA Region 1 Green Infrastructure Partnership with the City of Chelsea:

Technical Support Document to Assist the City to Further Encourage and Promote the Use of Green Infrastructure

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Purpose

The purpose of this document is to provide guidance to the members of the City of Chelsea's land use review Boards, City Departments, staff, and other interested parties on the basic requirements, benefits, and limitations of green infrastructure strategies. The manual provides:

- A concise list of green infrastructure practices that are applicable to Chelsea; and
- Guidance on how land use and environmental Board members might evaluate and insert green infrastructure practices into new and redevelopment projects.

The document concludes with two examples, illustrating how green infrastructure practices might have been integrated into two previously approved projects in the City of Chelsea.

Introduction

The City of Chelsea is an historic, highly urbanized, diverse, working class community just north of Boston bordered by the Mystic, Chelsea, and Island End Rivers. The City has high-density residential neighborhoods as well as significant industrial and commercial areas (see Figure 1).

Because Chelsea is highly urbanized, there are few natural areas that can readily absorb rainfall. Consequently, rainfall is quickly converted into surface runoff. Stormwater runoff carries sediments, oil/grease, nutrients, bacteria, and other contaminants to the Chelsea River, Mystic River, Island End River, and Mill Creek. More runoff volume entering into the combined sewer system means unnecessary wastewater treatment. Runoff can also overwhelm the combined sewer system, resulting in raw sewage flowing into Chelsea's waterways. Flooding can also cause damage to homes, businesses, and property.

Discharges from the City's Combined Sewer Overflow (CSOs) and the Municipal Separate Storm Sewer System (MS4) contribute to existing water quality impairments of the Mystic and Chelsea Rivers. Existing permits are in place to limit these discharges, but current and/or future Total Maximum Daily Loads (TMDLs) could trigger new permits or lower current permit limits and add to the cost of managing these discharges.

Figure 1. View of Chelsea from City Hall

Chelsea is seeking to improve its local water quality by using green infrastructure practices to minimize the impacts of stormwater runoff on water resources. Not only can green infrastructure allow urban areas to function better hydrologically, green infrastructure approaches can also provide significant ancillary benefits (e.g., energy savings from natural cooling, improved air quality, and increased real estate value from enhanced curb appeal).

Some sites in Chelsea suitable for the implementation of green infrastructure might be limited by existing contamination problems (21E sites), sites with activity and use limitations (AUL sites), shallow depth to groundwater, and steep slopes. The following map (Figure 2) shows areas where opportunities for green infrastructure might be limited.

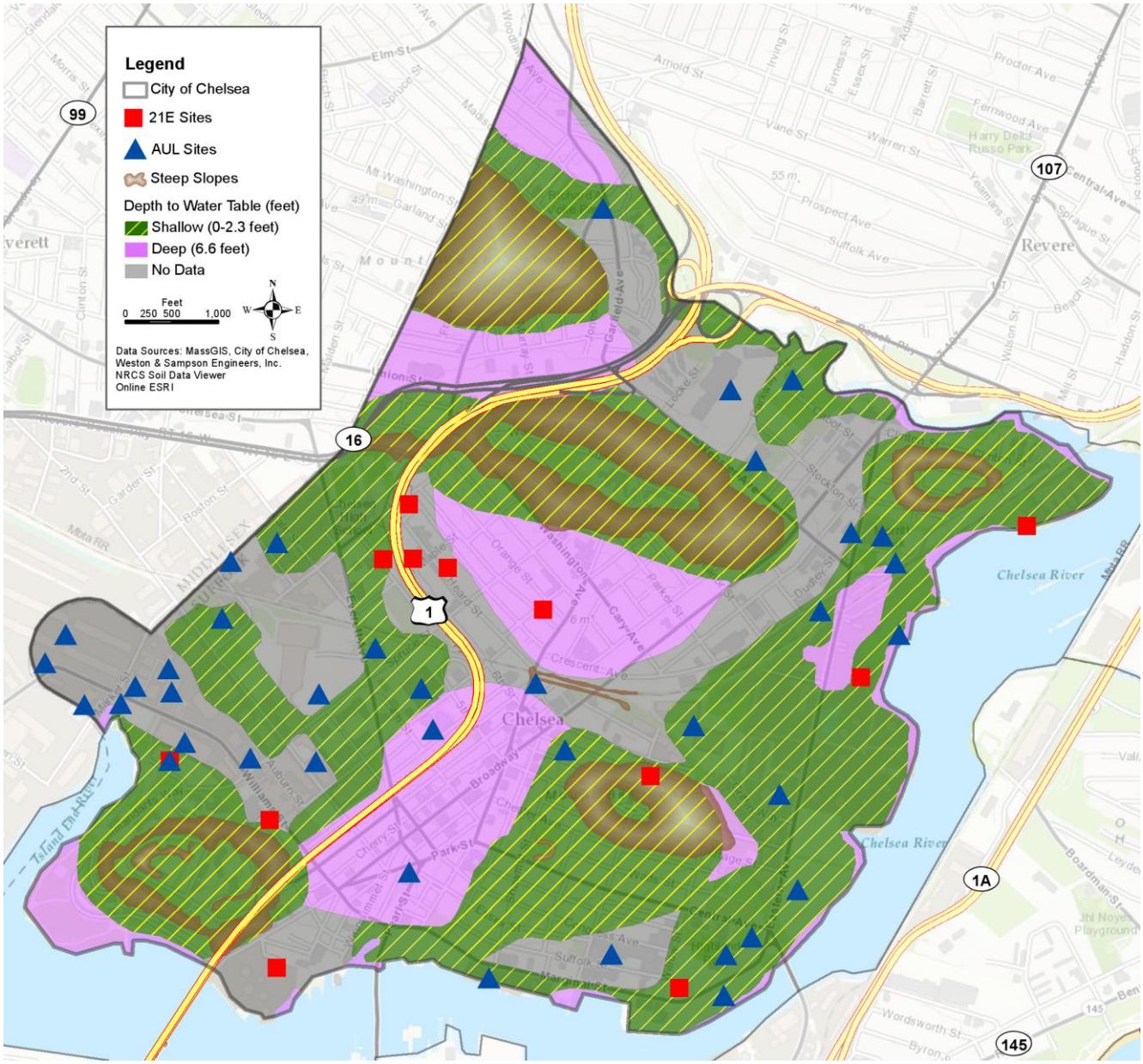


Figure 2. Map of Chelsea Showing Possible Site Limitations for Green Infrastructure

Green Infrastructure

> A green infrastructure approach treats stormwater as a ***resource*** rather than a waste product.

Green infrastructure is an approach to land development/redevelopment that is designed to mimic nature in managing stormwater runoff. "Green infrastructure" is a term that is used differently by different disciplines and in different contexts. However, in the context of urban water quality, the term generally refers to practices that infiltrate, evaporate, or harvest and use stormwater runoff as close to its source as possible. Green infrastructure can be used at a wide range of landscape scales in place of, or in addition to, more traditional stormwater control elements.

The green infrastructure approach is based on four fundamental principles:

- Treat stormwater as a *resource* rather than a waste product;
- Preserve and/or recreate natural landscape features;
- Minimize the effects of impervious cover; and
- Implement stormwater control measures that rely on natural systems to manage runoff.

There are many different control measures that practitioners have developed to apply these principles, including bioretention facilities (see Figure 3), rain gardens, vegetated rooftops, rain barrels/cisterns, infiltration practices, and permeable pavements. By implementing green infrastructure design principles and practices, stormwater runoff is managed in a way that reduces the impact of built areas and promotes the natural movement of water through vegetation and soils. Applied on a broad scale, green infrastructure can help maintain or restore a watershed's hydrologic and ecological functions. Green infrastructure has been characterized as a sustainable stormwater practice by the Water Environment Research Foundation and others.

Figure 3. Example of Bioretention System

Green infrastructure offers a newer approach to stormwater management. Municipalities and developers are realizing that the use of these stormwater management techniques can be a catalyst for the redevelopment of traditionally environmentally challenging urban sites. Green infrastructure can offer cost effective solutions to the numerous water related constraints associated with urban redevelopment including localized flooding, combined sewer overflows, Clean Water Act compliance requirements, and state and local stormwater requirements.

> The green infrastructure approach to stormwater management is not only sustainable and environmentally friendly, but generally more cost effective as well, particularly when project life-cycle costs are evaluated.

Using Green Infrastructure in Urban Areas

Renewed growth and revitalization of urban areas, consisting of commercial centers, neighborhoods, and brownfields, complement the green infrastructure approach by helping to reduce urban sprawl. Green infrastructure provides new and innovative solutions to stormwater runoff management that ensure communities can continue to grow while maintaining and improving their water resources.

Urban areas across the United States are faced with the challenge of protecting the water quality of their rivers, streams, lakes, and estuaries while at the same time promoting redevelopment and revitalization. Until recently, infill and redevelopment projects in urban centers generally used conventional stormwater management, such as closed pipe systems, underground water quality units, and tanks to manage and/or treat stormwater runoff. The practices documented in this guidance document will help demonstrate that green infrastructure can be a centerpiece of redevelopment and revitalization in urban areas and a highly effective stormwater management strategy for both large and small projects.

The potential benefits of green infrastructure have been documented by a number of authors in recent years. While the relative value of these benefits can vary as a function of physical constraints, land values, land use, and social perspectives, the benefits are quantifiable and repeatable. In urban areas where impervious cover often exceeds 75% of the total landscape, green infrastructure offers many opportunities. Listed below are some of the widely recognized benefits to green infrastructure implementation:

> Green infrastructure offers opportunities for multiple environmental, aesthetic, health, property, and resource-related benefits.

WATER

- Runoff volume reduction – *Most green infrastructure practices offer some infiltration and/or increased evapotranspiration of runoff volumes, not just control of the rate of runoff*;
- Natural recharge to groundwater – *Practices that promote infiltration of precipitation not only reduce runoff but also help to recharge groundwater supplies*;
- Less flooding – *Less runoff and greater infiltration equates to less localized flooding impacts and property damage. Widespread implementation of green infrastructure could result in reduction of regional flooding issues; and*
- Cleaner water – *Green infrastructure has been promoted as a water quality treatment approach. The advantage of multiple treatment pathways including settling, microbial breakdown, and infiltration result in better effluent quality than practices that rely simply on storage.*

ENERGY AND ENVIRONMENT

- Reduced urban heat island effect – *Enhanced evaporation from soils and evapotranspiration from plants creates a cooler environment and lower air temperatures;*
- Less energy use for cooling – *Reduced air temperatures mean less energy is expended by air conditioners for cooling in the summer; and*
- Increased awareness of stormwater impacts –*The value of increased awareness that green infrastructure can offer to the general public is often undocumented. Because green infrastructure practices are generally surface systems, and typically vegetated, these practices will also serve as environmental educational features.*

COMMUNITY AND HABITAT

- Wildlife habitat – *Green spaces, trees, shrubs, flowers, and other plant life attract a range of wildlife from birds and butterflies to small mammals*;
- Recreational space – *Open space and areas with landscaping can provide recreational space for people to sit and relax or walk through; and*
- Increased property values – *Properties that abut open space and areas with landscaping can be expected to have higher property values than those that abut other properties, streets or parking lots.*

COSTS

- Reduced landscaping costs – *Green infrastructure shares the expenses for landscaping;*
- Less wastewater treatment costs – *In communities like Chelsea that have combined sewer and drainage systems, both wastewater and stormwater go to a wastewater facility for treatment and discharge. Using green infrastructure to reduce stormwater volume reduces the water reaching the treatment facility and lowers the annual treatment costs for wastewater; and*
- Less life-cycle costs – *Some green infrastructure benefits can provide longevity in addition to other cost savings like energy. For example, green roofs seem to have a high initial cost but they can extend roof life and provide cooling. Life-cycle costs for green infrastructure can be less expensive than for traditional stormwater practices.*

AIR QUALITY

- Natural uptake of pollutants from air – *Green infrastructure typically utilizes soils and vegetation to manage stormwater and introduces a range of natural pollutant removal processes within the urban landscape.*

REGULATORY COMPLIANCE

- Compliance with stormwater permit requirements – *Another benefit of green infrastructure is that it can help meet the stormwater permit requirements for accounting and reporting of impervious area added or subtracted.*

Green Infrastructure Practices

This section presents concise fact sheets on the following green infrastructure practices:

- Bioretention and Green Street
- Permeable / Porous / Pervious Pavement
- Rainwater Harvesting / Storage
- Infiltration
- Green / Blue Roof
- Non-Structural

Although many design considerations are presented in these fact sheets, an engineer would be needed to actually design the stormwater practices.

Bioretention / Green Street

DESCRIPTION

Bioretention systems use soils and landscape vegetation to capture, store, and treat stormwater runoff. A bioretention practice is typically designed for smaller drainage areas and storms. Bioretention systems rely on vegetation in addition to filtration to promote pollutant uptake, attenuation, and evaporation. These systems can be aesthetically appealing and help offset the urban heat island effect. Bioretention practices include infiltrating systems on well-drained soils and filtering systems with an underdrain on poorly drained soils.

APPLICABILITY

Bioretention systems can be situated to accept runoff from lawns, roads, roofs, or parking lots. These systems offer appealing design options for retrofit projects because they use existing green area, such as parking lot islands, to serve a functional purpose while adding aesthetic appeal. Existing green areas are excavated to provide storage, the soil is altered to promote uptake and infiltration, and suitable plants are selected for landscaping. These systems are not suitable for areas with minimal depth to bedrock.

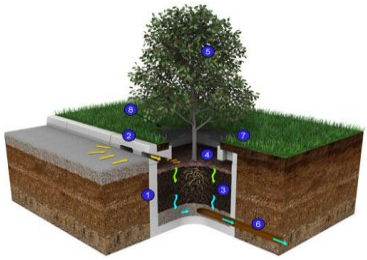
Benefits	WATER: Helps to maintain the natural water balance of the project site and can provide groundwater recharge
	COMMUNITY/HABITAT: Aesthetically enhances the existing landscape
	COMMUNITY/HABITAT: Requires limited additional space when integrated into landscaped areas
	ENERGY/ENVIRONMENT: Provides windbreaks and reduces the urban heat island effect
Limitations	Not recommended for steep slopes or large drainage areas
	Frequent maintenance and landscaping required during first two years
	Lack of long-term maintenance could result in clogging, poor performance, and negative aesthetic impacts
	Requires safety overflows or offline design for large storms that exceed the capacity

DESIGN AND SIZING

- Sized for smaller drainage areas (< 10 acres)
- Specific design provisions required in areas with minimal depth to groundwater or bedrock (< 1 foot)
- Bottom of planting bed should be almost completely flat to promote infiltration
- Suitable plant material like native, hardy species should be used
- Might require pre-treatment if runoff contains a high sediment load

SYSTEM TYPES

Bioretention system variants include bioretention cells, stormwater planters, tree pits, and rain gardens.

Bioretention Cells. These systems are most successful when accepting flows from small, gently sloping drainage areas. Careful plant selection based on site condition (i.e. shade, soil, weather patterns) is crucial for successful function.		
Tree Filters. These filters are compact, self-contained systems filled with soil media and vegetation. These systems are often seen in urban settings along sidewalks to collect and filter runoff from roadways and parking lots.		
Stormwater Planters. These systems are designed to treat limited volumes of runoff, typically from rooftops via downspouts. The planter boxes are filled with soil media and vegetation. These systems are easy to construct without the need for heavy excavation.		
Rain Gardens. These systems are a simpler form of bioretention cells that lack a complex soil matrix and underdrain. They are well-suited for installation in residential lots.		

MAINTENANCE

Regular landscaping activities such as mulching, weeding, and watering in dry times.
Remove sediment from pre-treatment areas, repair eroded areas, and replace media as needed.
Remove and replace dead vegetation and remove invasive species.
Mow upland or adjacent areas and provide vegetative stabilization in bare areas.

COSTS

Bioretention systems have a moderate cost. Implementation costs are typically in the range of $20-$30 per square foot of facility. Rain gardens are less complex with about half that cost. Tree pits and planters have a higher cost due to installation and associated underground storage.

Permeable / Porous / Pervious Pavement

DESCRIPTION

Permeable paving is used to capture and temporarily store rainfall from smaller storm events, dramatically reducing runoff volume compared to traditional paving. On sites with quickly draining soils, permeable pavement can be designed to infiltrate directly into the soil and recharge groundwater. Where infiltration is slow or not feasible, flow can be collected in an underdrain system and directed to other downstream practices. These systems consist of a porous surface, underlying layers of sand/stone, and an optional underdrain system for slowly draining soils.

APPLICABILITY

Permeable paving should generally be used in pedestrian-only areas and other low-volume, low-traffic applications like parking lots to capture rainfall before it becomes runoff and impacts any downstream facilities. Since permeable paving is installed over the land surface, it does not require any additional land consumption, so it would be an appropriate technique for many of the dense urban areas of Chelsea.

Benefits	WATER: Recharge to local groundwater, complete capture of small runoff volumes, and improved water quality from media filtration
	WATER: Less need for curbing and traditional storm sewers
	ENERGY/ENVIRONMENT: Highly reduced salt applications (up to 75%) for de-icing in the winter and reduced urban heat island effects
	COMMUNITY/HABITAT: Requires no additional space
Limitations	Higher maintenance requirements to prevent clogging
	Requires pervious soils and flatter slopes for infiltrating practices
	Not approved to treat high pollutant loads as contaminants can move into groundwater
	Sometimes porous asphalt and pervious concrete cannot be ordered in small quantities

DESIGN AND SIZING

- Slowly draining soils need an underdrain to convey excess downstream
- Restricted to lower-volume parking/traffic areas with low axle loads and pollutant loads
- Not feasible in areas with less than two feet to depth to groundwater or bedrock
- Can occupy any area but sub-base depth affects depth of rainfall stored
- Permeable/porous paving systems should be installed last to minimize premature clogging from construction sediment

SYSTEM TYPES

Permeable paving consists of various paver configurations, porous asphalt, and pervious concrete

Permeable Pavers. This pavement is created by using impermeable blocks of brick, stone, or concrete laid out in a grid with permeable sand or gravel installed in the voids between the blocks. This design allows rainfall to move between the blocks and percolate into the underlying soil.		
Porous Asphalt. This pavement looks similar to traditional roadway and parking lot pavement but it is coarser looking with less stone to increase void space.		
Pervious Concrete. This pavement also looks similar to traditional concrete pavement but it is made with less aggregate that allows for a permeable surface.		
Pervious Concrete Slabs. These slabs are manufactured off-site under controlled conditions to ensure good quality control then delivered to the site. They are installed over the sub-base using a backhoe and can be removed for future maintenance and/or replacement.		

MAINTENANCE

Needs routine cleaning with proper vacuum-assisted street sweeper.
Requires stringent sediment control plan for the contributing drainage area.
Significantly limit the use of salt and sand during winter months to prevent clogging.
Inspect annually for deterioration and after storms to ensure surface is draining properly.

COSTS

Porous pavement typically costs more than conventional pavement due to the sub-base which costs $3-$5 per square foot. The porous asphalt surface layer is similar in cost to conventional pavement. Pervious concrete and permeable pavers are more costly, typically about $9-$15 per square foot. The additional costs for paving are partially offset by the need for less infrastructure features and 75% less salting.

Rainwater Harvesting / Storage

DESCRIPTION

Rainwater harvesting / storage systems can be designed to capture and store runoff for future reuse or to reduce peak flows. Rain barrels, above-ground cisterns, and underground tanks are large sealed containers that retain rooftop runoff for non-potable reuse purposes such as for landscaping and car washing. Rooftop runoff is directed to these systems and can be retrieved from the tanks by gravity or by pressure pumps. When combined with a flow-control valve, these systems can also be used for reducing peak flows.

APPLICABILITY

Storage systems are excellent retrofit options for urban areas like Chelsea because they require minimal space and can be used on residential, commercial, and industrial sites. These systems are applicable to homes or buildings with existing gutters and downspouts that can be re-directed into the tanks. In flow-controlled systems designed to reduce peak flows, runoff to the downstream drainage and combined sewer systems can be reduced during larger storms.

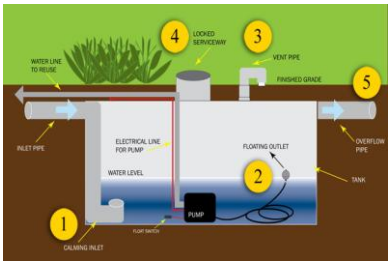
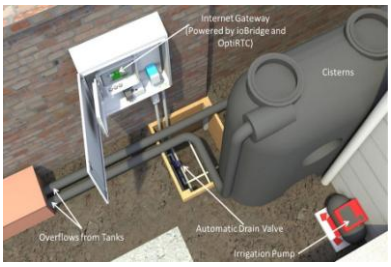
Benefits	WATER: Can be used to water plants when combined with an irrigation system
	WATER: Reduced runoff volume to conventional stormwater facilities, especially with flow-control valve
	WATER/ENERGY: Water reuse reduces demand for water supply and lowers water bills
	COMMUNITY/HABITAT: Requires very limited space so it is suitable for retrofits in urban areas
Limitations	No direct pollutant removal benefits
	Must be sealed from mosquitoes and for child safety
	Requires an overflow mechanism to bypass larger storms
	Retains only a portion of the tank volume if not emptied prior to a storm (without flow-control valve)

DESIGN AND SIZING

- Storage is sized for the rooftop surface area and the rainfall depth to be captured
- Household rain barrels are 50-100 gallons
- Cisterns and underground tanks can be thousands of gallons
- First-flush diverter required with some metal roofs
- Leaf litter and other trash must be captured with a sieve

SYSTEM TYPES

Storage systems include rain barrels, above-ground cisterns, and underground tanks.

Rain Barrels. Rain barrels are small, plastic barrels (50-100 gallons) used to store some of the roof runoff delivered via available downspouts. Banks of rain barrels can be used to create additional storage or elevated to improve gravity flow. The water can be used to irrigate small areas.		
Above-Ground Cisterns. Cisterns are large plastic or concrete tanks (1,000-5000 gallons) designed to store most of the roof runoff. Some of these systems are used for potable water supply in dry areas. Gravity flow or a pump is used to deliver the water to the house or garden.		
Underground Tanks. These tanks are large reinforced plastic, concrete, or membrane-lined tanks (5,000-20,000 gallons) designed to store roof runoff. These systems can be used for potable water supply in dry regions or for irrigation of large garden areas using a pump.		
Flow-Control Valves. Manual or electronic valves can be used to control storage. In areas prone to flooding and combined sewer overflows, these valves can be used to harvest the peak flow and reduce downstream runoff.		

MAINTENANCE

Plan use of stored water to allow room to capture rainfall from the next storm event.
Regularly inspect gutters/downspouts for clogging to ensure that water enters the tank.
Regularly inspect diverter/sieve for clogging to ensure that water makes it to the tank.
Tank should be left with the drain open for the winter months to prevent ice damage.

COSTS

The installed price ranges from $2-3 per gallon for small tanks to $1-2 per gallon for large tanks. Underground tanks cost more because of the excavation cost. Flow-control valves are an additional cost.

Infiltration

DESCRIPTION

Infiltration practices capture and store stormwater in order to allow runoff to infiltrate into the sub-soil and ultimately recharge the groundwater. Water is stored above the ground surface, in void spaces between gravel and stone, or in underground chambers. Above-ground practices use basins and trenches while sub-surface systems use chambers or dry wells. These systems typically do not offer the same aesthetic benefits as some other practices as they are generally not landscaped with vegetation, however, they are generally less intrusive than detention ponds.

APPLICABILITY

Infiltration practices can be sized to accept runoff from any drainage area. Pre-treatment using grass swales, filter strips, sediment forebays, or sediment basins is usually necessary so that the downstream infiltration system does not clog. Infiltration practices provide highly-effective peak flow control, pollutant reduction, and have the added benefit of groundwater recharge. These systems are not suitable for areas with poorly-drained soils or high groundwater elevations that are commonly encountered in Chelsea.

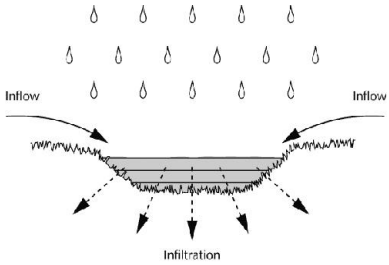
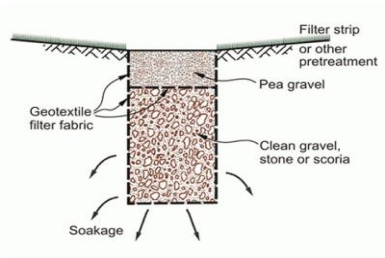
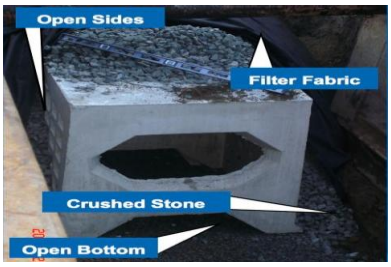
Benefits	WATER: Temporary storage helps reduce local flooding and combined sewer overflows
	WATER: Maintains the natural water balance of site by promoting infiltration and recharge
	WATER: Reduces the need for stormwater management structures downstream
	WATER: Good improvement in stormwater quality through infiltration and filtering
Limitations	Requires fast-draining soils and no water table limitations to infiltrate stored water
	Frequent maintenance required to remove any accumulated sediment
	Higher failure rate than other practices as it needs pre-treated runoff to maintain functionality
	Potential for groundwater contamination if not properly sited or pre-treated

DESIGN AND SIZING

- Sized for any drainage areas for small to large storm events
- Needs adequate depth to groundwater or bedrock (2 feet minimum) from bottom of system
- Needs highly permeable soils (class A or B) with a maximum site slope of 15%
- Drywells are only used for roof runoff with no pre-treatment required
- Limited applicability on brownfield sites or where groundwater contamination is a concern

SYSTEM TYPES

Infiltration practices are above-ground basins and trenches or below-ground chambers and drywells.

Infiltration Basins. These above-ground basins are excavated in fast-draining soils to create a temporary impoundment that allows for excellent infiltration and groundwater recharge.		
Infiltration Trenches. These trenches are shallow to deep excavations filled with stone to provide storage and infiltration into the sub-soil. These systems are practical for areas with limited space.		
Underground Chambers. These systems store runoff in the underground chamber and the surrounding gravel fill prior to gradually infiltrating the stored water into the sub-soil.		
Dry Wells. These wells are usually small underground pits filled with stone to infiltrate the uncontaminated runoff from roofs. Runoff is directed to wells via gutters and downspouts. These systems are feasible for retrofit projects. The overflow can be directed downstream.		

MAINTENANCE

Semi-annual inspection for erosion, sediment build up, and proper drainage.
Inspection following construction and after major storm events, or at least annually.
Direct access, like observation wells, should be provided for inspection and maintenance.
Remove excess sediment, repair eroded areas, and replace top few inches of soil.

COSTS

Costs for infiltration systems vary widely depending on site constraints and design options. Infiltration basins are typically the most cost effective. Infiltration trenches are usually in the range of $20-$30 per square foot. Underground chambers typically cost about twice as much as infiltration trenches.

Green / Blue Roof

DESCRIPTION

Green rooftops convert what is typically an impervious surface into a stormwater system that allows the rooftop runoff to be slowed down and cleaned before it enters the existing drainage system. Vegetated roof systems capture rainfall in an engineered drainage blanket using layers of vegetation and soil. Non-vegetated "blue" rooftop practices are designed to detain water providing temporary storage and evaporation. Both of these rooftop systems provide storage and detention to reduce peak flows and volume and provide some additional filtering of pollutants.

APPLICABILITY

Alternative roof systems can be used on many types of buildings, particularly those with a large surface area and a gentle slope. Roof systems are applicable in Chelsea where there is limited available land space and where infiltration practices are often restricted. Green and blue roofs both reduce and detain rooftop runoff thus minimizing the peak flows to downstream drainage and combined sewer systems that can be over-burdened during large storm events.

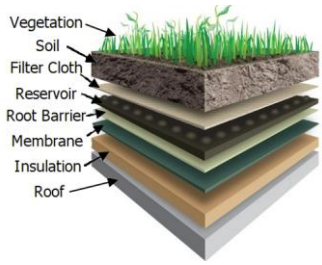
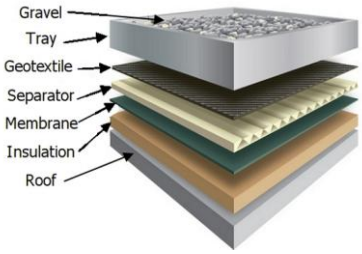
Benefits	WATER: Green and blue rooftops reduce stormwater peak flow rate and runoff volume
	WATER: Green roofs provide additional pollutant removal through uptake and filtering
	ENERGY/ENVIRONMENT: Green roofs have a longer lifespan than traditional roofs and reduce energy consumption
	COMMUNITY/HABITAT: Green roofs require no additional space and provide wildlife habitat and aesthetic value for residents
Limitations	No recharge benefits result from any rooftop system
	Blue roofs require almost flat rooftops
	Green roofs generally require slope less than 20%
	Load restrictions can limit applicability for retrofit projects

DESIGN AND SIZING

- Captures and stores the rainfall in the soil or stone matrix
- Requires an adequate drainage system and possible backup drain for excess water
- Roof loading capacity must be verified by a structural engineer
- Needs a high-quality impermeable barrier to prevent leakage problems
- Extensive versus intensive system depends on the projected public access to the facility

SYSTEM TYPES

Green roofs are vegetated systems that capture and filter rainwater using a soil medium. Blue roofs are non-vegetated systems designed to retain and store water without soil.

Green Roofs. These roofs convert rooftops into green space and manage stormwater while providing aesthetic and environmental benefits. Green roofs have vegetation, soil, and an underdrain to provide runoff storage, nutrient uptake, pollutant attenuation, and reduced runoff volume through evaporation.		
Extensive Green Roofs. These systems are shallow, large-area, vegetated roof systems. These green roofs are vegetated with low, drought-tolerant plants in less than 6 inches of soil. These systems are designed for functionality and not for public access.		
Intensive Green Roofs. These practices are deep, planter-type vegetated roof systems. These roofs hold more than 6" of soil and are able to support a diversity of vegetation including shrubs and small trees. These systems are typically designed for public access.		
Blue Roofs. These rooftop systems temporarily store water utilizing storage and control devices (trays, check dams, or outlet restrictions). Direct evaporation provides some runoff volume reduction. These effects reduce the peak flows to the existing drainage system.		

MAINTENANCE

Inspect the underlying roof materials regularly for water-tightness, deterioration, and cracks.
Inspect and/or clean the drainage pipes to ensure the system drains properly.
Water the entire landscape during establishment (all green roofs).
Periodically maintain the landscape by weeding and mulching (intensive green roofs only).

COSTS

Green roofs cost more than traditional roofs, ranging in cost from about $10 to $15 per square foot whereas conventional asphalt shingles run about $1 per square foot. However, green roofs have a long life and decrease building energy consumption. Blue roofs are less costly and more versatile but lack the additional benefits of green roofs.

Non-Structural Practices

DESCRIPTION
Non-structural green infrastructure practices refer to design strategies that limit and reduce the impacts of development/redevelopment on the local environment. Development projects typically increase pollutant/sediment loads and volumes of runoff leaving sites. Incorporating these non-structural practices into site design reduces runoff volume and enhances the quality of runoff, limiting the need for expensive structural systems to manage the effects of development.

PRACTICE TYPES

Practice	Benefits	Implementation Suggestions
Open Space Preservation	• Reduces impervious area and associated runoff while enhancing aesthetic value	• Require green and or/ green space for development projects • Define open and/or green areas before performing site layout
Encourage Natural Landscaping	• Mimicking pre-development land cover and topography encourages infiltration and use of natural vegetated spillways • Minimize steep slopes that can cause erosion and increased sediment loading	• Maintain pre-development vegetation • Minimize creation of steep slopes • Maintain natural buffers and drainage ways to carry runoff
Reduce Impervious Cover	• Since runoff is mainly generated from precipitation falling on impervious surfaces, limiting impervious area reduces the volume of runoff that must be managed • Impervious surfaces allow direct transport of pollutants and sediment over the land surface	• Reduce roadway, sidewalk, and driveway widths • Reduce parking lot area by minimizing space requirements and using landscape islands • Encourage shared parking for buildings and driveways • Use porous/permeable paving where feasible • Replace asphalt in school yards with fields
Street Sweeping	• Reduces sediment and debris making their way into the stormwater system	• Be sure to sweep entire street width as sediment builds close to the curb • Sweep at least every month and immediately following snowmelt

Opportunities for Encouraging Green Infrastructure Practices

The multiple benefits of green infrastructure can be achieved by incorporating green infrastructure practices and approaches into new development, redevelopment, and municipal projects. During the project review that most Boards use to evaluate projects, the most important questions to ask are:

How can new or existing impervious cover be reduced?
How can direct connection of impervious cover to storm drains be prevented?
What kind of green infrastructure practices can be used on the site?
What are the costs and benefits associated with green infrastructure practices?

Role of Boards and City Departments in Project Review

City Departments, as well as the land use and environmental City Boards, play a role in the review of permits for new and redevelopment projects. The following diagram (Figure 4) illustrates the jurisdiction of City Departments and Boards in the review of different types of projects. The Inspectional Services Department (ISD) and other City Departments also review projects that need special permits, variances, and site plan review by the Planning Board.

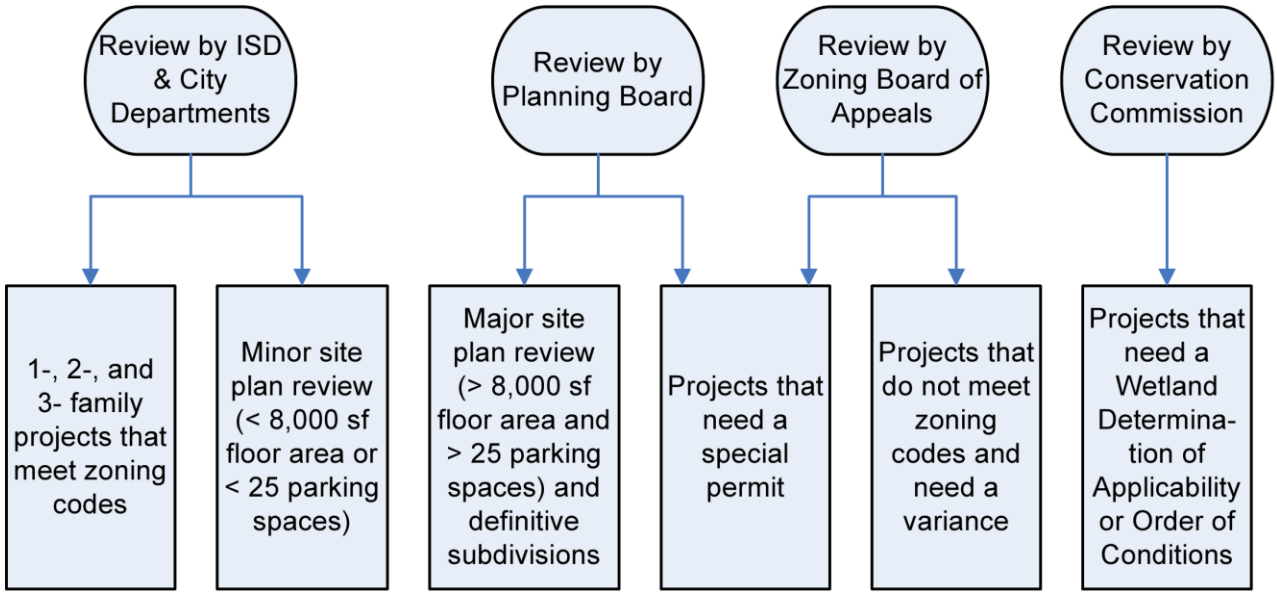


Figure 4. Jurisdiction of City Departments and Boards over Projects

Green Infrastructure Suitability and Performance

Not all green infrastructure practices are suitable for all sites. Table 1 gives a guide that Boards can use to evaluate what practices can be introduced under differing site conditions.

Table 1. Green Stormwater Infrastructure Suitability Matrix

Stormwater Practice	Flood Control	Infiltration	Filtering	Storage	Open Space	Reuse
Rainwater Harvesting	Y	N	N	Y	N	Y
Infiltration Practices	Y	Y	Y	Y	Y	N
Pervious Pavement	Y	Y	Y	Y	N	N
Raingardens	N	Y	Y	N	Y	N
Bioretention	N	N	Y	N	Y	N
Planters / Tree Filters	N	N	Y	N	Y	Y
Green Roofs	Y	N	Y	Y	Y	Y
Swales	N	Y	Y	N	Y	N

Green infrastructure practices have varied performance and while upfront construction costs might be more expensive than traditional costs, their true performance cost is almost always less than conventional practices. Figure 5 gives an indication of cost effectiveness[1] for phosphorus removal by green infrastructure practices compared to conventional practices (last three on the right). For most stormwater practices, runoff volume reduction is highly correlated with pollutant removal.

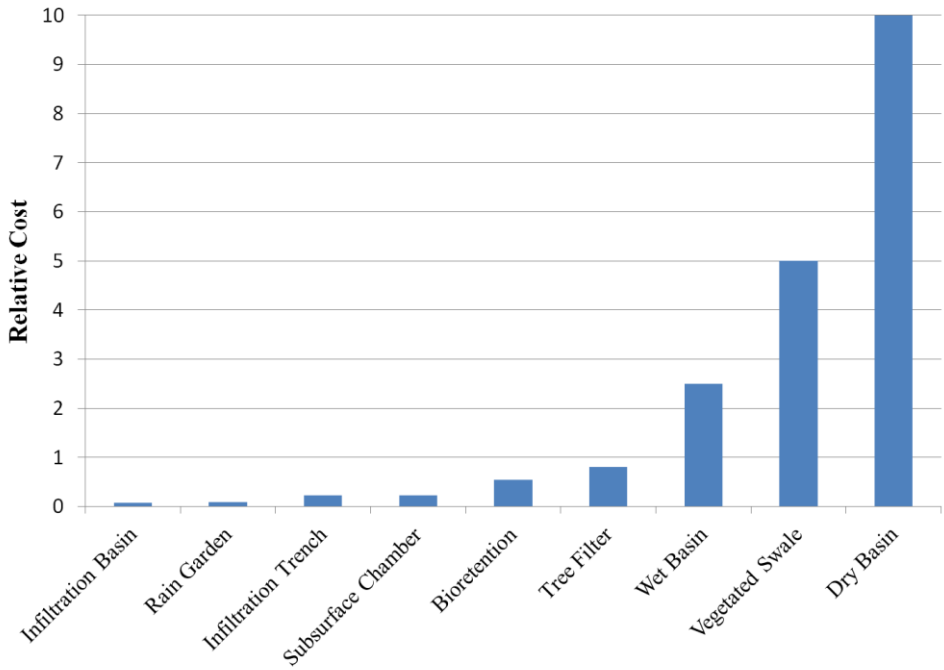


Figure 5. Example of Green Infrastructure Cost Effectiveness for Phosphorus Removal

[1] Cost effectiveness for sediment and metal removal, as well as runoff volume reduction, should have similar trends.

Example Projects

To illustrate how and where green infrastructure could be used, we retrospectively applied green infrastructure practices to two projects implemented in the City of Chelsea. The first is a small scale project that involved a "change of use" requiring the installation of additional parking and a review of the drainage by the Department of Public Works for connection into the City's drainage system. The second is a large scale project involving a major residential development that required a comprehensive review by the City's Boards and staff. In each case, the Approved Plan that was reviewed and approved by the City of Chelsea is shown, and then an Alternative Plan is presented to illustrate possible green infrastructure measures that could have been incorporated into the design. The suggested green infrastructure practices in the Alternative Plans are offered as potential options based on an initial review of the Approved Plans. Not all of the suggested measures will be possible or practicable depending on site-specific environmental or budgetary constraints. Furthermore, constraints such as high groundwater or prior soil contamination would influence practice selection and design considerations.

Project #1: 242 Everett Avenue

The site modifications at 242 Everett Avenue in Chelsea are fairly typical of many of the smaller site modifications that occur in Chelsea. The Approved Plan (see Figure 6) resulted in expanded parking, a wider driveway, and the installation of a bioretention area to offer some stormwater treatment. Adding additional parking spots and widening the existing driveway added impervious area to the small site. The bioretention area was designed to manage storms between the 0.5" and 1" rainfall with a drain to convey overflows to the existing City operated combined sewer system. The existing property prior to the modifications is shown in Figure 7.

Figure 7. Street View for Approved Plan at 242 Everett Avenue

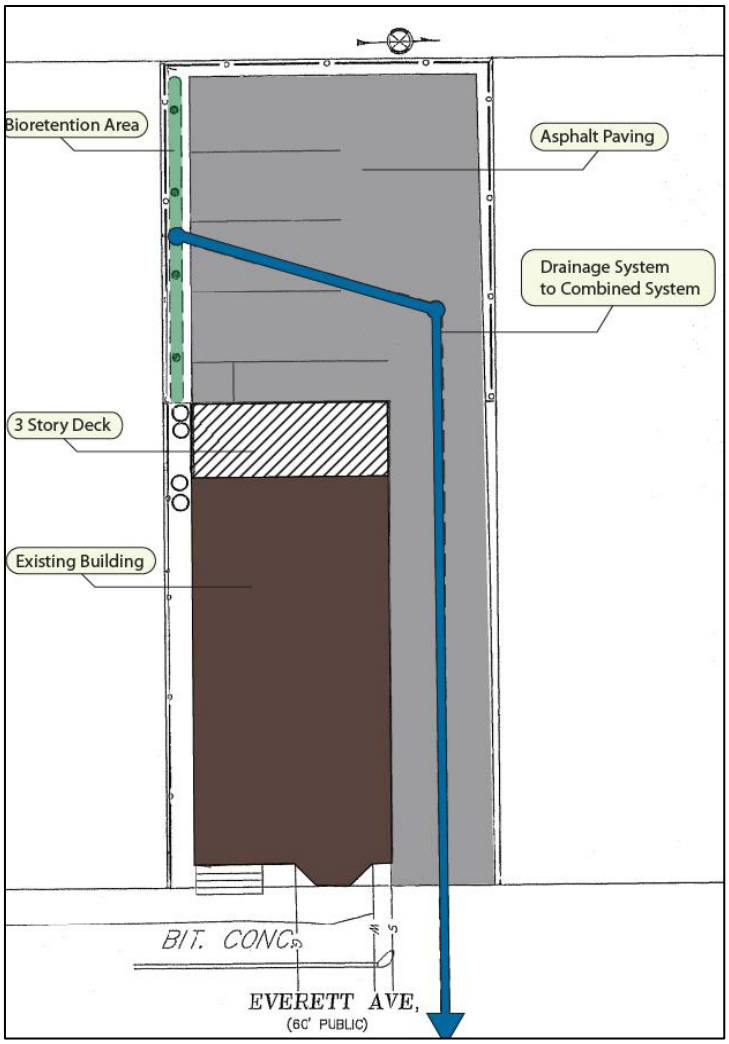


Figure 6. Existing Approved Plan for 242 Everett Avenue

With fairly modest changes to the Approved Plan design, the project could have implemented a few additional practices that would have benefited both the owner and the City (see "Benefits" discussion). These green infrastructure inspired modifications are illustrated in Figure 8.

Possible Green Infrastructure Modifications to the Approved Plan

The suggested green infrastructure elements include:

<u>Reducing driveway width from 11.9 feet to 10.9 feet:</u> The building had an external stairwell, constricting the existing driveway to 9.3 feet. Instead of using the full width of the drive, a one-foot wide planter is offered; this option still increases the drive width but results in reduced impervious area.

<u>Providing a one-foot wide planter at two levels along driveway:</u> The planter area could be split into two separate planters: One planter is proposed at grade to provide treatment for the beginning of the driveway and the second raised planting bed provides treatment for the rooftop downspout; both are sized to manage the 1" storm event.

<u>Connecting planters to the drainage system:</u> The overflow from the raised planter would discharge into the first planter. An overflow drain would convey larger storms to the storm drain system.

<u>Substituting porous asphalt for conventional asphalt in the parking area:</u> Porous asphalt could be used in the area of the parking spaces and turnaround area. The use of porous asphalt reduces the size of the originally proposed bioretention area, while also reducing impervious cover. The bioretention area would still be sized to treat the remaining impervious area of the driveway for the 1" storm event.

<u>Installing a rain barrel in the rear to collect rooftop runoff:</u> A rain barrel is also suggested as a way to ensure the bioretention area and planters can be easily watered during dry weather periods.

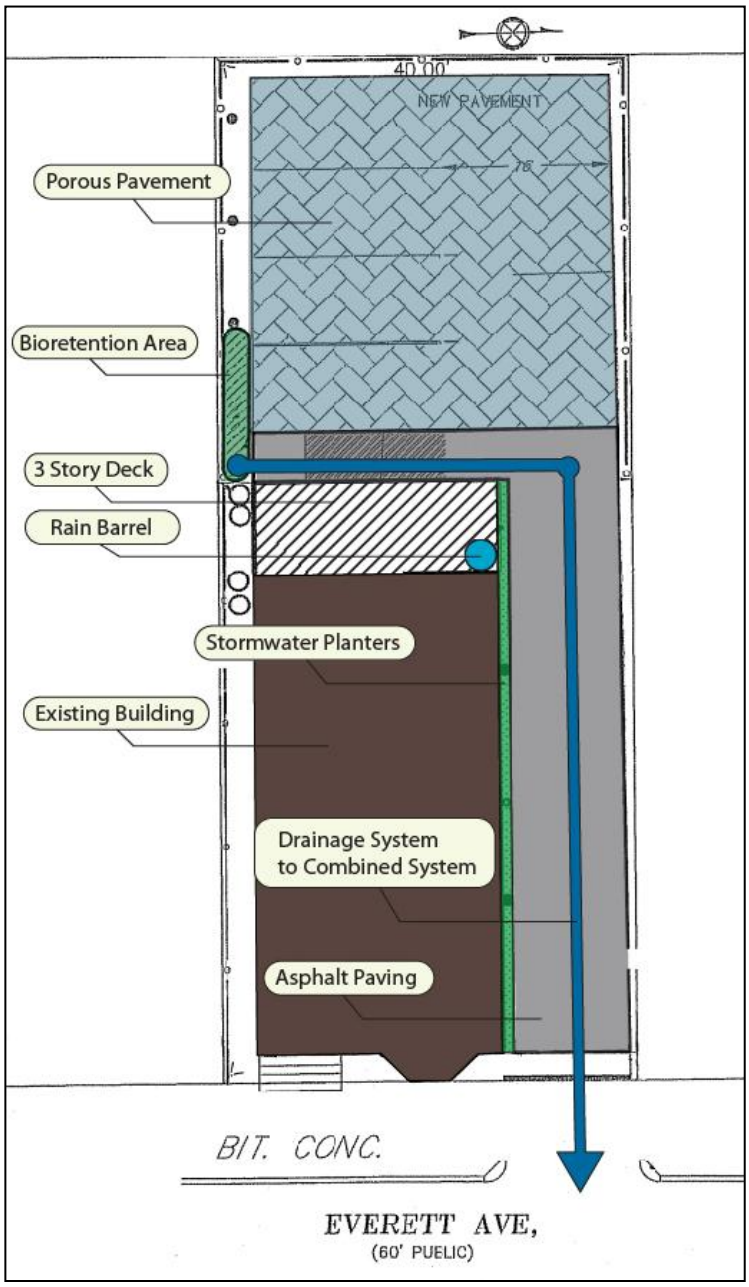


Figure 8. Alternative Plan for 242 Everett Avenue with Green Infrastructure Measures

Results, Benefits and Costs

The bioretention and planters provide for 78% reduction in annual runoff volume from an 830 square foot drainage area, while the permeable pavement provides for an 89% reduction in annual runoff volume from a 1,210 square foot area.

Overall, the Approved Plan increases impervious cover of the site from the existing 72% to 92%. With the green infrastructure suggestions in the Alternative Plan, there would be a decrease in impervious cover to 62% of the site.

The Alternative Plan in Table 2 offers additional benefits besides reducing the quantity and improving the quality of urban runoff. These are described in the box below:

Table 2. Benefit Assessment of Alternative Plan for 242 Everett Avenue

Description of Benefit	Category of Benefit	Beneficiary
• A reduction in imperviousness lessens the volume of runoff generated, which in turn helps relieve the strain on the aging combined sewer system.	Water	City and Owner
• Using more vegetative-based practices will result in increased evapotranspiration rates, better shading, introduction of micro-climates, and reduced summer temperatures.	Energy and Environment	City and Owner
• Increased landscaping can beneficially influence property values and the general well being of residents.	Community	City and Owner
• Increased landscaping also offers more habitat for wildlife such as birds and butterflies, thus improving biodiversity in an urban environment.	Habitat	Owner
• Planters allow for urban gardening opportunities.	Community	Owner
• Progressive site designs offer opportunities for an increased general awareness of environmental issues and better understanding of the linkage between urban environmental impacts and cleaner water.	Environment	City

The approximate cost differential between the Approved Plan and the Alternative Plan with green infrastructure suggested modifications is quantified in Table 3 below. Although the upfront costs of the Alternative Plan are higher, the benefits and lower life-cycle costs of green infrastructure should also be considered.

Table 3. Cost Comparison for 242 Everett Avenue
Approved Plan versus Alternative Green Infrastructure Approach

Approved Plan		**Alternative Plan**	
Practice	**Approx. Costs**	**Practice**	**Approx. Costs**
Bioretention	$2,500	Bioretention	$900
Asphalt Paving	$3,800	Porous Asphalt	$12,100
Drainage	$500	Planter	$2,000
Infrastructure		Rain Barrel	$200
Total Approx. Cost	$6,800		$15,200
Approx. Cost Differential			$8,400

Project #2: One Webster Avenue and Spencer Row

One Webster Avenue is a major infill project with 120 apartments and 5,000 square feet of retail space completed in 2011. Spencer Row is a 32-unit affordable housing development completed in 2010. The buildings, parking, and stormwater management plans for both of these projects are fairly typical of larger-scale redevelopment projects in the City of Chelsea. The Approved Plans (Figure 9) consist of two building structures, including residential and retail uses with accompanying parking. The stormwater management measures included a conventional enclosed drainage system, proprietary water quality treatment units using two technologies, and a large underground detention system. The site also had some contamination from the prior historical uses on the property that limits the allowable uses and potential for contact with underlying soils. This limitation would impact the selection and design of green infrastructure practices. The Approved Plan of the project is shown below as a birds-eye view in Figure 10.

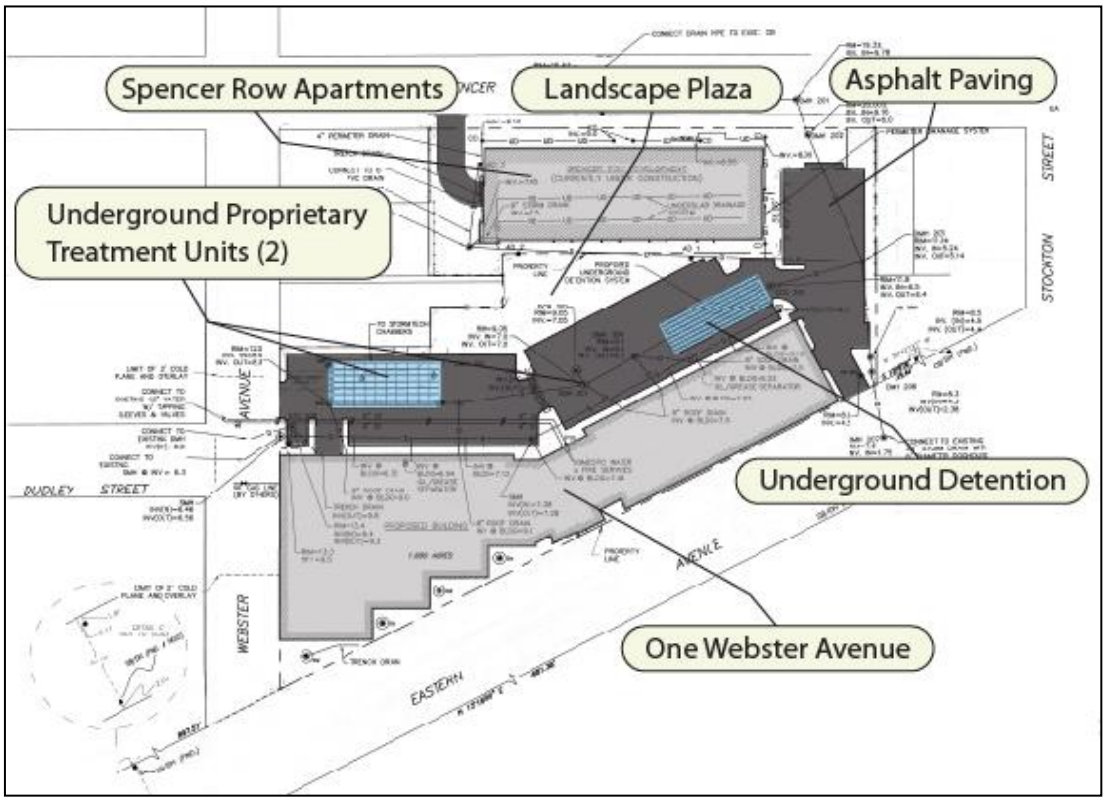


Figure 9. Existing Approved Plan View for One Webster Avenue and Spencer Row

With modest changes to the Approved Plans, the projects could have implemented an alternative stormwater approach that would likely have benefited the developers as well as the project residents and the City. These green infrastructure inspired modifications are shown in Figure 11.

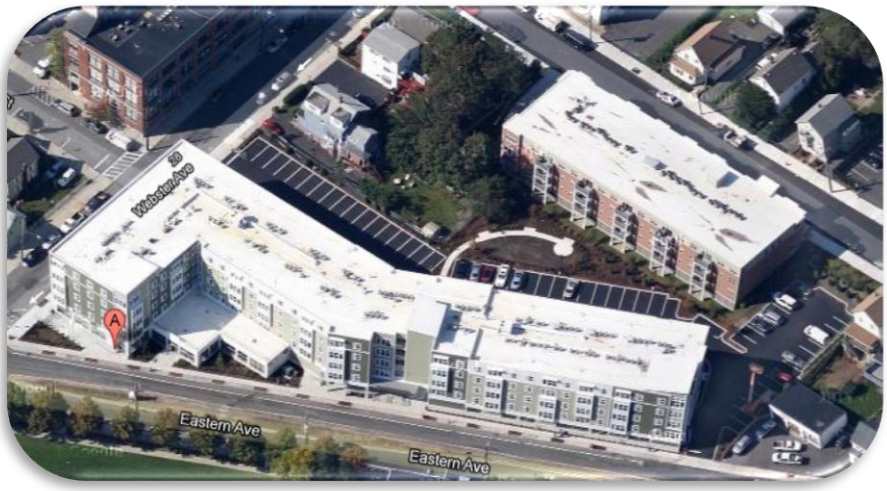


Figure 10. Birds-eye View for Approved Plan at One Webster Avenue and Spencer Row

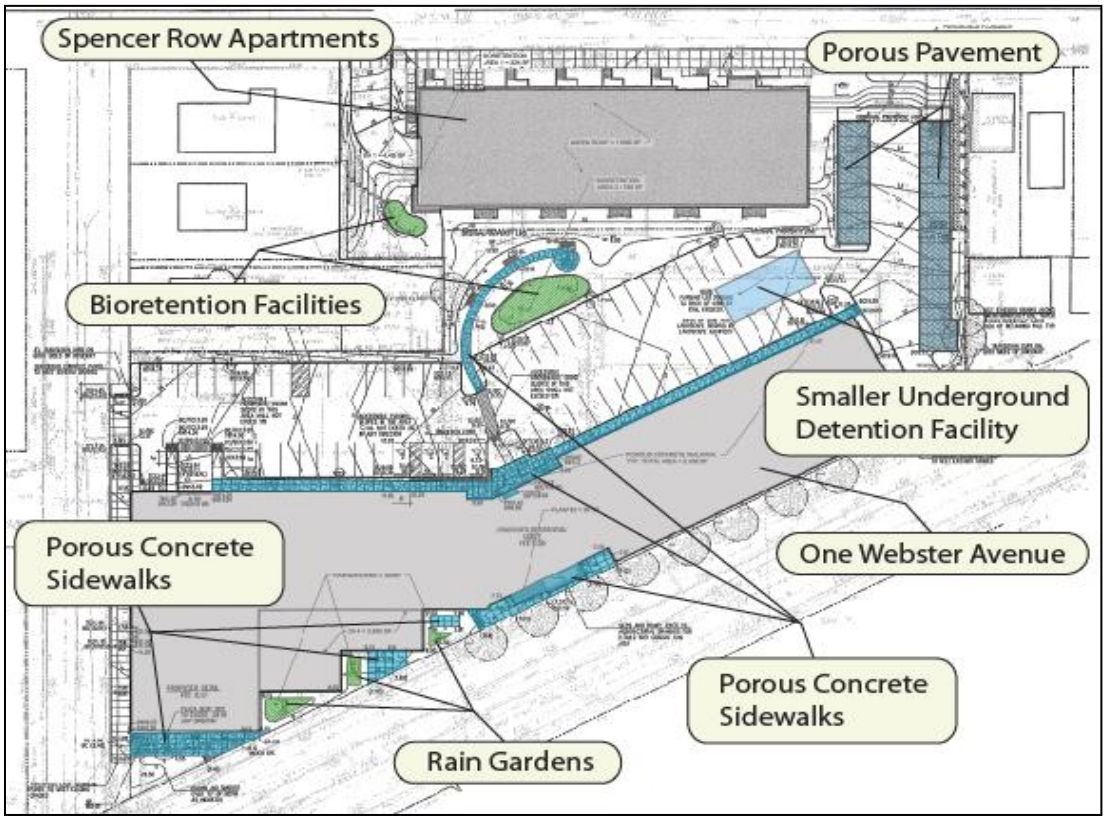


Figure 11. Alternative Plan for One Webster Ave/Spencer Row with Green Infrastructure Measures

Possible Modifications to the Approved Plan

The suggested green infrastructure elements include:

Substituting porous pavement for conventional asphalt for a limited number of parking spaces: Approximately 2,900 square feet of porous pavement could have been used in the area of the northern parking spaces to reduce impervious cover. In this location, permeable pavement is only proposed for the parking spaces themselves, as the drive aisles will likely see higher traffic volumes and consequently would be more likely to clog in the future. Prior contamination was deemed to be "not hydraulically mobile" so a limited increase in infiltration in this area would be appropriate.

Substituting porous concrete for conventional concrete for internal sidewalks and plazas: Porous concrete is proposed for all the new internal sidewalks and walkways. This approach would reduce impervious cover. A range of permeable products are appropriate for walkways and plaza areas and can easily be maintained to help reduce runoff. Permeable surfaces require less sand/salt for deicing and would likely result in safer pedestrian surfaces. The porous concrete would total around 3,500 square feet. Of note is that the external sidewalks on Eastern Avenue, Webster Avenue and Spencer Avenue are on public property. The funding for the sidewalks on Eastern Avenue and Webster Avenue, as shown on the Approved Plan, was paid for by a MORE grant from the Commonwealth of Massachusetts. Funding for a porous concrete walk might have exceeded the grant and therefore is not presented as an option on these streets.

Providing three small rain gardens to manage the small rooftop area at the entrance of Eastern Avenue: Three small rain gardens, totaling approximately 325 square feet, are suggested at the Eastern Avenue entrance to the One Webster Avenue building. These facilities could have been incorporated into the building landscaping and would have provided additional treatment for rooftop runoff from the small rooftop area located at the building entrance.

Providing a bioretention facility to manage a majority of the internal site area: A 780 square foot bioretention area is suggested for the central location in the area of the walkway and landscaping, as shown on the Approved Plan. This facility would be sufficient to treat the 0.5" storm from the majority of the parking lot. An overflow device would convey larger storms to the underground detention facility.

Providing a bioretention facility to manage the driveway and some rooftop area at Spencer Row: A second bioretention area of 225 square feet is suggested for the adjacent Spencer Row development and would be sized to treat runoff from the driveway and a portion of the roof top. This facility could be connected via an overflow device and piping to the first bioretention area.

Results, Benefits and Costs

The central bioretention area would provide a 58% reduction in annual runoff volume for a drainage area of approximately 23,600 square feet. The Spencer Row bioretention area and the rain gardens would provide 78% reduction in runoff volume for a drainage area of approximately 4,500 square feet. The permeable pavement and porous concrete would result in an 89% reduction in volume for an area of approximately 6,400 square feet. The green infrastructure suggestions in the Alternative Plan would result in a decrease in impervious cover from 80% to 73% at the two sites.

As noted above, these two projects were developed separately by separate developers. The timing of installation of green infrastructure practices is critical to their success. Since many green infrastructure practices rely to some degree on infiltration, developers have to maintain and City reviewers have to require strict erosion and sediment controls during construction. It is also important to sequence the installation for the later stages of construction to avoid clogging with construction sediments and debris. Projects such as these would need to clearly define the timing and conditions for installation.

The Alternative Plan in Table 4 offers additional benefits besides reducing the quantity and improving the quality of urban runoff. These benefits are described below:

Table 4. Benefit Assessment of Alternative Plan for One Webster Avenue and Spencer Row

Description of Benefit	Category of Benefit	Beneficiary
• By using bioretention areas, permeable pavement, porous concrete, and rain gardens, the stormwater management system is positioned at the ground surface. These above-ground systems are easier to maintain than underground ones and due to their high visibility are much more likely to be properly maintained, thus reducing risk of failure.	Water	City and Owner
• A reduction in imperviousness lessens the volume of runoff generated, which in turn helps relieve the strain on the aging combined sewer system.	Water	City and Owner
• Using vegetative-based practices will result in increased evapotranspiration rates, better shading, introduction of micro-climates, and reduced summer temperatures.	Energy and Environment	City and Owner
• Increased landscaping also offers more habitat for wildlife, such as birds and butterflies, thus improving biodiversity in an urban environment	Habitat	Owner
• Because this site is close to the Mary C. Burke Elementary School complex, there is an excellent educational opportunity to teach both Chelsea school children and the building residents about sustainable design.	Community	City
• The integration of a surface stormwater management system with site landscaping can save money and offers the combined benefits of increased awareness, a pleasant urban landscape, and perhaps more valuable housing.	Community	City and Owner

The approximate cost differential between the Approved Plan and the Alternative Plan with green infrastructure is indicated in Table 5 below. In this case, the upfront costs of the Alternative Plan are lower even without the considering the benefits and lower life-cycle costs of green infrastructure.

Table 5. Cost Comparison for One Webster Avenue and Spencer Row Approved Plan versus Alternative Green Infrastructure Approach

Approved Plan		**Alternative Plan**	
Practice	**Approx. Cost**	**Practice**	**Approx. Cost**
Landscaping	$15,000	Bioretention	$25,000
Asphalt Paving	$6,000	Porous Pavement	$29,000
Concrete Sidewalks	$30,000	Rain Gardens	$5,000
Stormceptor & Underground Stormwater Facility	$160,000	Porous Concrete	$53,000
		Underground Stormwater Facility	$80,000
Total Approx. Cost	$211,000		$192,000
Approx. Cost Savings			$19,000

The ideas presented here are some reasonable modifications that could have been made to the traditional site development to incorporate green infrastructure practices into the site design. Additional options for the site at One Webster Avenue and Spencer Row range from easily implemented modifications, such as adding planters around the buildings for rooftop runoff management, to installing a green roof on part or all of the buildings. While the initial capital costs for the green infrastructure designs might be higher, consideration of the benefits and the long-term life cycle costs could lower the net long-term cost of the green infrastructure plans.

References, Links, and Credits

References

Massachusetts Department of Environmental Protection (MA DEP). February, 2008. *Massachusetts Stormwater Handbook*. Revised and updated in accordance with revisions to the Wetlands regulations, 310 CMR 10.00, and the Water Quality Regulations, 314 CMR 9.00, relating to stormwater. http://www.mass.gov/dep/water/laws/policies.htm#storm

Rhode Island Department of Environmental Management (RIDEM) and Coastal Resources Management Council (CRMC). December, 2010. Rhode Island Stormwater Design and Installation Standards Manual. http://www.dem.ri.gov/pubs/regs/regs/water/swmanual.pdf

Links

http://water.epa.gov/infrastructure/greeninfrastructure

http://www.esf.edu/outreach/gi

http://ww.greeninfrastructure.net

http://www.cwp.org/your-watershed-101/stormwater-management.html

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