Green Infrastructure Toolbox

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2017

ABOVE
Oktibbeha County Heritage Museum
Starkville, MS
Image: Allen Engineering and Science

FRONT & BACK COVER
Oktibbeha County Heritage Museum
Starkville, MS
Image: Allen Engineering and Science

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1.0
GREEN INFRASTRUCTURE OVERVIEW

1.1 Introduction

As the nation's grey infrastructure is aging and many communities face expensive repairs or replacements, national policies are encouraging the use of green infrastructure. This chapter will explore green infrastructure practices for stormwater management.

1.2 What Are the EPA National Stormwater Policies Regarding Green Infrastructure?

One of the most basic objectives of the Clean Water Act (CWA) is to manage nonpoint source pollution and reduce pollutants carried by stormwater and discharged into our nation's waters. The United States Environmental Protection Agency (EPA) strongly encourages the use of green infrastructure and related innovative technologies, approaches, and practices to manage stormwater as a resource, reduce sewer overflows, enhance environmental quality, and achieve other economic and community benefits. Many cities and communities in the United States are now employing green infrastructure practices and recognize the value of such projects to not only protect water resources, but also to bring opportunities for greenways and multi-use recreational areas, thus improving property values, saving energy, and creating green jobs.

The EPA has published several policy memorandums regarding the integration of green infrastructure into federal regulatory programs. These policy memorandums include:

- *Achieving Water Quality through Integrated Municipal Stormwater and Wastewater Plans. October 27, 2011.*
- *Protecting Water Quality with Green Infrastructure in Water EPA Permitting and Enforcement Programs. April 20, 2011.*
- *Use of Green Infrastructure in NPDES Permits and Enforcement. August 16, 2007.*
- *Using Green Infrastructure to Protect Water Quality in Stormwater, CSO, Nonpoint Source, and other Water Programs. March 5, 2007.*

These policy memorandums reveal the EPA's desire for states to incorporate green infrastructure language into permit requirements. In developing the new Small Municipal Separate Storm Sewer System (MS4) General Permit, the Mississippi Department of Environmental Quality (MDEQ) encourages permittees to utilize green infrastructure approaches, where appropriate, in lieu of more traditional controls.

1.3 What Are the MDEQ State Stormwater Regulations Regarding Green Infrastructure?

The MDEQ worked closely with the EPA to update the statewide Phase II Municipal Separate Storm Sewer System (MS4) Phase II General Permit on March 18, 2016. The MS4 Phase II General Permit requires each regulated entity to prepare a Stormwater Management Plan (SWMP) and submit it to the state for review and approval. Keeping with the wishes of the EPA, the MDEQ added the following language in the MS4 General Permit that promotes green infrastructure:

ACT5(4)(B)

…MDEQ strongly recommends adopting ordinances to promote and encourage the implementation of non-structural BMPs [Best Management Practices], including Low Impact Development (LID) and Green Infrastructure (GI).[1]

ACT5(5)(E)

Develop site design standards for all new and redevelopment projects and require, in combination or alone, management measures that are designed, built and maintained to infiltrate, evapotranspire, harvest and/or use, at a minimum the first inch of every rainfall event preceded by 72 hours of no measurable precipitation. For all new and redevelopment on the private property, the MS4 may opt to have controls installed on that private property, in the public right-of-way, or a combination of both. Post-construction BMPs would include, but are not limited to: grass swales (Vol. 1, Ch. 4, pg. 162) for runoff conveyance, filter strips (Vol. 1, Ch. 4, pg. 261) and bioretention systems for filtration of sediment (Vol. 2, Ch. 1, pg. 14), runoff control using dry/wet retention/detention basins, and buffer zones for stream protection (Vol. 2, Ch. 1, pg. 25). Please refer to the Mississippi Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas for more information.[1]

ACT5(5)(C)

Within one year of obtaining permit coverage, the permittee shall review local codes and ordinances. Newly-designated and currently permitted MS4s shall update codes and ordinances, if necessary, within 4 years of coverage under this permit. Currently permitted MS4s shall continue to implement their existing permanent Stormwater Management Programs until the codes and ordinances review and update are completed. The permittee should consider making revisions to address post-construction runoff from publicly-owned and privately-owned new development and redevelopment projects to the extent allowable under State or local law. Existing ordinances and new (draft) ordinances addressing post-construction stormwater management shall be submitted to MDEQ for compliance review with the SWMP. In addition, the regulated entity must develop a regulatory mechanism (e.g. a post-construction ordinance) to allow inspections of post-construction BMPs for private development and redevelopment projects within the MS4. New (draft) ordinances shall be submitted to MDEQ for review 30 days before proposed adoption. The ordinance or regulatory mechanism shall not limit the post-construction minimum measure to a single type of best management practice. MDEQ recommends that post-construction stormwater control and treatment systems be implemented through a treatment train approach which would incorporate more than one BMP.[1]

Currently there are no legal impediments in Mississippi to harvest rainwater.

1.4 What Is Stormwater Runoff?

Stormwater runoff occurs when precipitation from rain flows over the ground. Impervious surfaces like driveways, sidewalks, and streets prevent stormwater from naturally soaking into the ground.[2]

1.5 Why Is Stormwater Runoff a Problem?

Stormwater can pick up debris, chemicals, dirt, and other pollutants and flow into a storm sewer system or directly into a lake, stream, river, wetland, or coastal water.[2] Additionally, anything entering a storm sewer system will be discharged untreated into the waterbodies used for swimming, fishing, and drinking water.[3]

TYPE	POLLUTANT	MAJOR SOURCES
Sediment	TSS	Construction runoff, Soil erosion, Roadway sanding
Nutrients	Phosphorous, Nitrogen	Fertilizers, Yard waste, Failed septic systems, POTWs, Atmospheric deposition
Metals	Copper, Lead, Zinc	Vehicle tire and brake wear, Paint
Oil and Grease	Oil and Grease	Vehicle emissions, Illicit discharges
Toxics	Pesticides, Herbicides, Cleaners	Lawn care, Vehicle cleaning, Illicit discharges
Pathogens	Bacteria, Viruses	Sanitary waste, Pets, Birds, Wildlife
Thermal Modification	Temperature	Pavement, Rooftops

Note: TSS (Total Suspended Solids), POTWs (Publicly Owned Treatment Works)

1.6 What Are the Impacts of Stormwater Runoff?

The impacts of stormwater runoff include:

IMPACT	RESULT
Increased flooding and property damage	Increased impervious surfaces decrease the amount of rainwater that can naturally infiltrate into the soil and increase the volume and rate of stormwater runoff.
Degradation of stream channel	One result of unmanaged stormwater runoff can be more water moving at higher velocities through stream channels.
Less groundwater recharge and dry weather flow	As impervious surfaces increase, the infiltration of stormwater to replenish groundwater decreases.
Impaired water quality	Impervious surfaces accumulate pollutants that are absorbed by stormwater runoff and carried to lakes and streams.
Increased water temperature	Impervious surfaces are warmed by the sun. Runoff from these warmed surfaces increase the temperature of water entering our rivers and lakes.
Loss of habitat	The decline in habitat due primarily to the erosive flows and the increased water temperature will negatively impact the diversity and amount of fish and aquatic insects.
Decreased recreational opportunities	Stormwater runoff can negatively impact water resources in many different ways from decreased water quality and increased temperature to decreased habitat.

(SEMCOG 2008, Low Impact Development Manual for Michigan: A design Guide for Implementors and Reviewers.)

1.7 What Is Green Infrastructure?

Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits. While single-purpose grey stormwater infrastructure (conventional piped drainage and water treatment systems) is designed to move urban stormwater away from the built environment quickly, green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits.[4] Green infrastructure can be used to address stormwater runoff problems.

Green infrastructure works by slowing down runoff, spreading it out over the land, and slowly soaking it into the ground, or in some cases reusing the water on-site. These techniques also help to remove pollutants from runoff by allowing plants to filter out pollutants as the water slowly infiltrates into the ground.[5]

1.8 How Does Green Infrastructure Work?

Green infrastructure employs the following processes that mimic predevelopment conditions:

- Infiltration (allowing water to slowly sink into the soil),
- Evaporation/transpiration using native vegetation, and
- Rainwater capture and reuse (storing runoff to water plants, flush toilets, etc.).[6]

1.9 What Are Secondary Benefits of Using Green Infrastructure Practices?

Environmental Benefits	Social Benefits	Economic Benefits
Recharges and improves quality of ground and surface waters	Improves aesthetics and livability of urban communities	Reduces grey infrastructure costs
Improves energy efficiency	Increases recreational opportunities	Increases property values
Reduces urban heat island effect	Improves water and air quality	Reduces energy consumption costs
Improves aquatic and wildlife habitat	Fosters environmental education opportunities	

(Appendix A – Green Infrastructure Technology Fact Sheets, City of Lancaster Green Infrastructure Plan)

1.10 What Are Green Infrastructure Best Management Practices to Better Manage Stormwater Runoff?

- Downspout Disconnection
- Cisterns and Rain Barrels
- Bioretention (Rain Gardens)
- Vegetated (“Green”) Roofs
- Stormwater Planter Boxes
- Infiltration Practices (Basins, Trenches, Dry Wells)
- Porous Pavement with Infiltration
- Green Streets/Green Alleys
- Vegetated Swales
- Tree Trenches
- Vegetated Curb Extensions

Downspout Disconnection[6]


Roof Downspout Disconnection

Description
Disconnecting downspouts is the process of separating roof downspouts from the sewer system and redirecting roof runoff onto pervious surfaces. This reduces the amount of directly connected impervious area in a drainage area.

Benefits
- Provides supplemental water supply when used in conjunction with capture/reuse systems.
- Wide applicability.
- Reduces potable water use and water supply costs when used in conjunction with capture/reuse systems.
- Related cost savings and environmental benefits.
- Reduced runoff volume.

Maintenance
- Check materials for leaks and defects.
- Remove accumulated debris as needed.

Cost
- Inexpensive materials are readily available at local hardware stores.

Potential Limitations
- Do not disconnect and allow stormwater runoff to flow directly onto adjacent property owners.
- Need adequate receiving area.

Stormwater Quantity Functions		Stormwater Quality Functions		Additional Considerations	
Volume	Medium	**TSS**	Medium	**Capital Cost**	Low
Groundwater Recharge	Medium/High	**TP**	N/A	**Maintenance**	Low
Peak Rate	Medium	**TN**	N/A	**Winter Performance**	High
Erosion Reduction	Medium	**Temperature**	Medium/High	**Fast Track Potential**	Low/Medium
Flood Protection	Low			**Aesthetics**	High

Note: TSS (Total Suspended Solids), TP (Total Phosphorous), TN (Total Nitrogen)
(Appendix A – Green Infrastructure Technology Fact Sheets, City of Lancaster Green Infrastructure plan)

Downspout Disconnection Stormwater Planter

Cistern/Rain Barrel[6]

Cistern - Oktibbeha County Heritage Museum
Starkville, Mississippi
Image Credit: Allen Engineering and Science, Inc.

Description

Cisterns and rain barrels are structures designed to intercept and store runoff from rooftops to allow for its reuse, reducing volume and overall water quality impairment. This green infrastructure technology reduces potable water needs while also reducing stormwater discharges.

Rain Barrel – An above-ground (typically) tank that is used to collect rainwater runoff, typically from rooftops via gutters and store it until needed for a specific use, such as landscape irrigation.

Cistern – An underground (typically) tank used to supplement greywater needs (i.e. toilet flushing in a building and/or irrigation).

Applications

Cisterns and rain barrels can be used in urbanized areas where the need for supplemental on-site irrigation or other high water use exists. Areas that would benefit from using a cistern or rain barrel container include:

- Parking garages,
- Office buildings, and
- Residential homes.[7]

Cistern
Bay St. Louis, Mississippi
Image Credit: Unabridged Architecture

Benefits

- Provides supplemental water supply.
- Wide applicability.
- Reduces potable water use.
- Reduced stormwater runoff impacts.

Maintenance

- Discharge before next storm event.
- Clean annually.
- May require flow bypass valves during the winter.

Cost

- Rain barrels typically range from $100-$300.
- Cisterns typically range from $500-$5,000.

Potential Limitations

- Manages only relatively small storm events which requires additional management practices.
- Typically requires additional management of runoff.
- Requires a use for the stored water.

Key Design Features

- Small storm events are captured with most structures.
- Need to provide overflow for large storm events.
- Place structure upgradient of planting (if applicable) in order to eliminate pumping needs.

Stormwater Quantity Functions		Stormwater Quality Functions		Additional Considerations	
Volume	Low/Medium	**TSS**	Medium	**Capital Cost**	Low/Medium
Groundwater Recharge	Low	**TP**	Medium	**Maintenance**	Medium
Peak Rate	Low	**TN**	Medium	**Winter Performance**	Medium
Erosion Reduction	Low	**Temperature**	Medium	**Fast Track Potential**	Medium/High
Flood Protection	Low/Medium			**Aesthetics**	Low/Medium

(Appendix A – Green Infrastructure Technology Fact Sheets, City of Lancaster Green Infrastructure Plan)

Rain Barrel - Residential Application

Rain Barrel - Residential Application

Rain Gardens[6]

Rain Garden - Landscape Architecture Department
Mississippi State University
Image Credit: Allen Engineering and Science, Inc.

Description

Rain gardens are shallow surface depressions planted with native vegetation to treat and capture runoff and are sometimes underlain by sand or gravel storage/infiltration bed. The shallow depression of the garden holds the water so it can slowly infiltrate back into the soil as the plants, mulch, and soil naturally remove pollutants from the runoff.

Applications

Bioretention areas can be used in a variety of applications, from small areas in residential lawns to extensive systems in commercial parking lots (incorporated into parking islands or perimeter areas).[7]

Benefits

- Volume control and groundwater recharge.
- Broad applicability.
- Enhance site aesthetics and habitat.
- Potential air quality and climate benefits.
- Filter runoff pollution.
- Improve water quality.
- Create habitat for birds and butterflies.
- Protect rivers and streams.

Maintenance

- Watering.
- Spot weeding, pruning, erosion repair, trash removal, and mulch raking.
- Remove dead plants, add reinforcement planting to maintain desired density, remove invasive plants, and stabilize contributing drainage area as needed.
- Annually inspect and cleanup the garden as well as prune trees and shrubs.
- At least once every 3 years: remove sediment in pretreatment cells/inflow points and replace mulch layer.

Rain Garden - Landscape Architecture Department
Mississippi State University
Image Credit: Cory Gallo

Cost

- Typical costs are $10-$17/sq. ft. but will vary depending on the garden size.

Potential Limitations

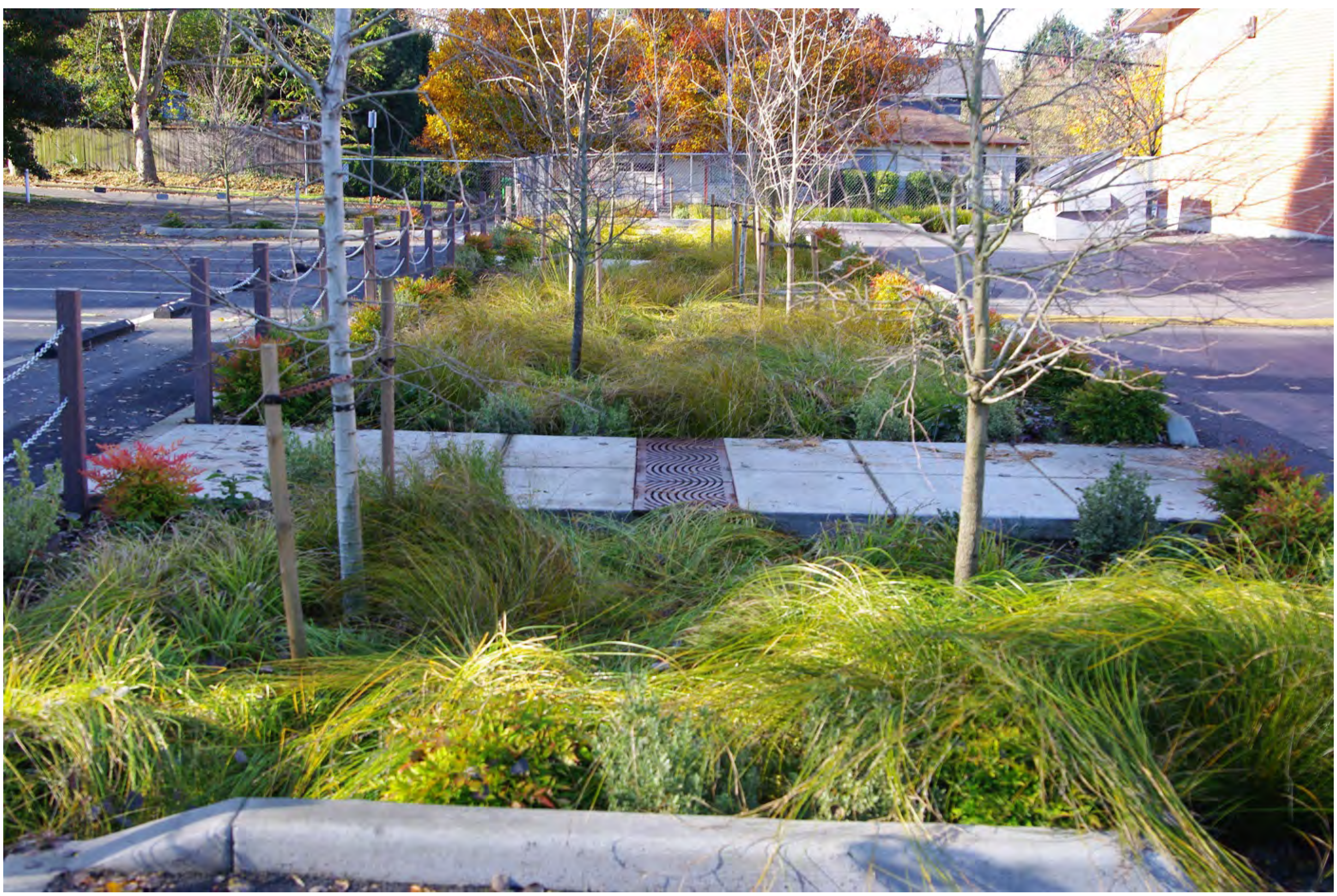
- Higher maintenance until vegetation is established.
- Limited impervious drainage area.
- Requires careful selection and establishment of plants.

Key Design Features

- Flexible in size and configuration.
- Ponding depths 6-18 inches.
- Plant selection (native vegetation that is tolerant of hydrologic variability, salts, and environmental stress).
- Amend soil as needed.
- Provide overflow structure for high-flow storm events.
- Use of underdrain is recommended in clay soils.

Stormwater Quantity Functions		Stormwater Quality Functions		Additional Considerations	
Volume	Medium/High	**TSS**	High (70%-90%)	**Capital Cost**	Medium
Groundwater Recharge	Medium/High	**TP**	Medium (60%)	**Maintenance**	Medium
Peak Rate	Medium	**TN**	Medium (40%-50%)	**Winter Performance**	Medium
Erosion Reduction	Medium	**Temperature**	High	**Fast Track Potential**	Medium
Flood Protection	Low/Medium			**Aesthetics**	High

(Appendix A – Green Infrastructure Technology Fact Sheets, City of Lancaster Green Infrastructure Plan)

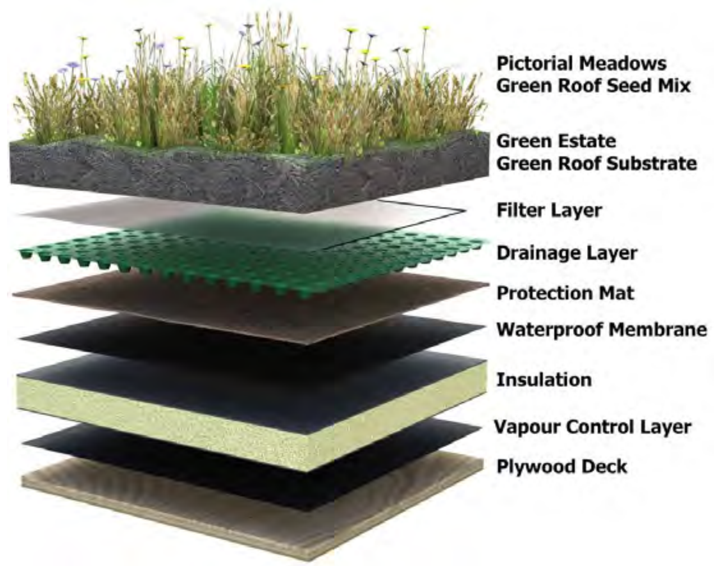


Mount Tabor Middle School Rain Garden - Portland, Oregon

Green Roof[6]

Description

A green roof or living roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. The overall thickness of the growing medium typically ranges from 2-6 inches and may contain multiple layers, consisting of waterproofing, synthetic insulation, engineered growth media, fabrics, root barrier, and synthetic components.



Typical Green Roof Section

Green roofs are typically categorized as 'extensive' or 'intensive' and are defined as:

Extensive – Green roofs that are lightweight with a shallow layer of growing substrate of less than 8 inches, requiring minimal maintenance. They generally have lower water requirements and use small, low-growing plant species.

Intensive – Green roofs are generally heavier, with a deeper layer of growing substrate, and support a wider variety of plant types. Intensive green roofs need more irrigation and maintenance and are highly engineered, often built directly on structures with considerable weight load capacity.

Benefits

- Expand roof life 2 to 3 times.
- Reduce winter heating costs.
- Reduce urban heat island effect.
- Reduce carbon monoxide impact.
- Improve aesthetics.
- Provide habitat for wildlife.
- Reduce air-conditioning costs.
- Reduce stormwater runoff.
- Reduce noise.
- Remove nitrogen pollution from rain.
- Provide green space.

Maintenance

- Once vegetation is established, little to no maintenance needed for the extensive system.
- Maintenance cost is similar to traditional landscaping, $0.25-$1.25/sq. ft.

Cost

- More expensive than traditional roofs but have longer lifespans. Green roofs generally range from $5-$50/sq. ft., including all structural components, soil, and plants.

Key Design Features

- Engineered media should have a high mineral content. Engineered media for extensive vegetated roof covers is typically 85%-97% nonorganic.
- 2-6 inches of non-soil engineered media.
- Vegetated roof covers intended to achieve water quality benefits should not be fertilized.
- Irrigation is generally not required.
- Internal building drainage must anticipate the need to manage large rainfall events without inundating the cover.

- Assemblies planned for roofs with pitches steeper than 2:12 (9.5 degrees) must incorporate supplemental measures to insure stability against sliding.
- The roof structure must be evaluated for compatibility with the maximum predicted dead and live loads.
- The waterproofing must be resistant to biological and root attack.

Stormwater Quantity Functions		Stormwater Quality Functions		Additional Considerations	
Volume	Medium/High	**TSS**	Medium	**Capital Cost**	High
Groundwater Recharge	Low	**TP**	Medium	**Maintenance**	Medium
Peak Rate	Medium	**TN**	Medium	**Winter Performance**	Medium
Erosion Reduction	Low/Medium	**Temperature**	Medium	**Fast Track Potential**	Low
Flood Protection	Low/Medium			**Aesthetics**	High

(Appendix A – Green Infrastructure Technology Fact Sheets, City of Lancaster Green Infrastructure Plan)

ASLA Green Roof - Washington, D.C.

Green Roof - Portland, Oregon

Green Roof - Bay St. Louis, Mississippi
Image Credit - Unabridged Architecture

Green Roof - Nashville, Tennessee

Stormwater Planter[6]


Stormwater Planter - Portland, Oregon


Stormwater Planter - Portland, Oregon

Description

A stormwater planter is a container or enclosed feature located either above ground or below ground, planted with vegetation that collects and treats stormwater using bioretention. Bioretention systems collect and filter stormwater through layers of mulch, soil, and plant root systems where pollutants such as bacteria, nitrogen, phosphorous, heavy metals, oil, and grease are retained, degraded, and absorbed.

Applications

Stormwater planters can be used in urbanized areas with high pollutant loads. They are especially applicable where there is limited area for construction of other BMPs. Stormwater planters may be used as a pretreatment BMP for other BMPs such as wet ponds or infiltration systems. Areas that would benefit from using stormwater planters include:

- Parking garages,
- Office buildings,
- Residential buildings,
- Other building uses (commercial, light industrial, institutional, etc.),
- Transportation facilities, and
- Urban streetscapes.[8]

Benefits

- Reduces stormwater runoff volume, flow rate, and temperature.
- Increases groundwater infiltration and recharge.
- Treats stormwater runoff.
- Improves aesthetic appeal of streets and neighborhoods.
- Provides wildlife habitat.
- Requires limited space.
- Flexible for use in areas of various shapes and sizes.

Maintenance

- Regular maintenance of vegetation, such as weeding, soil replacement, and watering during dry periods.
- Regular inspection of structural components, especially following large rain events.
- Periodic replacement of plants.
- Periodic cleaning of inflow and outflow mechanisms.
- Bypass valve during winter.
- Maintenance cost: $400-$500 per year for a 500 sq. ft. planter; varies based on type, size, plant selection, etc.

Cost

- Varies based on type, size, plant selection, etc. Typically $8-$15/sq. ft.

Potential Limitations

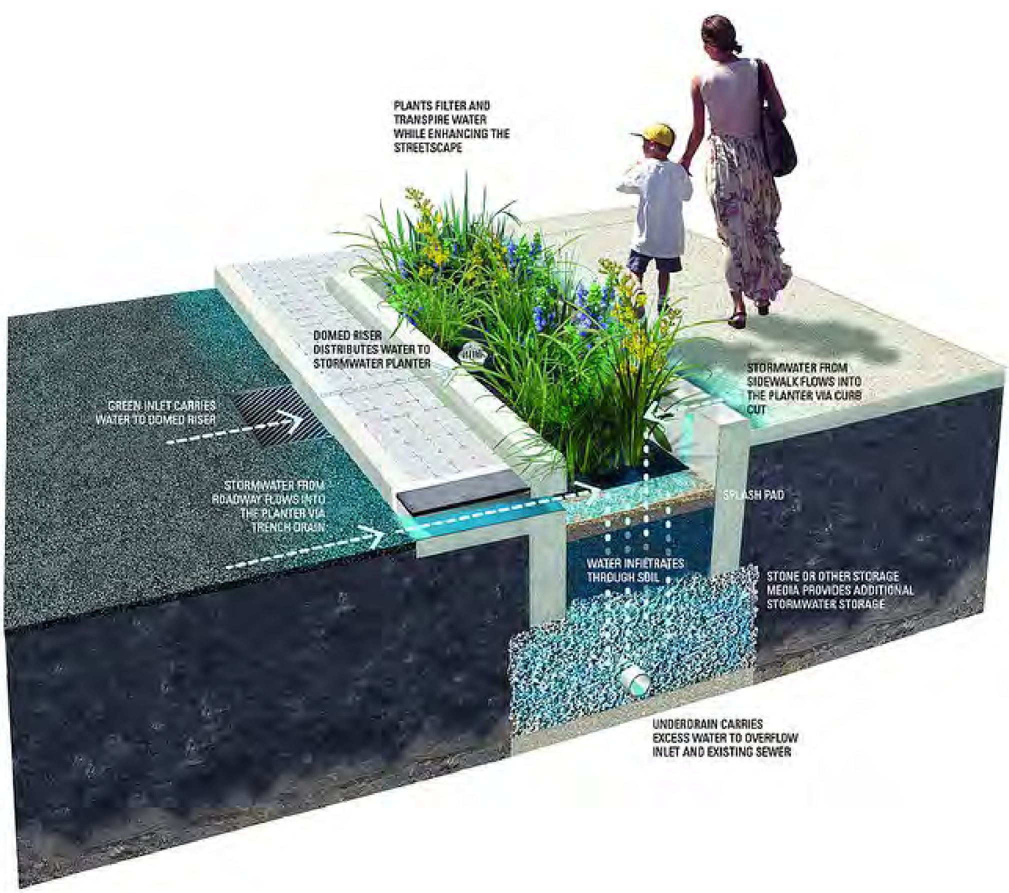
- Limited stormwater quantity/quality benefits.
- Relatively high cost due to structural components for some variations.

Key Design Features

- Plant native vegetation.
- May be designed as pretreatment for other BMP solutions.
- Captured runoff should drain out in 3-4 hours after storm events unless used for irrigation.
- The structural elements of the planters should be stone, concrete, brick, or pressure-treated wood.
- Flow bypass during winter.
- Use of underdrain is recommended in clay soils.

Stormwater Quantity Functions		Stormwater Quality Functions		Additional Considerations	
Volume	Low/Medium	**TSS**	Medium	**Capital Cost**	Low/Medium
Groundwater Recharge	Low	**TP**	Medium	**Maintenance**	Medium
Peak Rate	Low	**TN**	Medium	**Winter Performance**	Medium
Erosion Reduction	Low	**Temperature**	Medium	**Fast Track Potential**	Low
Flood Protection	Low			**Aesthetics**	High

(Appendix A – Green Infrastructure Technology Fact Sheets, City of Lancaster Green Infrastructure Plan)



Stormwater Planter - Philadelphia, Pennsylvania
Image Credit: Philadelphia Water Department

Stormwater Planter

Stormwater Planter

Infiltration Practices[6]

Description

Infiltration practices are designs that enhance water percolation through a media matrix that slows and partially holds stormwater runoff and facilitates pollutant removal.

Dry wells are a subsurface storage facility (structural chambers or excavated pits, backfilled with a coarse stone aggregate or alternative storage media) that temporarily store and infiltrate stormwater runoff from rooftops and paved areas. Due to their size, dry wells are typically designed to handle stormwater runoff from smaller drainage areas less than one acre in size. Dry wells should not be installed in areas of high sediment loading.

Infiltration basins are shallow surface impoundments that are designed to temporarily store, capture, and infiltrate runoff gradually back into the ground. Infiltration basins are typically used for drainage areas of 5 to 50 acres with land slopes that are less than 20%.

Infiltration trenches are linear subsurface infiltration structures typically composed of stone or gravel wrapped with geotextile which creates temporary subsurface storage of stormwater runoff. This practice is primarily designed for drainage areas less than five acres in size.

Subsurface infiltration beds generally consist of a rock storage bed below surfaces such as parking lots, lawns, and playfields for temporary storage until the water is able to seep back into the soil.

Applications

Infiltration systems can be used in a variety of applications, from small areas in residential properties to extensive systems under commercial parking lots. Industrial, retrofit, highway/road, and recreational areas can also readily incorporate infiltration BMPs.[8]

Benefits

- Reduces volume of stormwater runoff.
- Reduces peak rate runoff.
- Increases groundwater recharge.
- Provides thermal benefits.
- Increases aesthetic appeal.

Maintenance

There are a few general maintenance practices that should be followed for infiltration BMPs. These include:

- All catch basins and inlets should be inspected and cleaned at least twice per year.
- The overlying vegetation of subsurface infiltration feature should be maintained in good condition and any bare spots revegetated as soon as possible.
- Vehicular access on subsurface infiltration areas should be prohibited (unless designed to allow vehicles) and care should be taken to avoid excessive compaction by mowers.

Infiltration Basin - University of Wisconsin La Crosse

Infiltration Basin - University of Wisconsin La Crosse

Cost

- Dry Well: Construction costs – $4-$9/sq. ft., Maintenance Costs – 5%-10% of capital costs.
- Infiltration basin: Construction costs – varies depending on excavation, plantings, and pipe configuration.
- Infiltration Trench: Construction costs – $20-$30/sq. ft., Maintenance Costs – 5%-10% of capital costs.
- Subsurface Infiltration Bed: Construction costs – $13/sq. ft.

Infiltration Trench - Hill Center Belle Meade
Nashville, Tennessee
Image Credit: Hawkins Partners, Inc.

Potential Limitations

- Not recommended for areas with steep slopes.

Key Design Features

- Depth to water table.
- Pretreatment is often needed to prevent clogging.
- Often require level infiltration surface.
- Proximity to buildings and other sensitive areas.
- Soil types (permeability, limiting layer, etc.).
- Provide outfall structure in most uses.
- Use of underdrain is recommended in clay soils.

	Volume	Groundwater Recharge	Peak Rate	Erosion Reduction	Flood Protection
Dry Well	Medium	High	Medium	Medium	Low
Infiltration Basin	High	High	High	Medium	High
Infiltration Trench	Medium	High	Low/Medium	Medium/High	Low/Medium
Subsurface Infiltration Bed	High	High	High	Medium/High	Medium/High

(Appendix A – Green Infrastructure Technology Fact Sheets, City of Lancaster Green Infrastructure Plan)

	TSS	TP	TN	Temperature
Dry Well	Medium (85%)	High/Medium (85%)	Low/Medium (30%)	High
Infiltration Basin	High (85%)	Medium/High (85%)	Medium (30%)	High
Infiltration Trench	Medium (85%)	High/Medium (85%)	Low/Medium (30%)	High
Subsurface Infiltration Bed	High (85%)	Medium/High (85%)	Low (30%)	High

(Appendix A – Green Infrastructure Technology Fact Sheets, City of Lancaster Green Infrastructure Plan)

Pervious Pavement[6]

Description
Pervious pavement is a GI technique that combines stormwater infiltration, storage, and structural pavement consisting of a permeable surface underlain by a storage/infiltration bed. Pervious pavement is well suited for parking lots, walking paths, sidewalks, playgrounds, plazas, tennis courts, and other similar uses.

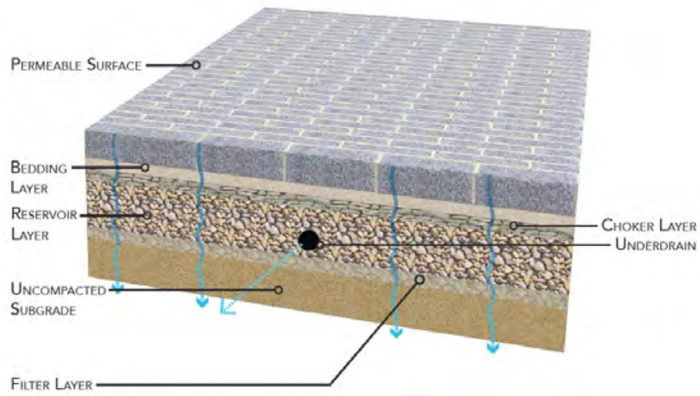
Applications
Pervious pavements have been widely applied in retrofit situations when existing standard pavements are being replaced. Care must be taken when using pervious pavements in industrial and commercial applications where pavement areas are used for material storage or the potential for surface clogging is high due to pavement use.[8]

Benefits
- Volume control and groundwater recharge, moderate peak rate control.
- Versatile with broad applicability.
- Dual use for pavement structure and stormwater management.
- Reduce the need for costly drainage systems.

Maintenance
- Clean inlets.
- Vacuum annually.
- Maintain adjacent landscaping/planting beds.
- Periodic replacement of paver blocks.
- Maintenance cost: approximately $400-$500 per year for vacuum sweeping of a half-acre parking lot.

Cost
- Varies by porous pavement type.
- $7-$15/sq. ft., including underground infiltration bed.
- Generally more than standard pavement, but saves on cost of other BMPs and traditional drainage infrastructure.

Potential Limitations
- Careful design and construction required.
- Pervious pavement not suitable for all uses.



Permeable Pavement Perspective


Uni-Eco Stone permeable paver driveway

- Higher maintenance needs than standard pavement.
- Steep slopes.

Key Design Features
- Infiltration testing required.
- Level storage bed bottoms.
- Provide positive stormwater overflow from bed.
- Secondary inflow mechanism recommended.
- Pretreatment for sediment-laden runoff.
- Use of underdrain is recommended in clay soils.

Stormwater Quantity Functions		Stormwater Quality Functions		Additional Considerations	
Volume	High	**TSS**	High	**Capital Cost**	Medium
Groundwater Recharge	High	**TP**	Medium	**Maintenance**	Medium
Peak Rate	Medium/High	**TN**	High	**Winter Performance**	Medium/High
Erosion Reduction	Medium/High	**Temperature**	High	**Fast Track Potential**	Low/Medium
Flood Protection	Medium/High			**Aesthetics**	Low/Medium

(Appendix A – Green Infrastructure Technology Fact Sheets, City of Lancaster Green Infrastructure Plan)

Permeable concrete with permeable paving
Image Credit: Pacific Interlock Pavingstone

Turfstone Pavers- Residential Application

Permeable Paving & Vegetated Swales - Elmhurst College, Illinois

Green Street/Green Alley[6]

Description

Green streets incorporate a wide variety of GI elements including street trees, permeable pavements, bioretention, water quality devices, stormwater planters, and swales. The goal of green streets is to provide source control of stormwater, limit its transport and pollutant conveyance to the collection system, restore predevelopment hydrology to the maximum extent possible, and provide environmentally enhanced roads. Also, other benefits include aesthetics, safety, walkability, and heat island reduction.


Green Street - Portland, Oregon

Green street technologies can be applied to residential, commercial, and arterial streets as well as to alleys. The range of GI technologies that can be incorporated into a green street allow its developer to manipulate the stormwater management strategy of a given project.

Benefits

- Provide efficient site design.
- Balance parking spaces with landscape space.
- Utilize surface conveyance of stormwater.
- Add significant tree canopy.
- Improve walkability.
- Increased pedestrian safety.
- Improved aesthetics.
- Reduction of urban heat island.
- Reduced runoff volume, increased groundwater recharge, and evapotranspiration.

Maintenance

- See maintenance requirements for individual GI practices.

Cost

- \$120-\$190 per linear foot of block managed (i.e. capture of 1” of runoff).

Potential Limitations

- Maintenance needs.
- Conflicts with structures, utilities, and other infrastructure (building foundations, etc).

Key Design Features

- See individual GI sections.

Stormwater Quantity Functions		Stormwater Quality Functions		Additional Considerations	
Volume	Medium	**TSS**	High (70%-90%)	**Capital Cost**	Medium
Groundwater Recharge	Medium	**TP**	Medium (60%)	**Maintenance**	Medium/High
Peak Rate	Medium	**TN**	Medium (40%-50%)	**Winter Performance**	High
Erosion Reduction	Medium	**Temperature**	High	**Fast Track Potential**	Low/Medium
Flood Protection	Low/Medium			**Aesthetics**	High

(Appendix A – Green Infrastructure Technology Fact Sheets, City of Lancaster Green Infrastructure Plan)

Green Street - Nashville, Tennessee
Image Credit: Hawkins Partners, Inc.

Green Street - Portland, Oregon


HOCKING VALLEY

Detroit's Green Alley Project - Detroit, Michigan

Bioswale[6]

Description

Bioswales are landscape elements designed to concentrate or remove silt and pollution from surface runoff water. They consist of a shallow stormwater channel that is densely planted with a variety of grasses, shrubs, and/or trees designed to slow, filter, and infiltrate stormwater runoff. While swales themselves are intended to effectively treat runoff from highly impervious surfaces, pretreatment measures are recommended to enhance swale performance. They also promote additional filtering and settling of nutrients and other pollutants.

Applications

Residential – Swales can be used along roadways and for side yard and backyard drainage.

Commercial/Industrial – Swales can provide drainage around a site, within a site, and can help slow discharge from other BMPs that outlet to the swale.

Highway/Road – Vegetated swales are an excellent alternative to curb and gutter systems. Appropriately sized roadside swales should be able to handle all the runoff from the roadway and may also be able to handle runoff from areas outside the road surface. [8]

Benefits

- Can replace curb and gutter for site drainage and provide significant cost savings.
- Water quality enhancement (i.e. filtration).
- Peak and volume control with infiltration.

Maintenance

- Remulch void areas, treat or replace diseased trees and shrubs, and keep overflow free and clear of leaves as needed.
- Inspect soil and repair eroded areas, remove litter and debris, and clear leaves and debris from overflow.
- Inspect trees and shrubs to evaluate health.
- Add additional mulch, inspect for sediment buildup, erosion, vegetative conditions, etc. annually.
- Maintenance cost: approximately $200 per year for a 900 sq. ft. vegetated swale.

Cost

- $5-$20 per linear foot depending on extent of grading and infrastructure required, as well as the vegetation used.

Potential Limitations

- Limited application in areas where space is limited.
- Unless designed for infiltration, there is limited peak and volume control.

Key Design Features

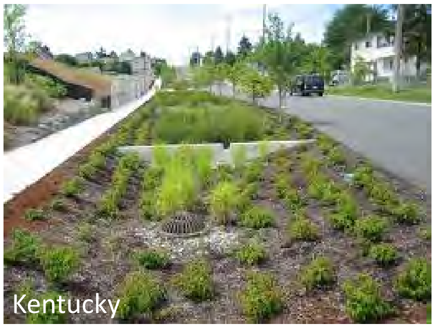
- Bottom width of 2-8 feet.
- Side slopes from 3:1 (H:V) to 5:1.
- Longitudinal slope from 1%-6%.
- Check dams can provide additional storage and infiltration.

Stormwater Quantity Functions		Stormwater Quality Functions		Additional Considerations	
Volume	Low/Medium	**TSS**	Medium	**Capital Cost**	Low/Medium
Groundwater Recharge	Low/Medium	**TP**	Low/Medium (50%)	**Maintenance**	Low/Medium
Peak Rate	Low/Medium	**TN**	Medium (20%)	**Winter Performance**	Medium
Erosion Reduction	Medium	**Temperature**	Medium/High	**Fast Track Potential**	High
Flood Protection	Low			**Aesthetics**	Medium

(Appendix A – Green Infrastructure Technology Fact Sheets, City of Lancaster Green Infrastructure Plan)

Bioswale Examples

NRCS - Iowa



Kentucky

Michigan

Portland, Oregon

Seattle, Washington

Tree Trench[6]

MWMO Facility
Minneapolis, Minnesota

Philadelphia, Pennsylvania

Description

A tree trench is a system that consists of piping for water storage, structural soils, and trees. It manages stormwater runoff and promotes the use of trees in urban areas.

Benefits

- Increased canopy cover.
- Enhanced site aesthetics.
- Air quality and climate benefits.
- Runoff reductions.
- Improved water quality.
- Enhanced tree health/longevity.

Maintenance

- Water, mulch, treat diseased trees, and remove litter as needed.
- Annual inspection for erosion, sediment buildup, and vegetative conditions.
- Biannual inspection of cleanouts, inlets, outlets, etc.

Cost

- Approximately $850 per tree.
- $10-$15/sq. ft.
- $8,000-$10,000 to purchase one prefabricated tree pit system including filter material, plants, and some maintenance; $1,500-$6,000 for installation.

Potential Limitations

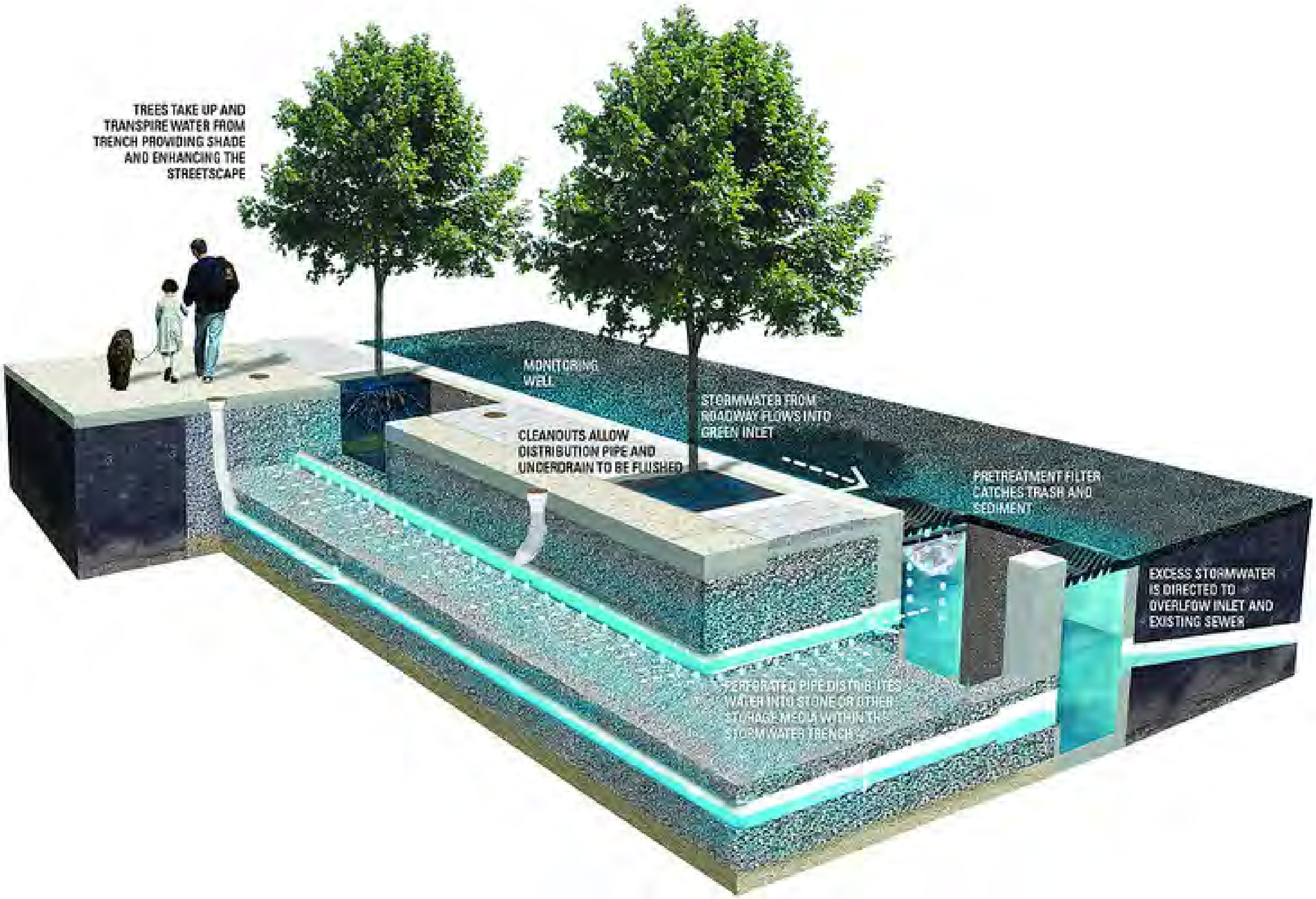
- Required careful selection of tree species.
- Required appropriate root zone area.
- Utility conflicts, including overhead electric wires, posts, signs, etc.
- Conflicts with other structures (basements, foundations, etc.).

Key Design Features

- Flexible in size.
- Use native plants.
- Quick drawdown.
- Linear infiltration/storage trench.
- Adequate tree species selection and spacing.
- Addition of new inlets, curb cuts, or other means to introduce runoff into the trench.
- Use of underdrain is recommended in clay soils.

Stormwater Quantity Functions		Stormwater Quality Functions		Additional Considerations	
Volume	Medium	**TSS**	High (70%-90%)	**Capital Cost**	Medium
Groundwater Recharge	Medium	**TP**	Medium (60%)	**Maintenance**	Medium
Peak Rate	Medium	**TN**	Medium (40%-50%)	**Winter Performance**	High
Erosion Reduction	Medium	**Temperature**	High	**Fast Track Potential**	High
Flood Protection	Low/Medium			**Aesthetics**	High

(Appendix A – Green Infrastructure Technology Fact Sheets, City of Lancaster Green Infrastructure Plan)



Stormwater Tree Trench - Philadelphia, Pennsylvania
Image Credit: Philadelphia Water Department

The Radian - Philadelphia, Pennsylvania
Image Credit: Paul Rider

Vegetated Curb Extensions[6]

Description
Vegetated curb extensions, also called stormwater curb extensions, are landscaped areas within the parking zone of a street that capture stormwater runoff in a depressed planting bed. The landscaped area can be designed similar to a rain garden or vegetated swale, utilizing infiltration and evapotranspiration for stormwater management. They can be planted with groundcover, grasses, shrubs, or trees depending on the site conditions, costs, and design context.

Benefits

- Traffic calming and pedestrian safety.
- Enhanced aesthetics.
- Potential air quality benefits.
- Wide applicability, including urban areas.
- Reduced runoff, improved water quality.

Maintenance

- Remove accumulated debris.
- Clean inlets.

Cost

- Relatively inexpensive to retrofit.
- $30/sq. ft. for new construction.

Potential Limitations

- Reduction of on-street parking spaces.
- May conflict with bike lanes.
- Utility and fire hydrant conflicts.

Key Design Features

- Design can incorporate existing inlets.
- Sizing based on drainage area.
- Infiltration testing required.
- Do not infiltrate on compacted soil.
- Level storage bed bottoms.
- Use native vegetation.
- Work around existing utilities.
- Mark curb cuts highly visible to motorists.
- Use of underdrain is recommended in clay soils.

Stormwater Quantity Functions		Stormwater Quality Functions		Additional Considerations	
Volume	Medium	**TSS**	Medium/High	**Capital Cost**	Low
Groundwater Recharge	Medium	**TP**	Medium	**Maintenance**	Low/Medium
Peak Rate	Medium	**TN**	Medium	**Winter Performance**	Medium
Erosion Reduction	Medium	**Temperature**	Medium/High	**Fast Track Potential**	Low/Medium
Flood Protection	Low/Medium			**Aesthetics**	High

(Appendix A – Green Infrastructure Technology Fact Sheets, City of Lancaster Green Infrastructure Plan)

Vegetated Curb Extensions - Philadelphia, Pennsylvania

Vegetated Curb Extensions - McComb, Mississippi
Image Credit: Unabridged Architecture

Vegetated Curb Extensions, Residential Application - Portland, Oregon

1.11 EPA/ASLA Case Study Analysis

The EPA asked the American Society of Landscape Architects (ASLA) to collect case studies on projects that successfully and sustainably manage stormwater. More than 300 ASLA members responded with 479 case studies from 43 states, the District of Columbia, and Canada. These projects demonstrate to policy makers the value of creating green infrastructure policies and investing in these approaches.

Below is an analysis of the 479 stormwater case studies:

Project Type	
Institutional/Education	21.5%
Open Space/Park	21.3%
Other	17.6%
Transportation Corridor/ Streetscape	11.9%
Commercial	8.6%
Single Family Residential	5.5%
Government Complex	4.2%
Multifamily Residential	3.7%
Open Space-Garden/ Arboretum	2.9%
Mixed Use	1.8%
Industrial	1.1%

Estimated Cost of Green Infrastructure	
$100,000-$500,000	29.2%
$1,000,000-$5,000,000	22.1%
$500,000-$1,000,000	13.2%
$50,000-$100,000	12.9%
$10,000-$50,000	12.1%
$10,000	3.5%

Green Infrastructure Type	
Retrofit of Existing Property	50.7%
New Development	30.7%
Redevelopment Project	18.6%

How Much Impervious Area was Managed?	
1 acre to 5 acres	34.5%
5,000 sq. ft. to 1 acre	31.3%
Greater than 5 acres	24.8%
Less than 5,000 sq. ft.	9.5%

Did Use of Green Infrastructure Increase Costs?	
Reduced Costs	44.1%
Did Not Influence Costs	31.4%
Increased Costs	24.5%

Green Infrastructure Design Approaches Used	
Bioswale	62.1%
Rain Garden	53.2%
Bioretention Facility	50.8%
Permeable Pavement Systems	47.3%
Curb Cuts	37.9%
Cistern	21.2%
Downspout Removal	18.1%
Green Roof	16.5%
Rain Barrels	5.7%

(https://dirt.asla.org/2011/09/26/asla-releases-more-than-475-stormwater-management-case-studies/)

1.12 Green Infrastructure and Stormwater Management Implementation Case Studies

The following section describes five of the EPA/ALSA case studies in more detail.[8,9]

Episcopal High School Stormwater Rain Garden
Location: Baton Rouge, Louisiana

Project Specifications	
Project Description	The school's quadrangle experienced flooding problems caused by an inadequate drainage system. BROWN+DANOS designed bioswales and a rain garden to capture the first 1" of rainfall to slow down the impact to the storm drain system. In an effort to quickly and economically implement the project because of lack of experience in the local market place, BROWN+DANOS employed approximately 20 landscape architecture students over the summer to implement the project as a demonstration and learning example. Two years following the implementation, the quadrangle has yet to experience flooding problems.
Project Type	Institutional/education – Retrofit of an existing property.
Design Features	Bioretention facility, rain garden, bioswale, cistern, and porous pavers.
Impervious area managed	1 acre to 5 acres.
Cost and Job Analysis	
Estimated Cost of Stormwater Project	$100,000-$500,000 (Public Funding: Not available).
Related Information	Of the $110,000 project, approximately 40% was materials.
Was a green vs. grey cost analysis performed?	Yes, we implemented the cost (design and build) for approximately $110,000 while estimates from engineers for re-piping was nearly $500,000.
Cost impact of conserving green/ open space to the overall costs of the site design/development project	Less cost in materials/infrastructure.
Cost impact of conserving green/ open space for stormwater management over traditional site design/site development approaches (grey infrastructure)	Significantly reduced costs (10% or greater savings).
Performance Measures	
Stormwater reduction performance analysis	The rain garden retained 39% of the 10-year, 1-hour rainfall of the watershed.
Community and economic benefits that have resulted from the project	The school now uses the rain garden as part of its environmental education curriculum.

(https://www.asla.org/stormwatercasestudies.aspx)

Ruffner Mountain Nature Center
Location: Birmingham, Alabama

Project Specifications	
Project Description	The first phase of the Ruffner Mountain Master Plan calls for a nature center and administrative building with an outdoor pavilion for school and other groups. Located on a steep, heavily-wooded portion of the northern slope of the mountain, the site is also a trailhead for three existing trails. The roof is approximately 50% green with the rest highly reflective. Rainwater is collected for use where potable water is not required, including the tanks for amphibians. Even the furnishings are made from recycled materials. Ruffner's education mission is served not only by the exhibits but also by the building itself whose design and construction will be interpreted for visitors.
Project Type	Institutional/education – Retrofit of an existing property.
Design Features	Green roof, cistern, porous pavers, and curb cuts.
Impervious area managed	5,000 sq. ft. to 1 acre.
Cost and Job Analysis	
Estimated Cost of Stormwater Project	$10,000-$50,000 (Public Funding: Federal).
Related Information	Cistern systems - $15,000 Green roof - $25,000 Porous paving/curb cuts - $10,000.
Was a green vs. grey cost analysis performed?	No.
Cost impact of conserving green/ open space to the overall costs of the site design/development project	The site development costs were reduced as very little of the overall site was impacted. The cost of constructing a "tree house" type building on a wooded site on the side of a mountain always costs more than standard building practices, but this approach was never a consideration for this type of educational facility.
Performance Measures	
Stormwater reduction performance analysis	No additional stormwater runoff was created with the construction of additional buildings, drive, and parking area.
Community and economic benefits that have resulted from the project	Ruffner Mountain is a destination point for school groups, tourists, and the citizens of Birmingham. Increasing the value of this property spills over to the neighboring properties and makes the nearby commercial area more appealing for the location of new businesses. Improved and expanded facilities also increases the number of visitors and dollars spent in the city. The educational and recreational benefits are also an extremely valuable asset to the city.

(https://www.asla.org/stormwatercasestudies.aspx)

Hinds Community College Multi-Purpose Center
Location: Pearl, Mississippi

Project Specifications	
Project Description	The existing site was an old borrow pit with various soil types and young pine trees. The northern section of the site was preserved with the southern section of the site prepared for the Multi-Purpose Center and associated parking. Each parking bay was designed to drain to a bioswale to take the initial impurities out. Stormwater is then piped to a detention pond for further cleansing before being released downstream. A lake was designed behind the building to catch a very limited amount of stormwater but is used more for aesthetics. The lake drains into a detention pond before being released downstream.
Project Type	Institutional/education – Part of a new development.
Design Features	Bioretention facility, bioswale, porous pavers, and curb cuts.
Impervious area managed	Less than 5,000 sq. ft.
Cost and Job Analysis	
Estimated Cost of Stormwater Project	$100,000-$500,000 (Public Funding: Local).
Related Information	Of the $110,000 project, approximately 40% was materials.
Was a green vs. grey cost analysis performed?	No.
Cost impact of conserving green/ open space to the overall costs of the site design/development project	Reduction in the amount of storm pipe to detention pond as well as a reduction in curb and gutter throughout the parking lots. Estimation is a net reduction of about 5% of the construction cost of the entire project.
Cost impact of conserving green/ open space for stormwater management over traditional site design/site development approaches (grey infrastructure)	Slightly reduced costs (1%-9% savings).
Performance Measures	
Stormwater reduction performance analysis	Civil engineer performed all performance analysis.
Community and economic benefits that have resulted from the project	Building is a premier facility to hold events such as product shows, local graduations, performing arts, etc. Also has a classroom wing for education of certain programs offered at the community college.
Additional Information	The Jackson-Metro area has a substantial expansive clay layer (Yazoo Clay) that is hard to work with. The biggest challenge was to place bioswales on the downside of parking bays and not allow the water to absorb back underneath the parking lots for the clay to expand. A large amount of time was spent on preventing, creating, and implementing a solution to this problem. The site and project is the only one within the Jackson-Metro area that utilizes bioswales as a part of their stormwater management.

(https://www.asla.org/stormwatercasestudies.aspx)

Green for Life! Boykin Community Center
Location: Auburn, Alabama

Project Specifications	
Project Description	During 2010 and 2011, teams of students from various CADC programs under the direction of Charlene LeBleu, Associate Professor of Landscape Architecture; Rebecca O'Neal Dagg, Interim Dean of CADC; and Carla Jackson Bell, Director of Multicultural Affairs, worked with the Boykin Community Center on the Green for Life! Demonstration project that corrected a stormwater runoff problem and provided a watershed education program. Fixing the erosion and drainage problems on the playground and in landscaped areas has created a more attractive and useable place for children to play and stops sediment from polluting the Saugahatchee Watershed. The project integrated their design with a watershed education program, Green for Life!, and educational signage around the community center. This curriculum targets after-school students, GreenKidz for Life! for grades K-8 and GreenTeenz for Life! for grades 9-12, by providing special indoor and outdoor classroom field days that offer green educational opportunities in a non-traditional environment.
Project Type	Other – Retrofit of an existing property.
Design Features	Bioretention facility, rain garden, bioswale, cistern, downspout removal, porous pavers, and infiltration trenches.
Impervious area managed	1 acre to 5 acres.
Cost and Job Analysis	
Estimated Cost of Stormwater Project	$50,000-$100,000 (Public Funding: Federal, state, regional, local, watershed grant/CWA 319 funds).
Related Information	Total $18,965 (supplies): grading, $760; topsoil/amendments, $600; stone, $400; drain tile, $300; drain boxes, $40; solid PVC pipe, $75; PVC pipe fittings, $50; tools, $50; landscape fabric, $500; plant material, $1,200; sod, $800; mulch, $400; cisterns (4-1,000 gal), $11,500; signage, $1,200; 700+ hours of volunteer labor.
Was a green vs. grey cost analysis performed?	Yes. $120,000 (underground piping) versus $20,000.
Cost impact of conserving green/ open space to the overall costs of the site design/development project	$100,000 was saved.
Cost impact of conserving green/ open space for stormwater management over traditional site design/site development approaches (grey infrastructure)	Significantly reduced costs (10% or greater savings).

Performance Measures	
Stormwater reduction performance analysis	85%
Community and economic benefits that have resulted from the project	Reduced downstream flooding, increase in property values (downstream), and aesthetics.
Additional Information	The Green for Life! program is two-fold. First, the program provided green retrofits to the community center and secondly, a green education curriculum empowered children and students to take their new "green knowledge" home and learn how "greening" the community will help to make communities stronger. The pilot program targeted after-school students [GreenKidz for Life! (K-8) and GreenTeenz for Life! (9-12)] at the Boykin Community Center by providing special indoor and outdoor classroom field days offering green educational opportunities and career development exposure in a non-traditional setting. The program format worked with the existing after-school curricula to stimulate academic achievement in science and arts through the age appropriate hands-on building of "green retrofits" to the local community center. After-school participants at Head Start, Joyland Child Care Center, and Auburn Day Care were taught hands-on activities by CADC architecture and landscape architecture design coordinators (LeBleu and O'Neal Dagg), an academic program coordinator (Dr. Jackson Bell), student volunteers (approximately 40-60 volunteers) from the Auburn University CADC Learning Communities, and neighborhood volunteers.

Note: CADC (College of Architecture, Design, and Construction)
(https://www.asla.org/stormwatercasestudies.aspx)

Green For Life! - Boykin Rain Gardens - Auburn, Alabama

Green For Life! - Boykin Rain Gardens - Auburn, Alabama

Applebee's Support Center – Rain Gardens
Location: Lenexa, Kansas

Project Specifications	
Project Description	The Applebee's Restaurant Support Center was designed to house more than 500 associates that provide assistance to approximately 2,000 Applebee's restaurants worldwide. The Center's design responds directly to the needs of Applebee's Services, Inc. with a focus on associate satisfaction, productivity, food innovation, and development of the land and facility in ways that minimize negative environmental impact. The two-story building is nestled into the sloped terrain and organized along a curved circulation system, with public entries above on a prairie level and private access below at lake level. Four open-office wings extend out from the circulation spine like "fingers" and are separated by three atria and exterior landscaped courtyards that connect down to the lake and trail system. The courtyards each have a unique design and extend the uses in each atrium. To showcase the company's focus, the Culinary Center is located on center stage directly off of the main entry in the first grand atrium. The building enclosure is energy efficient with increased thermal insulation and reflective roofing materials. The restorative site design incorporates native landscape with water-efficient and low-maintenance prairie grasses, wildflowers, and stormwater BMPs. Stormwater management is an integral part of the site design. All on-site stormwater, as well as a percentage of off-site water, is either absorbed or routed and cleaned within a treatment train of BMPs that include native vegetated swales, rain gardens, rock sediment forebay, a sand filter, and a wetland prior to reaching the existing neighboring lakes. Each of the courtyards includes a series of rain gardens that treat roof runoff.
Project Type	Other – Part of a new development.
Design Features	Applebee's courtyard rain gardens were integrated into the entire courtyard design. The rain gardens are oriented as long narrow swales, filtering water as it runs down the planted swales towards the outlet structure. The rain gardens have a large pervious zone and are heavily planted with wet-mesic plants to maximize infiltration and transpiration. The rain garden functions to not only clean runoff from each rain event, but also as a public amenity. The Applebee's courtyard rain garden is designed to create beautiful public spaces for people to enjoy and engage in informal business meetings. The rain garden manages stormwater well and helps create an outdoor environment for people to enjoy.
Monitoring Goals	• Define the appropriate ratio of rain garden area compared to the size of the watershed (the drainage area of the roof). • Determine the size of rainfall event when runoff will occur.
Impervious area managed	Less than 5,000 sq. ft.
Cost and Job Analysis	
Estimated Cost of Stormwater Project	$10,000-$50,000 (Public Funding: None)

Was a green vs. grey cost analysis performed?	No.
Cost impact of conserving green/open space to the overall costs of the site design/development project	There were no additional costs for stormwater management. The courtyard was landscaped to provide outdoor rooms for small private meetings and would have required storm drainage improvements.
Cost impact of conserving green/open space for stormwater management over traditional site design/site development approaches (grey infrastructure)	Did not influence costs.
Performance Measures	
Stormwater reduction performance analysis	*Water Quantity* – This courtyard has minimal storage capacity; however, it was observed that rain events of 1/3-inch or less did not reach the outlet structure. *Water Quality* – The rain garden did not show significant pollutant removal rates, and in some cases exported some constituents, although at fairly low levels. This is likely due to being undersized. The contaminant loading off the roof was low: • Total Nitrogen (TN): 2.5 ppm • Total Phosphorous (TP): 0.2 ppm • Total Suspended Solids (TSS): 40.4 mg/l The rain garden was successful in extracting soil nutrients from runoff: 56% reduction of TN and 50% reduction of TP. The rain garden exported Chloride (Cl), Sulfur (S), and Total Suspended Solids (TSS). *Soil/Infiltration* – The design with long, nearly flat rain gardens provides good infiltration rates, but does not provide much storage capacity. The rain garden does not have enough holding capacity to capture a 1.37-inch storm event. Although undersized for storage capacity, the garden is not washing out due to the distribution of water, swale size, use of rock, and native vegetation. If the BMP was dry, then there was about 38 minutes before runoff occurred from the courtyard. The rain gardens can infiltrate about 1/3-inch rain event. *Vegetation* – Except for the *Equisetum hyemale* (horsetail), which was planted in a shady corner, all of the plants within the rain gardens established well including Tussock sedge, Blue lobelia, Cardinal flower, Karl Forester feather reed grass, Brown-eyed Susan, Two-row Stonecrop sedum, and bamboo. The bamboo is spreading as expected within the east/west rain garden. Protected with a sidewalk on one side and concrete curb on the other, this plant species is establishing well. As expected, bamboo planted within Plant Hardiness Zones 5a/5b, have issues with winter tip freeze.
Community and economic benefits that have resulted from the project	The property was responsible for cleaning a majority of its runoff with a series of BMPs that provides clean runoff into the adjacent development lake and downstream neighbors.

Additional Information	• The design does not have to be complicated to be attractive. • BMPs can provide benefit even if their size is not ideal. However, undersizing BMPs makes them susceptible to erosion, so designs need to consider how larger storm events will pass through them without damage. • Distributing water from the roof throughout the rain garden (four entry points) likely helped limit erosion and plant disturbance. The layout of the rain garden also mimics tributary streams leading to a larger stream, providing a replication of stream forms found in nature. • Undersized BMPs will likely have limited pollutant removal performance. • We might be able to improve the performance of the rain garden/bioswale somewhat by the addition of mulch and periodic rock check dams to help hold sediment and mulch in place. • Native plants are often recommended for use in BMPs due to their adaptation to local conditions and habitat enhancement value. However, some horticultural favorites also perform well if personal tastes lean towards cultivars. Plant selections do not need to be rigid; however, potentially invasive species should not be considered.

(https://www.asla.org/stormwatercasestudies.aspx)

1.13 What Should Local Cities and Counties Consider?

1.13.1 Regulatory Strategies

Zoning and Subdivision Regulations

Local development codes and ordinances are often the best place to start when a municipality wants to increase the adoption of green infrastructure practices. Even when there is political and public support for green infrastructure, "existing requirements in comprehensive plans, zoning codes, and building standards may be silent on, ambiguous towards, or even in conflict with the principles of green infrastructure. Zoning density standards, storm sewer connection requirements, minimum parking standards, and road widths are just a few of the requirements that can limit opportunities for green infrastructure."[10]

A review or audit of local codes and ordinances allows municipal leaders to identify and remove regulatory barriers to using green infrastructure. Tools such as the EPA's Water Quality Scorecard and the Center for Watershed Protection's "Better Site Design Codes and Ordinances Worksheet" can help identify and overcome barriers, including ones that may not be immediately apparent. The code audit should include any regulation that might address stormwater, including:

Zoning ordinances	Development codes and design standards	Parks and open space plans and ordinances
Subdivision ordinances	Erosion and sediment control ordinances	Stormwater management ordinances

Within these ordinances, special attention should be given to "anything with the words 'roof,' 'curb,' 'edge,' or 'tree.'"[10]

Other elements to inspect include:

Dimensional standards: lot size, frontage, height, coverage, yards, parking	Building codes and public works standards: drains, roads, sewers
Landscaping, buffers, trees, and tree canopy (landscaping and planting requirements)	Maintenance requirements found in subdivision, site plan, and stormwater ordinances
Site plan review	Stormwater drainage and detention
Soil erosion and sediment control	Floodplain management
Stream and wetland protection	Landscaping standards
Natural area protection and management	Street and parking requirements (impervious area reduction)
Conservation design (look in zoning and subdivision codes)	

(U.S. Environmental Protection Agency, Region 5. 2011. Using Local Codes to Cultivate Green Infrastructure and Foster Sustainable Stormwater Management webinar. http://water.epa.gov/infrastructure/greeninfrastructure/gi_training.cfm)

Following the audit, codes and ordinances should be amended in order to "integrate the principles of green infrastructure into stated goals and add language that provides flexibility for green infrastructure."[10] Green infrastructure should be integrated into the entire planning and permitting process, including not only the zoning code, but also the comprehensive plan, the site plan review process, and the post-construction inspection and enforcement protocol. Equally as important, the audit should involve and educate all municipal staff and partners who influence green infrastructure adoption, including planning and zoning staff, consulting engineers, public works staff, and appointed citizen boards.[11]

Regulatory Design Guidelines

Amending codes to make green infrastructure legal, as described above, is a critical first step in the regulatory category. To further encourage the use of GI practices, municipalities can develop guidelines illustrating accepted designs. Design guidelines are an effective way to educate developers as well as public works staff who may not be familiar with GI techniques. Two approaches for developing design guidance are:

1) Adopt a design manual. A manual makes a clear statement about the intent to use green infrastructure practices, but it also typically provides more flexibility and discretion to use conventional techniques instead of GI. It can be a "kinder, gentler way to introduce these techniques, especially to engineers/ Departments of Public Works."[11]

2) Adopt design standards. Standards clearly delineate what is and isn't allowed. For example, green street standards might specify allowed street width, paving material, and stormwater management designs. While standards remove ambiguity, they can be inflexible.

Resources[12]

The following table lists good resources for information on regulatory strategies for implementing green infrastructure.

Title	Link	Date
Water Quality Scorecard	https://www.epa.gov/smartgrowth/water-quality-scorecard	2009
Better Site Design: A Handbook for Changing Development Rules in Your Community	http://chesapeakestormwater.net/wp-content/uploads/downloads/2012/03/Better-Site-Design-Handbook.pdf	1998
Better Site Design Code and Ordinance Worksheet	http://chesapeakestormwater.net/wp-content/uploads/downloads/2012/03/Better-Site-Design-Handbook.pdf	1998
Green Infrastructure Case Studies	http://www.epa.gov/owow/NPS/lid/gi_case_studies_2010.pdf	2010
Managing Wet Weather with Green Infrastructure Municipal Handbook	https://www.epa.gov/green-infrastructure/green-infrastructure-municipal-handbook	2008
Using Local Codes to Cultivate Green Infrastructure and Foster Sustainable Stormwater Management	https://www.epa.gov/sites/production/files/2015-09/documents/gi_webinar_part1.pdf	2011
Top Ten Green Infrastructure Issues in Plans and Codes	https://mostcenter.org/sites/default/files/resources/file/gi_webinar_part5.pdf	2011
Revising Local Plans, Codes, and Ordinances	https://www3.epa.gov/npdes/outreach_files/webcast/mar2409/137780/137780_od.html	2009
Low Impact Development Strategies and Tools for NPDES Phase II Communities	http://ascelibrary.org/doi/abs/10.1061/40856%28200%29393	On-going
Green Highways Partnership	http://www.greenhighwayspartnership.org/index.php	
Maryland Stormwater Design Manual	http://mde.maryland.gov/programs/water/StormwaterManagementProgram/Pages/stormwater_design.aspx	
New York State Stormwater Management Design Manual	http://www.dec.ny.gov/chemical/29072.html	2010
Mississippi Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas	http://deq.state.ms.us/MDEQ.nsf/page/NPS_PlanningandDesignManual2ndEd_Vol1?OpenDocument	2010
Municipal Green Street Policy Examples		
Portland, OR	http://www.portlandonline.com/bes/index.cfm?c=44407	
Ventura, CA	http://www.venturariver.org/2008/07/ventura-adopts-green-streets-policy.html	2008
Chicago, IL	https://www.cityofchicago.org/city/en/depts/cdot/provdrs/street/svcs/green_alleys.html	2010

(Promoting Green Infrastructure: Strategies, Case Studies, and Resources. Water Infrastructure Capacity Building Team. Capacity

Description
A program evaluation tool that local governments can use to collaboratively identify the barriers to green infrastructure in local codes and ordinances. The scorecard guides municipal staff through 230 policies, codes, and incentives that could be adapted to promote sustainable stormwater management. The scorecard also provides extensive references and case studies.
Covers everything from basic engineering principles to actual vs. perceived barriers to implementing better site designs. Outlines 22 guidelines for better developments and provides detailed rationale for each principle. Also examines current practices in local communities, details the economic and environmental benefits of better site designs, and presents case studies from across the country.
Allows you to enter data to see how the local development rules in your community stack up against the model development principles outlined in the Better Site Design Handbook (above).
Examines the policies adopted by 12 local governments that have successfully promoted green infrastructure as well as the policy drivers and policy outcomes. A menu of policy options is presented, and barriers and lessons learned are summarized.
Provides local governments with a step-by-step guide to growing green infrastructure in their communities. Chapters address funding options, retrofit policies, green streets, rainwater harvesting, and incentive mechanisms. Each chapter provides a discussion of available programs and policies, and several case studies.
Describes the interaction of zoning and building codes with water quality; presents several examples of code audits conducted in Illinois, Ohio, and Minnesota; and highlights the top 10 obstacles to green infrastructure in local codes and ordinances.
Part of the webcast listed above "Using Local Codes to Cultivate Green Infrastructure." Identifies common code barriers in local codes and ordinances, and offers solutions.
One of six two-hour webcasts on green infrastructure offered by EPA in the spring and summer of 2009. Presented by Abby Hall of US EPA, Chris Kloss of the Low Impact Development Center, and Bill Davis of Progressive Design and Planning.
Contains various resources to assist Stormwater Phase II communities integrate low impact development (LID) strategies into their compliance programs.
This website has lots of great information and examples on greening transportation infrastructure, including green streets and green parking lots. Their G3 initiative in particular focuses on green streets, jobs, and towns.
This manual consists of two volumes. The first volume provides designers a general overview of how to size, design, select, and locate BMPs at a new development site to comply with state stormwater performance standards. The second volume contains appendices with more detailed information on landscaping, BMP construction specifications, step-by-step BMP design examples, and other assorted design tools.
This manual provides designers a general overview of how to select, locate, size, and design BMPs at a development site to comply with state stormwater performance standards. Chapter 5 provides complete definitions, design specifications, and computational methods for particular green infrastructure practices.
This manual consists of three volumes. All three volumes serve to aid designers in proper planning, site design, BMP selection, and proper erosion and sediment control on active construction sites.
Portland, OR adopted a comprehensive Green Street Policy in 2007 to promote green street facilities in both public and private development.
Ventura, CA has had a green streets policy in place for almost as long as Portland. With the adoption of the policy in 2008, the city dedicated 20% of its street paving fund to incorporating green street elements into repaving projects on a citywide basis. It also led the way by designing and constructing a pilot project on a major street.
Chicago, IL has a green alleyways program, including a handbook/design manual. This approach works in Chicago, because alleys are public property in that city; however, even in communities where alleys are privately owned, an incentive program might be an option.

Building for Sustainable Communities. June 2012)

1.13.2 Zoning and Permitting Incentives

Various incentives can be integrated into the framework of existing development codes and regulations. Such incentives encourage private developers to implement green infrastructure practices in new or redevelopment projects in exchange for an easier and/or cheaper permitting process. Some common types of incentives include:

Density bonuses/ zoning upgrades	Reduced parking requirements	Installing green roofs, rain gardens, rain harvesting devices (barrels, cisterns), or permeable pavement
Increases in floor area ratios (FAR)	Reduced stormwater requirements	Free consulting from in-house design experts or other staff to help navigate the permit process
Expedited permitting	Expedited permitting	Removing impervious cover or disconnecting impervious areas from stormwater control system via infiltration systems
Vegetated Stream Buffers	Waived fees (consultant code review fees, application fees)	Green buildings and developments (as defined by the US Green Building Council or a state or local program)

Zoning and Permitting Incentive Case studies

- Chicago's Green Permit Program "reviews permits much faster, even in as few as 30 days, for projects that meet certain LEED (Leadership in Energy and Environmental Design) criteria that include better stormwater management practices." In addition, "participants that display a particularly high level of green strategy can possibly have consultant code review fees waived."[12]

- Portland, OR's "Floor Area Ratio (FAR) Bonus increases a building's allowable area in exchange for adding an ecoroof/greenroof. Portland has seen over $225 million in additional private development through this program, and more than 120 ecoroofs have been built in the center city district."[12]

- Knox County, TN's Water Quality Volume Credits program "allows for a reduction in the water quality treatment volume (WQv). The credit system directly translates into cost savings to the developer by reducing the size of structural stormwater control and conveyance facilities. Site designers are encouraged to utilize as many credits as they can on a site. Greater reductions in stormwater storage volumes can be achieved when many credits are combined (e.g., disconnecting rooftops and protecting natural conservation areas)."[12]

1.14 Municipal Policy Case Studies

Green infrastructure policies can achieve multiple municipal goals at the same time as meeting Federal Clean Water Act requirements, making them useful and efficient policy options for local decision makers. The communities in the following case studies were not motivated to build green infrastructure programs by federal regulations alone. Although they may identify overlaps with Clean Water Act requirements, these local governments are making investments in green infrastructure because of many other community, economic, and environmental benefits.

A fully developed municipal program that supports green infrastructure at every scale, including the watershed, neighborhood, and site levels, is not created all at once or through a single policy or initiative. Many of the municipalities in the following case studies found that incremental policy adoption and iterative processes led to a more widespread adoption of green infrastructure approaches. Some policies are easier than others to implement, because they require less funding, they can be incorporated into existing programs, or they can be undertaken by supportive municipal offices or agencies. Other policies may be more difficult because of known and unexpected barriers, including:

- Funding,
- Lack of political support/leadership,
- Resistance to change,
- Coordination of multiple stakeholders and partners,
- Legislative action,
- Conflicting regulations,
- Need for technical information and training,
- Emerging markets,
- Misunderstanding about land use issues, and
- Cost concerns.[10]

Municipal Policy Case Study - 1
Lenexa, Kansas

Overview

Lenexa, Kansas is a growing suburb in metropolitan Kansas City that faces increasing pressure from the impacts of new development including more homes, roads, and other impervious surfaces that create more runoff. In an effort to protect local water quality, as well as prevent flooding and improve the quality of life for residents, Lenexa's comprehensive plan, Vision 2020, initiated Rain to Recreation, an innovative and integrated watershed protection program.

Blackhoof Park - Lenexa, Kansas

Rain to Recreation outlines a number of policies and programs to protect land from future development and introduce new green infrastructure practices that limit imperviousness and manage runoff on-site.

Regulatory Changes

In 2001, as part of the larger comprehensive plan, Lenexa established an integrated Stormwater and Watershed Management Master Plan that focuses on correcting existing problems in developed areas, building new facilities to minimize runoff, and protecting undeveloped lands. In 2004, Lenexa increased its requirements in favor of stormwater management practices that infiltrate, reuse, and evapotranspirate runoff by passing a stormwater ordinance and design manual to comply with its new National Pollutant Discharge Elimination System (NPDES) Phase II permit.

Lenexa's updated post-construction stormwater ordinance applies to both new and redevelopment projects and prioritizes water quality by assigning rankings for different stormwater management practices based on their value for water quality performance. Developers are thinking creatively about how to meet the new standards, selecting low-impact development practices that are both functional and aesthetically pleasing for residents and tenants. These natural and functional green infrastructure designs complement neighborhood revitalization plans and gain multiple benefits for the environment and community.

Land Acquisition and Restoration Projects

Lenexa is not just motivated by water quality improvements but is also driven to use green infrastructure practices and plans to address flood concerns, stream erosion, and quality of life improvements for local citizens. Water quality and water quantity are addressed through different policy mechanisms. While the new stormwater ordinance deals directly with water quality, water quantity is being minimized through large-scale projects that the city builds on its own.

The city purchases land in priority areas to provide flood mitigation, stream protection, water quality improvement, and recreational amenities. For example, Lake of the Prairie and Mize Lake are two projects that restore and stabilize damaged sections of streams, create new wetland areas, and include plans to construct large recreational and educational amenities. The largest project in Lenexa is a $26 million project called Lake Lenexa, which includes a 35-acre lake at the center of a nearly 350-acre public park. The comprehensive design for Lake Lenexa includes wetlands, rain gardens, stream restorations, trails, boardwalks, recreational space, and art and education areas. The city bought the property to protect the land from potential development and to enhance existing natural resources.

Creative Funding

Lenexa uses creative and long-term funding for these major land purchases and projects as well as for the day-to-day staffing and management of the Rain to Recreation program. In 2000, Lenexa taxpayers voted for a ballot to add a 1/8-cent sales tax to support building stormwater facilities that repair existing infrastructure problems and protect against future flooding events. In addition, Lenexa established a stormwater utility to provide sustainable funding for its new programs. The stormwater utility charge is based on the amount of runoff surface on each parcel of land. Each property is charged $5.50 (in 2008) per equivalent dwelling unit (EDU), which is measured at 2,750 sq. ft., or about the average runoff surface area of a house with a driveway. Commercial and non-residential properties are charged based upon the amount of stormwater runoff generated, and rates are calculated by dividing total runoff surface area by the number of square feet in an EDU (2,750) to more closely charge these larger properties by runoff contributions to the public system.

In 2004, the Lenexa City Council adopted the Systems Development Charge to require new developments to pay a one-time fee at the time of the building permit as a means for recovering costs for capital improvement activities. This charge works like a fee-in-lieu mechanism where developers are paying the city to manage water quantity that is created by the addition of new impervious surfaces.

Continued grants from state and federal sources, such as Clean Water Act Section 319 Nonpoint Source funding for park construction and Surface Transportation Project funding for roadway projects, have assisted with capital and demonstration projects like Lake Lenexa. Other sources of funding also support Lenexa's stormwater program, including Johnson County Stormwater Management Advisory Council funding supported by a 1/10-cent sales tax and basic permitting fees charged to developers. Together, these funding sources ensure long-term watershed protection through the continued creation, operation, and maintenance of green infrastructure practices.

Overall, Lenexa wields strong local control to require more rain gardens, bioswales, and other forms of green infrastructure in private development projects. At the same time, through the Rain to Recreation program, the city invests heavily in large land preservation and restoration projects that provide key neighborhood and watershed scale green infrastructure.[14]

Bioretention Cells - Lifetime Fitness - Lenexa, Kansas

Municipal Policy Case Study - 2
Portland, Oregon

Overview

Portland, Oregon is often cited as the prime example for green stormwater management and with good reason. Portland has one of the most mature and comprehensive green infrastructure programs in the country, with multiple overlapping policies and programs that have seen several iterations over time to become as well established and successful as they are today. The city has taken the initiative, and to some degree, the risk, necessary to implement a citywide program. In addition to substantial combined sewer overflow (CSO) tunnel costs (total costs to sewer ratepayers is estimated at $1.4 billion), Portland is investing in green infrastructure, in part to offset costs for major grey infrastructure. The city considers its $9 million investment in green infrastructure to save ratepayers $224 million in CSO costs, such as in maintenance and repair costs. On top of the direct stormwater benefits, Portland sees a number of additional benefits whether for Coho salmon and Steelhead trout or for residents in neighborhoods with Green Streets and Watershed Stewardship Grant projects. The array of policies listed above attest to the fact that Portland considers stormwater a resource to highlight rather than a problem to quickly remove.

Build-out and Practices Used

Technologies as varied as planters, rain gardens, swales, porous paving, rainwater harvesting, green streets, and disconnected downspouts are found in abundance and with good representation throughout Portland. These practices are found in a range of settings, including parking lots, apartment buildings, schools, private businesses, government offices, and in public spaces like parks and riverside esplanades. Again, the multiplicity of policies, from requiring on-site management for public and private development to incentive-based programs for homeowners and developers, has resulted in innovation in design and function.

Tanner Springs Park - Portland, Oregon

Portland’s Downspout Disconnection Program targets homes and small businesses in the combined sewer areas and provides a great opportunity for public education about stormwater and CSOs. This is in addition to the direct benefit of having 56,000 properties with disconnected downspouts, resulting in 1.2 billion gallons of stormwater kept out of the combined sewer system since 1994. Portland’s Clean River Rewards, or stormwater charge discount program, has seen over 35,000 participants, including both residential and commercial property owners. These discounts have resulted in $4 million in retroactive credits for properties with low impact development (LID) already in place at the program’s inception and another $1.5 million in discounted fees for newly participating properties.

Portland effectively blends regulations with incentives. Where local codes and ordinances can make a difference, they are employed. For existing properties or for more immediate results, other programs have been created, including grants, incentives, and discounts.

Requiring Green Infrastructure

Portland’s current Stormwater Management Code and Manual outline the requirements that apply to all projects within the city, whether public or private. All projects developing or redeveloping over 500 sq. ft. of impervious surface, or existing properties proposing new stormwater discharges off-site, are required to comply with pollution reduction and flow control requirements. Projects of any size must meet the Destination/Disposal Requirement, which includes a hierarchical system designed to “mimic predeveloped hydrologic conditions by requiring on-site infiltration wherever practicable:”

1. On-site infiltration with a surface infiltration facility.
2. On-site infiltration with a public infiltration sump system, private drywell, or soakage trench.
3. Off-site flow to drainageway, river, or storm-only pipe system.
4. Off-site flow to a combined sewer pipe system.

Rain garden and interpretive kiosk at Portland Community College CLIMB Center - Portland, Oregon

Green Streets

Portland's Green Streets Program is a cross-bureau policy adopted by the city council in 2007 to "incorporate the use of green street facilities in public and private development" to achieve a range of benefits including:

- Handling stormwater on-site through use of vegetated facilities.
- Providing water quality benefits and replenishing groundwater (if an infiltration facility).
- Creating attractive streetscapes that enhance neighborhood livability by enhancing the pedestrian environment and introducing park-like elements into neighborhoods.
- Meeting broader community goals by providing pedestrian and, where appropriate, bicycle access.
- Serving as an urban greenway segment that connects neighborhoods, parks, recreation facilities, schools, main streets, and wildlife habitats.

Green streets are a citywide priority that formalizes the process to "overlay multi-bureau project plans and scheduled Capital Improvement Program (CIP) projects" to identify how LID can be incorporated into plans for new streets and retrofits. By locating the overlap of goals and beneficial outcomes of vegetated stormwater systems in the right-of-way, green streets have been institutionalized into citywide policies and funding.

Tours, Signage, and Public Outreach

Portland Bureau of Environmental Services has several pre-designed walking and cycling tours that encourage residents and tourists to explore the range of ecoroofs, stormwater projects, and green streets locations in the city. The signage and descriptions that accompany these facilities engage the public to be more aware and knowledgeable about the role of stormwater in the urban setting. They also provide demonstrations for practitioners and professionals in landscape architecture, engineering, and other relevant fields.

Floor Area Bonus for Roof Gardens and Ecoroofs

The Floor Area Bonus for roof gardens and ecoroofs increases a building's allowable area in exchange for adding an ecoroof. This incentive program has produced an estimated $225 million in additional private development at 11 participating sites. The program has stimulated ecoroof developments and added to the more than 120 ecoroofs in the city. This kind of local development incentive stimulates LID designs and practices while also encouraging further market development for green infrastructure.

One of many Portland Green Street Projects - Portland, Oregon

Community Watershed Stewardship Grants

Community Watershed Stewardship Grants provide technical assistance and financial support and foster partnerships for community-initiated projects to improve watershed health. Projects have included ecoroofs, parking lot swales, habitat restoration, and downspout disconnects. Between 1995 and 2005, the program awarded 108 grants in all subwatersheds around the city, engaging more than 27,000 citizens. This widespread community engagement and on-the-ground neighborhood improvements foster a larger support network for green infrastructure policies while also resulting in context-sensitive solutions that are both instigated and maintained by local stakeholders.

Clean River Rewards

Clean River Rewards discount stormwater user fees up to 100% of the on-site stormwater management services and up to 35% of the total stormwater bill. Fee reductions are calculated based on the extent and effectiveness of practices to limit flow rate, pollution, and disposal. Participation is expected to reach 110,000 of the 176,000 ratepayers in Portland. 14,000 registrations have been processed since October 2006.

Implementation

Monitoring and learning from demonstration projects was a key element in the early stages of implementing new policies for managing stormwater with vegetated systems. This iterative process of addressing the requirements for municipal separate storm sewer systems and combined sewer systems, while also demonstrating LID approaches, helped Portland to establish one of the most mature and functional hybrid stormwater systems in the United States.

The learning curve for practitioners (including local engineers, developers, and internal city staff such as permit reviewers and inspectors) can slow the process of transitioning from a purely piped system to a hybrid system that includes natural drainage elements. However, as Tom Liptan from the Bureau of Environmental Services has stated, the winning formula throughout the initial stages of creating new policies was to identify partners and start with small projects that can then evolve into official policy.[14]

1.14 Conclusion

For more information regarding the utilization of green infrastructure practices in your community, please contact Mississippi Department of Marine Resources at (228) 374-5000 or Mississippi Department of Environmental Quality at (601) 961-5171.

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Constructed Wetland - Chattanooga, Tennessee

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