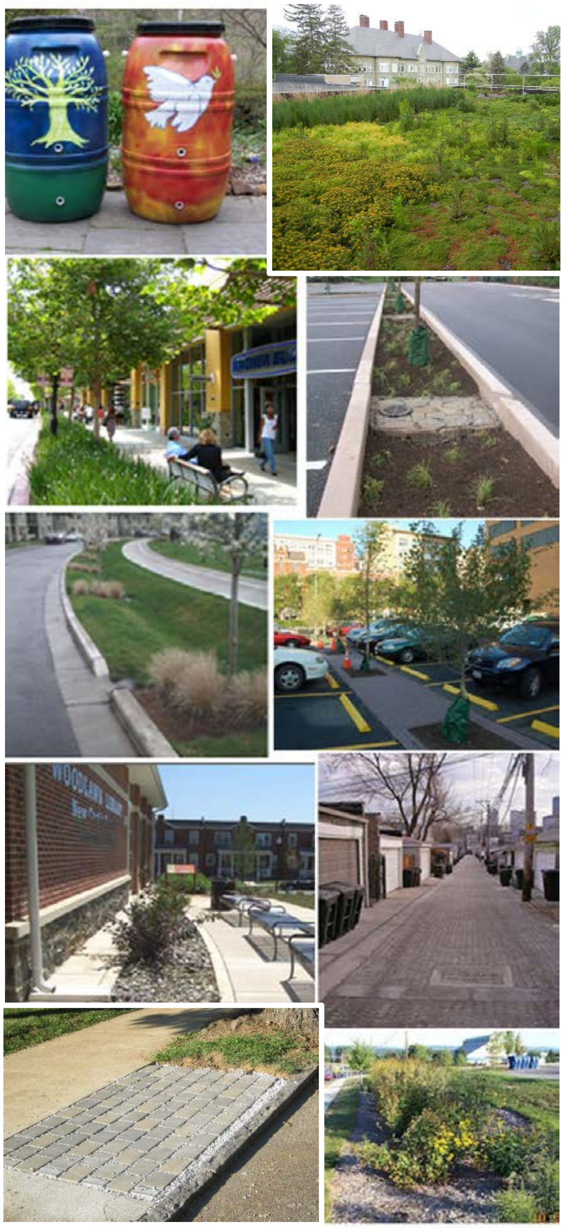
FACT SHEET: Overview of Green Infrastructure



Green infrastructure (GI) refers to a decentralized network of site-specific stormwater management techniques (see below for examples). GI techniques are implemented to reduce the amount of stormwater runoff entering the sewer system while also restoring the natural hydrologic cycle. As opposed to gray infrastructure - the traditional network of conveyance and treatment features such as pipes, detention basins, and holding tanks - green infrastructure manages stormwater through a variety of small, cost-effective landscape features located on-site.

Green infrastructure is particularly important in urban areas as it captures stormwater directly where it falls, enables rainwater to infiltrate through the soil and recharge groundwater resources, and slowly releases it back into local rivers and streams. Reducing the volume of stormwater that enters the sewer system is a critical solution to the problem of aging stormwater infrastructure. If storms continue to intensify as climate change models predict, GI will play a crucial role in supplementing sewers to manage urban runoff. Many municipalities are enacting stormwater ordinances to require property owners to bear the burden of managing their stormwater runoff, by paying a fee related to the total impervious area on their property.

How does Green Infrastructure work?

Green infrastructure employs the following processes to design a hydrologically functional site that mimics predevelopment conditions:

- Infiltration (allowing water to slowly percolate into the soil)
- Evaporation/transpiration using native vegetation
- Rainwater capture and re-use (storing runoff to water plants, flush toilets, etc.)

Common Green Infrastructure Applications

- Cisterns/Rain Barrels
- Bioretention (also called "Rain Gardens")
- Vegetated ("Green") Roofs
- Porous (Pervious) Pavement
- Downspout Disconnection
- Green Streets/Green Alleys
- Tree Trenches
- Vegetated Curb Extensions
- Infiltration Practices (Basins, Trenches, Dry Wells)

BENEFITS OF GREEN INFRASTRUCTURE

Environmental Benefits

- Recharges and improves quality of ground and surface waters
- Provides natural stormwater management
- Improves energy efficiency
- Reduces urban heat island effect
- Improves aquatic and wildlife habitat

Social Benefits

- Improves aesthetics and livability of urban communities
- Increases recreational opportunities
- Improves water and air quality
- Fosters environmental education opportunities

Economic Benefits

- Reduces existing and potential future costs of gray infrastructure
- Increases property values
- Reduces energy consumption costs

Image Source: artfulrainwaterdesign.net

REDUCING IMPERVIOUS SURFACES DECREASES SURFACE RUNOFF AND IMPROVES ENVIRONMENTAL CONDITIONS

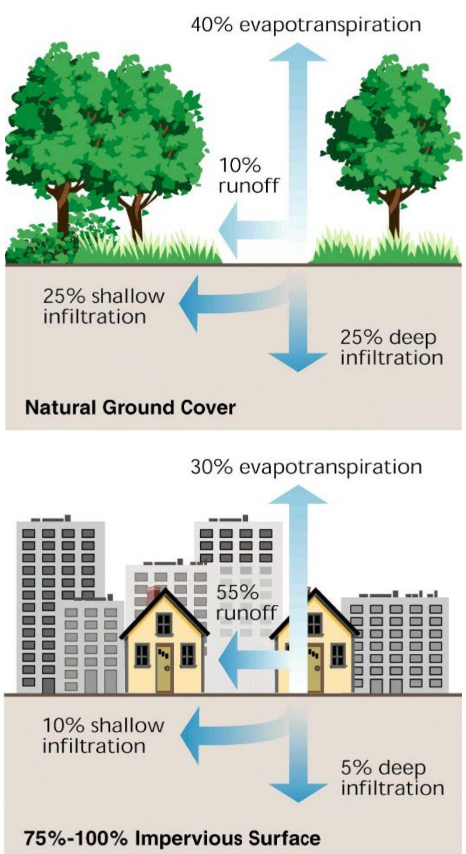


Image: FISRWG

ADDITIONAL CONSIDERATIONS

Maintenance of Green Infrastructure

Similar to conventional gray infrastructure, green infrastructure does require some level of maintenance to ensure optimal performance:

- Many GI techniques require regular maintenance, whether related to vegetation (weeding, pruning, mulching) or operational maintenance/repair (cleaning pervious pavement)
- The life cycle of the technology or vegetation used in the GI technique must be taken into account when preparing a maintenance plan

Cost of Green Infrastructure

- Costs for green infrastructure vary widely depending on specific site conditions and the type of GI techniques being used
- Often the cost of GI projects is competitive with or less than comparable gray infrastructure projects

FACT SHEET: DOWNSPOUT DISCONNECTION

In urban areas, roof runoff flows through gutters and downspouts and out to the storm or combined sewer. 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.

For disconnection to be safe and effective, each downspout must discharge into a suitable receiving area. Roof runoff can be redirected to a garden, yard, planter, or a rain barrel or cistern for eventual reuse. Runoff must not flow toward building foundations or onto adjacent property.

A plan for downspout disconnection will work with the existing downspouts on a building assuming there is an adequate receiving area; however, for buildings with internal drainage, disconnecting internal downspouts may be difficult or impractical.

BENEFITS

- Provides supplemental water supply when used in conjunction with capture/reuse systems
- Wide applicability
- Related cost savings and environmental benefits
- Reduced runoff volume, CSOs Peak

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Limited
Industrial	Yes
Retrofit	Limited
Highway	No

Residential downspout disconnect in Lancaster, PA and Portland, OR
(Source: Portland Stormwater Website)

VARIATIONS

- Scuppers
- Drip chains
- Decorative gargoyles

KEY DESIGN FEATURES

- Install splashblock at the end of the extension to prevent erosion
- Roof runoff must be discharged
  at least 5 feet away from property lines including basements and porches

SITE FACTORS

- Water table to bedrock depth – N/A
- Soils – N/A
- Slope – N/A
- Potential hotspots – Yes (with treatment)
- Maximum drainage area – N/A

MAINTENANCE

- Check materials for leaks and defects
- Remove accumulated debris, especially from gutters

COST

- Inexpensive; materials are readily available at hardware store

POTENTIAL LIMITATIONS

- Internal drainage more difficult to disconnect
- Do not disconnect onto adjacent property owner
- 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

FACT SHEET: CISTERNS/RAIN BARRELS


Example of above-ground cistern with vegetation screening

Cisterns (or rain barrels) are structures designed to intercept and store runoff from rooftops to allow for its reuse, reducing volume and overall water quality impairment. Stormwater is contained in the cistern structure and typically reused for irrigation or other water needs. This GI technology reduces potable water needs while also reducing stormwater discharges.

Cisterns are typically located underground and are a container or tank with a larger storage capacity than a rain barrel, and typically used to supplement greywater needs (i.e. toilet flushing) in a building, as well as irrigation. Rain barrels are above-ground structures connected to rooftop downspouts that collect rainwater and store it until needed for a specific use, such as landscape irrigation.

Cisterns and rain barrels can be used in urbanized areas where the need for supplemental onsite irrigation or other high water uses is especially apparent.

BENEFITS

- Provides supplemental water supply
- Wide applicability
- Reduces potable water use
- Related cost savings and environmental benefits
- Reduced stormwater runoff impacts

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Yes
Industrial	Yes
Retrofit	Yes
Highway/Road	No
Recreational	Yes
Public/Private	Yes/Yes


Rain barrel prototype example

VARIATIONS

- Cisterns – can be both underground and above ground
- Water storage tanks
- Storage beneath a surface using manufactured products
- Various sizes, materials, shapes, etc.

KEY DESIGN FEATURES

- Small storm events are captured with most structures
- Provide overflow for large storms events
- Discharge water before next storm event
- Consider site topography, placing structure up-gradient of plantings (if applicable) in order to eliminate pumping needs

SITE FACTORS

- Water table to bedrock depth – N/A (although must be considered for subsurface systems)
- Soils – N/A
- Slope – N/A
- Potential hotspots – yes with treatment
- Maximum drainage area – N/A

MAINTENANCE

- Discharge before next storm event
- Clean annually and check for loose valves, etc.
- May require flow bypass valves during the winter

COST

- Cisterns typically range from $500 to $5000/ Rain Barrels range from $100 to $300

POTENTIAL LIMITATIONS

- Manages only relatively small storm events which requires additional management and use for the stored water
- Typically requires additional management of runoff
- Requires a use for the stored water (irrigation, gray water, etc.)

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

FACT SHEET: BIORETENTION FEATURES – RAIN GARDENS AND PLANTERS

Rain garden in a public park setting in Lancaster, PA

Right-of-way bioretention planting in Syracuse, NY

Bioretention areas (often called Rain Gardens) are shallow surface depressions planted with specially selected native vegetation to treat and capture runoff and are sometimes underlain by sand or gravel storage/infiltration bed. Bioretention is a method of managing stormwater by pooling water within a planting area and then allowing the water to infiltrate the garden. In addition to managing runoff volume and mitigating peak discharge rates, this process filters suspended solids and related pollutants from stormwater runoff.

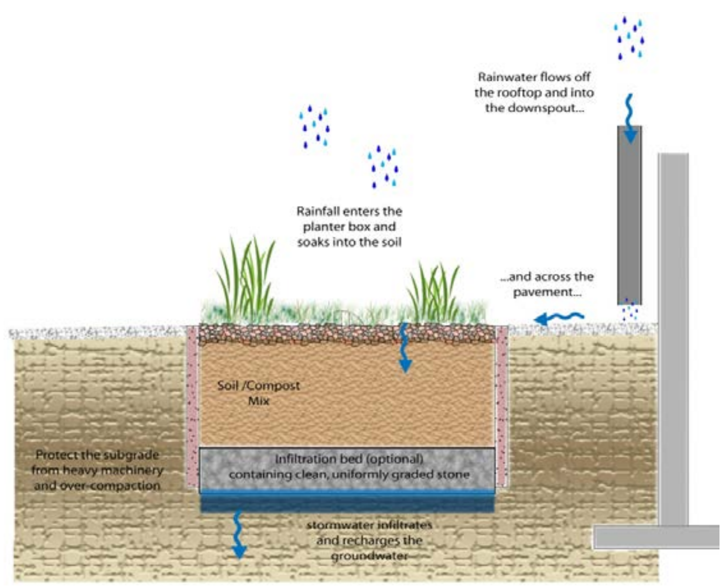
Bioretention can be designed into a landscape as a garden feature that helps to improve water quality while reducing runoff quantity. Rain Gardens can be integrated into a site with a high degree of flexibility and can balance nicely with other structural management systems including porous pavement parking lots, infiltration trenches, and other non-structural stormwater BMPs. Bioretention areas typically require little maintenance once established and often replace areas that were intensively landscaped and require high maintenance.

A Planter Box is a container or enclosed feature located either above ground or below ground, planted with vegetation that captures stormwater within the structure itself.

BENEFITS

- Volume control & GW recharge, moderate peak rate control
- Versatile w/ broad applicability
- Enhanced site aesthetics and habitat
- Potential air quality & climate benefits

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Yes (Planters)
Industrial	Yes
Retrofit	Yes
Recreational	Yes (Bioretention)
Public/Private	Yes
Residential	Yes



Conceptual cross-section showing planter with infiltration

VARIATIONS

- Subsurface storage/infiltration bed
- Use of underdrain and/or impervious liner
- Planters – Contained (above-ground), infiltration (below ground), flow-through
- Pre-treatment incorporated into design

KEY DESIGN FEATURES

- Ponding depths 6 to 18 inches for drawdown within 48 hours
- Plant selection (native vegetation that is tolerant of hydrologic variability, salts, and environmental stress)
- Amend soil as needed
- Stable inflow/outflow conditions and positive overflow for extreme storm events
- Planters require flow bypass during winter
- Planters - Captured runoff to drain out in 3 to 4 hours after storm even unless used for irrigation

SITE FACTORS

- Water Table/ Bedrock Separation: 2-foot minimum, 4-foot recommended (N/A for contained planter)
- Soils: HSG A and B preferred; C & D may require an underdrain (N/A for contained planter)
- Feasibility on steeper slopes: medium
- Potential Hotspots: yes with pretreatment and/or impervious liner, yes for contained planter
- Maximum drainage area: 5:1; not more than 1 acre to one rain garden

MAINTENANCE

- Requires watering during establishment
- Spot weeding, pruning, erosion repair, trash removal, mulch reapplication required 2-3x/growing season
- Maintenance tasks and costs are similar to traditional landscaping

COST

- Bioretention costs will vary depending on size/vegetation type; typical costs are $10-17 per sq. foot

POTENTIAL LIMITATIONS

- Higher maintenance until vegetation is established
- Limited impervious drainage area to each BMP
- Requires careful selection & establishment of plants
- Planters have relatively high cost due to structural components for some variations

STORMWATER QUANTITY FUNCTIONS		STORMWATER QUALITY FUNCTIONS		ADDITIONAL CONSIDERATIONS	
Volume	Medium/High	TSS	Medium/High	Capital Cost	Medium
Groundwater Recharge	Medium/High	TP	Medium	Maintenance	Medium
Peak Rate	Low/Medium	TN	Medium	Winter Performance	Medium
Erosion Reduction	Low/Medium	Temperature	Medium/High	Fast Track Potential	Medium
Flood Protection	Low/Medium			Aesthetics	High

FACT SHEET: VEGETATED (GREEN) ROOFS

Green roof at West Chester University

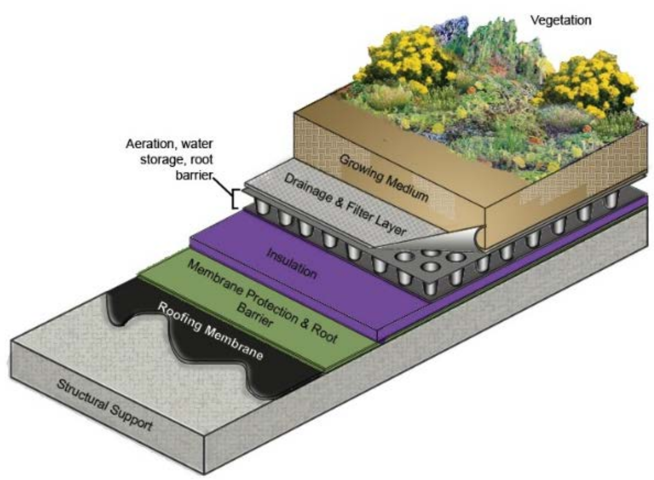
A green roof is a veneer of vegetation that is grown on and covers an otherwise conventional flat or pitched roof, endowing the roof (< 30 degree slope) with hydrologic characteristics that more closely match surface vegetation. The overall thickness of the veneer typically ranges from 2 to 6 inches and may contain multiple layers, consisting of waterproofing, synthetic insulation, non-soil engineered growth media, fabrics, and synthetic components. Vegetated roofs can be optimized to achieve water quantity and water quality benefits. Through the appropriate selection of materials, even thin vegetated covers can provide significant rainfall retention and detention functions.

Depending on the plant material and planned usage for the roof area, modern vegetated roofs can be categorized as systems that are intensive (usually > 4 inches of substrate), semi-intensive, or extensive (<4 inches). More maintenance, higher costs and more weight are the characteristics for the intensive system compared to that of the extensive vegetated roof.

BENEFITS

- High volume reduction (annual basis)
- Moderate ecological and habitat value
- High aesthetic value
- Energy benefits (heating/cooling)
- Urban heat island reduction

POTENTIAL APPLICATIONS	
Residential	Limited
Commercial	Yes
Ultra Urban	Yes
Industrial	Yes
Retrofit	Yes
Highway/Road	No
Recreational	Yes
Public/Private	Yes/Yes



Cross-section showing components of vegetated roof system ch2m

VARIATIONS

- Green roofs - single media system, dual media system (with synthetic liner)
- Green roofs - Intensive, Extensive, or Semi-intensive

KEY DESIGN FEATURES

- Engineered media should have a high mineral content and is typically 85% to 97% nonorganic.
- 2-6 inches of non-soil engineered media; assemblies that are 4 inches and deeper may include more than one type of engineered media.
- Irrigation is generally not required (or even desirable) for optimal stormwater management
- Internal building drainage, including provision to cover and protect deck drains or scuppers, 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 siding.
- The roof structure must be evaluated for compatibility with the maximum predicted dead and live loads. Typical dead loads for wet extensive vegetated covers range from 8 to 36 pounds per square foot.
- Waterproofing must be resistant to biological and root attack. In many instances a supplemental roof-fast layer is installed to protect the primary waterproofing.

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 per square foot

COST

- Green roofs: $5 - $50 per square foot, including all structural components, soil, and plants; more expensive than traditional roofs, but have longer lifespan; generally less expensive to install on new roof versus retrofit on existing roof

POTENTIAL LIMITATIONS

- Green roofs have higher maintenance needs until vegetation is established
- Need for adequate roof structure; can be challenging on retrofit application

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

FACT SHEET: POROUS PAVEMENT

Porous asphalt basketball court (Lancaster, PA)

Porous (pervious) pavement is a Green Infrastructure (GI) technique that combines stormwater infiltration, storage, and structural pavement consisting of a permeable surface underlain by a storage/infiltration bed. Porous pavement is well suited for parking lots, walking paths, sidewalks, playgrounds, plazas, basketball courts, and other similar uses.

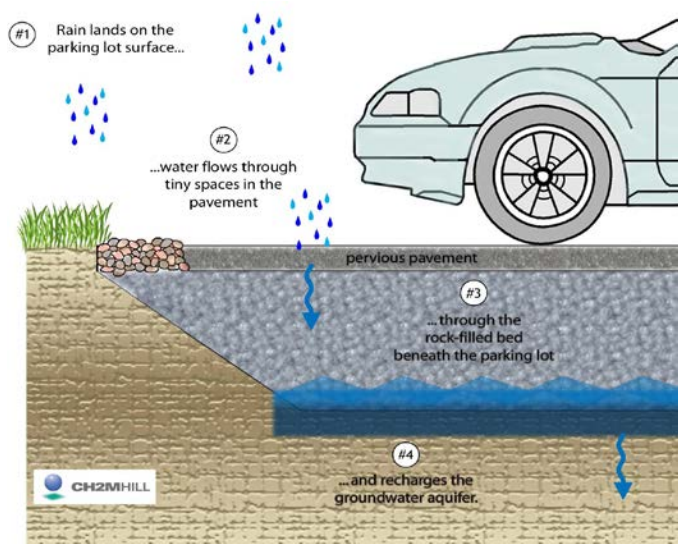
A porous pavement system consists of a pervious surface course underlain by a storage bed placed on uncompacted subgrade to facilitate stormwater infiltration. The subsurface storage reservoir may consist of a stone bed of uniformly graded, clean and washed course aggregate with a void space of approximately 40% or other pre-manufactured structural storage units. Porous pavement may be asphalt, concrete, permeable paver blocks, reinforced turf/gravel, or other emerging types of pavement.

Porous pavers at WCU

BENEFITS

- Volume control & GW recharge, moderate peak rate control
- Versatile with broad applicability
- Dual use for pavement structure and stormwater management
- Pavers come in range of sizes and colors

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Yes
Industrial	Yes
Retrofit	Yes
Highway	Limited
Recreational	Yes
Public/Private	Yes



Conceptual diagram showing how porous pavement functions

KEY DESIGN FEATURES

- Infiltration testing required
- Do not infiltrate on compacted soil
- Level storage bed bottoms
- Provide positive storm water overflow from bed
- Surface permeability >20"/hour
- Secondary inflow mechanism recommended
- Pretreatment for sediment-laden runoff

SITE FACTORS

- Water Table/Bedrock Separation: 2-foot minimum
- Soils: HSG A&B preferred; HSG C&D may require underdrains
- Feasibility on steeper slopes: Low
- Potential Hotspots: Not without design of pretreatment system/impervious liner

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

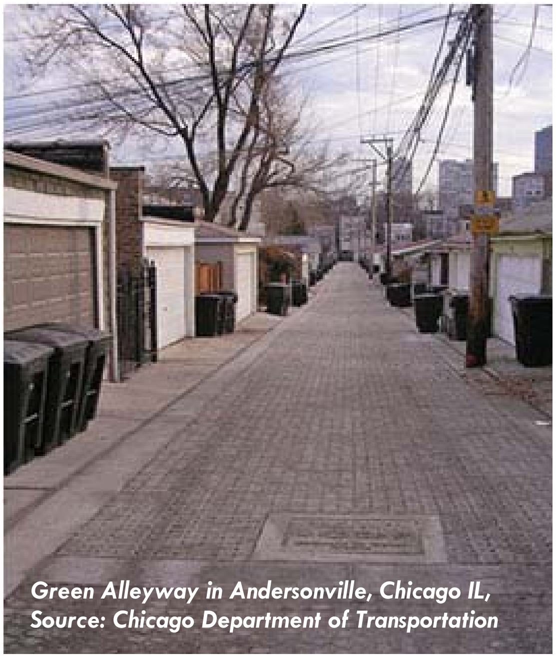
- Varies by porous pavement type
- Local quarry needed for stone filled infiltration bed
- $7-$15 per square foot, including underground infiltration bed
- Generally more than standard pavement, but saves on cost of other BMPs and traditional drainage infrastructure

POTENTIAL LIMITATIONS

- Careful design & construction required
- Pervious pavement not suitable for all uses/not suitable for steep slopes
- Higher maintenance needs than standard pavement

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

FACT SHEET: GREEN STREETS/GREEN ALLEYS



Green Alleyway in Andersonville, Chicago IL, Source: Chicago Department of Transportation

Green Streets incorporate a wide variety of Green Infrastructure (GI) elements including street trees, permeable pavements, bioretention, water quality devices, planter boxes and swales. Although the design and appearance of green streets will vary, the functional goals are the same: provide source control of stormwater, limit its transport and pollutant conveyance to the collection system, restore predevelopment hydrology to the extent possible, and provide environmentally enhanced roads. Also, other benefits include aesthetics, safety, walkability, and heat island reduction.

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
- Provide alternative transportation options/improve walkability
- Increased pedestrian safety and improved aesthetics
- Reduction of urban heat island
- Reduced runoff volume, increased groundwater recharge and evapotranspiration

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Yes
Industrial	Yes
Retrofit	Yes
Highway	Yes

Route 9A, NYC Source: NY Sustainable Stormwater Mgmt. Plan

VARIATIONS

- Porous pavement (street and/or sidewalk)
- Vegetated curb extensions
- Infiltration planters
- Infiltration trenches
- Enhanced tree plantings
- Water quality inlets

KEY DESIGN FEATURES

- See individual GI fact sheets: Tree Trench, Vegetated Curb Extension, Porous Pavement, etc.

SITE FACTORS

- Slope, Soils, Utilities, Size of right-of-way, Varies based on individual

MAINTENANCE

- Maintenance requirements vary according to individual GI practices

COST

- Varies by green infrastructure type
- \$120-\$190 per linear foot of block managed (i.e. capture of 1" of runoff)

POTENTIAL LIMITATIONS

- Maintenance needs
- Utility conflicts
- Conflicts with structures and other infrastructure (building foundations, etc)

STORMWATER QUANTITY FUNCTIONS		STORMWATER QUALITY FUNCTIONS		ADDITIONAL CONSIDERATIONS	
Volume	Medium	TSS	High	Capital Cost	Medium
Groundwater Recharge	Medium	TP	Medium	Maintenance	Medium/High
Peak Rate	Medium	TN	Medium	Winter Performance	High
Erosion Reduction	Medium	Temperature	High	Fast Track Potential	Low/Medium
Flood Protection	Low/Medium			Aesthetics	High

FACT SHEET: TREE TRENCH

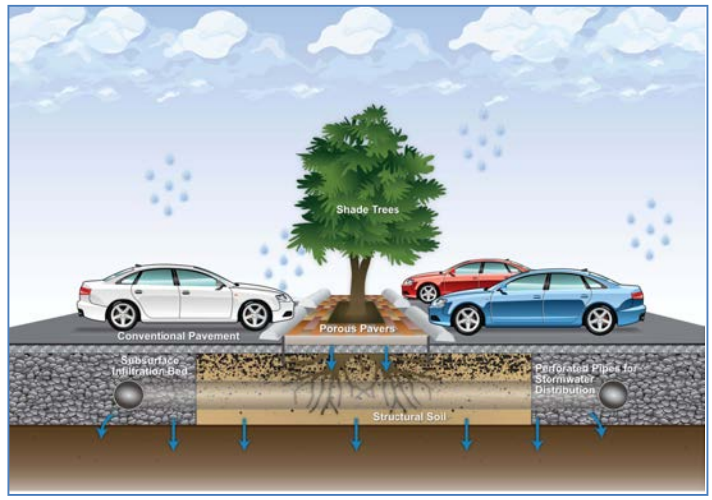
Tree trench in urban setting (Viridian Landscape Studio)

Tree trenches perform the same functions that other infiltration practices perform (infiltration, storage, evapotranspiration etc.) but in addition provide an increased tree canopy.

BENEFITS

- Increased canopy cover
- Enhanced site aesthetics
- Air quality and climate benefits
- Runoff reductions
- Water quality benefits
- High fast track potential
- Enhanced tree health/longevity

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Limited
Industrial	Yes
Retrofit	Yes
Highway	Yes



Example of Tree Trench in a parking lot adjacent to a Subsurface Infiltration Bed

Example of Street Tree Trench Attached to Trench Drain

VARIATIONS

- Structural soil or alternative (eg. Silva Cells)
- Porous pavers
- Open vegetated tree trench strip (planted with ground cover or grass)
- Tree grates
- Alternate storage media (modular storage units)
- Prefabricated tree pit

KEY DESIGN FEATURES

- Flexible in size and infiltration
- Native Species, Adequate tree species selection and spacing
- Quick drawdown
- Linear infiltration/storage trench
- New inlets, curb cuts, or other means to introduce runoff into the trench

SITE FACTORS

- Overhead clearance; minimize utility conflict
- Root zone
- Water table, Soil permeability/Limiting zones

MAINTENANCE

- Water, mulch, treat diseased trees, and remove litter as needed
- Annual inspection for erosion, sediment buildup, vegetative conditions
- Biannual inspection of cleanouts, inlets, outlets, etc.
- Maintenance cost for prefabricated tree pit: $100-$500 per year

COST

- $850 per tree/ $10-$15 per square foot
- $8000-$10,000 to purchase one prefabricated tree pit system including filter material, plants, and some maintenance; $1500-$6000 for installation

POTENTIAL LIMITATIONS

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

STORMWATER QUANTITY FUNCTIONS		STORMWATER QUALITY FUNCTIONS		ADDITIONAL CONSIDERATIONS	
Volume	Medium	TSS	High	Capital Cost	Medium
Groundwater Recharge	Medium	TP	Medium	Maintenance	Medium
Peak Rate	Medium	TN	Medium	Winter Performance	High
Erosion Reduction	Medium	Temperature	High	Fast Track Potential	High
Flood Protection	Low/Medium			Aesthetics	High

FACT SHEET: VEGETATED CURB EXTENSIONS

Urban application of a vegetated curb extension in Portland, OR (Source: www.artfulstormwater.net)

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.

Vegetated curb extensions can be used at a roadway intersection, midblock, or along the length or block of the roadway, and can be combined with pedestrian crosswalks to increase safety along a roadway. Additionally, vegetated curb extensions provide traffic calming opportunities along with stormwater management opportunities. Vegetated curb extensions can be added to existing roadways with minimal disturbance and are very cost effective as retrofit opportunities. They can be used in a variety of land uses, and are a good technique to incorporate along steeply sloping roadways. They are also effective pretreatment (i.e. filtration) practices for runoff entering other Green Street practices, such as infiltration trenches.

BENEFITS

- Traffic calming and pedestrian safety
- Enhanced site aesthetics, habitat
- Potential air quality and climate benefits
- Potential combined sewer overflow reductions
- Wide applicability, including in ultra-urban areas
- Reduced runoff, improved water quality

POTENTIAL APPLICATIONS	
Residential	Yes
Commercial	Yes
Ultra Urban	Yes
Industrial	Yes
Retrofit	Yes
Highway	Limited
Recreational	Yes

Vegetated curb extensions in Berwyn, PA
Source: CH2M HILL

VARIATIONS

- Bulb-out; Bump-out
- Stormwater Curb Extension

KEY DESIGN FEATURES

- Design can incorporate existing inlets
- Size to handle runoff from the catchment area
- Infiltration testing required
- Do not infiltrate on compacted soil
- Level storage bed bottoms
- Native vegetation
- Work around existing utilities
- Mark curb cuts highly visible to motorists

SITE FACTORS

- Water Table/Bedrock Separation; 2-foot minimum.
- Soils: HSG A&B preferred; HSG C&D may require underdrains
- Feasibility on steeper slopes: high. Design to include backstop or check dam

MAINTENANCE

- Remove accumulated debris
- Clean inlets

COST

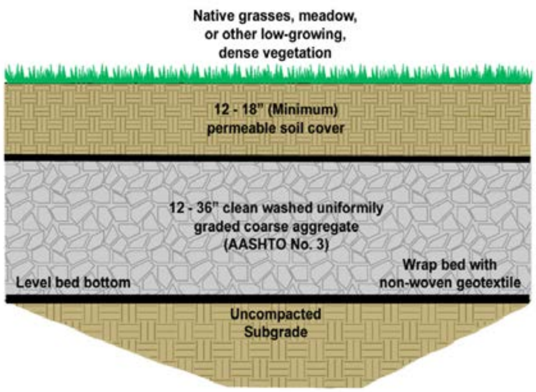
- Relatively inexpensive to retrofit
- $ 30/square foot for new construction

POTENTIAL LIMITATIONS

- Could require removal of on-street parking
- Conflict with bike lane
- Utility and fire hydrant conflicts

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

FACT SHEET: INFILTRATION PRACTICES



Typical cross-section of infiltration practices

Infiltration practices are natural or constructed areas located in permeable soils that capture, store, and infiltrate the volume of stormwater runoff through a stone-filled bed (typically) and then into surrounding soil.

Dry wells, also referred to as seepage pits, French drains, or Dutch drains, 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 rooftop structures. Due to their size, dry wells are typically designed to handle stormwater runoff from smaller drainage areas, less than one acre in size.

Infiltration basins are shallow surface impoundments that temporarily store, capture, and infiltrate runoff over a period of several days on a level and uncompacted surface. Infiltration basins are typically used for drainage areas of 5 to 50 acres with land slopes that are less than 20 percent.

Infiltration berms use a site's topography to manage stormwater and prevent erosion. Berms may function independently in grassy areas or may be incorporated into the design of other stormwater control facilities such as Bioretention and Constructed Wetlands. Berms may also serve various stormwater drainage functions including: creating a barrier to flow, retaining flow for volume control, and directing flows.

Infiltration trenches are linear subsurface infiltration structures typically composed of a stone trench wrapped with geotextile which is designed for both stormwater infiltration and conveyance in drainage areas less than five acres in size.

Subsurface infiltration beds generally consist of a rock storage (or alternative) bed below surfaces such as parking lots, lawns, and playfields for temporary storage and infiltration of stormwater runoff with a maximum drainage area of 10 acres.

Bioretention can be an infiltration practice and is discussed in the Bioretention fact sheet.

BENEFITS

- Reduces volume of stormwater runoff
- Reduces peak rate runoff
- Increases groundwater recharge
- Provides thermal benefits
- Multiple use/Dual use

Subsurface Infiltration Bed using Rainstore ™ blocks for storage media, Washington National Cathedral, DC

VARIATIONS

- Rain barrels
- Cistems - both underground and above ground
- Tanks
- Storage beneath a surface using manufactured products
- Various sizes, materials, shapes, etc.

KEY DESIGN FEATURES

- Depth to water table or bedrock
- Pretreatment is often needed to prevent clogging
- Often required level infiltration surface
- Proximity to buildings, drinking water supplies, karst features, and other sensitive areas
- Soil types (permeability, limiting layer, etc.)
- Provide positive overflow in most uses

SITE FACTORS

- Maximum Site Slope: 20 percent
- Minimum depth to bedrock: 2 feet
- Minimum depth to seasonally high water table: 2 feet
- Potential Hotspots: yes with pretreatment and/or impervious liner
- HSG Soil type: A and B preferred, C & D may require an underdrain

MAINTENANCE

- 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 re-vegetated 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.

COST

- Dry Well: Construction costs – \$4-9/ft^3, 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/ft^3, Maintenance Costs – 5-10% of capital costs
- Subsurface Infiltration Bed: Construction costs – 13/ft^3

POTENTIAL LIMITATIONS

- Pretreatment requirement to prevent clogging
- Not recommended for areas with steep slopes

ADDITIONAL CONSIDERATIONS	
Capital Cost	Medium
Life Cycle Costs	Medium
Maintenance	Medium
Winter Performance	High
Resistance to Heat	High
Fast Track Potential	Medium
Aesthetics	Medium

POTENTIAL APPLICATIONS						
	Residential	**Commercial**	**Ultra Urban**	**Industrial**	**Retrofit**	**Highway/Road**
Dry Well	Yes	Yes	Yes	Limited	Yes	No
Infiltration Basin	Yes	Yes	Limited	Yes	Yes	Limited
Infiltration Berm	Yes	Yes	Limited	Yes	Yes	Yes
Infiltration Trench	Yes	Yes	Yes	Yes	Yes	Yes
Subsurface Infiltration Bed	Yes	Yes	Yes	Yes	Yes	Limited

The Vegetated Infiltration Basin beneath this playfield manages rooftop runoff from the adjacent school building, Philadelphia, PA

Infiltration trench Chester County, PA

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

STORMWATER QUALITY FUNCTIONS				
	TSS	**TP**	**TN**	**Temperature**
Dry Well	Medium (85%)	High/Medium (85%)	Medium/Low (30%)	High
Infiltration Basin	High (85%)	Medium/High (85%)	Medium (30%)	High
Infiltration Berm	Medium/High (60%)	Medium (50%)	Medium (40%)	Medium
Infiltration Trench	Medium (85%)	High/Medium (85%)	Medium/Low (30%)	High
Subsurface Infiltration Bed	High (85%)	Medium/High (85%)	Low (30%)	High