Henry County Green Infrastructure Handbook

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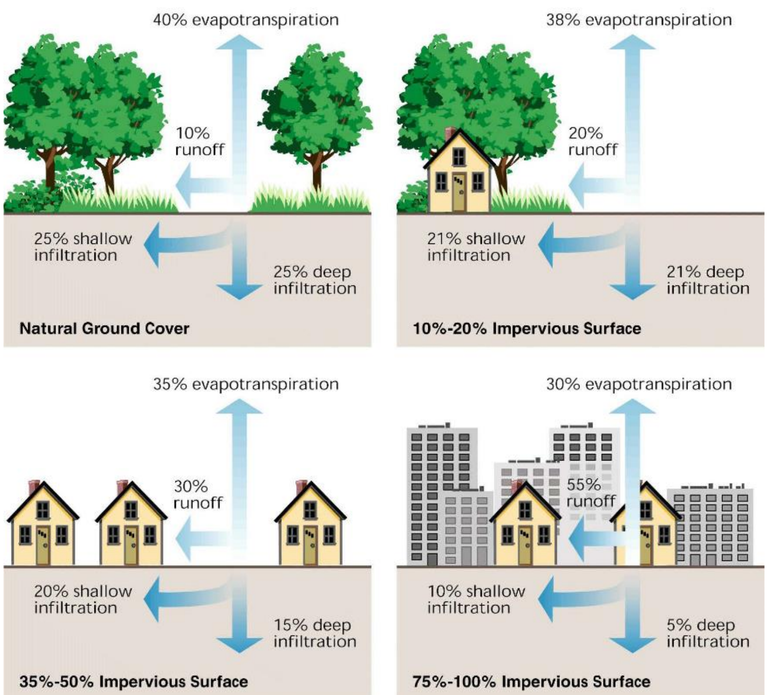
1.1 Introduction

Green infrastructure is defined by the Clean Water Act as "the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters."
Green infrastructure uses different methods to filter stormwater and restore natural processes to urban environments. Ultimately, green infrastructure is aimed at managing wet weather and stormwater pollution.

Urban environments reduce the amount of storm water absorbed into the ground. As a result, more runoff is generated. The stormwater runoff typically contains pollutants from the urban environment which then runs into the water system. Green infrastructure aims to restore an urban environment to its filtering capabilities before urbanization.

Figure 1. Image depicting the amount of storm water infiltration in varying environments.



1.2 Benefits of Green Infrastructure

There are many benefits to implementing green infrastructure. Green infrastructure can be more fiscally responsible. Construction costs can be saved by utilizing permeable surfaces. Open greenspaces, which are often a result of green infrastructure, lead to increased land values and a greater tax return for the community. Additionally, retaining trees reduces the need for stormwater retention facilities or other man-made flood solutions. Green infrastructure also has health and environmental benefits. Preserving forests and wetlands allows for a natural filtration system of water and air which reduces the risk of ailments caused by poor water or air quality. The implementation of green infrastructure reduces erosion and sedimentation drainage. Green infrastructure also provides habitats for wildlife.

1.3 Types of Green Infrastructure

Green infrastructure can be implemented on a small scale as well as on a larger scale. Some of the green infrastructure elements include:

- Bioretention
- Enhanced Swales
- Vegetated Filter Strip
- Permeable Pavements
- Downspout Disconnection
- Rainwater Harvesting
- Green Roofs
- Infiltration Practices
- Site Reforestation/Revegetation

1.4 Green Infrastructure Practice Selection

In general, the following information should be considered when deciding what green infrastructure practices to use on a development site:

- Ability to Help Satisfy the Stormwater Management Criteria
- Overall Feasibility
- Site Applicability

In addition, site planning and design teams should consider how the following site characteristics or design factors, will influence the use of green infrastructure practices on a development site:

- Drainage Area
- Poorly drained soils, such as hydrologic soil group C and D soils
- Well drained soils, such as hydrologic soil group A and B soils
- Terrain Slope
- Depth of water table

1.5 How Green Infrastructure Can Address Water Quality

Green Infrastructure Method	Median TSS Removal Efficiency	Probable Range of TSS Removal
Bioretention Cells	85%	80-92%
Bioswales	87%	83-92%
Vegetated Filter Strips	60%	60-80%
Permeable Pavements	64%	60-90%
Downspout Disconnection	80%	Varies
Rainwater Harvesting	Varies	Varies
Green Roofs	80%	80%-89%
Infiltration Practice	89%	50-100%
Site Reforestation/Revegetation	80%	Varies

1.6 Factors to consider when evaluating the applicability of Green Infrastructure Practices on a Development site

Green Infrastructure Practice	Rural Use	Suburban Use	Urban Use	Construction Cost	Maintenance
Bioretention Areas	▲	▲	▲	Medium	Medium
Bioswales	▲	▲	*	Medium	Medium
Vegetated Filter Strip	▲	▲	*	Low	Low
Permeable Pavement	*	▲	▲	Medium	High
Downspout Disconnection	▲	▲	*	Low	Low
Rainwater Harvesting	▲	▲	▲	Medium	Medium
Green Roofs	*	▲	▲	High	Medium
Infiltration Practices	▲	▲	▲	Medium	High

Site Reforestation/ Revegetation	N/A	N/A	N/A	Low	Low
Notes: ▲ = Suitable for use on development sites located in these areas * = Under certain situations, can be used on development sites located in those areas					

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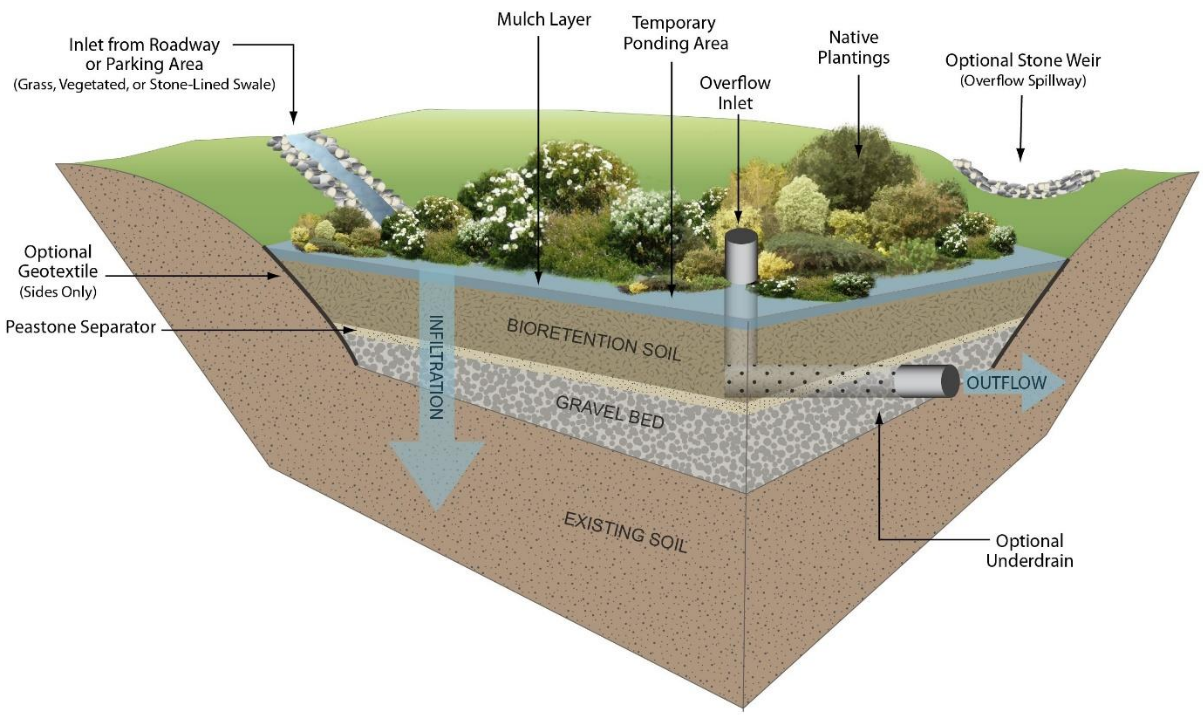
2 Bioretention

2.1 Overview

Bioretention areas are shallow, vegetated basins. They collect and absorb runoff from surrounding areas. Eventually the water retained is evaporated or transpired off. They support ground water recharge, pollutant removal, and runoff detention. They are particularly useful in areas where open spaces are limited. Bioretention areas cost between $5 and $30 per square foot.

Bioretention areas can be placed in most soils and topography. Select a location that will prevent vegetation damage and soil compaction. Bioretention areas should be placed close to the source of runoff. The most important factor when incorporating bioretention areas into development sites is to consider the scale. There are three main tiers of bioretention areas: rain gardens, bioretention basins, and urban bioretention (i.e. planter boxes). Planter boxes are another bioretention tool which can be used on small scale sites.

Figure 2-1. Diagram depicting the design and function of a rain garden.



2.2 Rain Gardens

Rain gardens are smaller bioretention areas designed to treat runoff from small areas, like individual rooftops, driveways, and other features in residential developments. They are also useful in parking lots or traffic islands.

Figure 2-2. Image of rain garden in a residential area.

Common locations for rain gardens:

- Parking lot islands
- Median strips
- Traffic islands
- Residential areas

Pollutant Removal Efficiencies:

- Total Suspended Solids (TSS) = 85% (with filter strip or equivalent pretreatment)
- Total Nitrogen = 30-50%
- Total Phosphorus = 30-90%
- Metals (copper, lead, zinc, cadmium) = 40-90%

Benefits:

- Can provide groundwater recharge
- Suitable in areas with space constraints
- Improves site aesthetics
- Can treat multiple pollutants
- Provides shade, windbreaks, and absorbs noise
- Good option for retrofit of existing infrastructure

Limitations:

- Requires careful landscaping/maintenance
- Not suitable for areas with slope greater than 20%
- Requires pretreatment
- Not suitable where groundwater table is within 6 feet of ground surface

2.3 Design

Bioretention areas are typically sized to capture between 0.5 and 1.0 inches of runoff. On residential sites, bioretention areas are used for rooftop and driveway runoff.

Design Criteria:

- Maximum contributing drainage area of 5 acres
- Treatment area consists of ponding area, organic/mulch layer planting media, and vegetation
- Requires landscaping plan
- Standing water has a maximum drain time of 24 hours
- Pretreatment recommended to prevent clogging of underdrains or native soil
- Ponding depth should be a maximum of 12 inches, preferably 9 inches

Bioretention areas are usually designed in layers (from bottom of excavation to surface):

- Impermeable liner (optional)
- Gravel layer (approximately 12 inches) with option underdrain
- Pea stone layer (approximately 4 inches)
- Bioretention soil media composed of 80-90% sand, 10-20% silt and clay, maximum 10% clay (between 18-48 inches total), 3-5% organic matter
- Fine-shredded hardwood mulch (approximately 3 inches)
- Ponding depth (varies, usually between 6-9 inches)
- Herbaceous perennials and shrubs which can tolerate frequent ponding, saline conditions, and extended dry periods

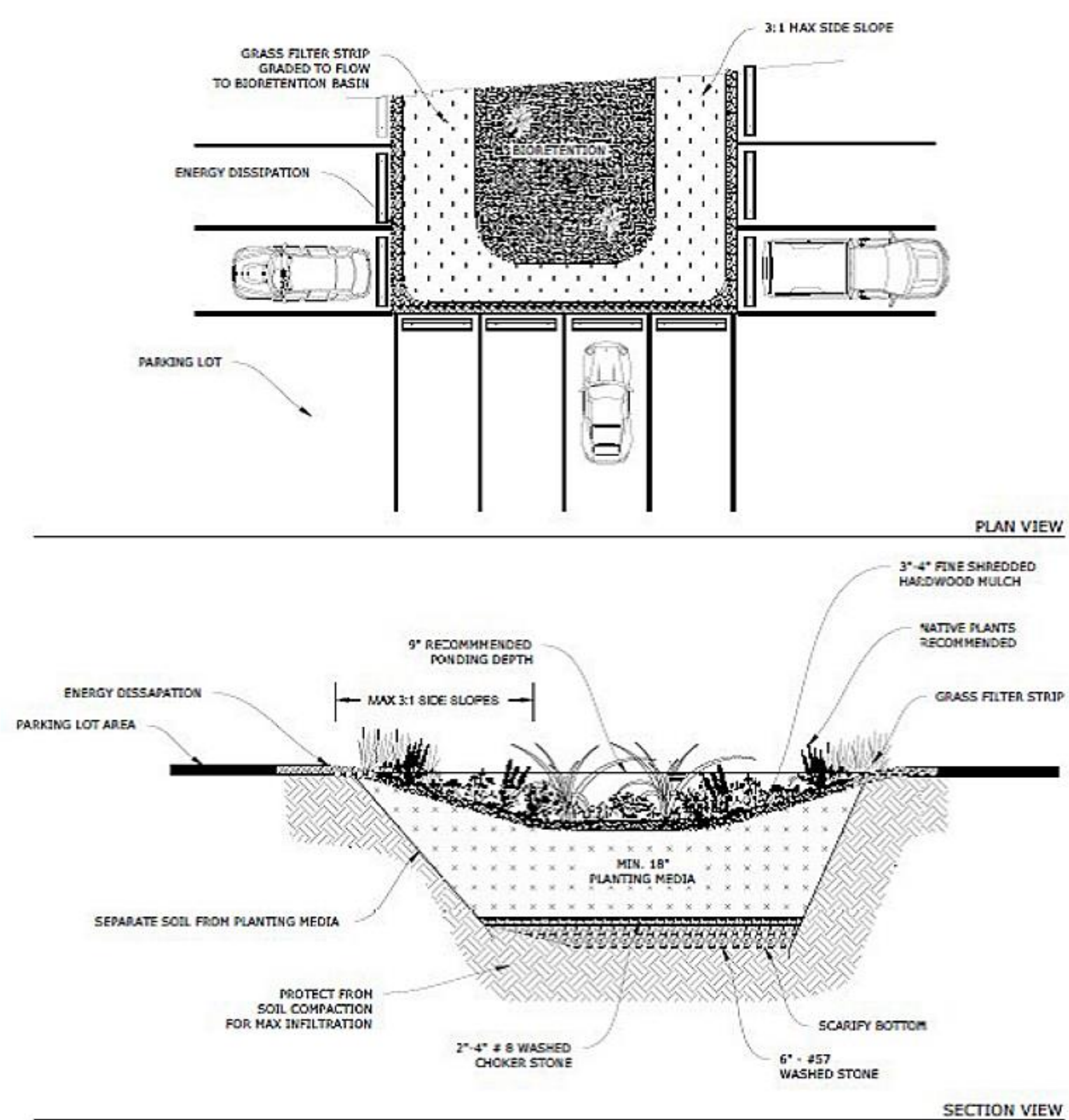
Plant Recommendations:

- Native plant species preferred
- Vegetation should be selected based on a specified zone of hydric tolerance
- A selection of trees with an understory of shrubs and herbaceous materials should be provided

Landscaping Plan Criteria:

- Common and botanical names of the plants used
- Size of planted materials
- Mature size of the plants
- Light requirements
- Maintenance requirements
- Source of planting stock
- Any other specifications
- Planting sequence

Figure 2-3. Schematic view of bioretention cell.



2.3.1 Pretreatment

Runoff entering bioretention areas must be pretreated to prevent prematurely clogging the filter bed. There are several different methods of pretreatment that work. One must be chosen depending on the scale of the bioretention area and whether it receives sheet flow, shallow concentrated flow, or deeper concentrated flow.

- Pretreatment Cells (channel flow): Located at piped inlets or curb cuts leading to the bioretention area. Consists of an energy dissipater sized for the expected rates of discharge. The cells may be formed by a wooden or stone check dam or an earthen or rock berm. The storage volume is equivalent to at least 15% of the total treatment volume with a 2:1 length-to-width ratio. They do not need underlying engineered soil media.

- Gravel or Stone Flow Spreaders (concentrated flow). The gravel flow spreader is located at curb cuts, downspouts, or other concentrated inflow points, and should have a 2 to 4 inch elevation drop from a hard-edged surface into a gravel or stone diaphragm. The gravel should extend the entire width of the opening and create a level stone weir at the bottom or treatment elevation of the basin.
- Grass Filter Strips (sheet flow): Extend from the edge of pavement to the bottom of the bioretention basin at a 5:1 slope or flatter. Alternatively, provide a combined 5 feet of grass filter strip at a maximum 5% slope and 3:1 or flatter side slopes on the bioretention basin.
- Gravel or Stone Trenches (sheet flow): A gravel trench located at the edge of the pavement should be oriented perpendicular to the flow path to pre-treat lateral runoff, with a 2 to 4 inch drop. The stone must be sized according to the expected rate of discharge.

Figure 2-4. Schematic depiction of pretreatment option: gravel trench for sheet flow (Source: VADCR).

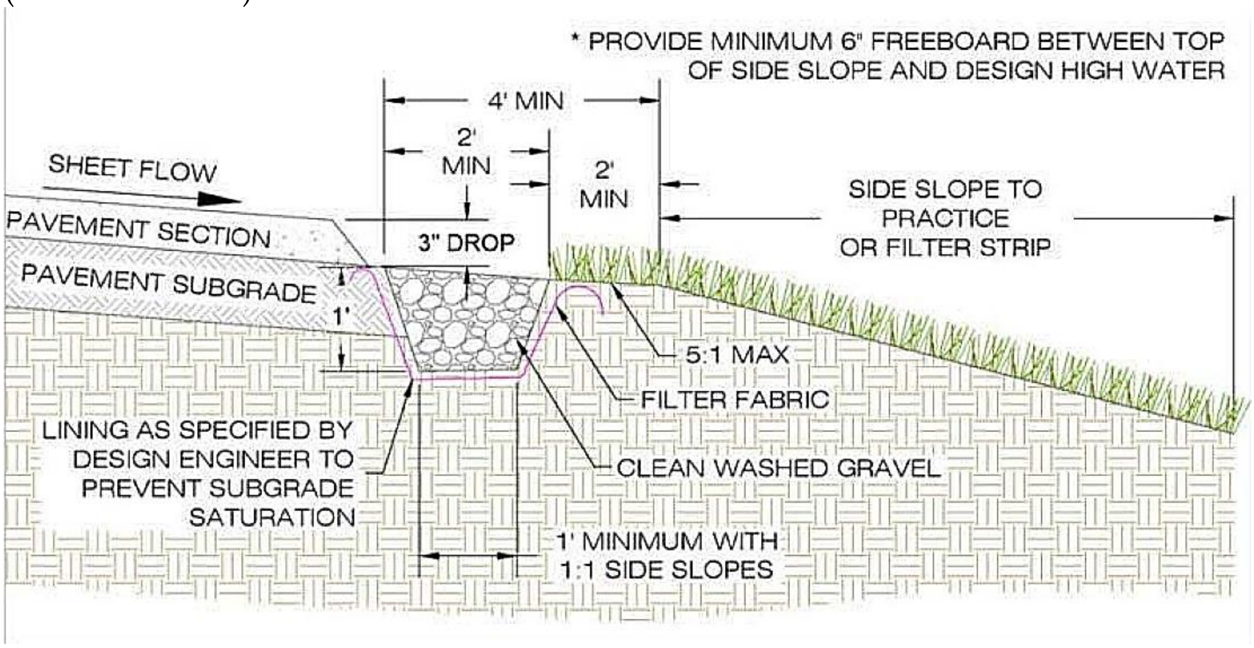


Figure 2-5. Schematic depiction of pretreatment option: grass filter sheet for flow pretreatment 1 (Source: VADCR).

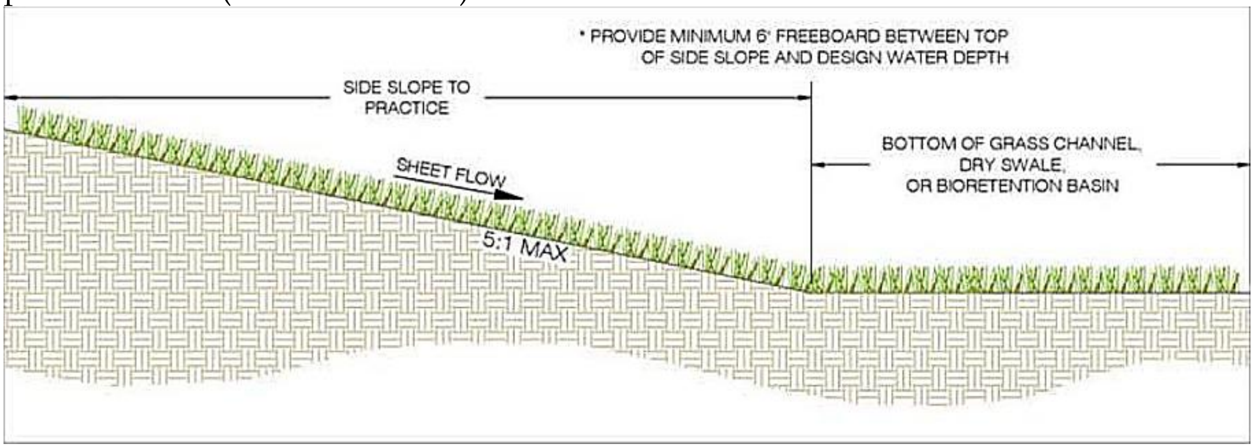
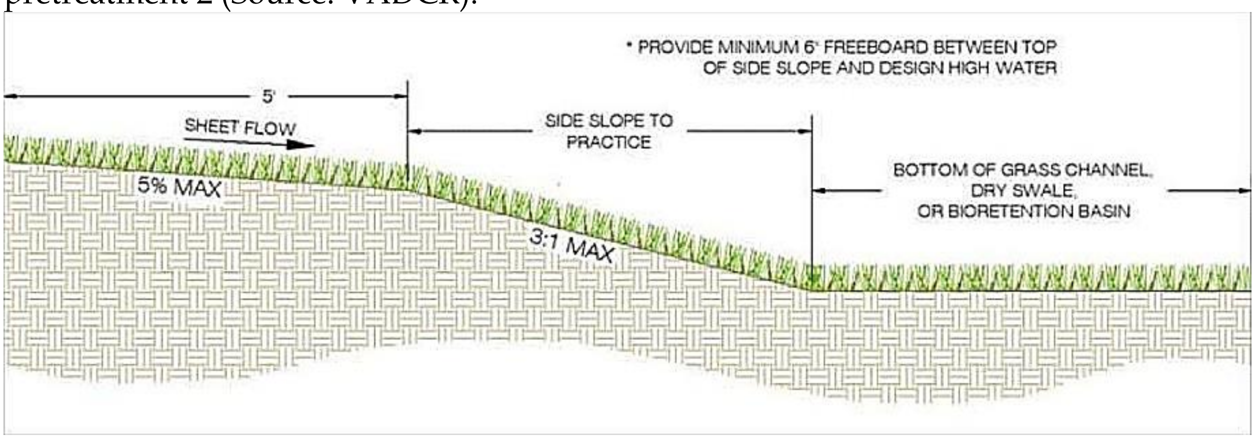


Figure 2-6. Schematic depiction of pretreatment option: grass filter for sheet flow pretreatment 2 (Source: VADCR).



2.4 Construction

Avoid excessively compacting soils around the bioretention area and accumulating silt around the drain field. To minimize sediment loading in the treatment are, direct runoff to the bioretention area from areas that are stabilized. Always divert construction runoff elsewhere. Place bioretention soil media in 1 to 2 foot lifts and compact with minimal pressure until the desired elevation is reached. Area soil can be flooded between each lift placement instead of packing.

Construction sequence for the installation of a bioretention basin:

- **Stabilize drainage area.** Construction cannot begin until the entire contributing drainage area has been stabilized with vegetation. The proposed site should be checked for existing utilities prior to excavation.
- **Install soil erosion and sediment control measures.** Temporary soil erosion and sediment controls (e.g., diversion dikes, reinforced silt fences) should be installed before construction to divert stormwater away from the bioretention area until it

is completed. Erosion control fabrics may be needed to protect vulnerable side slopes from erosion during the construction process.

- **Install pretreatment cells.** Any pretreatment cells should be excavated then sealed to trap sediment.
- **Promote infiltration rate.** If necessary, rip the bottom soils to a depth of 6 to 12 inches to promote greater infiltration.
- **Order of materials.** If using a geotextile fabric, place the fabric on the sides of the bioretention area with a 6 inch overlap on the sides. If a stone storage layer will be used, place the appropriate depth of stone on the bottom, install the perforated underdrain pipe, pack stone to 3 inches above the underdrain pipe, and add the choking layer or geotextile layer as a filter between the underdrain and the soil media layer. If no stone storage layer is used, start with 6 inches of stone on the bottom and proceed with layering.
- **Layered installation of media.** Apply the media in 12 inch lifts until the desired top elevation of the bioretention area is achieved. Wait a few days to check for settlement and add additional media to achieve the design elevation.
- **Prepare filter media for plants.** Prepare planting holes for any trees and shrubs, install the vegetation, and water accordingly. Install any temporary irrigation.
- **Planting.** Install the plant materials as shown in the landscaping plan, and water them as needed.
- **Secure surface area.** Place the surface cover (i.e., mulch, river stone, or turf) in both cells, depending on the design. If coir or jute matting will be used in lieu of mulch, the matting will need to be installed prior to planting, and holes or slits will have to be cut in the matting to install the plants.
- **Inflows.** If curb cuts or inlets are blocked during bioremediation installation, unblock these after the drainage area and side slopes have good vegetative cover. It is recommended that unblocking curb cuts and inlets take place after two to three storm events if the drainage area includes newly installed asphalt.

Table 2-1. Filter Media Criteria

<table>
<tr><th>Soil Media Criterion</th><th>Description</th><th colspan="3">Standard(s)</th></tr>
<tr><td>General Composition</td><td>Soil media must have the proper proportions of sand, fines, and organic matter to promote plant growth, drain at the proper rate, and filter pollutants.</td><td colspan="3">80% to 90% sand (75% of which is course or very course);
10% to 20% soil fines;
Maximum of 10% clay;
3% to 5% organic matter</td></tr>
<tr><td rowspan="9">Sand</td><td rowspan="9">Silica based coarse aggregate</td><th>Sieve Type</th><th>Particle Size (mm)</th><th>Percent Passing (%)</th></tr>
<tr><td>3/8 in.</td><td>9.50</td><td>100</td></tr>
<tr><td>No. 4</td><td>4.75</td><td>95-100</td></tr>
<tr><td>No. 8</td><td>2.36</td><td>80-100</td></tr>
<tr><td>No. 16</td><td>1.18</td><td>45-85</td></tr>
<tr><td>No. 30</td><td>0.6</td><td>15-60</td></tr>
<tr><td>No. 50</td><td>03</td><td>3-15</td></tr>
<tr><td>No. 100</td><td>0.15</td><td>0-4</td></tr>
<tr><td colspan="3">Effective particle size (D10) > 0.3 mm
Uniformity coefficient (D60/D10) < 4.0</td></tr>
<tr><td>Top Soil</td><td>Loamy sand or sandy loam</td><td colspan="3">USDA textural triangle</td></tr>
<tr><td>Organic Matter</td><td>Well-aged, clean compost</td><td colspan="3">Appendix A</td></tr>
<tr><td>Phosphorus Content</td><td>Soil media with high P levels will export P through the media and potentially to downstream conveyances or receiving waters</td><td colspan="3">P content = 5 to 15 mg/kg (Mehlich I) or 18 to 40 mg/kg (Mehlich III)</td></tr>
<tr><td>Cation Exchange Capacity (CEC)</td><td>The CEC is determined by the amount of soil fines and organic matter. Higher CEC will promote pollutant removal.</td><td colspan="3">CEC > 5 milliequivalents per 100 grams</td></tr>
</table>

2.5 Inspection and Maintenance

Bioretention areas should be inspected to ensure the area is functioning correctly. Recommendations for inspections are as follows:

- Inspect pretreatment devices regularly for sediment build-up, structural damage, and standing water
- Inspect for erosion and re-mulch void areas on a regular basis
- Remove and replace dead vegetation in spring and fall
- Remove invasive species to prevent from spreading within bioretention area
- Observe under wet weather conditions

Table 2-2. As-built Inspection Form for bioretention areas.

Bioretention Area					
Maintenance Item	Condition				Comment
	Good	Marginal	Poor	N/A	
General Inspection					
Access to the site is adequately maintained for inspection and maintenance.					
Area is clean (trash, debris, grass clippings, etc. removed)					
Inlet Structure					
Drainage ways (overland flow or pipes) to the practice are free of trash, debris, large branches, etc.					
Area around the inlet structure is mowed and grass clippings are removed.					
No evidence of gullies, rills, or excessive erosion around the inlet structure.					
Water is going through the structure (no evidence of water going around the structure).					
Diversion structure (high flow bypass structure or other) is free of trash, debris, or sediment.					
Pretreatment (Choose One)					

Forebay – area is free of trash, debris, and sediment.					
Weir – area is free of trash, debris, and sediment is less than 25% of the total depth of the weir.					
Filter Strip or Grass Channels – area is free of trash, debris, and sediment. Area has been mowed and grass clippings are removed. No evidence of erosion.					
Rock Lined Plunge Pools – area is free of trash, debris, and sediment. Rock thickness in pool is adequate.					
Main Treatment					
Main treatment area is free of trash, debris, and sediment.					
Erosion protection is present on site (i.e. turf reinforcement mats).					
No evidence of long-term ponding or standing water in the ponding area of the practice (ex. Stains, odors, mosquito larvae, etc)					
Structure seems to be working properly. No settling around the structure.					
Vegetation within and around practice is maintained per landscaping plan. Grass clippings are removed.					
Mulching depth of 3-4 inches is maintained.					
Native plants were used in the practice.					

No evidence of use of fertilizer on plants (fertilizer crusting on the surface, tips of leaves turning brown or yellow, blackened roots, etc.)					
Plants seem to be healthy and in good condition.					
Emergency Overflow					
Emergency overflow is free of trash, debris, and sediment.					
No evidence of erosion, scour, or flooding around the structure.					
Outlet Structure					
Outlet structure is free of trash, debris, and sediment.					
No evidence of erosion, scour, or flooding around the structure.					
Results					
Overall condition of bioretention area					
Additional Comments					

Bioretention areas must be maintained on a regular basis. It is the owner's responsibility to ensure the area is maintained properly. Maintenance of bioretention areas can be integrated into routine landscaping maintenance tasks with the proper education. Maintenance tasks may vary between bioretention areas, but a general summary of tasks is found in table 2-3.

Table 2-3. Maintenance Schedule for bioretention areas.

Activity	Schedule
• Prune and weed to maintain appearance. • Dissipate flow when erosion is evident. • Remove trash and debris. • Remove sediment and debris from inlets and outlets. • Remove and replace dead or damaged plants. • Mow around the bioretention area as necessary, ensuring grass not placed in the bioretention area. • Observe infiltration rates after rain events. Bioretention areas should not have any standing water within 24 hours of a storm event. • Inspect for evidence of animal activity.	As needed or four times during growing season
• Inspect for erosion, rills, or gullies and repair. • Inspect filter strip/grass channel for erosion or gullying, if applicable re-seed or sod as necessary • Inspect trees and shrubs to evaluate their health and remove any dead or severely diseased vegetation • A mulch depth of at least 3 to 4 inches should be inspected and obtained. Additional mulch should be added as necessary.	Semi-annually in spring and fall
• Trim planting material • Inspect for snow accumulation	As needed or during winter months
• Test the planting soils for pH levels. Consult with a qualified licensed professional to determine and maintain the proper pH levels.	Annually
• Replace/repair inlets, outlets, scour protection or other structures as needed. • Implement plant maintenance plan to trim and divide perennials to prevent overcrowding and stress. • Check soil infiltration rates to ensure the bioretention area soil is draining the water at a proper rate. Re-aerate or replace soil and mulch layers as needed to achieve infiltration rate of at least 0.5 inches per hour.	2 to 3 years

Table 2-4. Maintenance checklist for bioretention areas.

Maintenance Checklist for Bioretention Areas			
Maintenance Item	Complete?		Comment
	Yes	No	
As needed or four times during growing season			
Prune and weed area.			
Remove trash and debris.			
Remove sediment and debris from inlets and outlets.			
Remove and replace dad or damaged plants.			
Mow around bioretention area.			
Ensure bioretention area does not have standing water more than 24 hours after a storm event.			
Inspect for evidence of animal activity.			
Semi-annually in spring and fall			
Inspect for erosion, rills, or gullies and repair.			
Inspect filter strip/ grass channel for erosion or gullying. Re-seed and sod as necessary.			
Inspect trees and shrubs and remove			

any dead or severely diseased vegetation.			
Obtain and inspect a mulch depth of 3 to 4 inches.			
As needed or during winter months			
Trim planting material.			
Inspect for snow accumulation.			
Annually			
Test the planting soils for pH levels. Maintain proper pH levels as advised by a licensed professional.			
2 to 3 years			
Replace/repair inlets, outlets, scour protection, or other structures as needed.			
Implement plant maintenance plan to trip and divide perennials.			
Check soil infiltration rates to ensure the bioretention area soil is draining the water at a proper rate.			

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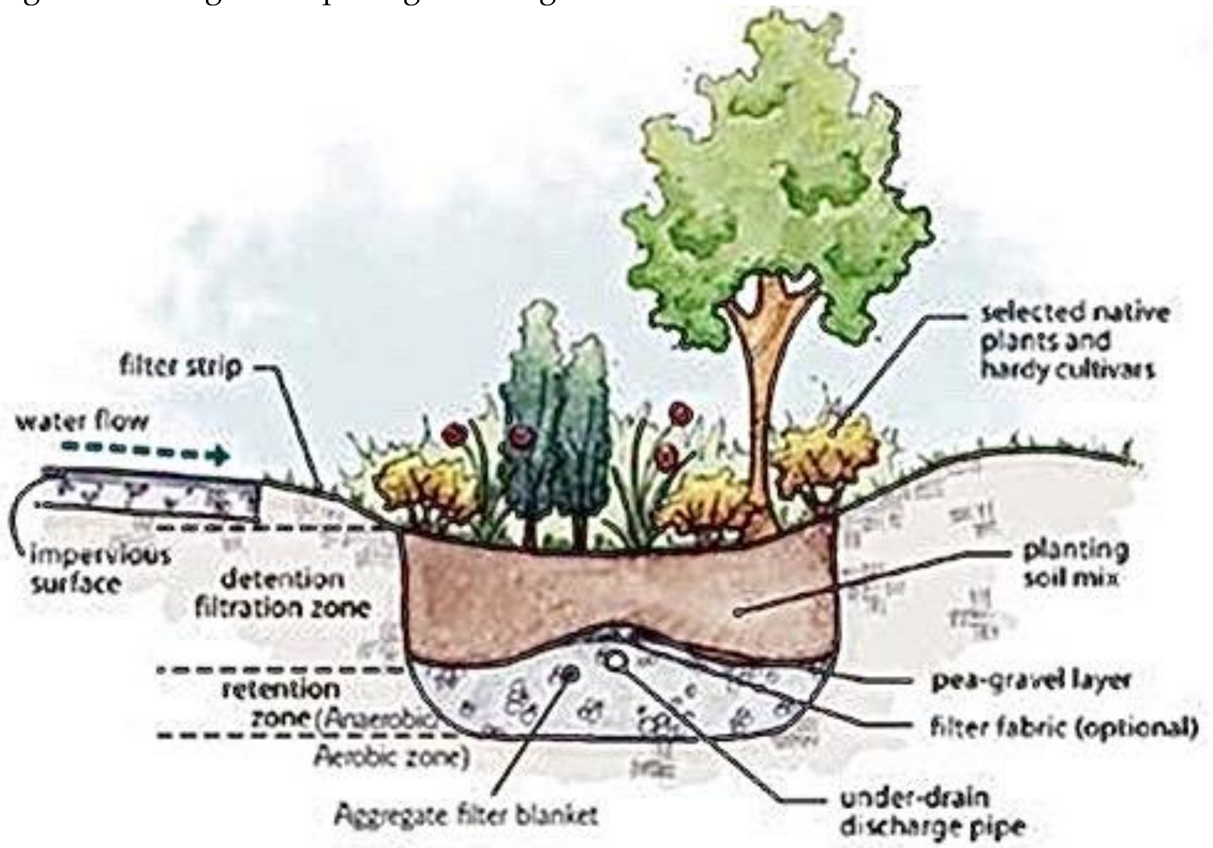
3 Enhanced Swales

3.1 Overview

Enhanced swales are linear, vegetated ditches. They are bioretention cells that are shallower, and covered with turf or other surface material. They allow for the collection, conveyance, filtration, and infiltration of stormwater. The vegetation reduces water’s velocity which allows for treatment and infiltration. They are designed to manage a larger amount of runoff. They typically have an underdrain system which consists of a perforated pipe within a gravel layer on the bottom of the swale, beneath the filter media. Typically, bioswales costs $0.50 per square foot.

Figure 3-1. Diagram depicting the design and function of a bioswale.



Common Locations:

- Within a roadway or bicycle path right-of-way
- Along the margins of small parking lots
- Oriented from the roof (downspout discharge) to the street
- Disconnecting small impervious areas
- Used to treat the managed turf areas of parks, sports fields, golf courses, or other turf-intensive land uses

Pollutant Removal Efficiencies:

- Total Suspended Solids (TSS) = 83-92%
- Total Nitrogen = 39-89%
- Total Phosphorus = 29-80%
- Metals (copper, lead, zinc, cadmium) = 30-67%

Benefits:

- Provides pretreatment when used as part of runoff conveyance system
- Less expensive that typical curb and gutter
- Provides partial infiltration of runoff in pervious soils

- Reduces thermal effects of impervious surfaces
- More visually pleasing than typical roadside conveyance systems
- Provide habitat for wildlife species

Limitations:

- Minimal runoff volume and pollutant reduction
- May allow sediment re-suspension
- Poor design may lead to standing water and mosquito problems

3.2.1 Dry Swales

There are two main types of dry swales: a dry conveyance swale and a dry treatment swale. A dry conveyance swale is aligned along a contributing impervious surface such as a roadway or parking lot. The runoff enters the dry conveyance swale as lateral sheet flow. The total contributing drainage area increases along the length of the swale. The treatment component of the swale may extend farther for additional storage. A dry treatment swale is located to accept runoff as concentrated flow or sheet flow from non-linear drainage areas at one or more locations. A dry treatment swale can be used to convey stormwater from the contributing drainage area to a discharge point. The cumulative drainage area does not necessarily increase along the linear dimension.

Figure 3-2. Image of a typical dry bioswale.

Table 3-1. Summary of stormwater functions performed by dry swales.

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction	40%	60%
Total Phosphorus Mean Concentration Reduction	20%	40%

Total Phosphorus Mass Load Removal	52%	76%
Total Nitrogen Mean Concentration Reduction	25%	35%
Total Nitrogen Mass Load Removal	55%	74%

Table 3-2. Comparison of Level 1 and Level 2 designs of dry swales.

Level 1 Design	Level 2 Design
Sizing: Surface area (sq. ft.) = Tv (the volume reduced by an upstream BMP) / Storage depth	Sizing: Surface area (sq. ft.) = {(1.1)(Tv) – the volume reduced by an upstream BMP} / Storage depth
Effective swale slope ≤ 2%	Effective swale slope ≤ 1%
Media depth: Minimum = 18 inches Recommended Maximum = 36 inches	Media depth: Minimum = 24 inches Recommended Maximum = 36 inches
Sub-soil testing: not needed if an underdrain is used, minimum infiltration rate must be > ½ inch/hour to remove the underdrain requirement	Sub-soil testing: one per 200 linear feet of filter surface, minimum infiltration rate must be > ½ inch/hour to remove the underdrain requirement
Underdrain: Schedule 40 PVC with clean-outs	Underdrain and Underground Storage Layer: Schedule 40 PVC with clean-outs and a minimum 12-inch stone sump below the invert; or none if the soil infiltration requirements are met
Media: must be tested for an acceptable phosphorus index: P-index between 10 and 30; or between 7 and 23 mg/kg of P in the soil media	
Inflow: sheet or concentrated flow with appropriate pre-treatment	
Pre-treatment: a pretreatment cell, grass filter strip, gravel diaphragm, gravel flow spreader or another approved pre-treatment structure	
On-line design	Off-line design or multiple treatment cells
Turf cover	Turf cover, with trees and shrubs
Acceptable media mix tested for phosphorus index	

Figure 3-3. Schematic view of a dry swale.

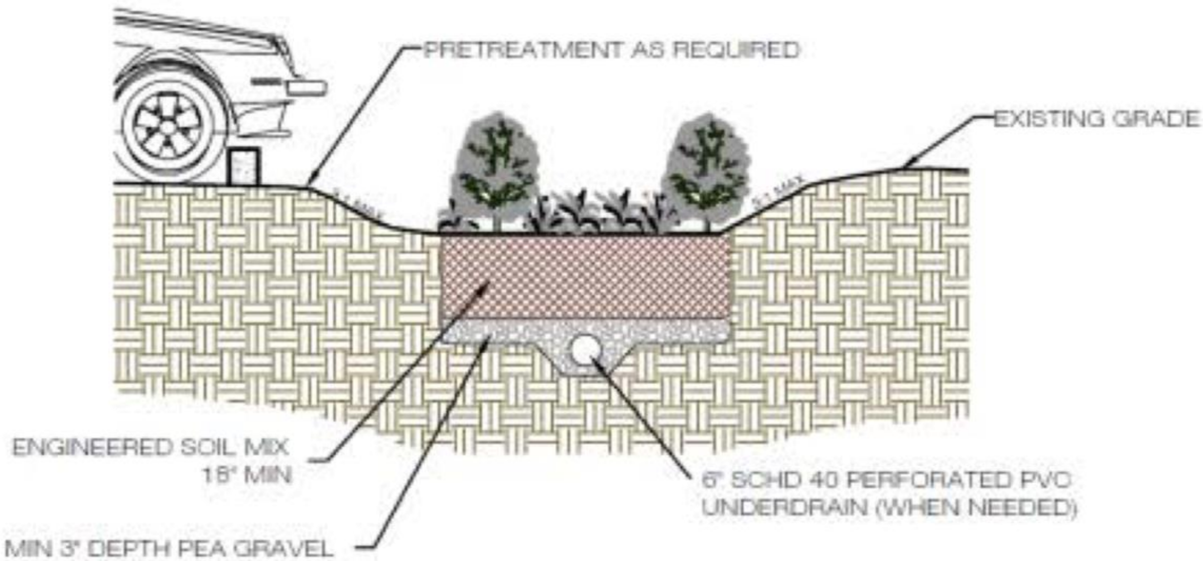
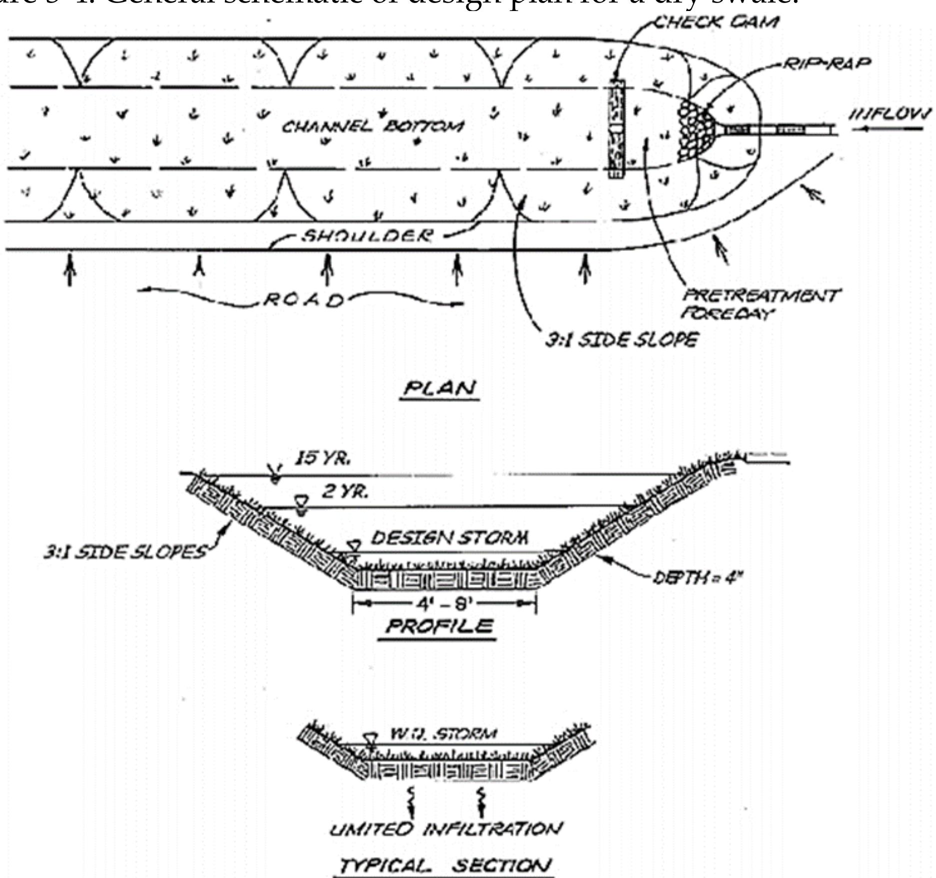


Figure 3-4. General schematic of design plan for a dry swale.



3.2.2 Wet Swales

Wet swales are a cross between a wetland and a swale. Wet swales provide runoff filtering and treatment. They are typically formed within a channel to intercept shallow groundwater or retain runoff to create saturated soil or shallow standing water conditions (typically less than 6 inches deep). This creates an ideal environment for gravitational settling, biological uptake, and microbial activity. Wet swales are generally recommended only for flat coastal plain conditions with a high water table.

Figure 3-5. Image of a typical wet swale.

Table 3-3. Summary of stormwater functions performed by wet swales.

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction	0%	0%
Total Phosphorus Mean Concentration Reduction	20%	40%
Total Phosphorus Mass Load Removal	20%	40%
Total Nitrogen Mean Concentration Reduction	25%	35%

Total Nitrogen Mass Load Removal	25%	35%

Table 3-4. Comparison of Level 1 and Level 2 designs for wet swales.

Level 1 Design	Level 2 Design
Sizing: Tv = {(1 inch)(Rv)(A)} / 12 – the volume reduced by an upstream runoff reducer BMP	Sizing: Tv = {(1.25 inch)(Rv)(A)} / 12 – the volume reduced by an upstream runoff reducer BMP
Effective swale slope ≤ 2%	Effective swale slope ≤ 1%
On-line design	Off-line swale cells
Minimal planting, volunteer vegetation	Wetland planting within swale cells
Turn cover in buffer	Trees, shrubs, and/or ground cover within swale cells and buffer

Figure 3-6. Design Plan of a wet swale.

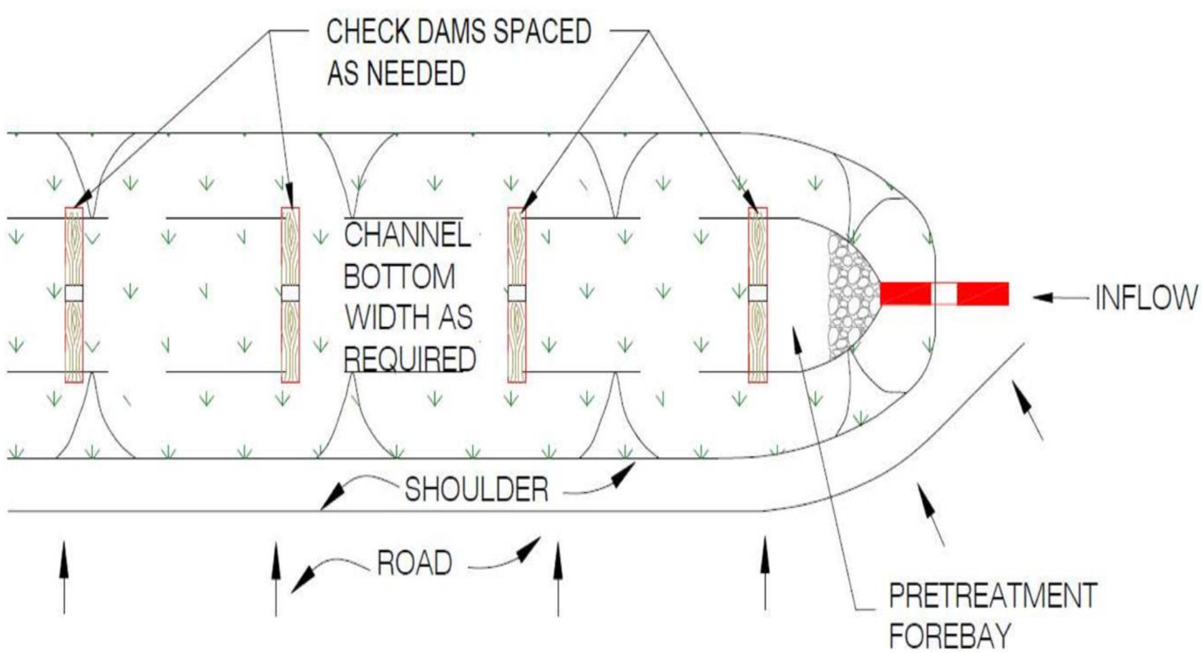
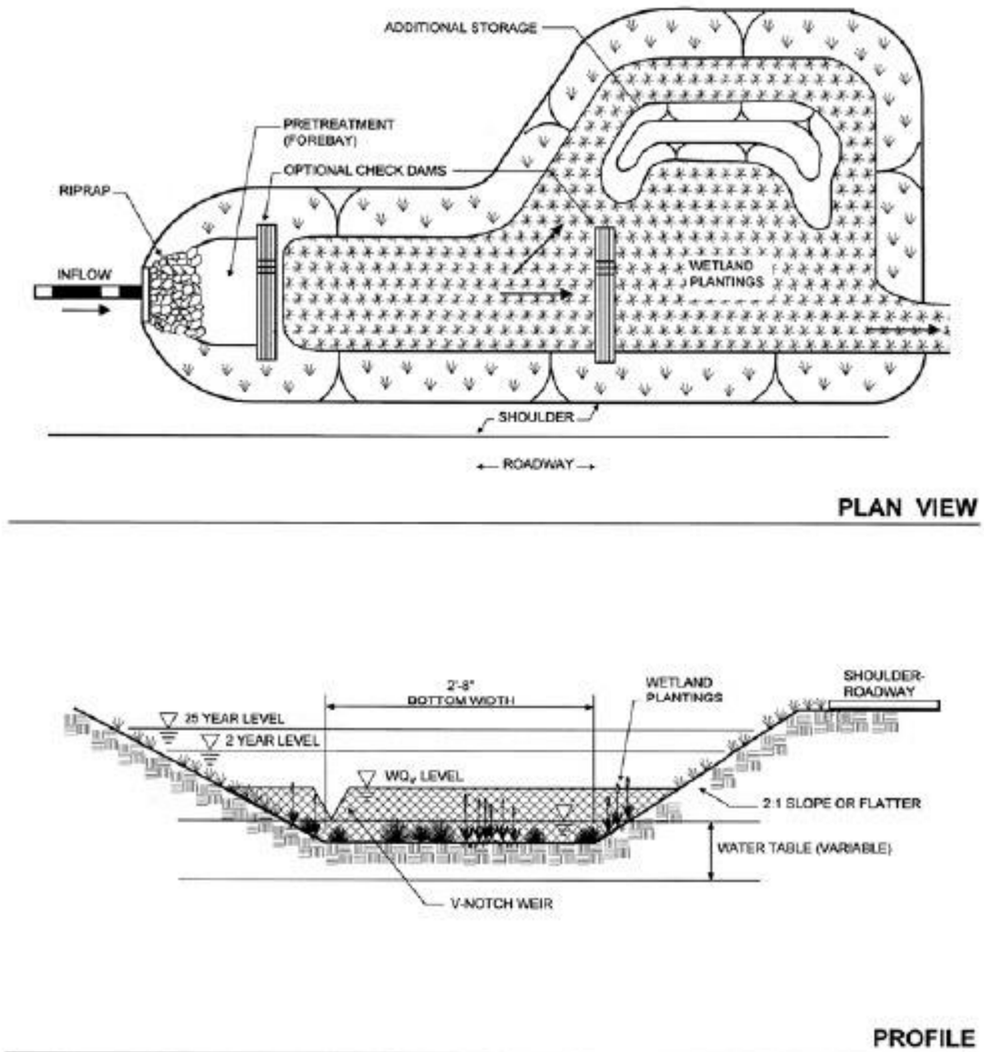


Figure 3-7. General schematic of a wet swale.



3.3 Design

Bioswales should only be placed parallel to the contributing impervious cover, such as parking lots or roads. Bioswales are not recommended when residential density exceeds more than 4 residential units per acre. Bioswales should not be used for treatment of runoff from stormwater hotspots.

Design Criteria:

- Contributing drainage area ≤ 5 acres
- Longitudinal slope ≤ 4%
- Side slopes 3:1 (H:V) or flatter
- Bottom width of channel should be between 4 and 8 feet wide
- Flow velocities in channel must be less than 1 foot per second during a 1″ storm event and non-erosive during the 2 year and 10 year design storm events

- 10 year design flow must be contained within the channel which must have a 6″ minimum freeboard
- Dense vegetation capable of withstanding relatively high flow velocities and alternating dry and wet periods
- Bioswales should not be installed in areas with high water tables where groundwater reaches the bottom of the swale
- Check dams and compost material can be added to maximize pollutant capture and stormwater infiltration

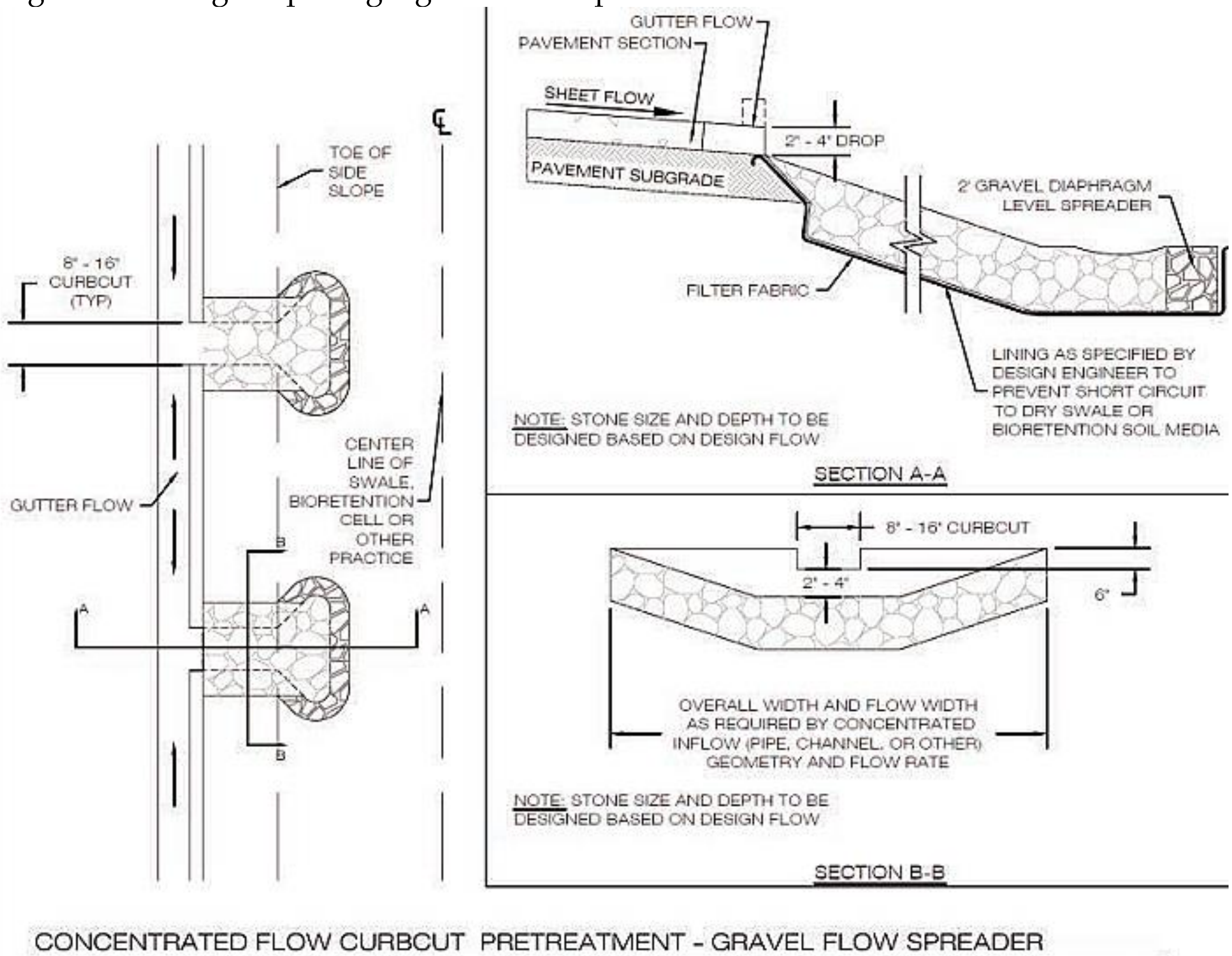
3.3.1 Pretreatment

Pretreatment is required to dissipate energy, trap sediments, and slow down the runoff velocity. Pretreatment methods should be utilized depending on whether the channel receives sheet flow or concentrated flow. The options for pretreatment for bioswales are:

- Check Dams (channel flow): These are acceptable as pretreatment on bioswales with contributing drainage areas of less than 1 acre. The pretreatment volume stored must be 15% of the design volume.
- Tree Check Dams (channel flow): Street tree mounds that placed within the bottom of grass channels up to an elevation of 9 to 12 inches above the channel invert. One side features a gravel or river stone bypass to allow runoff to percolate through. The pretreatment volume stored must be 15% of the design volume.
- Grass Filter Strip (sheet flow): Grass filter strips extend from the edge of the pavement to the bottom of the open channel at a slope of 5:1 or flatter. Also acceptable is a combined 5 feet of grass filter strip at a maximum 5% cross slope and 3:1 or flatter side slopes.
- Gravel or Stone Flow Trenches (sheet flow): A gravel or stone trench should be located at the edge of the pavement or the edge of the roadway shoulder and extends the length of the channel to pretreat lateral runoff. This requires a 2 to 4 inch elevation drop from a hard edged surface into a gravel or stone trench. The stone must be sized according to the expected rate of discharge.
- Gravel or Stone Flow Spreaders (concentrated flow): A gravel or stone flow spreader should be placed at curb cuts, downspouts, or other concentrated inflow points, and should have a 2 to 4 inch elevation drop from a hard-edged surface into a gravel or stone trench. The gravel should extend the entire width of the opening and create a level stone weir at the bottom or treatment elevation of the channel.
- Initial Sediment Forebay (channel flow): This is a grassed cell placed at the upper end of the bioswale with a recommended 2:1 length to width ratio and a storage

volume equivalent to at least 15% of the total design storm volume. If the volume of the forebay will be included as part of the dry swale storage volume, the forebay must de-water between storm events.

Figure 3-8. Image depicting a gravel flow spreader.



3.4 Construction

- **Grade channel.** Grade the vegetated swale to the final dimensions shown on the plan. Do not compact existing subgrade in vegetated channels. Protect areas with construction fence, silt fence, or compost sock. Rough grade the vegetated channel. If excavation leads to substantial compaction of the subgrade, 18 inches should be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth.
- **Install necessary treatment structures.** Install check dams, driveway culverts, and internal pre-treatment features as shown on the plan. Fill material used to construct dams should be placed in 8 to 12 inch lifts and compacted to prevent settlement. The top of each check dam should be constructed level at the design elevation. Install overflow structure and other stormwater structures: close and

secure all inlets, pipes, trench drains, and other structures to prevent runoff from entering the vegetated channel prior to completion and site stabilization. Maintain drainage overflow pathways during construction while the vegetated channel is closed to provide for drainage during storm events.

- **Add necessary soil amendments.** Till the bottom of the channel to a depth of 1 foot and incorporate compost amendments as needed.
- **Vegetate channel.** Hydro-seed the bottom and banks of the grass channel. Peg in erosion control fabric or blanket where needed. After initial planting, a biodegradable erosion control fabric should be used. Prepare planting holes for any trees and shrubs, then plant materials as shown in the landscaping plan and water them weekly in the first two months.

3.5 Inspection and Maintenance

Inspections of bioswales must be completed to ensure the swale is constructed and functioning properly.

Table 3-5. As-built inspection form for bioswales.

Bioswale					
Maintenance Item	Condition				Comment
	Good	Marginal	Poor	N/A	
General Inspection					
Access to the site is adequately maintained for inspection and maintenance.					
Area is clean (trash, debris, grass clippings, etc. removed)					
Pretreatment					
Filter strips and bioswale floor does not have excessive deposition of sediment					
No signs of erosion at the points of inflow or within the ponding area					
Culverts					
If culverts are a part of the bioswale system, ensure erosion does not occur at the outfall of culverts					
Check Dams					
If used, no signs of excessive deposition of sediment.					

Ensure choker layer materials on the front side of rock checks are present and functioning					
Plants					
Inspect for at least 50% of specified vegetation cover at the end of the first growing season, at least 90% vegetation cover at the end of the third growing season					
Ensure plant and tree health and no undesirable plant growth					
Inlets and Outlets					
Inlet and Outlet structures are free of trash, debris, and sediment.					
No evidence of erosion, scour, or flooding around the structure.					
Inlet and Outlets are free flowing and working properly					
Observation Ports					
Look for evidence of standing water in the observation port or outlet structure					
Mulch					
Ensure mulch is present and in place					
Runoff					
Ensure runoff is getting into the bioswale as intended					
Water Infiltration					
Ensure the water infiltrates and that ponding does not occur for more than 12 to 24 hours					
Results					

Overall condition of bioswale					
Additional Comments					

Maintenance:
Regular maintenance inspections should be conducted to identify signs of erosion, accumulation of debris around structures, and signs of excessive sedimentation.

- Keep the bioswale's grass thick and healthy (mowed to 3-4 inches)
- Prune or trim trees to allow for sunlight to reach the bioswale
- Remove any trash or contaminants from the bioswale

Table 3-6. Maintenance checklist for dry swale.

Maintenance Checklist for Basic Dry Swale				
Maintenance Item	Condition			Comment
	Good	Marginal	Poor	
Site				
Site is free from trash or debris.				
No contaminants or pollution present.				
Swale Section				
No sediment deposits in grass treatment area of the bioswale.				
Grass growth not inhibited by sediment.				
Flow spreads evenly through swale.				
No eroded or scoured areas in bioswale.				

Swale has no bare spots.				
Grass is between 3 and 4 inches tall, thick, and healthy.				
No clippings left in swale. No nuisance vegetation present.				
Base flow removed from swale by a low-flow pea-gravel drain or bypassed around the swale.				
Swale freely drains and there is no standing water in swale between storms.				
No flow channels in swale.				
Flow Spreader				
Flows are spread evenly over entire swale width.				
Inlet/Outlet Pipe				
Inlet/outlet pipes clear of sediment.				
No trash or debris in pipes.				
No cracks more than ¼ inch at the joint of the inlet/outlet pipe.				

Table 3-7. Maintenance checklist for wet swale.

Maintenance Checklist for Wet Swale				
Maintenance Item	Condition			Comment
	Good	Marginal	Poor	
Site				
Site is free from trash or debris.				
No contaminants or pollution present.				
Swale Section				
No sediment deposits in grass treatment area of the bioswale.				
No eroded or scoured areas in bioswale.				
Swale has no bare spots.				
Water depth of 4 inches throughout swale for most of wet season.				

Table 3-4. Maintenance requirements for bioswales.

Maintenance Requirements for Dry Swale			
Maintenance Component	**Problem**	**Condition when maintenance is needed.**	**Results expected when maintenance is performed.**
Site	Trash and debris	Any trash and/or debris accumulated on the bioswale site.	No trash or debris on the bioswale site.
	Contaminants and pollution	Any evidence of contaminants or pollution such as	Materials removed and disposed of according to

		oil, gasoline, concrete slurries, or paint.	applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Swale Section	Sediment accumulation	Sediment depth exceeds 2 inches in 10% of the swale treatment area.	No sediment deposits in grass treatment area of the bioswale.
		Sediment inhibits grass growth over 10% of swale length.	Grass growth not inhibited by sediment.
		Sediment inhibits even spreading of flow.	Flow spreads evenly through swale
	Erosion/scouring	Eroded or scoured swale bottom due to channelization or high flows.	No eroded or scoured areas in bioswale. Cause of erosion or scour addressed.
	Poor vegetation coverage	Grass is sparse or bare or eroded patches occur in more than 10% of the swale bottom.	Swale has no bare spots and grass is thick and healthy.
	Grass too tall	Grass excessively tall (greater than 10 inches), grass is thin or nuisance weeds and other vegetation has taken over.	Grass is between 3 and 4 inches tall, thick, and healthy. No clippings left in swale. No nuisance vegetation present.
	Excessive shade	Grass growth is poor because sunlight does not reach swale.	Health grass growth or swale converted to a wet bioswale.
	Constant base flow	Continuous flow through the swale, even when it has	Base flow removed from swale by a low-flow pea-

		been dry for weeks or an eroded, muddy channel has formed in the swale bottom.	gravel drain or bypassed around the swale.
	Standing water	Water pools in the swale between storms or does not drain freely.	Swale freely drains and there is no standing water in swale between storms.
	Channelization	Flow concentrates and erodes channel through swale.	No flow channels in swale.
Flow Spreader	Concentrated flow	Flow from spreader not uniformly distributed across entire swale width.	Flows are spread evenly over entire swale width.
Inlet/Outlet Pipe	Sediment Accumulation	Sediment filling 20% or more of the pipe.	Inlet/outlet pipes clear of sediment.
	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	Damaged	Cracks wider than ½-inch at the joint of the inlet/outlet pipes or any evidence of soil entering at the joints of inlet/outlet pipes.	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe.
Wet Swale			
Site	Trash and debris	Any trash and/or debris accumulated at the site.	No trash or debris at the site.
	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs

			implemented if appropriate. No contaminants present other than a surface oil film.
Swale Section	Sediment accumulation	Sediment depth exceeds 2 inches in 10% of the swale treatment area.	No sediment deposits in treatment area.
	Erosion/scouring	Eroded or scoured swale bottom due to channelization or high flows	No eroded or scoured areas in bioswale. Cause of erosion or scour addressed.
	Water depth	Water not retained to a depth of about 4 inches during the wet season.	Water depth of 4 inches throughout swale for most of wet season.
	Vegetation ineffective	Vegetation sparse, does not provide adequate filtration or crowded out by very dense clumps of cattails or nuisance vegetation.	

Table 3-8. Maintenance schedule for bioswales.

Activity	Schedule
• Irrigate if plants appear wilted; replace dead plants • Check for erosion, cracking, embankment failure, burrowing animals, and sediment clogging the drain and other pipes • Repair erosion with additional plant material similar to original and/or small stones for stability • Remove trash, debris, and sediment • Remove weeds and invasive plants • Replace mulch on bare, exposed soil	As Needed & Following > 1” Rainfall
• Irrigate 1” water per week during the first growing season • Check/clean inlets, outlets, overflows, and curb cuts from debris • Check plants for pest damage or disease • Remove trash, debris, and sediment • Remove weeds and invasive plants	Monthly (during growing season)
• Redefine lawn edge	Semi-annually (Spring & Fall)
• Cut perennial plantings and divide grasses and perennials to prevent overcrowding (Fall) • Mow bioswale (>6”) (Fall) • Check overflow and subsurface drain; check infiltration and flow-through rates (0.5”/hr) • Check pH of infiltration/ planting soil (<5.2 = add limestone; >7.0 add iron sulfate plus sulfur) • Check for uniformity in cross-section and longitudinal slope • Replace mulch minimum every 3 years • Remove accumulated sediment and replace with approved soil mix, mulch, and vegetation minimum every 5 years	Annually

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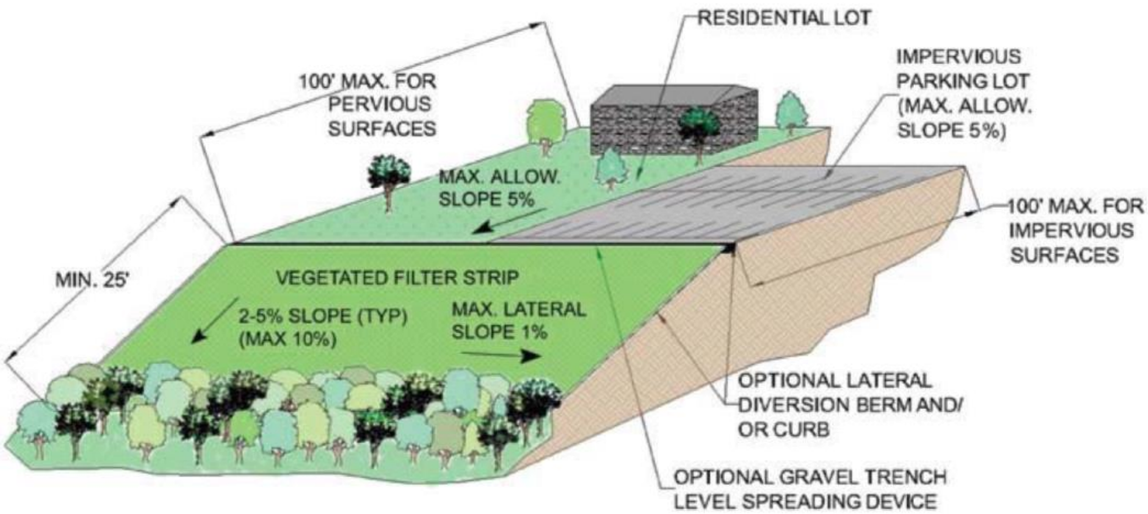
4 Vegetated Filter Strip

4.1 Overview

Vegetated filter strips are land areas with indigenous or planted vegetation found between a potential pollutant source and a surface waterbody that receives runoff. Vegetated filter strips provide water quality enhancement by reducing the amount of sediment, organic matter, and some nutrients and pesticides in runoff via filtering and infiltration. Vegetated filter strips are often used as pretreatment for other BMPs. They can be used to recreate sheet flow.

Figure 4-1. Vegetated filter strip illustration.



Common Locations:

- Road and highway shoulders and medians
- Parking edges
- Along edges of public playgrounds
- Around buildings and structures

Pollution Removal Efficiencies:

- Total Suspended Solids (TSS) = 60%
- Total Nitrogen = 20%
- Total Phosphorus = 20%
- Metals (copper, lead, zinc, cadmium) = 40%

Benefits:

- Low cost
- Can provide groundwater recharge
- Works well for highway runoff pollution
- Flexible in design and layout
- Adaptable to a variety of site conditions
- Provides aesthetic value

Limitations:

- Cannot remove 80% TSS without other treatments
- Large land requirement
- Vulnerable to erosion and concentrated flow
- Requires periodic repair, regrading, and sediment removal
- Provides less runoff reduction than most BMPs

Figure 4-2. Image of a vegetated filter strip along a roadway.

4.2 Design

Filter strips function best when they are treating runoff from small segments of impervious cover. Stormwater must enter the vegetated filter strip as sheet flow. If sheet flow cannot be obtained naturally, an engineered level spreader must be used to convert concentrated flow to sheet flow.

Design Criteria:

- Maximum contributing area < 5,000 sf
- Contributing area flow path length for impervious area ≤ 100 feet
- Contributing area flow path length for pervious areas ≤ 150 feet
- Maximum contributing drainage area slope = 5%
- Drainage area = 5 acres or less, 2 acres preferred
- 90% grass/vegetation cover after the second growing season
- Drainage area to filter strip surface area ratio is 10:1

- A separation distance of 1 to 2 feet is recommended between the bottom of the filter strip and the elevation of the water table
- Plan out vegetation. Utilize native species only if possible.

Table 4-1. Vegetated filter strip material list with specifications.

Material	Specification
Gravel Diaphragm	Pea gravel. Diaphragm should be 2 feet wide, 1 foot deep, and at least 3 inches below the edge of the pavement
Permeable Berm	40% excavated soil, 40% sand, and 20% pea gravel to serve as the media for the berm.
Geotextile	Needled, non-woven, geotextile meeting the following specifications: • Grab tensile strength > 120 lbs • Mullen burst strength >225 lbs/sq in • Flow rate > 125 gpm/sq ft • Apparent opening size: US #70 or #80 sieve
Engineered Level Spreader	Lip should be concrete, metal, timber, or other rigid material; reinforced channel on upstream of lip.
Erosion Control Fabric or Matting	Where flow velocities dictate, use woven biodegradable erosion control fabric or mats that are durable enough to last at least 2 growing seasons.
Topsoil	Imported loamy sand or sandy loam topsoil with less than 5% clay content, corrected pH at 6 to 7, a soluble salt content not exceeding 500 ppm, and an organic matter content of at least 2% should be used. Topsoil should be uniformly distributed and lightly compacted to a minimum depth of 6 to 8 inches.
Compost	Compost should be derived from plant material and provided by a member of the U.S. Composting Seal of Testing Assurance program.

Figure 4-3. Typical vegetated filter strip design.

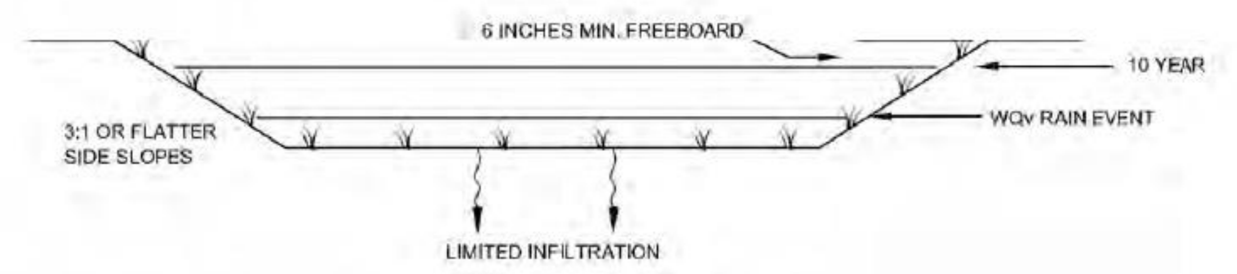
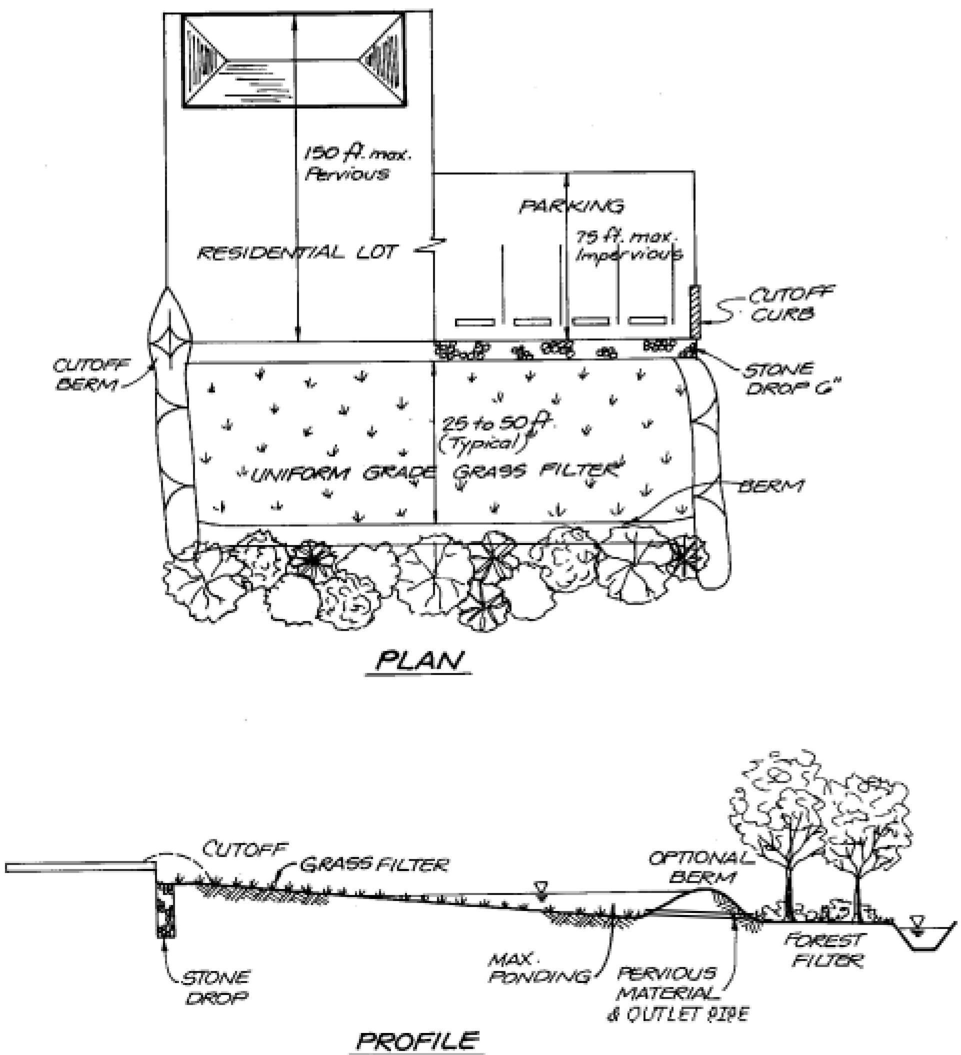


Figure 4-4. Schematic plan for vegetated filter strips.



4.3.1 Pretreatment

Vegetated filter strips should only be used in conjunction with other BMPs. Moreover, pretreatment is required before stormwater can trespass the filter strip. The options for pretreatment for vegetated filter strips are:

- Gravel Diaphragms: Found at the top of the slope, it settles out sediment before it reaches the filter strip. It also acts as a level spreader to maintain sheet flow over the filter strip.
- Permeable Berm: Placed at the toe of the filter strip to create a shallow ponding area. Runoff ponds behind the berm and flows through outlet pipes in the berm.
- Engineered Level Spreaders: Used to ensure level, sheet flow throughout vegetated filter strips. This area may need to be stabilized with temporary or permanent materials so it can withstand the flow of the stormwater.

Figure 4-5. Vegetated filter strip design featuring a gravel diaphragm.

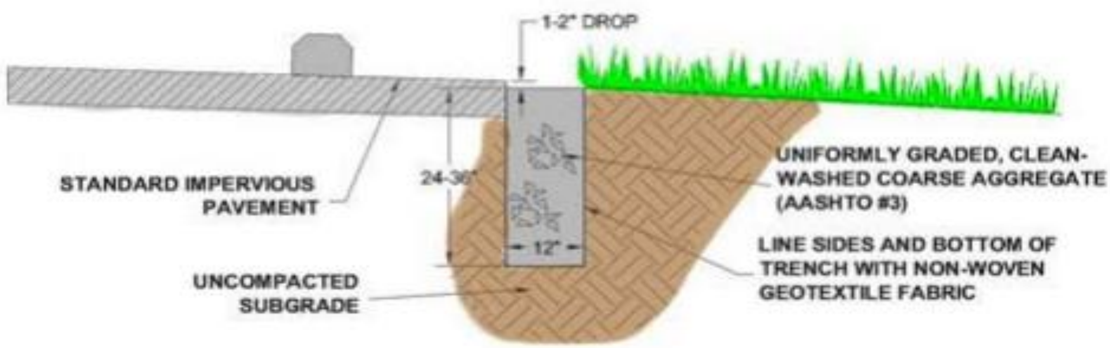


Figure 4-6. Vegetated filter strip with a berm.

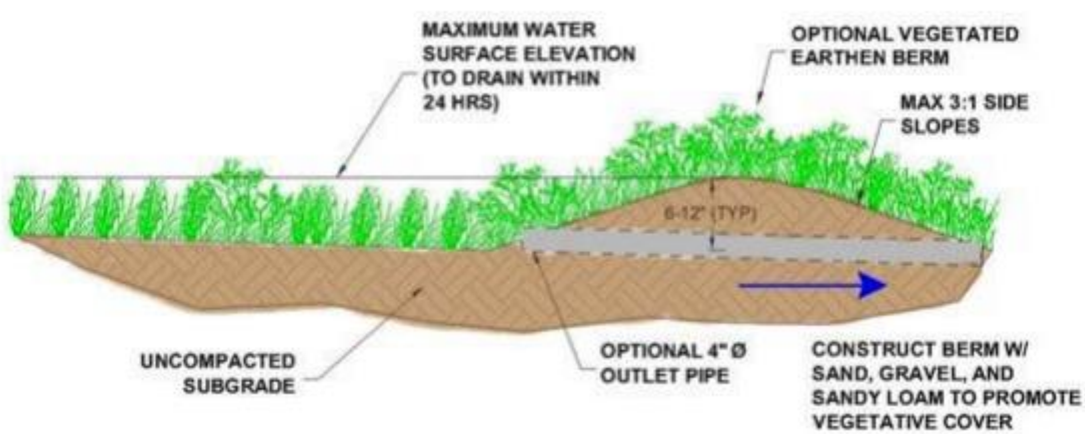
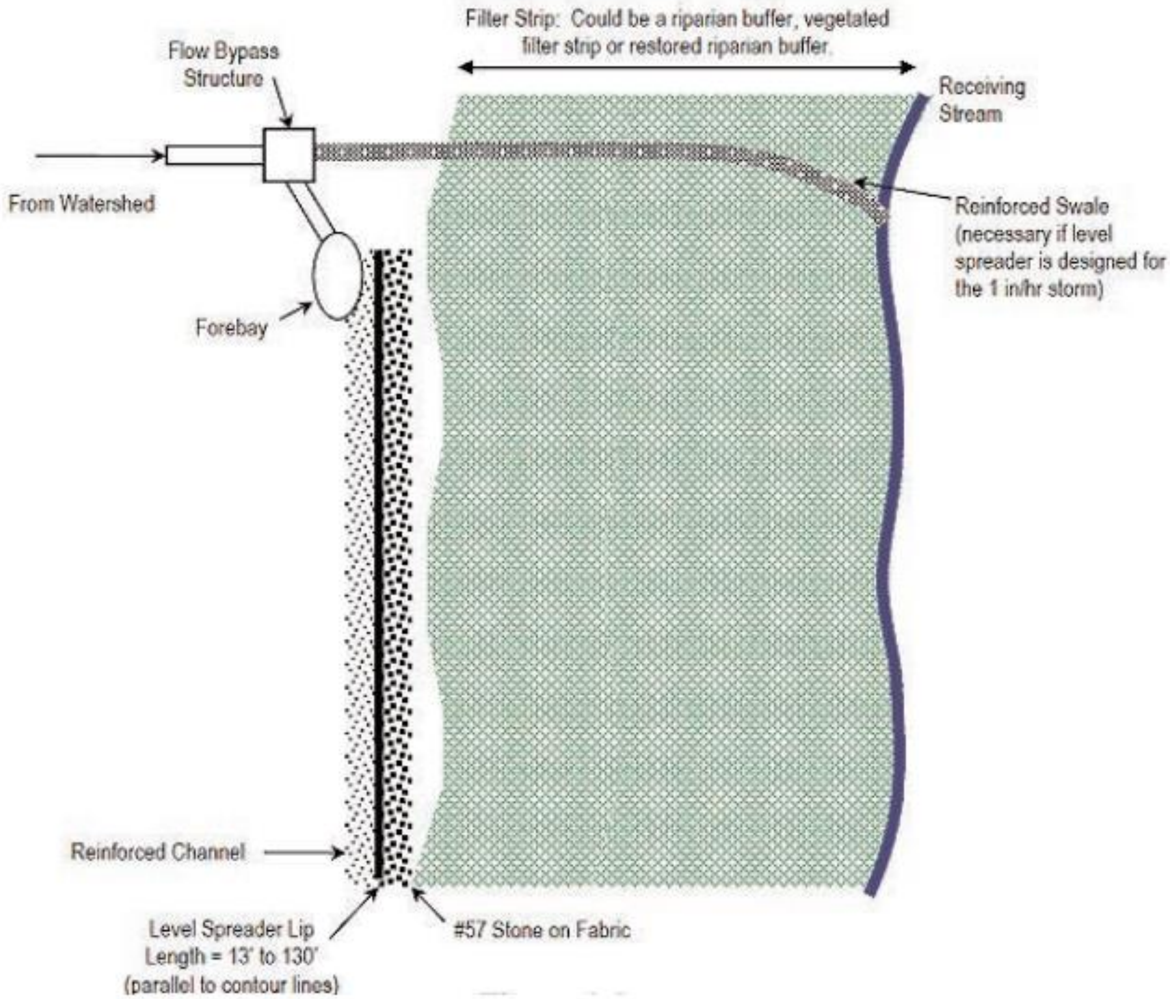


Figure 4-7. Engineered level spreader with vegetated filter strip plan.



4.4 Construction

All actions to stabilize and protect the site should be installed prior to the installation of a vegetated filter strip. Erosion control for seeded vegetation strips should be mandated for the first 75 days after the first storm event of the season. After stabilization, a vegetated filter strip can be constructed via the following steps:

- **Stabilize strip area.** Protect areas from vehicle traffic during construction. Clear and grub site as needed. Disturb as little existing vegetation as possible.
- **Rough grade the filter strip area.** Use the lightest, least disruptive equipment to avoid excessive compaction and/or disturbing the land.
- **Construct level spreader device at the up gradient of the strip.** Do not compact subgrade for gravel trenches.
- **Fine grade vegetated filter strip area.** This is one of the most crucial steps. Grading must be precise to preserve sheet flow.

- **Seed and vegetate according to plans.** It is advised to plant more substantial vegetation, such as shrubs and trees. If using sod, be sure to prevent air pockets from forming between sod and soil.
- **Stabilize topsoil.** This can be accomplished with erosion control matting or blankets.
- **Remove erosion and sediment controls.** These can be removed after the filter strip is fully stabilized, a minimum of 75 days after the first storm event.

4.5 Inspection and Maintenance

It is critical to inspect and maintain vegetated filter strips on a regular basis. Some key points to look for when inspecting are:

- Ensure the gravel diaphragm or engineered level spreader is completely level
- Performance of the filter strip
- Evidence of erosion
- Proper vegetative cover
- Sediment build-up
- Concentrated flow

Table 4-2. As-built inspection form for vegetated filter strips.

Vegetated Filter Strip					
Maintenance Item	Condition				Comment
	Good	Marginal	Poor	N/A	
General Inspection					
Access to the site is adequately maintained for inspection and maintenance.					
Area is clean (trash, debris, grass clippings, etc. removed).					
Inlet					
Drainage ways to the practice are free of trash, debris, grass clippings, etc).					
Area around the inlet is mowed and grass clippings are removed.					
No evidence of gullies, rills, or erosion around the inlet.					

Water is going through the filter (no evidence of water going around the filter)					
Diversion structure is free of trash, debris, or sediment.					
Pretreatment					
Area is free of trash, debris, and sediment.					
No signs of erosion, rills, or gullies					
Pea gravel diaphragm or flow spreader: no cracks or structural damage in concrete trough					
Main Treatment					
Main treatment area is free of trash, debris, and sediment.					
No signs of erosion, rills, or gullies.					
No evidence of long-term ponding or standing water in the ponding area of the practice (ex: stains, odors, mosquito larvae, etc).					
Practice seems to be working properly.					
No areas of unhealthy grass or bare areas.					
No unwanted or invasive vegetation.					
No evidence of use of fertilizer on plants.					
Grass is kept at the proper mowing height, 3-12 inches and 6-15 inches along the roadway. Grass clippings are removed.					
Outlet Structure					
Outlet is free of trash, debris, and sediment.					

No evidence of erosion, scour, or flooding.					
Results					
Overall condition of filter strip					
Additional Comments					

Routine maintenance should be performed on vegetated filter strips to ensure they're functioning properly. Maintenance may need to take place more often while vegetation is being established. Also, be sure to look for signs of erosion.

Table 4-3. Maintenance checklist for vegetated filter strip.

Maintenance Checklist for Vegetated Filter Strip				
Maintenance Item	Condition			Comment
	Good	Marginal	Poor	
Site				
Site is free from trash or debris.				
No contaminants or pollution present.				
Main Treatment				
No sediment deposits in grass treatment area of the strip.				
No eroded or scoured areas.				
Strip has no bare spots. Vegetation is healthy.				
No evidence of ant mounds.				
Sheet flow is preserved.				
No clogging in the pea gravel diaphragm or flow spreader.				

Table 4-4. Maintenance schedule for vegetated filter strip.

Activity	Schedule
• Mow grass to a height that will maintain dense vegetative cover. It is recommended the grass is 3-12 inches and 6-15 inches along a roadway. Remove any grass clippings. • Keep the vegetated strip clean by removing any trash, sediment, or debris. • Reseed any eroded or bare spots. • Water during dry conditions.	As Needed

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5 Permeable Pavements

5.1 Overview

Permeable, or pervious, pavement combines stormwater infiltration, storage, and structural pavement. Permeable pavements have a high porosity which allows stormwater to pass through it to the ground below. This mimics the process of natural surfaces. There are a few different types of materials that can be used for permeable pavements. Possible materials include pervious concrete, porous asphalt, reinforced turf/gravel, and permeable interlocking pavers. Permeable pavements can be implemented in residential, commercial, ultra-urban, and industrial settings.

Figure 5-1. Image of permeable pavements.

Common locations:

- Low-volume pavements
- Sidewalks
- Parking lots
- Patios
- Well linings
- Walls
- Residential roads and driveways
- Low-water bridges
- Golf cart paths
- Tennis courts

Pollution Removal Efficiencies:

- Total Suspended Solids (TSS) = 80%
- Total Nitrogen = 50-65%
- Total Phosphorus = 50%
- Metals (copper, lead, zinc, cadmium) = 60%

Benefits:

- Provides water quality treatment
- Increases aesthetic value
- Easy to retrofit existing developed areas

Limitations:

- Increased cost
- Increased maintenance
- Limited to low traffic areas
- Ineffective on steep slopes
- Potential issues with handicap access

5.2 Types of Permeable Pavement

5.2.1 Pervious Concrete

Pervious concrete is a mixture of coarse aggregate, Portland cement, and water. It allows for rapid infiltration of water. Pervious concrete is placed over a stone aggregate reservoir. This provides temporary storage of stormwater as runoff infiltrates into the underlying permeable soils. Pervious concrete is typically used in places with low volume auto traffic, but it can be designed to withstand heavier vehicles if necessary.

Figure 5-2. Image of pervious concrete.

Benefits:

- Provides reductions in runoff volume, stormwater runoff, and impervious area
- Well suited to capture “first flush”
- Reduces standing water on pavement
- Helps minimize size of detention ponds
- May help reduce stormwater management costs

Limitations:

- Higher installation cost than traditional pavement
- Infiltration testing of existing soils is sometimes required
- Not recommended for areas with heavy traffic
- Not recommended under tree canopy

5.2.2 Porous Asphalt

Porous asphalt is asphalt with small sands or fines and larger void spaces. This allows water to infiltrate into the subsoil. Porous asphalt is poured on top of an aggregate base layer which temporarily holds stormwater. A soil infiltration rate of 0.5 in/hour or greater is required if no underdrain is present. Porous asphalt is placed directly on a stone subbase in a single 3 ½ inch to 4 inch lift that is lightly rolled to a finished thickness of 2 ½ inches to 3 inches.

Figure 5-3. Image of a parking lot made with porous asphalt.

Benefits:

- Surface flow reduction
- Can be used as pretreatment for other BMPs for pollutants other than TSS
- High level of pollutant removal other than TSS
- Decreases impermeable area

Limitations:

- Potential for high failure rate
- Not recommended for areas with runoff with high sediment content
- Subgrade cannot be over-compacted
- Construction must be sequenced very specifically

Limitations:

5.2.3 Permeable Interlocking Pavers

Permeable interlocking paver systems are a pavement surface with openings filled with pervious materials like gravel, sand, or grass turf. They are installed over a gravel base course to provide structural support. They are intended for low traffic areas. Permeable paver systems must be Americans with Disabilities Act (ADA) compliant. They should be a minimum of two feet above the natural water table and a minimum of 15 feet away from buildings. Permeable paver systems require a high level of construction workmanship to be installed properly. In addition, they have to be monitored frequently to ensure the voids do not become clogged.

Figure 5-4. Image of a permeable interlocking paver system.

Benefits:

- Surface flow reduction
- High level of pollutant removal
- Aesthetically pleasing options
- Reusable product
- Longer life than traditional pavement
- Decreases impermeable area

Limitations:

- Potential for high failure rate
- Ineffective under tree canopy
- High cost
- Requires specialized knowledge for installation

- Geotechnical analysis of soils required

5.3 Design

All permeable pavements have a few design characteristics in common. Each type of material overlays some kind of infiltration aide such as gravel, a stone aggregate reservoir, or other drainage system. Pervious concrete systems can be used without underdrains when the underlying subsoils have an infiltration rate greater than 0.5 inches per hour. Soil conditions dictate whether or not an underdrain is needed. Underdrains are required if the measured permeability of the underlying soil is less than 0.5 inches per hour.

Design Criteria:

- Minimum 2 feet clearance above the water table, 4 feet preferred
- Bed bottoms should be level
- All systems should contain an overflow system
- Infiltration beds should empty within 72 hours, 48 hours preferred
- Infiltration beds should be sized to handle a 2 year storm and mitigate the peak of more intense storms
- A weir within an inlet may be used to maximize the water level in the stone bed
- Perforated pipes may be used along the bottom of the bed to evenly distribute runoff
- Underdrains must be double-walled and accessible for maintenance
- The underlying infiltration bed / reservoir layer should be 8 to 36 inches deep and contain clean, graded aggregate with approximately 40% void space

Figure 5-5. Cross section of a pervious concrete system.

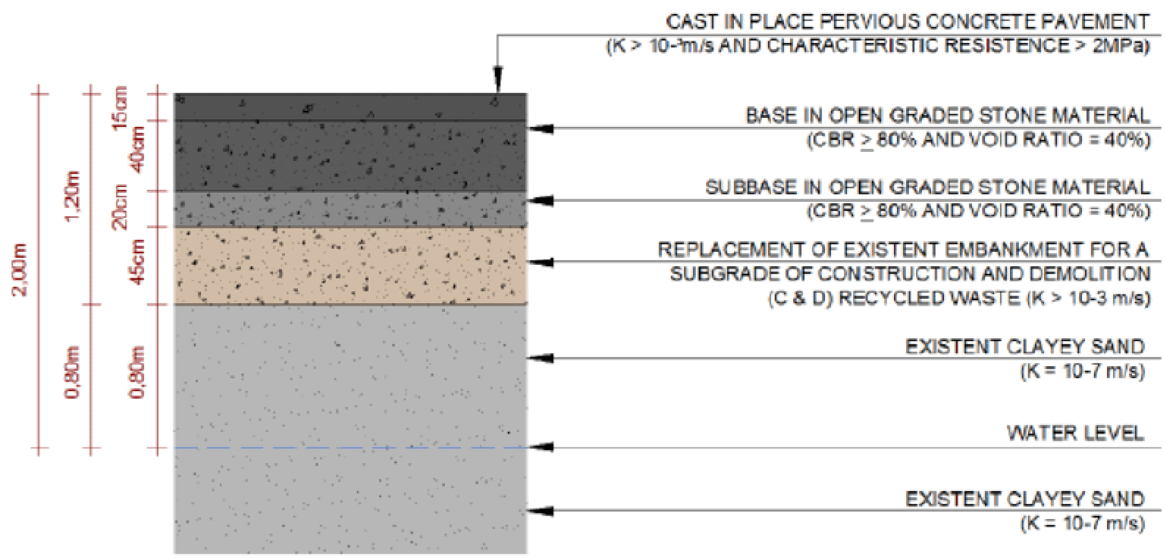

Figure 5-6. Cross section of a porous asphalt system.

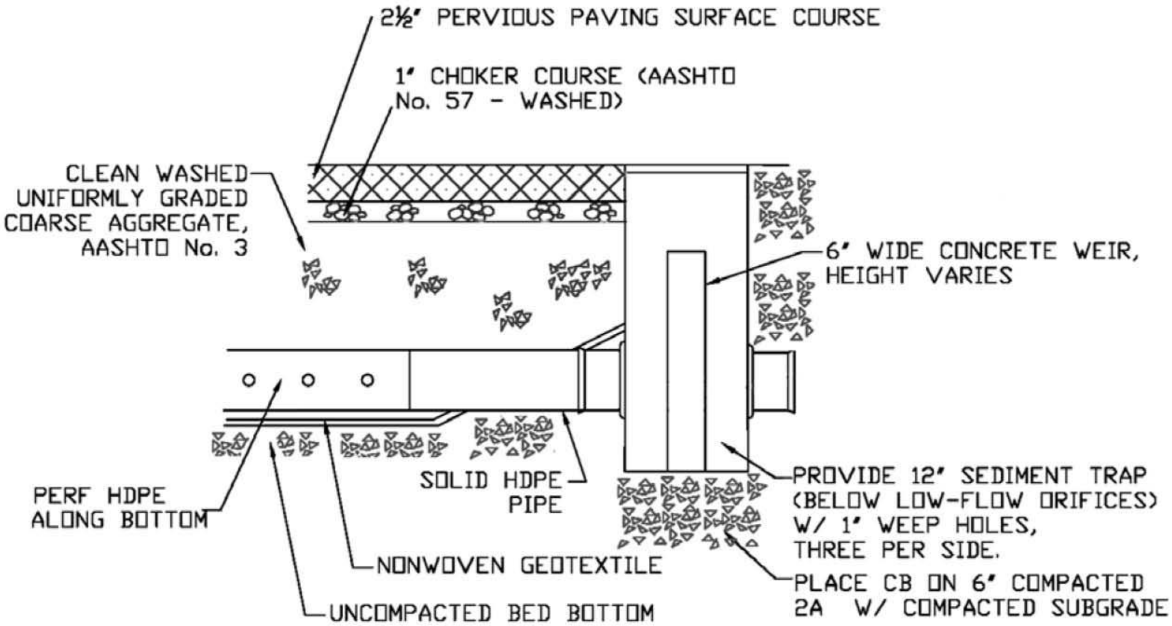

Figure 5-7. Cross section of a permeable paver system.

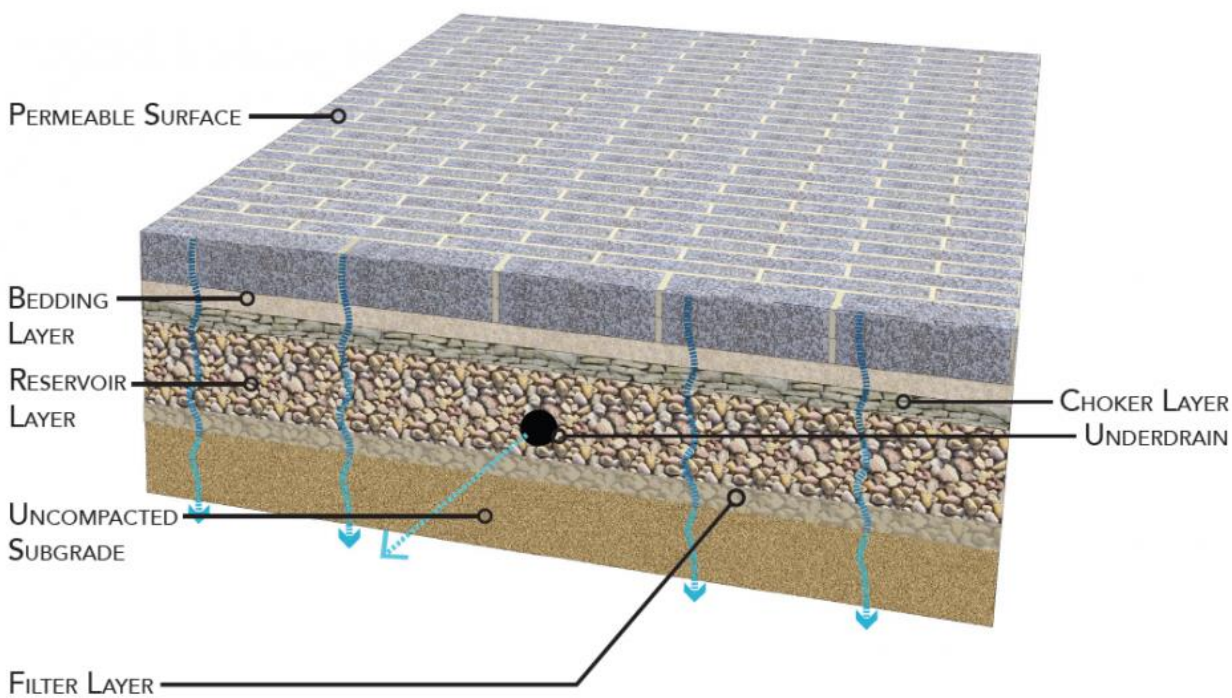

Table 5-1. Permeable pavement specifications.

Material	Specification	Notes
Pervious Concrete	Void content: 15% - 25% Material thickness: typically 4 – 8 inches Compressive strength: 2.8 to 28 MPa Open void fill media: none	May not require a reservoir layer to support the structural load. A layer may be included to increase the storage or infiltration.
Porous Asphalt	Void content: 15% - 20% Material thickness: typically 3 – 7 inches Open void fill media: none	Reservoir layer required to support the structural load.
Permeable Pavers	Void content, material thickness, and compressive strength vary based on type and manufacturer Open void fill media: aggregate, topsoil and grass, coarse sand, etc.	Reservoir layer required to support the structural load.

Table 5-2. Material specifications for permeable pavement layers.

Material	Specification
Bedding Layer	Pervious concrete: 3 – 4 inches of No. 57 stone if No. 2 stone is used for reservoir layer Porous asphalt: 3 – 4 inches of No. 57 stone Permeable pavers: Follow manufacturer specifications
Reservoir Layer	Pervious concrete: No. 57 stone or No. 2 stone Porous asphalt: No. 2 stone Permeable pavers: Follow manufacturer specifications
Underdrain	Use a 4 – 6 inch diameter perforated PVC pipe with 3/8 perforations at 6 inches on center.
Infiltration Sump (optional)	An aggregate storage layer below the underdrain invert. Material specifications are the same as the reservoir layer.
Filter Layer (optional)	The underlying native soils should be separated from the stone reservoir by a 2 – 4 inch layer of choker stone (e.g. No. 8).
Geotextile (optional)	Use an appropriate geotextile fabric that complies with AASHTOM-288 Class 2 requirements and has a permeability of at least an order of magnitude higher (10x) than the soil subgrade permeability.

Impermeable Liner (optional)	If appropriate, use a 30 milliliter minimum PVC Geomembrane liner.
Observation Well	Use a perforated 4 – 6 inch vertical PVC pipe with a lockable cap, installed flush with the surface.

5.4.1 Pretreatment
Pretreatment for permeable pavements is not necessary.

5.5 Construction
Construction for permeable pavement systems may vary slightly depending on the materials used. A general construction sequence is included below. It may need to be modified for specific materials.

- **Stabilize Drainage Area.** Construction cannot begin until the entire contributing drainage area has been stabilized. The site needs to be checked for utilities before construction begins.
- **Install Soil and Erosion Control Measures.** Special erosion control measures may need to be implemented to protect vulnerable side slopes during construction. The permeable pavement area must be kept free from sediment and debris during the construction process.
- **Minimize Impact of Heavy Installation Equipment.** Equipment should work from the sides to excavate the reservoir layer. Compaction should be avoided by utilizing equipment with adequate extension and using a cell construction approach.
- **Promote Infiltration Rate.** Native soils should be tilled to a depth of 3 – 4 inches prior to the placement of the filter layer or geotextile fabric. The soil subgrade may need to be compacted to 95% of the Standard Proctor Density to achieve the necessary load-bearing capacity.
- **Order of Materials.** Geotextile fabric should be installed on the sides of the reservoir layer. Geotextile fabric strips should overlap downslope by a minimum of 2 feet and be secured a minimum of 4 feet beyond the edge of the excavation. If the filter layer extends beyond the edge of the pavement, install an additional layer of geotextile fabric 1 foot below the surface to prevent sediment from entering the reservoir layer.
- **Install Base Material Components.** Supply a minimum of 2 inches of aggregate above and below the underdrains. The up-gradient end of underdrains in the reservoir layer should be capped. Ensure there are no perforation sin clean-outs and observation wells within 1 foot of the surface.

- **Stone Media.** Spread 6 inch lifts of the designated clean, double washed stone aggregate. Place at least 4 inches of additional aggregate above the underdrain, and then compact it until there is no visible movement of the aggregate.
- **Reservoir Media.** Install the desired depth of the bedding layer.
- **Paving Media.** Install paving materials in accordance with industry specifications for the type of pavement.

Pervious Concrete:

- Water the underlying aggregate before the concrete is placed.
- After the concrete is placed, strike off approximately 3/8 to 1/2 inches is struck off using a vibratory screed to allow for compaction of the concrete pavement.
- Compact the pavement with a steep pipe roller.
- Cut joints for the concrete to a depth of ¼ inch.
- Follow manufacturer guidelines for curing pervious concrete. This may require covering the pavement with plastic sheeting within 20 minutes of the strike off and leaving it covered for at least 7 days.
- Remove the plastic sheeting after the proper curing time.

Porous Asphalt:

- Install porous asphalt similarly to regular asphalt pavement. The pavement should be laid in a single lift over the filter course. The laying temperature should be between 230°F and 260°F, with a minimum air temperature of 50°F, to ensure the surface does not stiffen before compaction.
- Complete compaction on the surface course when the surface is cool enough to resist a 10 ton roller. Roll over the surface one or two times only for proper compaction.
- The asphalt mix’s estimated coating area should be above 95%. If it is not, additional anti-stripping agents must be added to the mix.
- Transport the mix to the site in a clean vehicle with smooth dump beds sprayed with a non-petroleum release agent. The mix should be covered during transportation.
- Test the permeability of the pavement surface by applying clean water at a rate of at least five gallons per minute over the entire surface. All water should infiltrate directly without puddle formation or surface runoff.

Permeable Interlocking Pavers:

- Place edge restraints for open-jointed pavement blocks before the bedding layer and pavement blocks are installed. Edge restraints are required to prevent vehicle loads from moving the paver blocks. Edge restraints may include standard curbs or gutter pans, or precast or cast-in-place reinforced concrete borders a minimum of 6 inches wide and 18 inches deep, constructed with class A3 concrete.

- Place the double washed No. 57 stone in a single lift. Level the filter course and compact it into the reservoir course beneath with at least 4 passes of a 10-ton steel drum static roller until there is no visible movement.
- Place and screed the bedding course material (usually No. 8 stone).
- Fill gaps at the edge of the paved areas with cut pavers or edge units. If cut pavers are needed, cut the pavers with a paver splitter no smaller than 1/3 of the full unit size.
- Place pavers by hand or using mechanical installers. Fill the joints and openings with stone. Remove excess stones from the paver surface.
- Compact and seat the pavers into the bedding course with a minimum low-amplitude 5,000-lb, 75 to 95 Hz plate compacter.
- The paver system must be swept or vacuumed immediately after construction to remove any sediment or excess aggregate.

5.6 Inspection and Maintenance

Permeable pavement structures should be inspected 18 to 30 hours after a significant rainfall and yearly thereafter.

Table 5-3. As-built inspection form for permeable pavement systems.

Permeable Pavement					
Maintenance Item	Condition				Comment
	Good	Marginal	Poor	N/A	
General Inspection					
Access to the site is adequately maintained for inspection and maintenance.					
Area is clean (trash, debris, grass clippings, etc. removed).					
Area around the practice is mowed and grass clippings are removed. No signs of bare or dead grass.					
No evidence of gullies, rills, or erosion around the inlet.					
Water is permeating the bricks/blocks.					
Bricks/blocks are structurally sound. No signs of cracking or splitting.					

Aggregate between the bricks/blocks is reasonable.					
No evidence of long-term ponding or standing water in the practice.					
Grass in the concrete grid is healthy and mowed, no dead or bare spots.					
Structure seems to be working properly. No signs of the bricks/blocks settling.					
Vegetation within and around practice is maintained. Grass clippings are removed.					
No exposed soil near the bricks/blocks that could cause sediment accumulation within the practice					
Cleanout caps are present (if applicable)					
The underdrain system has been flushed properly and there is no sign of clogging (if applicable)					
Results					
Overall condition of permeable pavement system					
Additional Comments					

Permeable pavement structures must be maintained regularly to ensure they are functioning properly. If permeable pavement structures are not cleaned out frequently, they will become impervious surface. Some important things to watch out for include sediment build-up, clogging between bricks/blocks, settling, and bricks/blocks cracking or splitting.

Table 5-4. Maintenance checklist for permeable pavement systems.

Maintenance Checklist for Permeable Pavement Systems			
Maintenance Item	Complete?		Comment
	Yes	No	
After Installation			
Conduct any needed repairs for stabilization.			
Once every 1-2 months during the growing season			
Mow grass in grid paver applications			
As needed			
Stabilize the contributing drainage area to prevent erosion			
Remove any soil or sediment on pavement			
Replace or repair any pavement surfaces that are degenerating			
Annually			
Test the planting soils for pH levels. Maintain proper pH levels as advised by a licensed professional.			
2-4 Times Per Year			
Mechanically sweep pavement with a street sweeper to prevent clogging			
Annually			

Conduct a maintenance inspection			
Spot weed for grass applications			
Once Every 2-3 Years			
Remove any accumulated sediment in pretreatment cells and inflow points			
If Clogged			
Conduct maintenance using a regenerative street sweeper or a vacuum sweeper			
Replace any necessary joint material			

Table 5-5. Maintenance schedule for permeable pavement systems.

Activity	Schedule
• Conduct any needed repairs for stabilization.	After Installation
• Mow grass in grid paver applications	Once every 1-2 months during the growing season
• Stabilize the contributing drainage area to prevent erosion • Remove any soil or sediment on pavement • Replace or repair any pavement surfaces that are degenerating	As Needed
• Mechanically sweep pavement with a street sweeper to prevent clogging	2-4 Times Per Year
• Conduct a maintenance inspection • Spot weed for grass applications	Annually
• Remove any accumulated sediment in pretreatment cells and inflow points	Once Every 2-3 Years
• Conduct maintenance using a regenerative street sweeper or a vacuum sweeper • Replace any necessary joint material	If Clogged

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6 Downspout Disconnection

6.1 Overview

A downspout disconnection is the most basic low impact development practice. Downspout disconnects diverts water from flowing over an impervious area to a pervious area. This allows for the water to be slowed, filtered, and infiltrate the soil. The pervious area located below the downspout disconnect should slope away from buildings and other impervious surfaces. This prevents damage to building foundations and discourages rooftop runoff from entering the storm drain system.

Figure 6-1. Image of a typical downspout disconnection.

Common locations:

- Commercial rooftops
- Residential rooftops

Pollution Removal Efficiencies:

- Total Suspended Solids (TSS) = 80%
- Total Nitrogen = 25%
- Total Phosphorus = 25%
- Metals (copper, lead, zinc, cadmium) = 40%

Benefits:

- Helps restore pre-development hydrology on development sites
- Reduces post-construction stormwater runoff rates, volumes, and pollutant loads
- Relatively low construction cost and long-term maintenance burden
- Encourages groundwater recharge
- Increases water quality benefits

Limitations:

- Level spreaders are needed at the downspout to dissipate flow
- Clay soils or soils that have been greatly compacted greatly reduce the effectiveness of the practice
- Requires area for infiltration
- Difficult to regulate and oversee, particularly for subdivision grading permit projects

6.2 Design

Downspout disconnects should be designed to convey stormwater runoff away from buildings to prevent damage to building foundations. Runoff should be conveyed as sheet flow from the downspout.

Design Criteria:

- Maximum length of flow path in contributing drainage area is 75 feet

- Minimum length of flow path in pervious areas below simple downspout disconnects is at least 15 feet and equal to or greater than the length of the flow path in the contributing drainage area
- The maximum impervious rooftop drainage area to one disconnected downspout
- Maximum slope site of 6%
- No restrictions on depth to water table
- Maximum drainage area of 2,500 ft^2
- Disconnects should be directed over HSG A, B, or C soils (e.g. sands, sandy loams, loams)
- Must be a minimum distance of 500 feet away from steep slopes or landslide-prone areas

Vegetation:
- Turf
- Trees
- Shrubs
- Herbaceous vegetation
- Native vegetation

Figure 6-2. Schematic drawing of downspout disconnect.

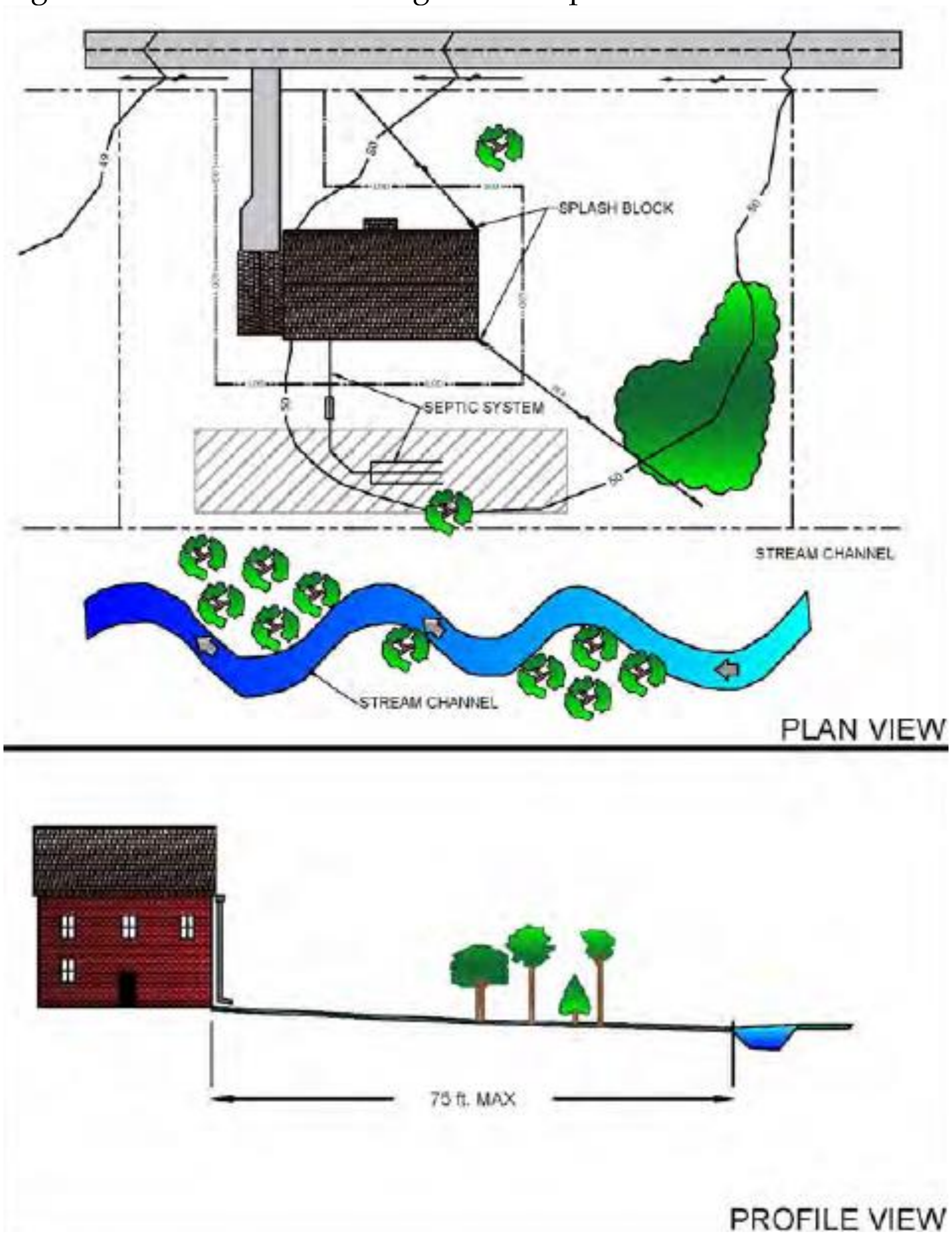
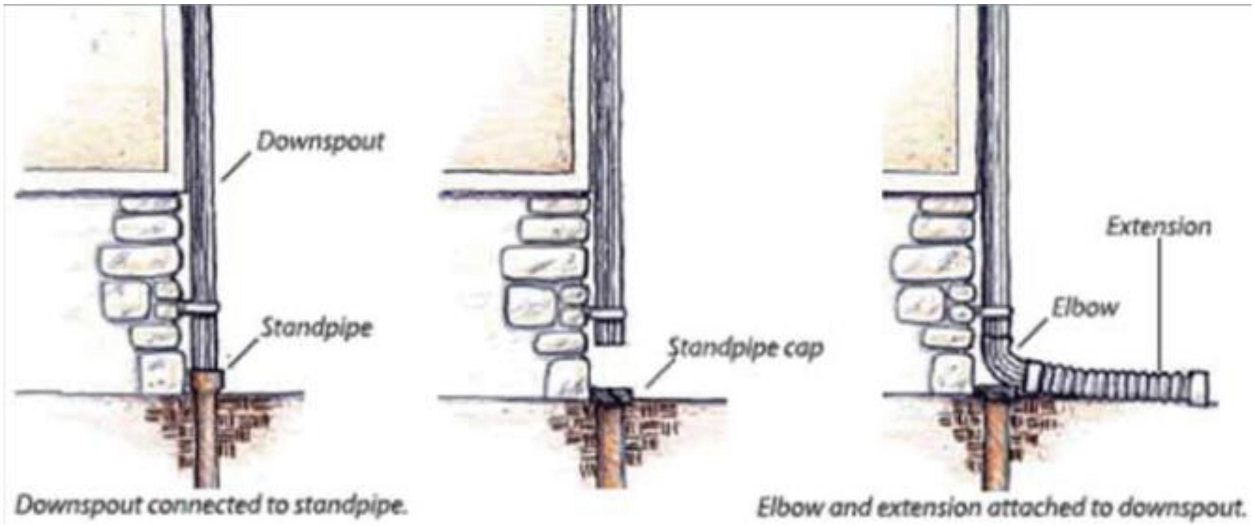


Figure 6-3. Depiction of establishing a downspout disconnect.



6.3 Pretreatment

External pretreatment can be implemented for downspout disconnects. Leaf screens can be used to prevent the downspouts from becoming clogged.

6.4 Construction

Downspout disconnects should be installed properly with erosion and sediment control measures. These include temporary seeding and erosion control mats. Construction vehicles should avoid the pervious area as much as possible to prevent compaction of the soils.

- **Measure the existing downspout** from the top of the standpipe. Mark it about 9 inches above the standpipe.
- **Measure and cut the downspout extension.** The length of the extension will depend on site conditions and where you want the downspout to drain.
- **Cut the existing downspout.** Remove the cut piece.
- **Plug or cap the standpipe.** Use an in-pipe test plug or over-the-pipe cap secured by a hose clamp.
- **Attach the elbow** over the downspout.
- **Attach the extension to the elbow.** Put the extension over the end of the elbow.
- **Secure the pieces** with sheet metal screws at each joint where the downspout, elbow, and extension connect.
- **Install a splash block.** Place it at the end of the extension to help prevent soil erosion.

6.5 Inspection and Maintenance

Downspout disconnects should be inspected after construction and large rain events. The primary things to look for are clogged gutters or downspouts, poorly draining soils, and cracks within the downspout extension.

Table 6-1. As-built inspection form for downspout disconnects.

<table>
<tr><td colspan="6">Downspout Disconnects</td></tr>
<tr><td rowspan="2">Maintenance Item</td><td colspan="4">Condition</td><td rowspan="2">Comment</td></tr>
<tr><td>Good</td><td>Marginal</td><td>Poor</td><td>N/A</td></tr>
<tr><td>Access to the site is adequately maintained for inspection and maintenance.</td><td></td><td></td><td></td><td></td><td rowspan="9"></td></tr>
<tr><td>Gutters are clean. No sediment, debris, or trash to clog the system.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Downspouts are properly fastened to convey water from the roof.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Downspouts are free of trash, debris, and sediment and conveying water properly.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>No evidence of leaks at joints or other components of downspouts.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Erosion control mats are present on site to prevent erosion on pervious area below downspout disconnects.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Area is clean.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Vegetation is in place and healthy. No bare or dying areas.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Unwanted vegetation is trimmed and/or removed.</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Results</td></tr>
<tr><td>Overall condition of downspout disconnects</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Additional Comments</td></tr>
<tr><td colspan="6"></td></tr>
</table>

Routine maintenance should be performed on the downspout disconnects to ensure it is functioning properly. A major concern to be aware of is erosion at the base of the downspout disconnect.

Table 6-2. Maintenance checklist for downspout disconnects.

Maintenance Checklist for Downspout Disconnects			
Maintenance Item	Complete?		Comment
	Yes	No	
As Needed & Following Construction			
Water pervious areas located below simple downspout disconnections to promote plant growth and survival			
Inspect the pervious areas below simple downspout disconnections following rain events. Plant replacement vegetation in any eroded areas.			
Monthly			
Inspect pervious areas located below simple downspout disconnection. Maintain vegetation.			
Remove accumulated trash and debris in pervious area located below the simple downspout disconnection.			
Annually (Semi-Annually During First Year)			
Remove any accumulated leaves and debris from			

gutters and downspouts.			
Inspect the pervious areas below simple downspout disconnections for erosion and the formation of rills and gullies. Plant vegetation in any eroded areas.			
Replace any dead or dying vegetation with new vegetation.			

Table 6-3. Maintenance schedule for downspout disconnects.

Activity	Schedule
• Water pervious areas located below simple downspout disconnections to promote plant growth and survival • Inspect the pervious areas below simple downspout disconnections following rain events. Plant replacement vegetation in any eroded areas.	As Needed & Following Construction
• Inspect pervious areas located below simple downspout disconnection. Maintain vegetation. • Remove accumulated trash and debris in pervious area located below the simple downspout disconnection.	Monthly
• Remove any accumulated leaves and debris from gutters and downspouts. • Inspect the pervious areas below simple downspout disconnections for erosion and the formation of rills and gullies. Plant vegetation in any eroded areas. • Replace any dead or dying vegetation with new vegetation.	Annually (Semi-Annually During First Year)

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7 Rainwater Harvesting

7.1 Overview

Rainwater harvesting is the practice of intercepting, diverting, and storing stormwater runoff for later use. Rainfall is collected from a gutter or downspout system, screened, and conveyed into a storage tank or cistern. Rainwater harvesting reduces the demand on public water supplies. There are two main types of rainwater harvesting systems: systems that are used to supply water for non-potable outdoor uses and systems that are used to supply water for non-potable indoor uses.

Figure 7-1. Image of a rainwater harvesting systems.

Variations:

- Rain barrels
- Cisterns
- Tanks
- Storage beneath a surface

Pollution Removal Efficiencies:

- Total Suspended Solids (TSS) = Varies
- Total Nitrogen = Varies
- Total Phosphorus = Varies
- Metals (copper, lead, zinc, cadmium) = Varies

Benefits:

- May reduce water bill
- Allows beneficial reuse of stormwater
- Helps restore pre-development hydrology
- Reduces post-construction runoff rates, volumes, and pollutant loads
- Can be used on almost any development site
- Reduces demand on public water supplies which protects groundwater aquifers from drawdown and seawater intrusion

Limitations:

- Stored rainwater should be used on a regular basis to maintain system storage capacity
- A pump may be required if system is below ground

- Not aesthetically pleasing in some cases
- Plumbing codes may be required if the system is inside
- Should not be used with tar, gravel, and/or asbestos shingled roofs

7.2 Design

A rainwater harvesting system consists of five major components: the collection and conveyance system, pretreatment devices, the storage tank or cistern, the overflow pipe, and the distribution system.

Design Criteria:

- Collection and Conveyance system: This consists of the gutters, downspouts, and pipes that channel stormwater runoff into storage tanks. Aluminum, round bottom gutters and round downspouts are recommended for rainwater harvesting. Gutters should be sized with slopes to contain the 1 inch storm at a rate of 1 inch/hour. Gutters should be hung at a minimum of 0.5% slope for 2/3 of the length and at 1% slope for the remaining 1/3 of the length.
- Pretreatment Devices: Rooftop runoff should be filtered to remove sediment before it is stored. Pretreatment devices should be low maintenance or maintenance-free. For first flush diverters, 0.02 to 0.06 inches of runoff should be directed to an acceptable pervious flow path. For the 1 inch storm treatment volume, a minimum of 95% filter efficiency is required. For 2 and 10 year storms, a minimum filter efficiency of 90% should be met. Leaf screens should be installed over the gutter or downspout to separate leaves and debris from rooftop runoff. Roof washers are placed ahead of storage tanks to filter small debris.
- Storage Tank: Storage tanks are sized based on indoor and outdoor water demand, long-term rainfall, and rooftop capture area. Tank capacity can range from 250 to over 30,000 gallons. Storage tanks should be designed to meet the area's specifications. Materials used and shape of the tank can be altered depending on the site. Aboveground storage tanks should be UV and impact resistant. Storage tanks should be opaque or protected from direct sunlight to inhibit algae growth.
- Overflow Pipe: Overflows should divert runoff to pervious areas when the storage tanks are full. The size of the overflow device should be equal in area to the total of all inlet orifices. The overflow pipe should be screened to prevent access to the tank by rodents and birds.
- Distribution System: Distribution lines should be installed with shutoff valves and cleanouts. They should be buried beneath the frost line or insulated to prevent freezing. A typical pump and pressure tank arrangement uses a centrifugal pump to draw water out of the storage tank and send it to the pressure tank where it is stored for distribution.

Table 7-1. Design specifications for rainwater harvesting systems.

Item	Specification
Gutters and Downspouts	Materials commonly used or gutters and downspouts include PVC pipe, vinyl, aluminum, and galvanized steel. • The length of the gutters and downspouts is determined by the size and layout of the catchment and the location of the storage tanks.
Pretreatment	• Leaf screen • First flush diverter • Roof washer
Storage Tanks	• Materials used should be structurally sound. • Tanks should be constructed where native soils can support the load of the tank with stored water. • Tanks should be opaque to prevent the growth of algae. • Underground rainwater harvesting systems should have a minimum of 18 to 24 inches of soil cover and be located below the frost line.

7.3 Pretreatment

Pretreatment is used to remove debris, dust, leaves, and other materials that accumulate on rooftops and could cause clogging within the rainwater harvesting system. Some pretreatment devices for rainwater harvesting systems include:

- Leaf screens: These are mesh screens installed in the gutter or downspout that are used to remove leaves and other large debris from rooftop runoff. They must be maintained regularly to prevent clogging.
- First flush diverters: First flush diverters direct the initial pulse of stormwater runoff away from the storage tank into an adjacent pervious area. These are used to remove smaller contaminants like dust, pollen, and animal feces.
- Roof washers: Roof washers are placed ahead of storage tanks. They are used to filter small debris from the harvested rainwater. They consist of a 25-50 gallon tank with leaf strainers and filters with openings as small as 30 microns. The filter removes small particulate matter from the harvested rainwater. Roof washers must be cleaned regularly to prevent clogging and breeding of bacteria or other pathogens.

Figure 7-2. Image of a leaf screen on a gutter system.

Figure 7-3. Diagram of a first flush diverter.

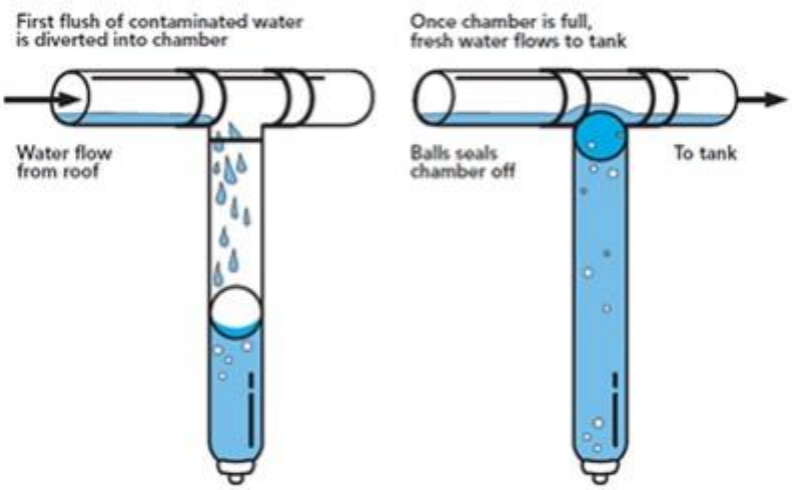
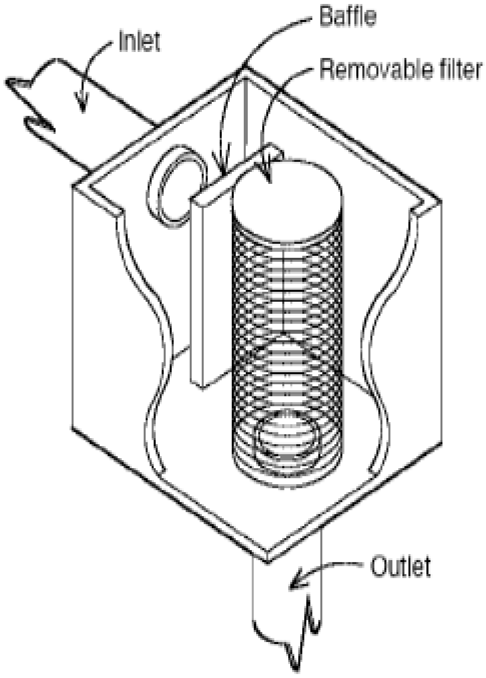


Figure 7-4. Depiction of a roof washer.



7.4 Construction

It is advised to have a single contractor install the entire rainwater harvesting unit to ensure cohesiveness throughout the project. A licensed plumber is required to install the rainwater harvesting components to the plumbing system. A typical construction sequence for installing rainwater harvesting systems is included below. It can be modified based on site conditions and system applications.

- Choose the tank location on the site.
- Route all downspouts or roof drains to pre-screening devices and first flush diverters.
- Install the tank.
- Install the pump (if necessary) and piping to end-uses (indoor, outdoor irrigation, or tank dewatering release).
- Route all pipes to the tank.
- Stabilize the pervious area with vegetation.
- Install rain barrels and cisterns on level surfaces.

7.5 Inspection and Maintenance

Rainwater harvesting systems should be inspected following construction and regularly thereafter. Common problems with rainwater harvesting systems are sediment build-up, clogging in the gutters or downspout connections, algae growing in the rainwater system, and wear and tear on pumping equipment (if applicable).

Table 7-1. As-built inspection form for rainwater harvesting system.

Rainwater Harvesting					
Maintenance Item	Condition				Comment
	Good	Marginal	Poor	N/A	
Access to the site is adequately maintained for inspection and maintenance.					
Area is clean (trash, debris, etc. removed).					
Gutters and downspouts are free of trash and debris.					
Leaf screens are clean and in good condition.					
First flush diverter is working properly (if applicable).					
Roof washer is working properly (if applicable).					
Cistern inlet and downspout fits tightly.					
Cistern tank is clean and free of sediment.					
Plants being watered from the rainwater system are healthy and in good condition.					
No signs of overflow valve leaking (stains, dampness).					
Cistern is in good condition. No signs of cracking or leaking.					
Performance of pump matches pumping details (if applicable).					
Results					
Overall condition of rainwater harvesting system					
Additional Comments					

Regular maintenance is required on a rainwater harvesting system. It is important to inspect and maintain each aspect of the rainwater harvesting system. Typically, maintenance should be performed in the spring and fall.

Table 7-2. Maintenance checklist for rainwater harvesting systems.

<table>
<tr><td colspan="4">Maintenance Checklist for Rainwater Harvesting Systems</td></tr>
<tr><td rowspan="2">Maintenance Item</td><td colspan="2">Complete?</td><td rowspan="2">Comment</td></tr>
<tr><td>Yes</td><td>No</td></tr>
<tr><td colspan="4">Late Fall or Before A Major Freeze</td></tr>
<tr><td>Disconnect rainwater harvesting system from roof downspouts.</td><td></td><td></td><td></td></tr>
<tr><td>Drain aboveground cisterns and clean for winter.</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Early Spring or After Last Major Freeze</td></tr>
<tr><td>Connect rainwater harvesting system to roof downspouts</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Regularly During Above Freezing Temperatures</td></tr>
<tr><td>Empty rainwater harvesting system periodically by watering vegetation.</td><td></td><td></td><td></td></tr>
<tr><td>Examine vegetation for health and determine if additional watering needs are required</td><td></td><td></td><td></td></tr>
<tr><td>Inspect storage tank screens and pretreatment devices. Clean as needed.</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Semi-annually in Spring and Fall</td></tr>
<tr><td>Inspect gutters and downspouts. Remove any accumulated leaves or debris.</td><td></td><td></td><td></td></tr>
<tr><td>Clean storage tank screens.</td><td></td><td></td><td></td></tr>
</table>

Inspect pretreatment devices for sediment accumulation. Remove accumulated trash and debris.			
Inspect for tight connection at inlet and drain valve.			
Verify pumping system is working properly.			
Keep pipe clear of obstructions.			
Inspect storage tank for algal blooms. Treat if present.			
Inspect overflow areas for erosion or rills and gullies. Plant vegetation in any eroded areas.			
Annually			
Check system for sediment. Clean out the tank when the sediment is more than 5% of the volume in the cistern.			

Table 7-3. Maintenance schedule for rainwater harvesting systems.

Activity	Schedule
• Disconnect rainwater harvesting system from roof downspouts. • Drain aboveground cisterns and clean for winter.	Late Fall or Before A Major Freeze
• Connect rainwater harvesting system to roof downspouts	Early Spring or After Last Major Freeze
• Empty rainwater harvesting system periodically by watering vegetation. • Examine vegetation for health and determine if additional watering needs are required. • Inspect storage tank screens and pretreatment devices. Clean as needed.	Regularly During Above Freezing Temperatures
• Inspect gutters and downspouts. Remove any accumulated leaves or debris. • Clean storage tank screens. • Inspect pretreatment devices for sediment accumulation. Remove accumulated trash and debris. • Inspect for tight connection at inlet and drain valve. • Verify pumping system is working properly. • Keep pipe clear of obstructions. • Inspect storage tank for algal blooms. Treat if present. • Inspect overflow areas for erosion or rills and gullies. Plant vegetation in any eroded areas.	Semi-annually in Spring and Fall
• Check system for sediment. Clean out the tank when the sediment is more than 5% of the volume in the cistern.	Annually

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8 Green Roofs

8.1 Overview

Green roofs provide an alternative to traditional impervious roof surfaces. They consist of underlying waterproofing and drainage materials with an overlying engineered growing media designed to support plant growth. Stormwater runoff is captured and temporarily stored in the engineered growing media before it is evaporated or transpired off or conveyed into the storm drain system. Green roofs provide measurable reductions in post-construction stormwater runoff rates, volumes, and pollutant loads on development sites. There are two types of green roof systems: intensive and extensive. Intensive green roof systems have a thick layer of engineered growing media (6 inches to 4 feet) and support a diverse plant community. Extensive green roof systems have a thinner layer of engineered growing media (6 inches and under) and support a plant community comprised of primarily drought tolerant vegetation.

Figure 8-1. Image of a green roof.

Pollution Removal Efficiencies:

- Total Suspended Solids (TSS) = 80%
- Total Nitrogen = 50%
- Total Phosphorus = 50%

- Metals (copper, lead, zinc, cadmium) = N/A

Benefits:
- Helps reduce post-construction stormwater runoff rates, volumes, and pollutant loads
- Well-suited for use on urban development and redevelopment sites
- Allows for more development space on a project site
- Does not consume significant valuable land
- Wildlife habitat potential
- Provides sound insulation
- Reduces urban heat island effect
- Protects roof structure from weathering

Limitations:
- Roof structure must be capable of supporting the additional weight of a green roof
- Can be difficult to establish vegetation in certain areas featuring harsh conditions
- More maintenance than a conventional roof
- Potential for roof leaks
- Not suitable for groundwater recharge

8.2 Design

Green roofs consist of waterproofing and drainage materials as well as engineered growing media designed to support plant growth. Green roofs are typically flat or slightly sloped. The optimal roof slope is 1-2%. The roof can be sloped a maximum of 25% with baffles. Green roofs are composed of eight layers. Details of each layer are provided below.

Design Criteria:
- Deck layer: The roof deck acts as the foundation of the green roof. It may be composed of concrete, wood, metal, plastic, gypsum, or a composite material. Concrete decks are preferred for green roofs.
- Waterproofing layer: Green roofs require a waterproofing layer to prevent water damage to the deck layer. It must be 100% waterproof and have an expected life span as long as the other elements of the green roof system.
- Insulation layer (optional): The drainage layer should consist of synthetic or inorganic materials capable of retaining water and providing efficient drainage. The required depth of the insulation layer is dependent on the required stormwater storage capacity and the structural capacity of the rooftop. The drainage layer should convey a 10 year storm without inundating the growing media.
- Root barrier: A root barrier protects the waterproof membrane from root penetration.

- Drainage layer: Placed between the root barrier and growing media to convey excess water from the vegetation root zone. The drainage layer should consist of synthetic or inorganic materials capable of retaining moisture while providing efficient drainage.
- Root-permeable filter fabric: Semi-permeable polypropylene filter fabric placed between the drainage layer and the growing media to prevent the media from migrating into the drainage layer and clogging it.
- Growing media: The depth of the growing media is dependent on the type of green roof system. The growing media should be approximately 80% to 90% lightweight inorganic materials and no more than 15% organic matter. The growing media should have a maximum water retention capacity of around 30%.
- Plant cover: A planting plan should be prepared by a landscape architect, botanist, or other professional experienced with green roofs. The plant cover should consist of slow-growing, shallow-rooted, perennial plants. Designers should take into consideration the local climate, native species, and building conditions when choosing vegetation.

Figure 8-2. Depiction of the layers of a green roof.

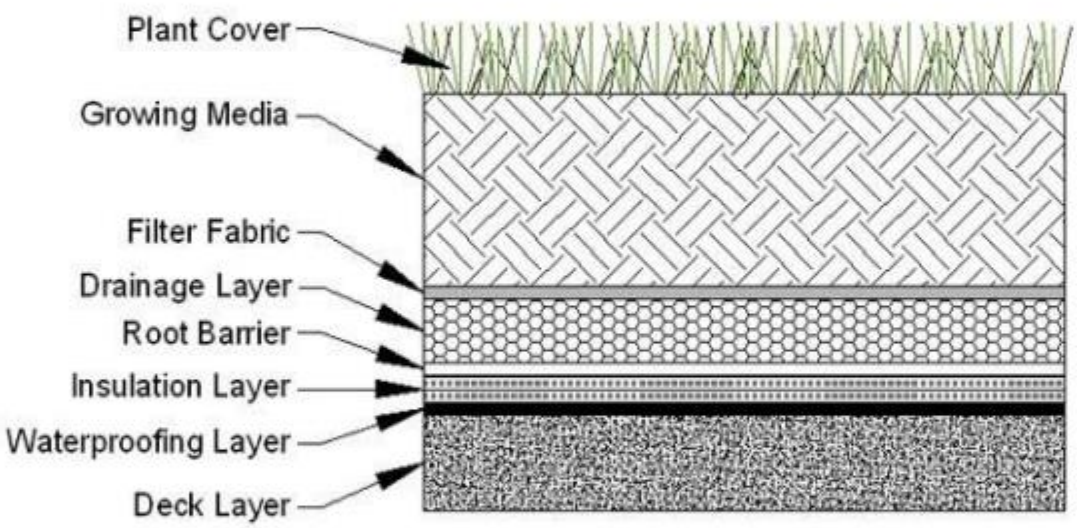


Table 8-1. Material specifications for a green roof.

Material	Specification
Waterproof membrane	A wide range of materials can be used including built up roofs, modified bitumen, single-ply, and liquid-applied methods.
Root barrier (optional)	Impermeable liner that impedes root penetration of the membrane.
Drainage layer	1 to 2 inch layer of clean, washed granular material, such as No. 8 stone. Roof drains and emergency overflow should be designed in accordance with local codes.
Filter fabric	Needled, non-woven, polypropylene geotextile. Density > 16 oz./sq. yd. Puncture resistance > 220 lbs
Growth media	85% lightweight inorganic materials and 15% organic matter (e.g. well-aged compost). Media should have a maximum water retention capacity of around 30%. Media should provide sufficient nutrients and water holding capacity to support the proposed plant materials.
Plant materials	For extensive roof systems: low plants, like sedum, herbaceous plants, and perennial grasses. For intensive roof systems: perennials, shrubs, and trees.

Figure 8-3. Schematic of an extensive vegetated roof.

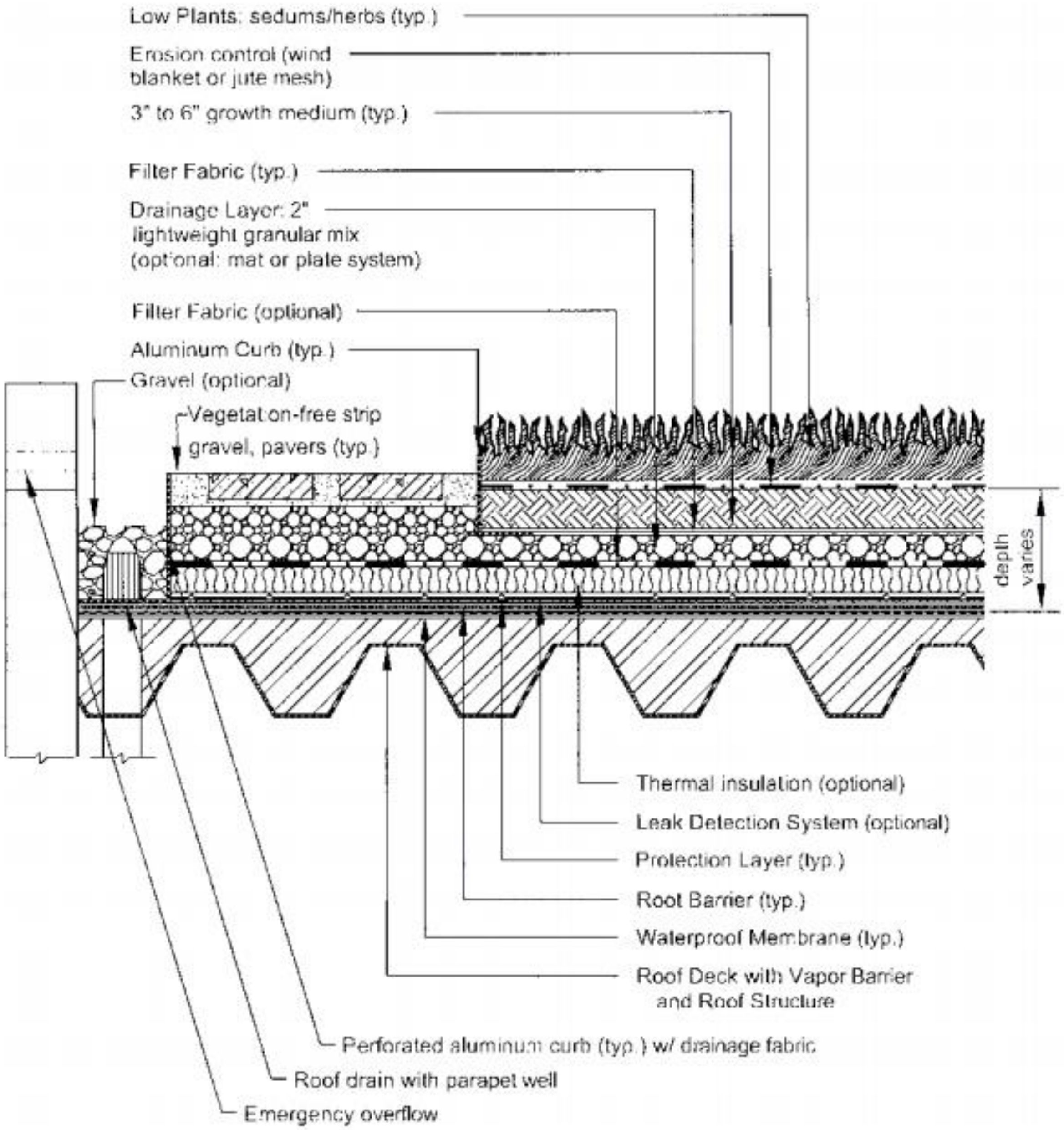
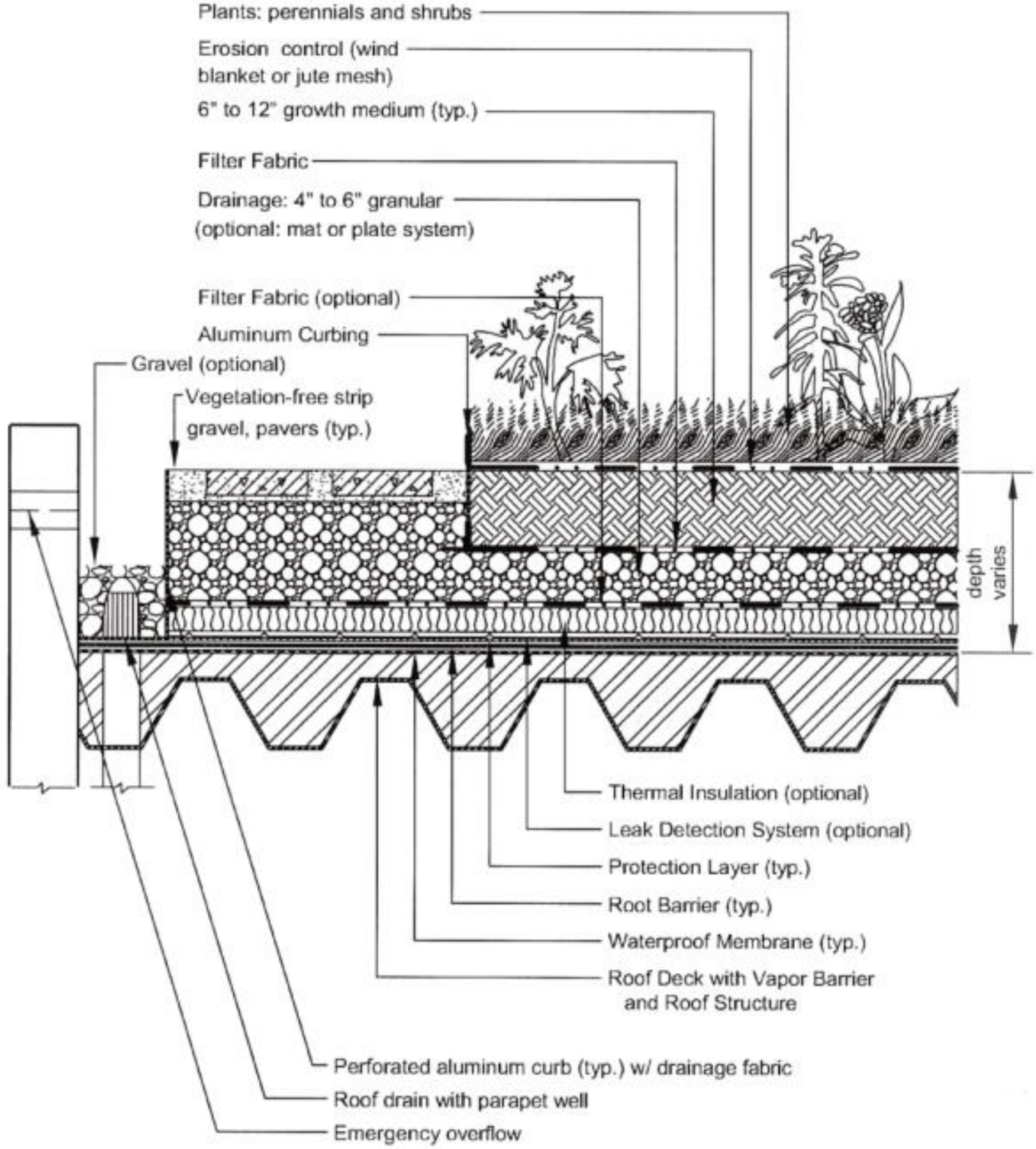


Figure 8-4. Schematic of an intensive vegetated roof.



8.3 Pretreatment

Pretreatment is not necessary for green roofs.

8.4 Construction

Construction of a green roof should be individualized based on the conditions of the roof. A general construction sequence is provided below.

- Construct the roof deck with the appropriate slope and material.
- Install the waterproofing method according to manufacturing specifications.
- Conduct a flood or electronic test to ensure the system is water tight.

- Add additional system components (e.g. insulation, root barrier, drainage layer, and filter fabric). Drain collars and protective flashing should be installed to ensure free flow of excess stormwater.
- Spread growing media over the filter fabric surface. Allow for some settlement by adding additional medium depth. Cover the growing media until planting is ready to occur. Equipment and foot traffic should be limited over the growing media to prevent compaction.
- Fertilize using slow release fertilizer to help establish vegetation. It typically takes 12 to 18 months to fully establish the green roof.

8.5 Inspection and Maintenance

Green roofs should be inspected frequently during the first year to ensure they become established. They should also be inspected after a large rainstorm to ensure they function properly.

Table 8-2. As-built inspection form for green roofs.

Green Roof					
Maintenance Item	Condition				Comment
	Good	Marginal	Poor	N/A	
Access to the site is adequately maintained for inspection and maintenance.					
Area is clean (trash, debris, etc. removed)					
Inlet and outlet pipes are free of trash, debris, etc.					
Inspect waterproof membrane for leaks.					
No evidence of structural deficiency or settling.					
Water can flow freely in the drainage routes, no obstructions.					
Native plants were used in the practice. Plants seem to be in good condition.					
No unwanted vegetation in the practice.					
No evidence of use of fertilizer on plants.					
No evidence of long-term ponding or standing water.					
Results					

Overall condition of green roof					
Additional Comments					

It is important to maintain green roofs diligently. They need significant attention in the first year while they are being established. Some common problems to look for are clogging in the outlet structure, clogging in the drainage layer, and maintaining proper pH levels for plants.

Table 8-3. Maintenance checklist for green roofs.

Maintenance Checklist for Rainwater Harvesting Systems			
Maintenance Item	Complete?		Comment
	Yes	No	
As Needed			
Water to promote plant growth and survival.			
Observe infiltration rates after rain events.			
Mow and remove grass clippings.			
Inspect green roof for dying or dead vegetation. Remove dead vegetation and plant replacement vegetation as needed.			
Remove trash, debris, and other pollutants from the rooftop.			
Semi-Annually (Quarterly During First Year)			
Inspect outflow and overflow areas for trash, debris, and sediment accumulation. Remove any accumulated sediment and debris.			

Weed and prune vegetation.			
Inspect waterproof membrane for leaks. Repair as needed.			
Inspect vegetation for signs of stress. If found, treat the problem or replace the vegetation.			
Annually			
Test the planting soils for pH levels.			

Table 8-4. Maintenance schedule for green roofs.

Activity	Schedule
• Water to promote plant growth and survival. • Observe infiltration rates after rain events. • Mow and remove grass clippings. • Inspect green roof for dying or dead vegetation. Remove dead vegetation and plant replacement vegetation as needed. • Remove trash, debris, and other pollutants from the rooftop.	As Needed
• Inspect outflow and overflow areas for trash, debris, and sediment accumulation. Remove any accumulated sediment and debris. • Weed and prune vegetation. • Inspect waterproof membrane for leaks. Repair as needed. • Inspect vegetation for signs of stress. If found, treat the problem or replace the vegetation.	Semi-Annually (Quarterly During First Year)
• Test the planting soils for pH levels.	Annually

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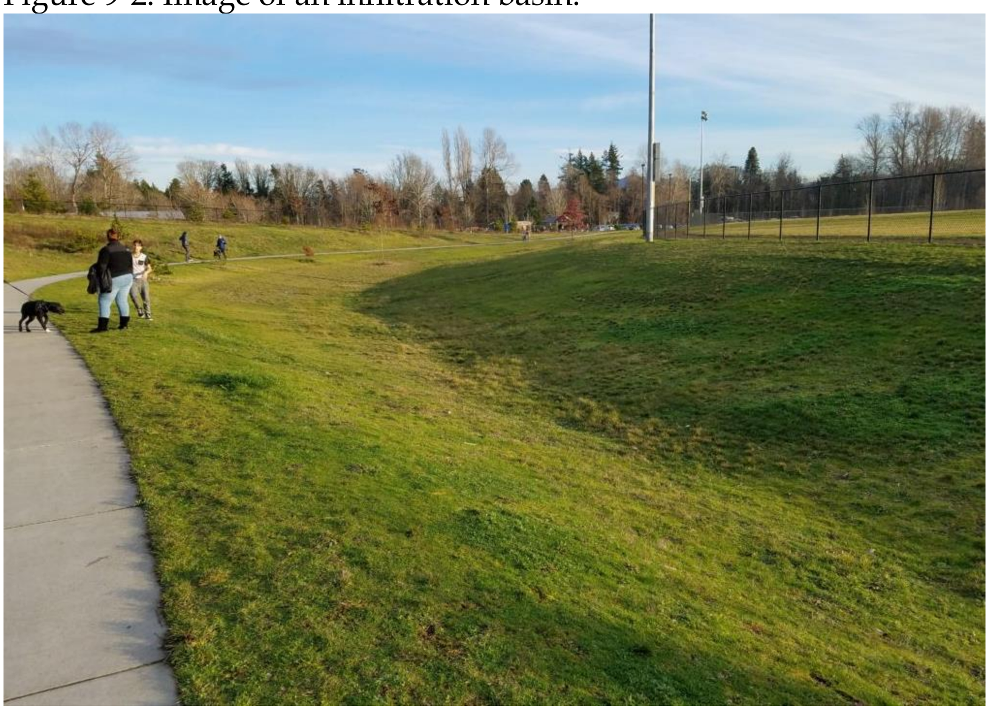
9 Infiltration Practices

9.1 Overview

Infiltration practices are shallow excavations filled with stone or an engineered soil mix. They are designed to intercept and temporarily store stormwater runoff until it infiltrates into the surrounding soils. Infiltration practices provide runoff reduction and improved water quality. Infiltration practices are limited to areas with highly porous soils or where the water table and/or bedrock are located below the bottom of the trench. Infiltration practices must be carefully sited to avoid the potential for groundwater contamination. There are two main types of infiltration practices: infiltration trenches and infiltration basins.

Figure 9-1. Image of an infiltration trench.


Figure 9-2. Image of an infiltration basin.


Pollution Removal Efficiencies:
- Total Suspended Solids (TSS) = 100%
- Total Nitrogen = 100%
- Total Phosphorus = 100%
- Metals (copper, lead, zinc, cadmium) = 100%

Benefits:
- Provides for groundwater recharge
- Good for small sites with porous soils
- Helps restore pre-development hydrology
- Reduces post-construction stormwater runoff rates, volumes, and pollutant loads
- Can be integrated into development plans as attractive landscaping features

Limitations:
- Can only be used to manage runoff from relatively small drainage areas of 5 acres or less
- Potential for groundwater contamination
- High clogging potential

9.2 Design

Infiltration practices are designed to trap sediment. They can also provide runoff reduction and reduce pollutant loads if they are properly designed and maintained. There are two main types of infiltration practices: infiltration trenches and infiltration basins. Infiltration trenches are excavated trenches filled with stone. Stormwater runoff is captured and temporarily stored in the reservoir before it exfiltrates into surrounding soils. They can be used to manage post-construction runoff from contributing drainage areas of up to 2 acres. Infiltration trenches should only be used on sites where sediment loads can be kept relatively low. Infiltration basins are shallow, landscaped excavations filled with an engineered soil mix. They capture and temporarily store runoff in the engineered soil mix where it is then subjected to evaporation and transpiration while infiltrating into surrounding soils. They should only be used on sites where the sediment load can be kept relatively low.

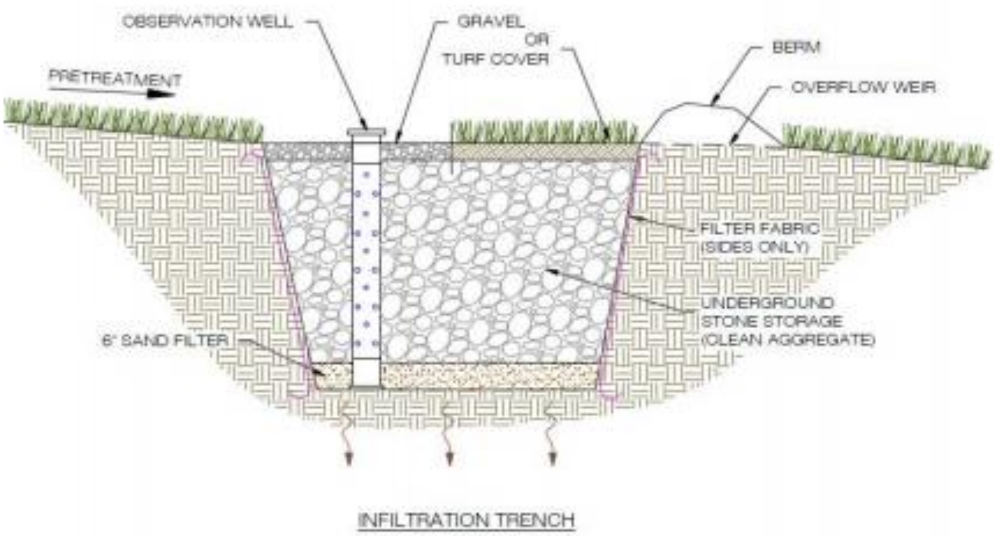
Design Criteria:
- Pretreatment should be provided upstream
- Infiltration practice depths should be between 3-8 feet
- Infiltration trenches should be less than 25 feet wide
- Infiltration practices should not be placed under pavement or concrete
- Infiltration practices should be designed to completely drain within 72 hours of the end of a rainfall event
- Underlying native soils should have an infiltration rate of 0.5 in./hr or more

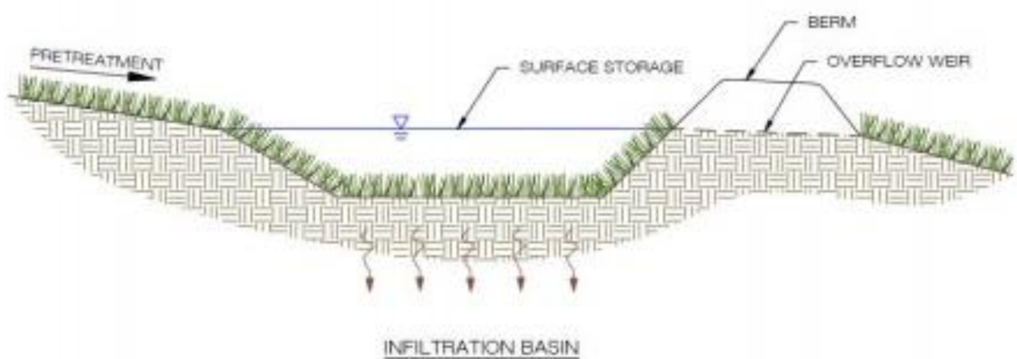
- There should be 2 feet or more from the bottom of the infiltration practice to the top of the water table
- Observation wells are used to monitor percolation and performance of the practice
- Placed on uncompacted soils
- Infiltration trench should be wrapped in nonwoven geotextile

Table 9-1. Infiltration material specifications.

Material	Specification
Surface Layer (optional)	Topsoil and grass layer
Surface Stone	Install a 3 inch layer of river stone or pea gravel
Observation Well	Install a vertical 6 inch schedule 40 PVC perforated pipe with a lockable cap and anchor plate
Overflow Collection Pipe (optional)	Use 4 or 6 inch rigid schedule 40 PVC pipe with 3 or 4 rows of 3/8 inch perforations at 6 inches on center
Trench Bottom	Install a 6 to 8 inch sand layer
Geotextile Fabric	Must have a permeability of at least 10 times higher than the soil subgrade permeability

Figure 9-3. Design view of an infiltration trench and an infiltration basin.





9.3 Pretreatment

Infiltration practices require multiple pretreatment techniques. For an infiltration practice receiving sheet flow, the pretreatment should consist of a vegetated filter strip. For concentrated flow, pretreatment should consist of a sediment forebay, vault, plunge pool, or similar sedimentation chamber.

Infiltration practices can be applied on various scales. They can be considered micro infiltration, small-scale infiltration, and conventional infiltration. They design for each is similar, but the pretreatment varies. Below is a table detailing the differences in pretreatment for each scale infiltration practice.

Table 9-2. Pretreatment elements for infiltration practices.

Pretreatment	Scale of Infiltration		
	Micro Infiltration	Small-scale Infiltration	Conventional Infiltration
Number & Volume of Pretreatment	2 external techniques; no minimum	3 techniques; 15% minimum	3 techniques; 25% minimum pretreatment

Techniques Employed	pretreatment volume required	pretreatment volume required	volume required; at least one separate pretreatment cell
Acceptable Pretreatment Techniques	Leaf gutter screens Grass filter strip Upper sand layer Washed bank run gravel	Grass filter strip Grass channel Plunge pool Gravel diaphragm	Sediment trap cell Sand filter cell Sump pit Grass filter strip Gravel diaphragm

9.4 Construction

Infiltration practices should be constructed correctly with a licensed professional. Construction crews must pay special attention not to compact the soils surrounding the infiltration areas. If possible, infiltration practices should be installed during later phases of site construction to prevent sedimentation or damage to the infiltration areas. Infiltration trenches and infiltration basins have slightly different construction sequences.

Infiltration trench:

- Install and maintain proper erosion and sedimentation control devices during construction.
- Excavate infiltration trench bottom to a uniform, level uncompacted subgrade free from rocks and debris.
- Place nonwoven geotextile along bottom and sides of trench. Nonwoven geotextile rolls should overlap a minimum of 16 inches within the trench.
- Install upstream and downstream control structures, cleanouts, etc.
- Place uniformly graded, clean-washed aggregate in 8 inch lifts, lightly compacting between lifts.
- Install continuously perforated pipe as indicated on plans. Backfill with uniformly graded clean-washed aggregate in 8 inch lifts, lightly compacting between lifts.
- Fold and secure nonwoven geotextile over infiltration trench with a minimum 16 inch overlap.
- Place 6 inch lift of approved topsoil over infiltration trench.
- Seed and stabilize topsoil.

Figure 9-4. Image of an infiltration trench being constructed.

Infiltration Basin:

- Install and maintain proper erosion and sediment control measures during construction.
- Excavate infiltration basin bottom to an uncompacted subgrade free from rocks and debris. Do not compact subgrade.
- Install outlet control structures.
- Seed and stabilize topsoil.

Figure 9-5. Image of an infiltration basin being constructed.

9.5 Inspection and Maintenance

Infiltration practices should be inspected to ensure they are functioning properly. Inspections should be performed after the first major storm event and regularly thereafter.

Table 9-3. As-built inspection form for infiltration practices.

Infiltration Practice					
Maintenance Item	Condition				Comment
	Good	Marginal	Poor	N/A	
General Inspection					
Access to the site is adequately maintained for inspection and maintenance.					
Area is clean (trash, debris, grass clippings, etc. removed)					
Inlet Structure					
Drainage ways (overland flow or pipes) to the practice are free of trash, debris, large branches, etc.					
Area around the inlet structure is mowed and grass clippings are removed.					
No evidence of gullies, rills, or excessive erosion around the inlet structure.					
Water is going through the structure (no evidence of water going around the structure).					
Diversion structure (high flow bypass structure or other) is free of trash, debris, or sediment. Comment on overall condition of diversion structure and list type.					
Pretreatment (Choose One)					
Forebay – area is free of trash, debris, and sediment.					

Forebay – No undesirable vegetation.					
Forebay – No signs of erosion, rills, or gullies.					
Forebay – No signs of standing water.					
Filter Strip – No signs of unhealthy grass, bare, or dying grass. Grass height is maintained to height of 6-15 inches.					
Filter Strip – area is free of trash, debris, and sediment. Area has been mowed and grass clippings are removed. No evidence of erosion.					
Filter Strip – No signs of erosion, rills, or gullies.					
Filter Strip – No signs of standing water.					
Main Treatment					
Main treatment area is free of trash, debris, and sediment.					
Erosion protection is present on site (i.e. turf reinforcement mats).					
No signs of ponding water more than 48 hours after a rain event.					
Structure seems to be working properly. No settling around the structure.					
No undesirable vegetation growing within the practice.					
Native plants were used in the practice according to the landscaping plan.					
Observation well is capped and locked when not in use.					
Flow testing has been performed on infiltration					

practice to determine if underdrain is clogged.					
Emergency Overflow and Outlet Structure					
Area is free of trash, debris, and sediment.					
No evidence of erosion, scour, or flooding around the structure.					
No signs of sediment accumulation.					
Grass height of 6 – 15 inches is maintained.					
Results					
Overall condition of infiltration practice					
Additional Comments					

Maintenance should be performed on infiltration practices regularly to ensure its function. Important things to look for in infiltration practices are sediment build-up, clogging in the inlet and outlet structure, and mosquitoes breeding in the practice.

Table 9-4. Maintenance checklist for infiltration practices.

Maintenance Checklist for Rainwater Harvesting Systems			
Maintenance Item	Complete?		Comment
	Yes	No	
Monthly			
Inspect to ensure the contributing drainage area and infiltration practice are free of sediment, trash, and debris. Remove any accumulated sediment and debris.			
Check observation well to ensure the infiltration practice is properly dewatering after storm events.			

Ensure the contributing drainage area is stabilized. Plant replacement vegetation as needed.			
Semi-Annually During First Year and Annually Thereafter			
Inspect pretreatment devices for sediment accumulation. Remove accumulated sediment, trash, and debris.			
Inspect the practice for damage. Repair or replace any damaged components as needed.			
Inspect top layer of filter fabric and pea gravel or landscaping for sediment accumulation. Remove or replace if clogged.			
Inspect the practice following rainfall events. Check observation well to ensure that complete drawdown has occurred within 72 hours after the end of a rainfall event.			
Upon Failure			
Remove aggregate and install clean, washed trench aggregate.			
Replace piping, filter fabric, etc. as necessary.			

Table 9-5. Maintenance schedule for infiltration practices.

Activity	Schedule
• Inspect to ensure the contributing drainage area and infiltration practice are free of sediment, trash, and debris. Remove any accumulated sediment and debris. • Check observation well to ensure the infiltration practice is properly dewatering after storm events. • Ensure the contributing drainage area is stabilized. Plant replacement vegetation as needed.	Monthly
• Inspect pretreatment devices for sediment accumulation. Remove accumulated sediment, trash, and debris. • Inspect the practice for damage. Repair or replace any damaged components as needed. • Inspect top layer of filter fabric and pea gravel or landscaping for sediment accumulation. Remove or replace if clogged. • Inspect the practice following rainfall events. Check observation well to ensure that complete drawdown has occurred within 72 hours after the end of a rainfall event.	Semi-Annually During First Year and Annually Thereafter
• Remove aggregate and install clean, washed trench aggregate. • Replace piping, filter fabric, etc. as necessary.	Upon Failure

References
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10 Site Reforestation/Revegetation

10.1 Overview

Site reforestation/revegetation refers to the process of planting trees and other native vegetation in disturbed pervious areas to restore them to their pre-development conditions. This process is used to help establish mature native plant communities in pervious areas that have been previously disturbed. Tree canopies can intercept rainfall before it becomes runoff. Additionally, root growth from trees can improve the infiltration capacity of the soils in which they grow. It is preferred to preserve trees initially during the construction process.

Figure 10-1. Image of a reforested/revegetated area.

Benefits:

- Reduces the amount of runoff
- Improves the infiltration capacity of soils
- Applicable to small drainage areas
- Good for highly impervious areas
- Good retrofit capability
- Provides habitat for plant and animal species

Limitations:

- Potentially high maintenance burden
- Not recommended for areas with high sediment content in stormwater or clay/silt runoff areas
- Relatively costly
- Possible odor problems

10.2 Design

Reforested/revegetated areas should have a contiguous area of 10,000 square feet or more. These areas must be protected in perpetuity though a legally enforceable conservation instrument. A soil test should be performed to determine which types of vegetation best suits the area.

Table 10-1. Methods for addressing urban planting constraints.

Potential Impact	Potential Resolution
Limited Soil Volume	• Provide 1,500 cubic feet of rootable soil volume per large tree (mature canopy spread > 40 feet) and 600 cubic feet per small tree (mature canopy spread < 40 feet). This soil must be within 3 feet of the surface. • Use planting arrangements that allow shared rooting space. A minimum of 1,000 cubic feet of rootable soil volume must be provided for each large tree in shared rooting space arrangements.

	• A minimum of 400 cubic feet of rootable soil volume must be provided for each small tree in shared rooting arrangements.
Poor Soil Quality	• Test soil and perform appropriate restoration. • Select species tolerant of soil pH, compaction, drainage, etc. • Replace very poor soils if necessary.
Air Pollution	• Select species tolerant of air pollutants.
Damage from lawnmowers	• Use mulch to protect trees.
Damage from vandalism	• Use tree cages or benches to protect trees. • Select species with inconspicuous bark or thorns. • Install lighting nearby.
Damage from vehicles	• Provide adequate setbacks between vehicle parking stalls and trees.
Damage from animals	• Use protective fencing or chemical retardants.
Exposure to pollutants in stormwater and snowmelt runoff	• Select species that are tolerant of specific pollutants, such as salt and metals.
Soil Moisture Extremes	• Select species that are tolerant of inundation or drought. • Install underdrains if necessary. • Select appropriate backfill soil and mix thoroughly with site soil. • Improve soil drainage with amendments and tillage if needed.
Increased Temperature and Wind	• Select drought tolerant species.
Abundant Populations of Invasive Species	• Control invasive species prior to planting. • Continually monitor for and remove invasive species.

10.3 Pretreatment
Pretreatment is not required for site reforestation/revegetation.

10.4 Construction

Native species should be installed to revert post-construction sites to their original state as much as possible. Install native vegetation of varying sizes and maturity.

10.5 Inspection and Maintenance

Inspections should be performed as part of the maintenance of reforestation/revegetation. The area needs to be watered if enough water is not provided naturally. Ensure the site does not show signs of erosion.

Table 10-2. Inspection form for site reforestation/revegetation.

Site Reforestation/Revegetation					
Maintenance Item	Condition				Comment
	Good	Marginal	Poor	N/A	
General Inspection					
Access to the site is adequately maintained for inspection and maintenance.					
Drainage ways (overland flow or pipes) to the practice are free of trash, debris, large branches, etc.					
No evidence of gullies, rills, or excessive erosion.					
Area is free of trash, debris, and sediment.					
No evidence of long term ponding or standing water.					
Vegetation within and around practice is maintained per landscaping plan. Grass clippings are removed.					
Native plants were used in the practice according to the planting plan.					
No evidence of excessive use of fertilizer on plants.					
Plants seem to be healthy and in good condition.					
Results					

Overall condition of site reforestation/revegetation area					
Additional Comments					

Routine maintenance should be performed during the first year to ensure the vegetation is properly established. After the vegetation is established, simple maintenance is required to keep the vegetation healthy.

Table 10-3. Maintenance schedule for site reforestation/revegetation.

Activity	Schedule
• Water to promote plant establishment, growth, and survival • Plant replacement vegetation in any eroded areas • Remove sediment from practice	As Needed (Following Construction)
• Plant replacement vegetation in any eroded areas • Prune and care for individual trees and shrubs as needed	Annually (Semi-Annually During First Year)

References

Atlanta Regional Commission. 2016. "Georgia Stormwater Management Manual Volume 1". https://atlantaregional.org/natural-resources/water/georgia-stormwater-management-manual/

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Appendix A

Compost Specifications. The basic material specifications for compost amendments are outlined below:

- Compost shall be derived from plant material and provided by a member of the U.S. Composting Seal of Testing Assurance (STA) program. See https://compostingcouncil.org/ for a list of local providers.
- Alternative specifications and/or certifications, such as those administered by the Maryland Department of Agriculture or other agencies, may be substituted, as authorized by DOEE. In all cases, compost material must meet standards for chemical contamination and pathogen limits pertaining to source materials, as well as reasonable limits on phosphorus and nitrogen content to avoid excessive leaching of nutrients.
- The compost shall be the result of the biological degradation and transformation of plant derived materials under conditions that promote aerobic decomposition. The material shall be well composted, free of viable weed seeds, and stable with regard to oxygen consumption and carbon dioxide generation. The compost shall have a moisture content that has no visible free water or dust produced when handling the material. It shall meet the following criteria, as reported by the U.S. Composting Council STA Compost Technical Data Sheet provided by the vendor:
    - 100% of the material must pass through a half-inch screen
    - The pH of the material shall be between 6 and 8
    - Manufactured inert material (plastic, concrete, ceramics, metal, etc.) shall be less than 1.0% by weight
    - The organic matter content shall be between 35%–65%
    - Soluble salt content shall be less than 6.0 mmhos/cm
    - Maturity must be greater than 80%
    - Stability shall be 7 or less (h) Carbon/nitrogen ratio shall be less than 25:1
    - Trace metal test result = "pass"
    - The compost must have a dry bulk density ranging from 40 to 50 lb/ft3