Guide To Green Stormwater Infrastructure

BRANDYWINE CONSERVANCY

Brandywine Red Clay Alliance

Storm drain leading to a Bioswale at Veterans Memorial Park West Chester Borough

One of the most effective ways to improve water quality in our streams, reduce the impacts of flooding and reduce erosion is to address stormwater runoff from new and existing development, roads, parking lots, commercial and residential lots. In the past, the building of stormwater infrastructure required catchments, pipes, and other "hard" infrastructure to move stormwater runoff as quickly as possible to the closest waterway. This resulted in a rush of stormwater into our streams during each rain event causing erosion, flooding, and the flushing of pollutants from the land and impervious surfaces directly into our waterways. The development of new Green Stormwater Infrastructure closely mimics natural systems to address these issues. Intended for landowners, HOA's, developers, business owners, and municipal and government officials, this guide introduces 16 practices and encourages implementation.

Introduction to Green Stormwater Infrastructure

Green Stormwater Infrastructure (GSI) is a form of stormwater management that mimics the natural water cycle by promoting infiltration at the source of stormwater runoff. Unlike gray stormwater infrastructure—designed to move stormwater as quickly as possible—GSI aims to treat stormwater at its source and then slowly and naturally absorb it into the soil or native vegetation or filters into the groundwater and streams. Compared to highly engineered gray conveyance systems, GSI is cost-effective, resilient, and provides communities with enhanced aesthetics and natural resource benefits. In addition to effectively managing stormwater, GSI also helps filter air pollutants, regulates temperatures, sequesters carbon, provides habitat, and reduces energy and water demands.

Contents

Bioretention

A bioretention system is a shallow, vegetated depression that helps store, filter, and infiltrate stormwater. Typically, retention basins include an underdrain pipe that drains excess water into existing stormwater systems. By providing temporary stormwater storage, bioretention basins filter out pollutants and debris before releasing water into local waterways. Bioretention basins also slow the release of stormwater, decreasing stream erosion. The use of native, water-tolerant vegetation can increase absorption rates, reducing the amount of stormwater released into streams.

Bioretention basin in West Chester Borough, PA.

Benefits

- Filters pollution
- Increases soil infiltration
- Encourages groundwater recharge
- Reduces runoff
- Increases plant absorption

Applications

- Commercial developments
- Cultural and community facilities
- Residential yards and subdivisions
- Parking lot islands
- Along roadways
- Areas near downspouts
- Basin retrofitting

Cost

- The approximate cost per acre is between $5,000 to $10,000 and $3 to $15 per square foot*
- The maintenance cost is like other landscaped areas

Residential bioretention basin in Westtown Township, PA.

Operation and Maintenance

Green stormwater infrastructure requires regular maintenance of vegetation, like any landscaped area. An Operation and Maintenance (O & M) plan is recommended and may be requred for larger projects to ensure long term maintenance.

- Removal of debris (4 times annually and after every storm event of over 1 inch)
- Replace mulch seasonally until establishing 75% ground cover
- Remove invasive plants; replace any dead native plants twice a year
- Mowing should occur outside of the retention area once a month
- Trim the grass and wildflowers in the bioretention area annually using handheld trimmers to prevent compaction
- Conduct regular inspections until established vegetation is in the bioretention area; after that, twice a year
- For the first growing season, water regularly until vegetation is established
- Inspect vegetation, inlet, and outlet structures twice a year

Additional Resources: **Philadelphia Water Department's Stormwater Management Practice Guidance: Chapter 4.1 Bioinfiltration/Bioretention.**

www.pwdplanreview.org/manual/chapter-4/4.1-bioinfiltration-bioretention

Steps

- Identify low lying sites adjacent to stormwater discharge areas like parking lots and downspouts
- Evaluate soil conditions for permeable soils and stormwater volumes
- Develop a site-sensitive design with a landscape architect or qualified professional
- Select native plants that are water tolerant and provide aesthetic value
- Installation by a landscaper or trained crew
- Once established, regular maintenance is required

Bioretention basin at Hillendale Elementary School, Pennsbury Township, PA.

Bioretention basin in Unionville Community Park, East Marlborough Township, PA.

Bioswales

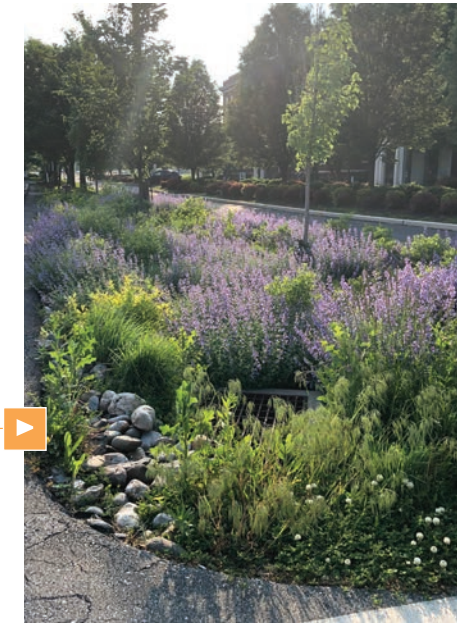
A bioswale is a linear, vegetated trench or ditch that helps convey stormwater while slowing down water flow to remove debris and pollutants. Like bioretention basins, bioswales often have drainage pipes that transport excess water to existing stormwater systems. Bioswales do not require much space and can replace traditional grass swales and storm drain pipes and gutters in parking lots or along roadways.

Benefits

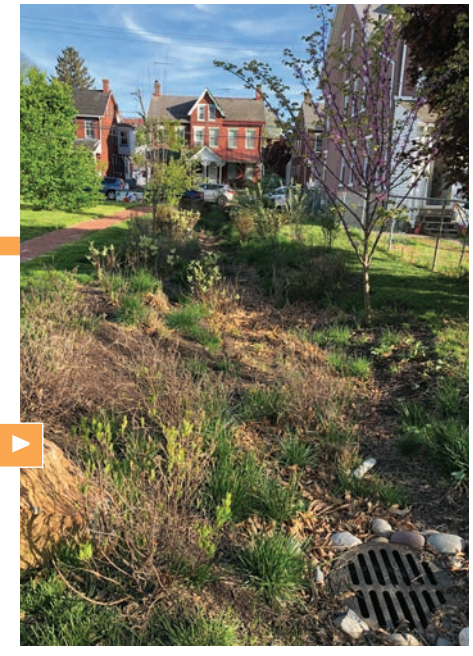
- Slow stormwater runoff
- Increase soil infiltration
- Filter debris and pollutants
- Provides additional habitat
- Aesthetic value

Applications

- Parking lots
- Along roadways, driveways, and trails
- Replacement for mowed grassed swales



Bioswale between parking lot and roadway in Lancaster City, PA.



Bioswale in Veterans Memorial Park in West Chester Borough, PA.

Operation and Maintenance

Green stormwater infrastructure requires regular maintenance of vegetation, like any landscaped area. An Operation and Maintenance (O & M) plan is recommended and may be requred for larger projects to ensure long term maintenance.

- Removal of debris (4 times annually and after every storm event of over 1 inch)
- Remove invasive plants; replace any dead native plants twice a year
- Trim grass and wildflowers within the bioretention area annually using handheld trimmers to prevent compaction
- Conduct regular inspections until vegetation is established; after that, twice a year
- For the first growing season, water regularly until vegetation is established
- Inspect vegetation, inlet, and outlet structures twice a year

Steps

- Identify low lying sites adjacent to stormwater discharge areas like parking lots and downspouts
- Evaluate soil conditions for permeable soils and stormwater volumes
- Develop a site-sensitive design with a landscape architect or qualified professional
- Select native plants that are water tolerant and provide aesthetic value
- Installation by a landscaper or trained crew
- Once established, regular maintenance is required

Cost

- The cost ranges between $5 to $25 per square foot*
- The maintenance cost is between $0.06 to $0.21 per square foot*
- Green Values Stormwater Management Calculator (cnt.org)

Bioswale planting at Myrick Conservation Ctr., Pocopson Township, PA.

Additional Resources: **Urban Green-Blue Grids' guidance on bioswales**
www.urbangreenbluegrids.com/measures/bioswales

Rain Garden Systems

A rain garden design collects rain from roofs, driveways, sidewalks, roads, and other areas that contribute to runoff. Unlike bioretention areas and bioswales, rain gardens are used for smaller sites, yet a series of rain gardens can be used for larger areas. Rain gardens are close to stormwater sources on the ground level, allowing water to pool and infiltrate the soil. They use native plants that effectively absorb and filter water. Depending on the type of storm, rain gardens typically take between 12 to 72 hours to drain and remain dry, to prevent mosquito breeding, until the next storm.

Rain Garden at Avon Grove Library, West Grove Borough, PA.

Benefits

- Maintains clean rainwater
- Creates habitat
- Prevents local flooding
- Filters pollution
- Improves community aesthetics

Applications

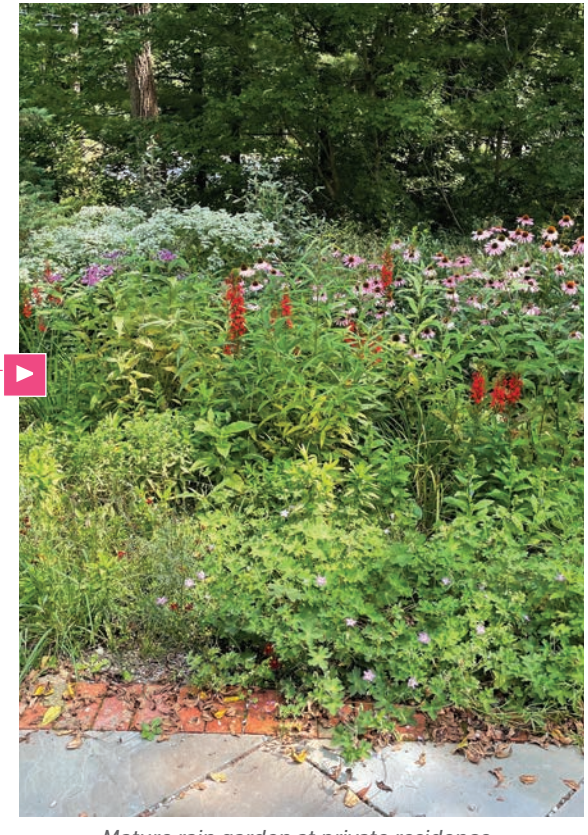
- Private residences
- Cultural and community facilities
- Small lots
- Urban areas
- Parking lots

Operation and Maintenance

- Water new plants every other day for the first two weeks
- Fertilizers are not necessary; maintain the mulch until establishing vegetated groundcover
- Minimal weeding after the first summer of growth
- Cut back growth after each winter
- Inspect inlets, outlets, and invasive plants at least twice a year

Steps

- Identify a low-lying area at least 10’ away from foundations
- Evaluate soil conditions for permeability
- Create a depression at least 6” deep
- Direct runoff to the site by redirecting downspouts and creating curb cuts
- Create an outlet for overflow during storm events
- Select a variety of native plants, grasses, and wildflowers to ensure a strong root system to prevent erosion



Mature rain garden at private residence.

Newly planted rain garden collecting stormwater, West Grove Borough, PA.

Cost

- Prices for Rain Gardens vary based on size, site conditions, soil, and selected plants. General cost estimates range between $1 to $16 per square foot depending on installation by a landscaper or a landowner*
- Maintenance cost would be equivalent to other forms of landscaping, approximately $0.31 to $0.61 per square foot*
- Green Values Stormwater Management Calculator (cnt.org)

Additional Resources: **Penn State Extension’s An Introduction to Rain Gardens**
https://extension.psu.edu/an-introduction-to-rain-gardens

Downspout Planters

Downspout planters are planted boxes layered with gravel, soil and plants, ideally native water-tolerant plants. These planters are connected to downspouts, slowing down the flow of stormwater and providing water for the plants. The excess water then filters through soil and stones and drains back to the stormwater system. These planters come in varied sizes, provide temporary stormwater storage, enhance the aesthetic value of properties, and require less watering than typical gardens.

Benefits

- Temporary water storage
- Compact alternative to a rain garden
- Water filtration
- Water conservation
- Aesthetic Value

Applications

- Buildings with external downspouts
- Urban areas with less room for traditional rain gardens

Cost

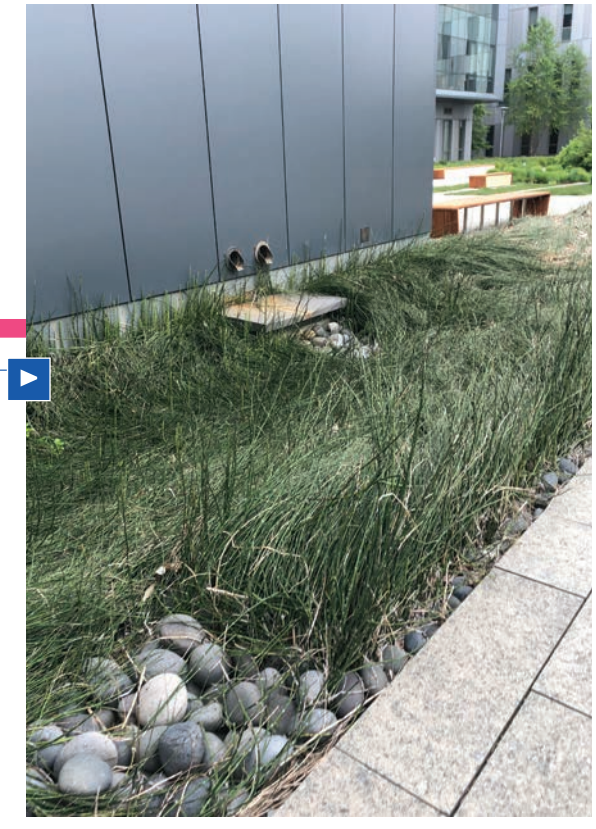
- Costs vary based on the size and materials used. On average, downspout planters cost $5 per square foot; however, they can range between $0.55 to $24 per square foot*
- Green Values Stormwater Management Calculator (cnt.org)

Operation and Maintenance

- Water newly planted vegetation for the first several weeks
- Water during droughts
- Check overflow drains for debris periodically after rainstorms
- Ensure the downspout remains connected after intense storms
- Keep gutters clear of leaves and debris

Steps

- Select a flat site near a building downspout
- Choose or build a planter
- Determine the size of the roof that will drain to the downspout
- Depending on the size of the roof, it may be necessary to install a diverter to limit the direct flow of runoff to the planter
- Install planter drainage system
- Connect to downspout
- Plant with native plants



Large downspout planter at University of Delaware, Newark, DE.

Large in ground downspout planter.
(Photo credit- "Flow-Through Planters" by Michael Feagans is licensed under CC BY-NC-SA 2.0).

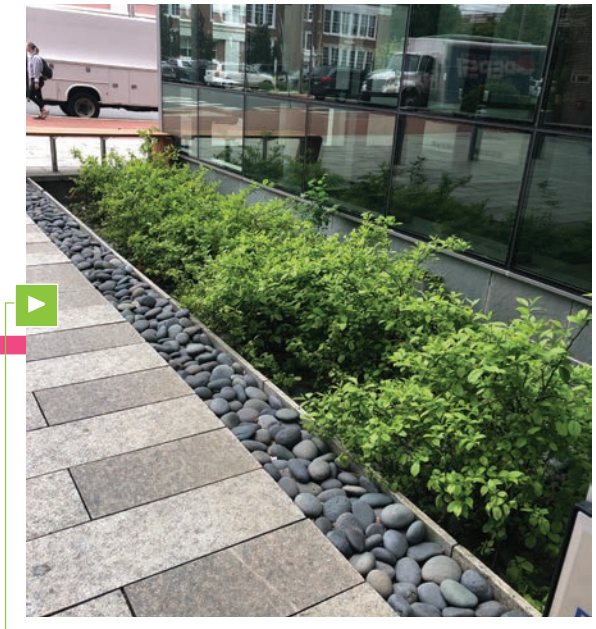
Residential downspout planter installed through the Philadelphia Water Department's Rain Check program.
(Photo credit- "Downspout Planter" by Home Science is licensed under CC BY-SA 2.0).

Additional Resources: **Philadelphia Water Department's Stormwater Management Practice Guidance: Chapter 4.1 Bioinfiltration/Bioretention.**

https://www.pwdraincheck.org/en/stormwater-tools/metal-downspout-planters

Stormwater Planters

Stormwater planters are built along the sidewalk, between the sidewalk and street, and collect stormwater runoff from the sidewalk and road. These planters usually have concrete sides to provide structure for the plants and are lined with permeable fabric and stones, then topped with soil and plants. The concrete sides have inlets or cutouts to allow water to flow in and overflow pipes to drain excess water to existing storm sewers. Most stormwater planter designs allow water to infiltrate the ground; however, some simply filter stormwater before directing water back to the storm sewer system. When used with other forms of green infrastructure, the effectiveness of stormwater planters can increase.



Stormwater planter along sidewalk at University of Delaware, Newark, DE.

Benefits

- Provides storage
- Decreases stormwater flow rate
- Infiltration
- Aesthetic value
- A buffer between pedestrians and motorists
- Cost-effective

Applications

- Between sidewalks and roadways

Cost

- Stormwater planters' cost between $4 to $8 per square foot; however, this cost varies based on site conditions and size*
- Green Values Stormwater Management Calculator (cnt.org)

Operation and Maintenance

Green stormwater infrastructure requires regular maintenance of vegetation, like any landscaped area. An Operation and Maintenance (O & M) plan is recommended and may be requred for larger projects to ensure long term maintenance.

- Weeding out invasive plants
- Replace mulch until established vegetated cover exists
- Debris removal
- Check the structure periodically and after severe storms to ensure everything is working properly
- Check and clean the drainage system periodically

Steps

- Evaluate soil conditions, may require soil amendments
- Install drainage system
- Plant with native plants

Stormwater planter along residential street in West Chester Borough, PA.

Additional Resources: **Green Building Aliance's guidence on stormwater planters**
https://www.go-gba.org/resources/green-building-methods/stormwater-planters/

Stormwater Curb Bump-Out

As the name suggests, stormwater curb bump-outs are vegetated areas where the curb extends several feet into the street. Stormwater bump-outs are usually placed at the corners of intersections or in the middle of a block. These bump-outs are planted with short shrubs and other plants to maintain driver eyelines. Curb cuts allow stormwater to flow into the bump-out, where the water is filtered and absorbed by the plants, and the remaining water can soak into the ground. Bump-outs direct excess water to the existing stormwater sewers in extreme storm events.

Benefits

- Filters and stores stormwater
- Traffic calming
- Pedestrian safety, when located at crosswalks
- Works with existing infrastructure
- Prevents illegal parking at corners

Applications

- Along low-lying streets
- Urban and Suburban streets
- Retrofits

Cost

- Stormwater bump-outs cost between $4 to $30 per square foot; however, this cost varies based on site conditions and size*
- Green Values Stormwater Management Calculator (cnt.org)

Stormwater bump-out along the street in West Chester Borough, PA.

Operation and Maintenance

Green stormwater infrastructure requires regular maintenance of vegetation, like any landscaped area. An Operation and Maintenance (O & M) plan is recommended and may be requred for larger projects to ensure long term maintenance.

- Weeding out invasives
- Replace mulch until established with vegetative cover
- Debris removal
- Check the structure periodically or after severe storms to ensure everything is working properly
- Check and clean the drainage system periodically

Stormwater bump-out at an intersection in West Chester Borough, PA.

Steps

- Select a low-lying site at intersections or mid-block
- Evaluate soil conditions
- Install drainage system
- Plant with native plants
- Work with local municipality to determine the right of way and traffic needs

Crosswalk with stormwater bump-out in Lancaster City, PA.

Additional Resources: Stormwater PA's Case study on stormwater bumpouts.
http://www.stormwaterpa.org/stormwater-bumpouts.html

Cisterns & Rain Barrels

Rain barrels and cisterns are rainwater storage systems that collect water from rooftops. These temporary storage systems reduce the volume of stormwater inundating storm sewers on rainy days. Some systems slowly drain into nearby natural areas—rain gardens, bioswales, and stormwater planters, while other systems provide the property with non-potable water for gardening, toilets, showers, etc.

Benefits

- Supplemental water supply
- Reduces water use
- Reduces stormwater runoff
- Reduces water bill

Applications

- Residential
- Commercial
- Can be used for indoor or outdoor grey water

Cost

- Cisterns cost between $500 to $5,000*
- Rain Barrels cost between $100 to $300 depending on their size and plumbing requirements*
- Green Values Stormwater Management Calculator (cnt.org)

Operation and Maintenance

- Water must be discharged before the next storm
- Clean annually
- Periodically check to ensure everything is functioning properly

Steps

- Select a flat site near a building downspout
- Determine the size of the roof that will drain to the storage system
- Choose a cistern or rain barrel
- Install storage system
- Install a fine mesh to the top of rain barrel to prevent mosquito breeding

Rainwater cistern at Stroud Water Research Center, West Marlborough Township, PA.

Typical rain barrel downspout connection, private residence.

Additional Resources: **Penn State Extension's guidence on rain barrels.**
https://extension.psu.edu/rain-barrels-for-water-conservation

Permeable Pavement

The permeable or porous pavement design allows water to filter quickly and infiltrate the underlying soil. Some examples of permeable pavement include pervious asphalt or concrete, interlocking concrete pavers, or permeable lattice pavers. Unlike pervious asphalt and concrete, which allows water to percolate through, concrete pavers provide gaps in or between the pavers to allow water to pass between those gaps and infiltrate into the ground. Project sites require permeable soils and a deeper stone base to store water while infiltrating.

Installing permeable paving at West Chester University, West Chester Borough, PA.

Benefits

- Stormwater volume control
- Groundwater recharge
- Cost-effective

Applications

- Parking lots
- Overflow parking
- Residential driveways
- Sidewalks
- Sports courts
- Must have permeable soils, on flat or gradual surfaces

Operation and Maintenance

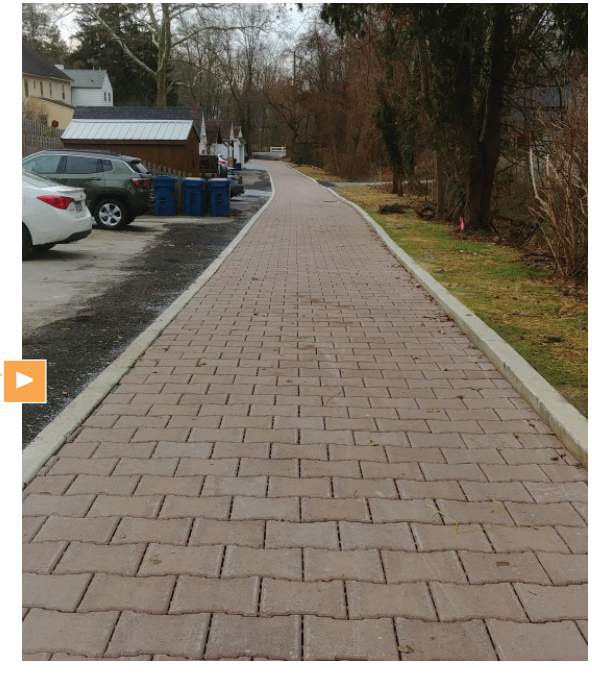
- Clean outlets
- Vacuum or sweep debris depending on the type of surface
- Keep soil and sediment off permeable paving

Steps

- Determine if the site has permeable soils
- Requires design by a landscape architect or engineer
- Install porous pavement
- Maintain and inspect annually

Cost

- Installation Cost: between $5 to $15 per square foot, with infiltration bed*
- Maintenance Cost: between $400 to $500 per year for vacuuming a half-acre lot (only for porous asphalt and concrete*
- Green Values Stormwater Management Calculator (cnt.org)



Permeable paving in West Chester Borough, PA.

Pervious overflow grassed parking area at Dansko Company store and outlet, Penn Township, PA.

Pervious paver parking spaces at Chadds Ford, Chadds Ford Township, PA.

Additional Resources: **Penn State Extension's guidence on porous and permeable paving.**
https://extension.psu.edu/roadside-guide-to-clean-water-porous-and-permeable-paving-materials

Tree Trenches and Filter Boxes

Tree trenches and filter boxes are used along streetscapes and parking lots to store and filter stormwater. These trenches and filter boxes typically connect to an underground engineered system that directs stormwater into the tree trench for storage, absorption, and infiltration. This underground trench or box is lined with permeable fabric and stone, then topped with soil. Redirected stormwater waters trees while discharging the remaining filtered water into the existing stormwater system.

Benefits

- Reduce and filter stormwater
- Increase tree canopy
- Provide buffer for pedestrians
- Benefits of street trees
  - Temperature regulation
  - Air quality
  - Aesthetic value
  - Increased property value
- Enhance tree health

Cost

- Construction: Installation can cost between $50 to $600 per tree*
- Maintenance can cost between $100 to $500 per year*
- Some systems can be large and elaborate and more costly*
- Green Values Stormwater Management Calculator (cnt.org)

Applications

- Incorporate in existing streetscapes

Operation and Maintenance

- Tree Maintenance
  - Water Trees
  - Mulch as needed
  - Treat diseased trees
  - Remove litter
- Inspect erosion, sediment buildup, and tree conditions annually
- Inspect the pipe system bi-annually

Steps

- Select appropriate site next to sidewalks, roads, and gathering areas
- Evaluate soil conditions, may require soil amendments
- Install drainage system
- Plant with native trees

Tree trench on the sidewalk along an urban street. (Photo Credit- "Washington Ave Tree Trench" by Philadelphia Water Department is licensed under CC BY 2.0).

Tree trenches lining Ben Franklin Parkway, Philadelphia. (Photo credit- "Tree Trenches on Ben Franklin Parkway" by Philadelphia Water Department is licensed under CC BY 2.0).

Tree trenches in Hoyer Heights, Minneapolis. (Photo credit- "Hoyer Heights Tree Trenches" by Mississippi WMO is licensed under CC BY-NC 2.0).

Construction of tree trench in Hoyer Heights, Minneapolis. (Photo credit- "Hoyer Heights Tree Trenches" by Mississippi WMO is licensed under CC BY-NC 2.0).

Additional Resources: **New Jersey Rutgers Cooperative Extension Fact sheet on Tree Boxes**
https://njaes.rutgers.edu/fs1209/

Delaware Department of Environmental Resources Green Infrastructure Fact Sheet for Tree Boxes and Tree Trenches
https://documents.dnrec.delaware.gov/GI/Documents/Green%20Infrastructure/Tree%20Box%20FS_04-1.pdf

Lawn to Meadow Conversion

Converting mowed lawn areas to native wildflower pollinator and grass meadows reduces stormwater runoff through infiltration since turfgrass has shallow roots and compacted soils while meadow plants have deep roots and porous soils. These plants stabilize soils to help reduce erosion along streams. Meadows also help to filter fertilizers and other pollutants from stormwater runoff. Meadows require less mowing and maintenance, with benefits for native wildlife and pollinators.

Benefits

- Reduces stormwater runoff and erosion
- Filter pollutants carried in stormwater runoff
- Increase wildlife biodiversity
- Provides valuable pollinator habitat
- Provides year-round aesthetic beauty
- Reduces costs of weekly mowing

Cost

- $250- 300 per 1,000 sq. Ft "do it yourself costs" without labor, contracted costs are $1,000- 2,500 per 1,000 sq. Ft. For installation by qualified landscaper*

Applications

- Residential and HOA areas
- Parks, cultural, and community sites
- Commercial sites and schools

Operation and Maintenance

- Seasonal mowing until a meadow is established
- Annual mowing after establishment
- Annual removal of invasive plants

Steps

- Must kill off turf grasses with herbicide, tilling, or black plastic
- Planting with native meadow mix, typically late fall or spring
- Annual mowing and invasive removal

Meadow plantings at Kennett Golf and Country Club, East Marlborough Township, PA.

Area of lawn converted to a wildflower meadow during the first year in Broad Run Park, West Bradford. As the meadow matures, more diverse vegetation is likely to be established.

Naturalized landscaping at Hillendale Elementary School in Pennsbury Township, PA..

Meadow planting at Unionville Community Park, East Marlborough Township, PA.

Additional Resources: **Pennsylvania Department of Conservation & Natural Resources guidence on lawn conversion.**

https://www.dcnr.pa.gov/Conservation/Water/LawnConversion/Pages/default.aspx

Riparian Buffer Plantings

Planting the riparian zones, a minimum of 35 feet on both sides of streams with native meadow, shrubs, and trees provides water quality benefits. The native vegetation is deep-rooted, prevents erosion, and filters pollution from stormwater runoff from entering the stream. Shade from a forested stream buffer reduces the stream's water temperatures, and leaves provide nutrients to aquatic wildlife. Establishing a forested stream buffer is one of the most effective water quality improvements.

Benefits

- Reduces stormwater runoff and erosion
- Filters pollutants carried in stormwater runoff
- Shades streams for cooler water temperatures
- Provides nutrients to streams
- Increase wildlife biodiversity
- Provides year-round aesthetic beauty

Applications

- Residential and HOA areas
- Parks, cultural, and community sites
- Commercial sites and schools

Cost

- $1,000 - $3,200 per acre depending on size of trees and planting density*
- Add $6 to $15 per tree for planting if using paid crews*
- Annual maintenance costs $500 - $1,000 using contracted crews*
- Grants may be available through conservation districts and conservation organizations

Operation and Maintenance

- Seasonal mowing or weed trimming between trees until trees are 6 – 8 feet tall
- Maintain deer/mammal protection for the first 4 – 10 years
- Remove invasive vines and plants competing with trees seasonally

Steps

- Identify riparian buffer zone, prevent future mowing and livestock access
- Develop a planting plan with experienced professional
- Purchase plant material at local nurseries or through conservation organization plant sales
- Plant trees with volunteers or paid crews
- Install deer protection tubes or wire caging
- Inspect after major storms

Volunteer tree planting on Black Horse Run, East Bradford- by fire department.

Buffer planting on Plum Run, East Bradford, PA.

Maturing buffer planting, Parkesburg, PA.

Additional Resources: **The Brandywine Conservancy's Riparian Buffer Guide.**
https://www.brandywine.org/sites/default/files/media/BrandywineConservancy-RiparianBufferGuide.pdf

Underground Infiltration Systems

An underground infiltration system comprises of a series of pipes, vaults, or modular structures designed to store and infiltrate stormwater underground temporarily. This practice requires permeable soils and the excavation of soils replaced with gravel and storage systems. These systems are an alternative to above-ground detention basins, especially in areas with limited space. These infiltration systems can be located under other land use such as parking lots, lawns or play areas.

Benefits

- Promotes infiltration of stormwater runoff
- Reduces stormwater runoff to streams
- Pre-treatment systems may capture sediment and other pollutants
- Replaces need for above ground detention basins
- Saves space in small project sites

Applications

- Residential lots (<10 acres)
- Commercial sites and schools (<10 acres)
- Under parking lots, play areas or other compatible land uses

Cost

- Average costs range between $1.19- $2.68 per square foot*
- Some systems can be large and elaborate and more costly*

Operation and Maintenance

- Inspect after every major storm for the first few months after installation
- Semi-annually inspect pretreatment devices for sediment build up and damage
- Semi-annually check drainage three days after a storm to ensure proper percolation

Steps

- Hire engineering or a similar firm to calculate stormwater needs, design system and apply for required permits
- Identify site, test soils for permeability
- Hire contractor to excavate site and install infiltration system
- Identify and mark off the location to ensure no soil compaction occurs from heavy equipment
- Replace topsoil and appropriate geotextile fabrics over infiltration system
- Connect infiltration system to the downspouts and catch basins

Excavation of hookup to underground infiltration system in Coatesville, PA.

An underground stormwater infiltration system under construction at a park in Minneapolis.
(Photo credit-"Infiltration System" by Mississippi WMO is licensed under CC BY-NC 2.0).

Installation of an underground infiltration system in Coatesville, PA.

Additional Resources: **Philadelphia Water Department's Stormwater Management Practice Guidance: Chapter 4.8 Subsurface Detention**
https://www.pwdplanreview.org/manual/chapter-4/4.8-subsurface-detention

Dry Well and Small-Scale Infiltration Trenches

These practices are a small-scale version of an underground storage and infiltration system that temporarily stores and then infiltrates stormwater runoff from roofs and other surfaces. Rainwater is directed from the roof or other surfaces into an underground gravel pit with a prefabricated plastic container or into a linear trench lined with geotextile fabric. These underground pits or trenches drain stormwater into the surrounding soil slowly. If designed properly, these should drain within 72 hours of a rain event. These features may require a pretreatment system to prevent clogging and potential groundwater contamination.

Benefits

- Reduces stormwater runoff
- Increase groundwater recharge
- Can help reduce the size of downstream stormwater management structures
- Save above ground space, especially on small lots because the system is located underground

Applications

- Residential lots (<5 acres)
- Commercial sites and schools (<5 acres)

Cost

- Average costs range between $1.19-$2.68 per square foot*
- Approximately $250 for a 50-gallon dry well/ additional costs for perforated pipe in trench applications*

Operation and Maintenance

- Inspect after every major storm for the first few months after installation
- Semi-annually inspect pretreatment devices for sediment build up and damage
- Semi-annually check drainage three days after a storm to ensure proper percolation

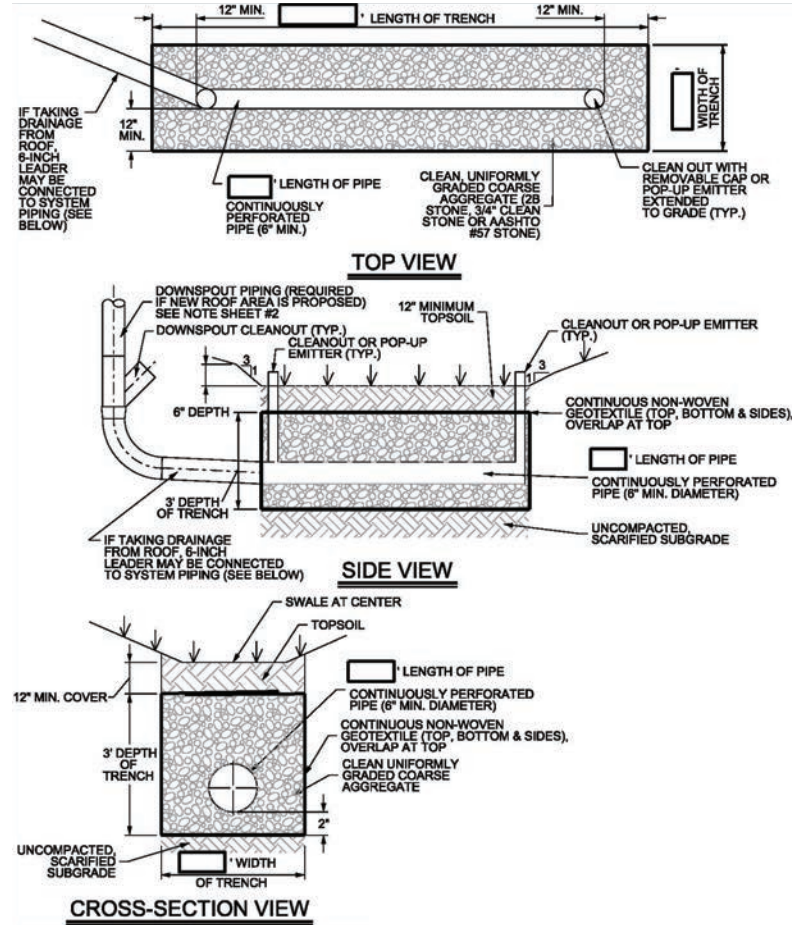
Steps

- Hire engineering company, landscape company or you may be able to complete installation yourself
- Measure surface area of new impervious surfaces and calculate size of pit/ trench for infiltration
- Identify and mark off the location of the dry well/trench to ensure no soil compaction occurs from heavy equipment
- Begin dry well/trench installation after site construction is completed or protect the location with a berm, silt fence, or compost sock to prevent sediment build-up in the area
- Install dry well/trench, line with geotextile fabric and stone
- Replace topsoil, seed and stabilize topsoil
- Connect dry well/trench to the downspout

Additional Resources: New Jersey Department of Environmental Protection's Stormwater Best Management Practices Manual, Chapter 9.2: Dry Wells.

https://www.nj.gov/dep/stormwater/bmp_manual/NJ_SWBMP_9.2-dry-wells.pdf

Infiltration trench design and concept developed by CEDARVILLE Engineering Group, LLC (CEG) and included in the Chester County Act 167 Stormwater Management Model Ordinance, Appendix A.



Simple infiltration design that can be installed by homeowner or landscape company.

Green Roofs

Vegetative or green roofs typically consist of 3-6 inches of growth media over a waterproof roof membrane on flat or gently sloped roofs. The growth media is planted with vegetation selected for year-round cover withstanding heat, cold, drought, and rain events. The growth media with vegetative cover can absorb a 1/4 inch rain or more, reducing or delaying stormwater run-off from typical impervious roof systems.

Benefits

- Reduce and delay stormwater runoff
- Filters stormwater runoff leaving roof system
- Reduces "heat island effect" and can provide cooler buildings
- Extends life of roofing membranes by preventing UV light degradation
- Provides aesthetic beauty in urban environments

Applications

- Commercial buildings
- Cultural buildings and schools
- Small scale residential applications

Operation and Maintenance

- Watering is only needed in the first growing season
- Seasonal weeding of vegetation
- Inspect roof outlets

Steps

- Determine if roof structure can support additional weight of green roof system
- Contract with green roof professional to design green roof system
- Select appropriate vegetation
- Installation by qualified work crews

Cost

- Commercially designed and installed green roofs cost $20 to $30/ square foot*

Typical green roof vegetation.

Green roof at West Chester University, West Chester Borough, PA.

Green roof at University of Delaware, Newark, DE.

Green roof with pavilion and patio area at Dansko Company store and outlet, Penn Township, PA.

Additional Resources: **Penn State Extension's guidence on green roofs.**

https://extension.psu.edu/green-roofs-for-stormwater

Conservation Design / Reducing Paved Areas

Hard, impervious surfaces like concrete and pavement speed up stormwater runoff. By decreasing or removing these surfaces, stormwater can be absorbed into the ground naturally, reducing runoff from that area. New site plans can employ conservation design and low impact strategies that allow for greater densities of development areas that preserve greater area for open spaces. These plans often utilize many of the practices featured in this guide. In new or redeveloped areas where it is not practical to remove all paved surfaces—parking lots or driveways, other solutions may be possible, like using permeable paving materials or reducing the paved area. For instance, a parking lot with two-way cart paths could be converted into a one-way cart path. Where pavement can be removed, depaved areas can be planted with native vegetation that can provide multiple benefits.

Benefits

- Reduces stormwater runoff
- Revegetated areas provide additional stormwater filtration and habitat creation
- Traffic calming (when cartway widths are reduced)
- Increased open space areas and lots with access to open spaces
- Greater wildlife biodiversity
- Aesthetic beauty

Applications

- Residential and HOA areas
- Parks, cultural, and community sites
- Commercial sites and schools

Operation and Maintenance

- Operation and Maintenance costs would be the same as other paved surfaces but may decrease as the amount of paved surfaces decrease
- If paved areas were converted to vegetated areas or permeable paving, additional maintenance would be required

Steps

- Hire engineer/planning firm with experience in conservation design
- In new developments, identify natural areas and features to preserve as open space, restrict new development outside of these areas
- If planning areas with new pavement, identify ways to reduce paving during the design process
- In areas with existing pavement, identify areas of unused or underused impervious surfaces
- Determine if the paved area can be eliminated and revegetated or if the area could be converted to permeable paving

Cost

- For new development: If conservation design is a priority at the beginning, costs may be similar to conventional designs while infrastructure costs are often lower due to less pavement, utility lengths, stormwater pipes and infrastructure
- For existing developments:
  - Average costs range between $0.27-$0.69 per square foot*.
  - An additional cost would be added for any conversion to pervious paving or vegetated landscapes

Conservation design images and concept development courtesy of Gaadt Perspectives, LLC, Chester County Planning Commission, and Chester County Water Resources Authority, as appears in Chester County's Act 167 Stormwater Management Model Ordinance, Appendix B (https://www.chesco.org/757/About-CCWRA)

Cul de sac with landscaped island to reduce the amount of paving.

Existing Conditions: *Identify natural features and sensitive areas to preserve, focus new development outside of these areas*

Conventional Layout: *Seek to maximize number of lots, but increase length of paved surfaces, utilities and storm water infrastructure*

Conservation Design : *Increases density of lots while decreasing pavement and length of utilities, while increasing preservation of open spaces and natural areas*

Constructed Wetlands

Constructed wetlands allow natural treatment utilizing wetland vegetation, soils, and microbial assemblages. Water filtration systems refine water sources—oceans, lakes, and streams, from pollutants for improved water quality regarding the health and safety of individuals, vegetation, and species within the ecosystem. When water flows through a constructed wetland, filtration begins as solids suspend within the vegetation, and plants or microorganisms absorb less soluble pollutants. For example, wetland microbes transform nitrogen into NO3 or NH4, an inorganic form, for plant growth within the wetland.

Constructed wetland at Dansko distribution warehouse in Penn Township, PA.

Benefits

- Utilizes natural resources for water filtration
- Allows for a self-renewal process as nitrogen naturally encourages plant growth
- Reduces wastewater odors
- Supports current wildlife and natural resources
- Restores aquatic systems
- Low cost
- Utilizes little energy for operation

Applications

- Sites in proximity to streams, lakes, or other water sources
- Low, flat areas, with water flow sloping down for gravity flow
- Drained wetlands
- Sites with compacted soil for seepage

Cost

- Average costs range between $0.27-$0.54 per square foot*

Constructed wetland at Dansko distribution warehouse in Penn Township, PA.

Trail through constructed wetlands at University of Delaware, Newark, DE.

Operation and Maintenance

Green stormwater infrastructure requires regular maintenance of vegetation, like any landscaped area. An Operation and Maintenance (O & M) plan is recommended and may be requred for larger projects to ensure long term maintenance.

- Remove solids and floatable substances blocking water flow
- Remove unwanted/harmful species
- Remove accumulated sediment
- Access inlet and outlet structures
- Constructed wetlands require a maintenance operator for regular inspections

Trail through constructed wetlands at University of Delaware, Newark, DE.

Steps

- Constructed Wetlands require a general construction storm water CWA Section 402 (NPDES) permit and a Storm Water Pollution Prevention Plan permit
- Construction must not harm current wildlife and water systems but also must allow for continued growth

Additional Resources: The EPA's guidence on constructed wetlands
https://www.epa.gov/wetlands/constructed-wetlands

Local Resources and Funding

A wide variety of public and private funding sources may assist in planning and implementing these GSI practices. Many require matching funds from the landowner, local municipality, or other partners. Funding sources include:

- Chester County Planning Commission
- Chester County Conservation District
- City of Newark
- Delaware Department of Natural Resources and Environmental Control (DNREC)
- Local municipalities, park authorities
- National Fish and Wildlife Foundation (Both private and federal funds from US Fish and Wildlife)
- New Castle County,(DE) Conservation District
- PADEP Growing Greener program
- PADCED Watershed Restoration Program
- PA DCNR grant programs
- Water Utilities and other businesses with an interest in clean water
- TreeVitalize Watershed Grants (Tree planting)
- US EPA and other federal funding programs

Brandywine Conservancy and Brandywine Red Clay Alliance prepared this booklet as part of our participation in the Brandywine Christina Cluster of the Delaware River Watershed Initiative (DRWI). Funding provided by William Penn Foundation. The opinions expressed in this publication are those of the authors and do not necessarily reflect the views of the William Penn Foundation.

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For more information about addressing stormwater pollution, practices, and funding, visit the Christina Watersheds Municipal Partnership (CWMP) website at www.cwmp.org

If your property is in the White Clay Creek, Red Clay Creek or Plum Run watersheds, additional resources may be available through the Catch the Rain program, which is a voluntary program for suburban homeowners in these watersheds.

For more information about these Green Stormwater Infrastructure Practices and sources of technical assistance and funding, contact:

Brandywine Conservancy
www.brandywine.org/conservancy
conservancy@brandywine.org
610-388-2700

Brandywine Red Clay Alliance
www.brandywineredclay.org
info@brandywineredclay.org
610-793-1090

The Brandywine-Christina Cluster of the DRWI is working to improve the water quality in our watershed through land preservation, agricultural best practices, stream restoration, and addressing stormwater impacts. Members are:

- Brandywine Conservancy
- Brandywine Red Clay Alliance
- Natural Lands
- Stroud Water Research Center
- The Nature Conservancy of Pennsylvania and Delaware
- University of Delaware Water Resources Center

Brandywine Red Clay Alliance

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