Vermont Green Stormwater Infrastructure (GSI) Simplified Sizing Tool for Small Projects

Fact Sheet No. 1: Introduction

October, 2015

Background and Purpose

The Vermont League of Cities and Towns (VLCT), in partnership with the Vermont Department of Environmental Conservation, Ecosystem Restoration Program (ERP), has updated the Vermont Model Low Impact Development Stormwater Management Bylaw, which was released in 2008. As part of the update, this guidance and attendant suite of tools was created with the goal of making stormwater management more accessible to small and moderately-sized towns seeking to manage stormwater from development and re-development projects that fall below the permitting thresholds for State stormwater permitting, often referred to as "sub-jurisdictional".

This suite of tools can be utilized to size, and aid in the review of, green stormwater infrastructure (GSI) best management practices (BMPs) for small projects – projects creating up to ½-acre of impervious surface. The sizing criteria for BMPs included in this guidance are calibrated to meet the draft Water Quality Treatment Standard, which will require treatment of the "first inch" of runoff from proposed impervious surfaces.

When to Use The GSI Simplified Sizing Tool

The fact sheets and simplified sizing calculator included in this guidance are intended for use when a development or re-development project will create at least 2,500 square feet of new impervious surface. Impervious surfaces can include rooftops, patios, sidewalks, driveways, parking areas, and roadways.

Practices can be sized using the simplified criteria in this tool to treat stormwater from up to 10,000 square feet of impervious surface draining to a single point. Some of the practices included here are only applicable for treating runoff from smaller areas of impervious cover, consistent with the guidance provided in the *Vermont Stormwater Management Manual* and other sources. For example, the "rooftop disconnection" practice, where downspouts are routed to properly graded lawn areas, is limited to a rooftop area of 1,000 square feet per downspout—but multiple downspouts from the same building can be routed to different lawn areas.

Up to half an acre of impervious cover may be treated using three or more BMPs sized using the simplified sizing criteria, as long as no single BMP captures and treats runoff from more than 10,000 square feet of impervious cover. For applications for development with impervious surfaces of over half an acre, but not more than 1 acre, an independent technical review is highly recommended.

Managing Stormwater from Small Developments

In Vermont, development projects that will have less than one acre of impervious surface after construction is complete are often not required to provide the same types of stormwater management, or undergo the same level of permitting or detailed review, as larger projects. However, the cumulative effect of these smaller projects on local rivers and streams can be significant. Certain requirements should be met to ensure that runoff does not overwhelm downstream stormwater infrastructure, impact local water quality, or impact adjacent properties. Key principles for managing stormwater from small projects include:

- Proper grading techniques and erosion control during construction;
- Use of green stormwater infrastructure to manage runoff close to where it is generated wherever possible (see below);
- Reliance on infiltration only where site conditions are appropriate (meaning that the water table or bedrock layer is at least 2-3 feet below the bottom of the practice); and
- Proper installation and maintenance of downspouts, channels, curb cuts, and any other sources of concentrated flow.

WHAT IS GREEN STORMWATER INFRASTRUCTURE?

Vermont DEC defines Green Stormwater Infrastructure (GSI) as "systems and practices that restore and maintain natural hydrologic processes in order to reduce the volume and water quality impacts of the built environment while providing multiple societal benefits."

Traditionally, stormwater runoff has been collected and conveyed in closed systems to off-site locations as quickly as possible where it is then discharged, without treatment on surface waters. The series of pipes, catch basins, and storm drains that result is known as 'gray infrastructure.' Because 'gray infrastructure' does little to improve water quality and reduce water quantity, stormwater discharges from these systems often contribute to unhealthy stream flow regimes marked by chronic flash flooding, altered stream morphologies, elevated nutrient and contaminant levels, excessive sedimentation, loss of species diversity, and higher water temperatures.

Green stormwater infrastructure is a complimentary and sometimes alternative system to 'gray infrastructure' that emphasizes infiltration, evapotranspiration, and storage and reuse. GSI is decentralized by design and either prevents runoff from occurring or treats it as close to the source as possible.

GSI provides multiple benefits and functions such as reduced and delayed stormwater flows, enhanced groundwater recharge, stormwater pollutant reductions, reduced sewer overflows, urban heat island mitigation, improved air quality, additional wildlife habitat and recreational space, improved human health, and increased land values. GSI can be used at many spatial scales, from an individual site to an entire watershed. Examples of GSI practices that can be applied to small development or redevelopment projects include any appropriate combination of the following:

- installing a rain garden or bioretention area,
- replacing traditionally impervious surfaces (driveways, patios, etc.) with permeable pavers,
- routing downspouts to lawn areas instead of driveways,
- routing downspouts to infiltration trenches,
- using cisterns for reuse or irrigation, and
- directing sheet flow to adequately sized vegetated filter strips.

The GSI practices included in this guidance are sized for a performance goal of capturing and evapotranspiring, infiltrating, or re-using the volume of runoff generated by the first one inch of rain that falls on impervious surfaces. Other GSI practices may be used instead of these techniques, with proper documentation of design criteria and details.

Applicants can meet this requirement by using the practices in this technical guidance document or by utilizing the *Vermont Stormwater Management Manual* to design an appropriate stormwater management plan.

What needs to be submitted?

As part of a zoning or building permit application, applicants should develop a site plan following the guidelines appropriate for the town. Normal site plan items relevant to stormwater management include:

- Existing and proposed ground contours and elevations;
- Locations of existing sanitary and storm sewers (if any), on-site wells and septic systems (if any), structures, and easements;
- Location, configuration, and finished floor elevations for existing and proposed structures;
- Location, configuration, and finished elevations for existing and proposed paved areas;
- Erosion and sediment control practices as included in The Low Risk Site Handbook for Erosion Prevention and Sediment Control or other appropriate guidance; and

For stormwater management, the following guidance applies to all designs:

- Stormwater runoff from the first one inch of rainfall on any impervious surface must be captured on site and dissipated through the use of infiltration, evapotranspiration, or alternate use (such as irrigation). It cannot run off the site.
- Details of all Green Stormwater Infrastructure practices should be attached to the site plan. Wherever possible, use the specification sheets from this guidance document, or sets of plans of equal detail and coverage.

What is in the rest of this guidance?

The remainder of this document contains:

1. A set of ten fact sheets with specifications, one for each of the Green Stormwater Infrastructure practices. The last two pages of each fact sheet include specifications and standard schematic drawings that can be filled in by the applicant and stapled to construction plans.
2. An Appendix that describes how to conduct infiltration testing.

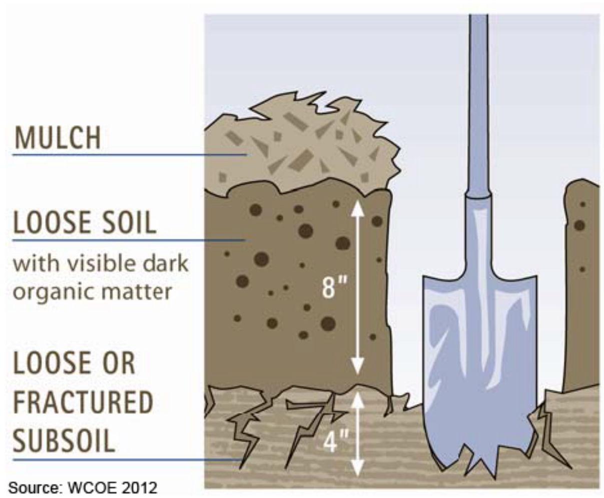
VERMONT GREEN STORMWATER INFRASTRUCTURE (GSI) SIMPLIFIED SIZING TOOL FOR SMALL PROJECTS

Fact Sheet No. 2: Post-Construction Soil Depth and Quality

October, 2015

Naturally occurring (undisturbed) soil and vegetation provide important stormwater functions including: water infiltration; nutrient, sediment, and pollutant adsorption; sediment and pollutant biofiltration; water interflow storage and transmission; and pollutant decomposition. These functions are largely lost when development strips away native soil and vegetation and replaces it with minimal topsoil and sod. Not only are these important stormwater management functions diminished, but such landscapes may themselves become pollution generating pervious surfaces due to increased use of pesticides, fertilizers and other landscaping and household/industrial chemicals, the concentration of pet wastes, and pollutants that accompany roadside litter.

Establishing a standard for soil quality and depth regains greater stormwater functions in the post-development landscape, provides increased treatment of pollutants and sediments that result from development and habitation, and minimizes the need for some landscaping chemicals, thus reducing pollution through prevention.



Verifying post-construction soil depth and quality using a test hole. Test holes should be about one foot deep (after first scraping away any mulch) and about one foot square. Mulch should only be applied to planting beds.

LOCATION

The soil depth and quality requirements apply to all disturbed areas that are not covered by an impervious surface, incorporated into a stormwater treatment practice, or engineered as structural fill or slope once development is complete.

Undisturbed areas where the duff layer and native topsoil are retained meet the intent of this standard and should not be disturbed just for the purpose of soil amendment.

DESIGN AND SIZING

The duff layer and native topsoil should be retained in an undisturbed state wherever possible. In any areas requiring grading, the duff layer and topsoil should be removed and stockpiled on site in a designated, controlled area, and re-applied to other portions of the site.

All areas subject to clearing and grading that are not covered by impervious surface, incorporated into a stormwater practice, or engineered as structural fill or slope shall meet the following standards when the project is complete:

- A topsoil layer with a minimum organic matter content of 10% dry weight in planting beds, and 5% organic matter content in turf areas, and a pH from 6.0 to 8.0 or matching the pH of the undisturbed soil. The topsoil layer shall have a minimum depth of eight inches except where tree roots limit the depth of incorporation of amendments needed to meet the criteria. Subsoils below the topsoil layer shall be scarified at least 4 inches with some incorporation of the upper material to avoid stratified layers, where feasible (see figure above).
- Mulch planting beds only with 2 inches of organic material.
- Compost and other materials shall be used that meet these organic content requirements:
  - The organic content for “pre-approved” amendment rates can be met only using compost that meets the definition of “compost” in the Vermont Solid Waste Management Rules §6-1102. This rule is available online at: http://www.anr.state.vt.us/dec/wastediv/solid/documents/SWRule.final.pdf.
  - The compost must also have an organic matter content of 40% to 65%, and a carbon to nitrogen ratio below 25:1.
- The resulting soil should be appropriate for the type of vegetation to be established.

The soil quality requirements listed above can be met by using one of the following methods:

- Option 1: Leave undisturbed native vegetation and soil, and protect from compaction during construction.
- Option 2: Amend existing site topsoil or subsoil at default “pre-approved” rates.
- Option 3: Stockpile existing topsoil during grading, and replace it prior to planting. Stockpiled topsoil must also be amended if needed to meet the organic matter or depth requirements, at a default “pre-approved” rate.
- Option 4: Import topsoil mix of sufficient organic content and depth to meet the requirements.

More than one method may be used on different portions of the same site. Soil that already meets the depth and organic matter quality standards, and is not compacted, does not need to be amended.

VEGETATION AND LANDSCAPING

The site plan and soil management plan should include:

- A scale drawing identifying areas where undisturbed native soil and vegetation will be retained, and which soil treatments will applied in disturbed areas.
- A completed worksheet identifying treatments and products to be used to meet the soil depth and organic content requirements for each site area.
- Computations of compost or topsoil volumes to be imported (and/or site soil to be stockpiled) to meet “pre-approved” amendment rates.
- Copies of laboratory analyses for compost and topsoil products to be used, documenting organic matter contents and carbon to nitrogen ratios.

Once activities to establish post-construction depth and quality are complete and verified, establish a dense and vigorous vegetative cover over turf areas. Cover planting beds with 2 inches of organic mulch.

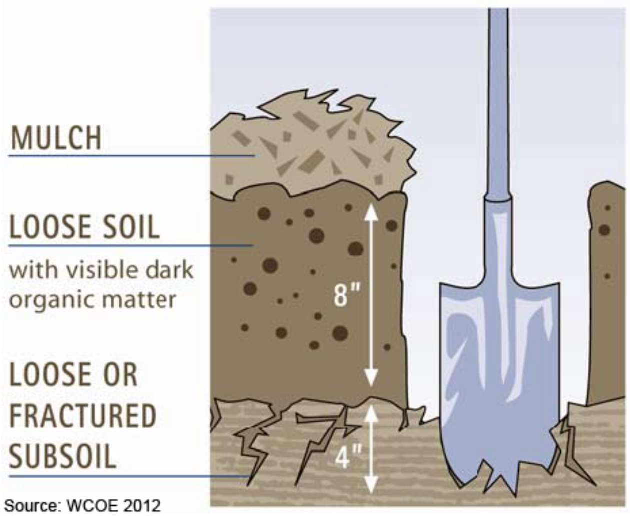
MAINTENANCE

Establish soil quality and depth toward the end of construction and once established, protect from compaction, such as from large machinery use, and from erosion.

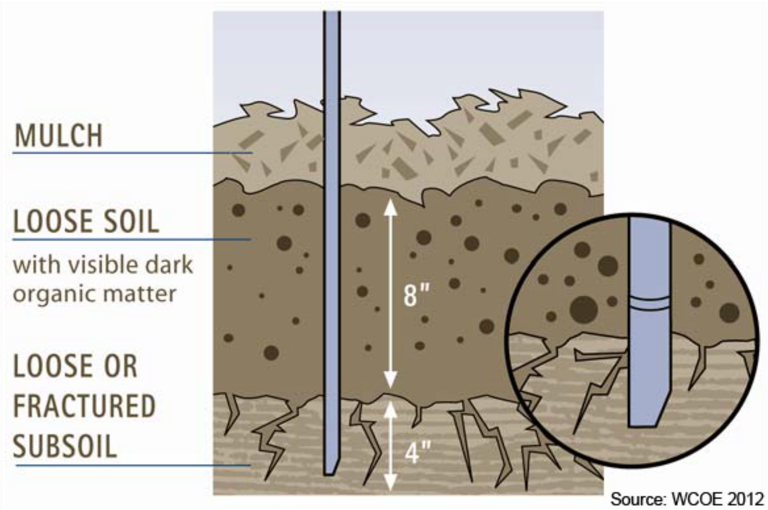
Plant vegetation and mulch the amended soil area after installation.

After construction, check following rainfall events to ensure that erosion is not occurring, and fix any areas of erosion immediately.

Grass clippings may be left on the soil surface to replenish organic matter. The use of irrigation, fertilizers, herbicides, and pesticides should be adjusted to the minimum necessary needed to ensure robust vegetated cover.



Verifying post-construction soil depth and quality using a test hole. Test holes should be about one foot deep (after first scraping away any mulch) and about one foot square. Mulch should be applied only to planting beds, not lawn areas.



Verifying post-construction soil depth and quality using a rod penetrometer.

TYPICAL COMPONENTS AND INSPECTION PROCEDURES

CONSTRUCTION STEPS:

1. Establish soil quality and depth toward the end of construction. Once established, protect from compaction, such as from large machinery use, and from erosion. Erosion and sediment control practices should be established as included in *The Low Risk Site Handbook for Erosion Prevention and Sediment Control* or other appropriate guidance.
2. Implement soil preparation options that best suit each area of the site, as identified on the site-specific soil management plan. Construction steps for each option are outlined on Page 2 of this specification.
3. Complete a post-construction inspection, preferably prior to planting, so that omissions can easily be corrected:
4. Verify that compost, mulch, topsoil and amendment delivery tickets match volumes, types and sources approved in the site specific plan. If materials other than those approved in the plan were delivered, submissions by the supplier should verify that they are equivalent to approved products.
5. Check soil for compaction, scarification and amendment incorporation by digging at least one 12 inch deep test hole (schematic on left, above). Test holes must be excavated using only a garden spade driven by the inspector's weight.
6. Test up to 5 locations for compaction, using a simple "rod penetrometer" (a 4 foot long 3/8th inch diameter stainless steel rod, with a 30 degree bevel cut into the side at that goes in 1/8 inch at the tip). Rod must penetrate to 12" depth driven solely by inspector's weight (see schematic on right, above).
7. Verify placement of two inches of organic mulch material on planting beds.
8. If inspection indicates that an installation does not fulfill the soil depth and quality standard, correct any deficiencies before vegetation is planted or other landscaping is completed.
9. Plant vegetation and mulch the amended soil areas after installation is complete and inspection verifies the standard is met.

Construction Sequence Options for Meeting the Post Construction Soil Depth and Quality Standard

<table>
<tr><th>Option</th><th colspan="2">Construction Sequence</th></tr>
<tr><td colspan="3">OPTION 1: Leave native vegetation and soil undisturbed, and protect from compaction during construction.</td></tr>
<tr><td></td><td colspan="2">Identify areas of the site that will not be stripped, logged, graded or driven on, and fence off those areas to prevent impacts during construction. If neither soils nor vegetation are disturbed, these areas do not require amendment.</td></tr>
<tr><td colspan="3">OPTION 2: Amend existing site topsoil or subsoil at default “pre-approved” rates.</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Scarification. Scarify or till subgrade to 8 inches depth (or to depth needed to achieve a total depth of 12 inches of uncompacted soil after calculated amount of amendment is added). Entire surface should be disturbed by scarification. Do not scarify within drip line of existing trees to be retained. Amend soil to meet required organic content.</td></tr>
<tr><td>A. Planting Beds
PRE-APPROVED RATE: Place 3 inches of composted material and rototill into 5 inches of soil (a total amended depth of about 9.5 inches, for a settled depth of 8 inches).
Rake beds to smooth and remove surface rocks larger than 2 inches diameter.
Mulch planting beds with 2 inches of organic mulch.</td><td>B. Turf Areas
PRE-APPROVED RATE: Place 1.75 inches of composted material and rototill into 6.25 inches of soil (a total amended depth of about 9.5 inches, for a settled depth of 8 inches).
Water or roll to compact to 85% of maximum dry density.
Rake to level, and remove surface woody debris and rocks larger than 1 inch diameter.</td></tr>
<tr><td colspan="3">OPTION 3: Stockpile existing topsoil during grading. Replace it before planting.
Stockpiled topsoil must also be amended at a pre-approved default rate if needed to meet the organic matter or depth requirements.</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Scarification. If placed topsoil plus compost or other organic material will amount to less than 12 inches: Scarify or till subgrade to depth needed to achieve 12 inches of loosened soil after topsoil and amendment are placed. Entire surface should be disturbed by scarification. Do not scarify within drip line of existing trees to be retained.
Stockpile and cover soil with weed barrier material that sheds moisture yet allows air transmission, in approved location, prior to grading.
Replace stockpiled topsoil prior to planting. Amend if needed to meet required organic content.</td></tr>
<tr><td>A. Planting Beds
PRE-APPROVED RATE: Place 3 inches of composted material and rototill into 5 inches of replaced soil (a total amended depth of about 9.5 inches, for a settled depth of 8 inches).
Rake beds to smooth and remove surface rocks larger than 2 inches diameter.
Mulch planting beds with 2 inches of organic mulch or stockpiled duff.</td><td>B. Turf Areas
PRE-APPROVED RATE: Place 1.75 inches of composted material and rototill into 6.25 inches of replaced soil (a total amended depth of about 9.5 inches, for a settled depth of 8 inches).
Water or roll to compact soil to 85% of maximum dry density.
Rake to level, and remove surface rocks larger than 1 inch diameter.</td></tr>
<tr><td colspan="3">OPTION 4: Import topsoil mix of sufficient organic content and depth to meet the requirements.</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Scarification. Scarify or till subgrade in two directions to 6 inches depth.
Entire surface should be disturbed by scarification. Do not scarify within drip line of existing trees to be retained.</td></tr>
<tr><td>A. Planting Beds
Use imported topsoil mix containing 10% organic matter (typically around 40% compost). Soil portion must be sand or sandy loam as defined by the USDA.
Place 3 inches of imported topsoil mix on surface and till into 2 inches of soil.
Place 3 inches of imported topsoil mix on surface and till into 2 inches of soil.
Place second lift of 3 inches topsoil mix on surface.
Rake beds to smooth, and remove surface rocks over 2 inches diameter.
Mulch planting beds with 2 inches of organic mulch.</td><td>B. Turf Areas
Use imported topsoil mix containing 5% organic matter (typically around 25% compost). Soil portion must be sand or sandy loam as defined by the USDA.
Place 3 inches of imported topsoil mix on surface and till into 2 inches of soil.
Place second lift of 3 inches topsoil mix on surface.
Water or roll to compact soil to 85% of maximum dry density.
Rake to level, and remove surface rocks larger than 1 inch diameter.</td></tr>
</table>

Model SOIL MANAGEMENT PLAN for POST-CONSTRUCTION SOIL DEPTH AND QUALITY

(Available as MS Word file at vlct.org)

PROJECT INFORMATION **Page # ____ of ____ pages**

Complete all information on page 1; only site address and permit number on additional pages.

Site Address / Lot No.:	
Permit Type:	**Permit Number:**
Applicant Name:	**Phone:**
Mailing Address:	
Contact Person:	**Phone:**
Plan Prepared By:	

ATTACHMENTS REQUIRED (*Check off required items that are attached to this plan*)

___ **Site Plan showing, to scale:**	___ Areas of undisturbed native vegetation (no amendment required) ___ New planting beds and turf areas (amendment required) ___ Type of soil improvement proposed for each area
___ **Product test results for proposed amendments**	

AREA #________ (*should match Area # on Site Plan*)

PLANTING TYPE ___ Turf ___ Undisturbed native vegetation ___ Planting Beds ___ Other: ________________________________		
SQUARE FOOTAGE OF THIS AREA: _______ square feet		
SCARIFICATION ___ Subsoil will be scarified	______ inches (depth) of scarification needed to achieve finished total 12" loosened depth.	
PRE-APPROVED AMENDMENT METHOD: ___ Topsoil import ___ Amend with compost ___ Stockpile and amend (____ cu. yds. stockpiled)	____inches of compost or imported topsoil applied X 3.1 (*conversion factor, inches to cubic yards*) _____= cu. yards per 1,000 sq. ft. X ___ ,000 sq.ft. in this area ____ = cubic yards of amendment → → → → → (*needed to cover this area to designated depth*)	PRODUCT:________________________ ________________________________ QUANTITY: ________CU. YDS.
MULCH	______ ,000 sq.ft. X 6.2 (*conversion, to give 2 inch mulch depth*) ____ = cubic yards of mulch → → → → → →	PRODUCT:________________________ QUANTITY: ________CU. YDS.

TOTAL AMENDMENT/TOPSOIL/MULCH FOR ALL AREAS (*complete on page 1 only, totaling all areas/pages in this Plan*)

- ❑ **Product #1:**____ ❑ **Quantity: _________cu. yds.**
- ❑ **Test Results: ___ % organic matter ____C:N ratio <25:1** (except mulch, or <35:1 for native plants) ____ **"stable"** (yes/no)
- ❑ **Product #2:**____ ❑ **Quantity: _________cu. yds.**
- ❑ **Test Results: ___ % organic matter ____C:N ratio <25:1** (except mulch, or <35:1 for native plants) ____ **"stable"** (yes/no)
- ❑ **Product #3:**____ ❑ **Quantity: _________cu. yds.**
- ❑ **Test Results: ___ % organic matter ____C:N ratio <25:1** (except mulch, or <35:1 for native plants) ____ **"stable"** (yes/no)

Date:	**Inspector:**	**Approved:**	**Revisions Required:**
Date:	**Inspector:**	**Approved:**	**Revisions Required:**

COMMENTS:

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Vermont Green Stormwater Infrastructure (GSI) Simplified Sizing Tool for Small Projects

Fact Sheet No. 3: Retention or Planting of Trees

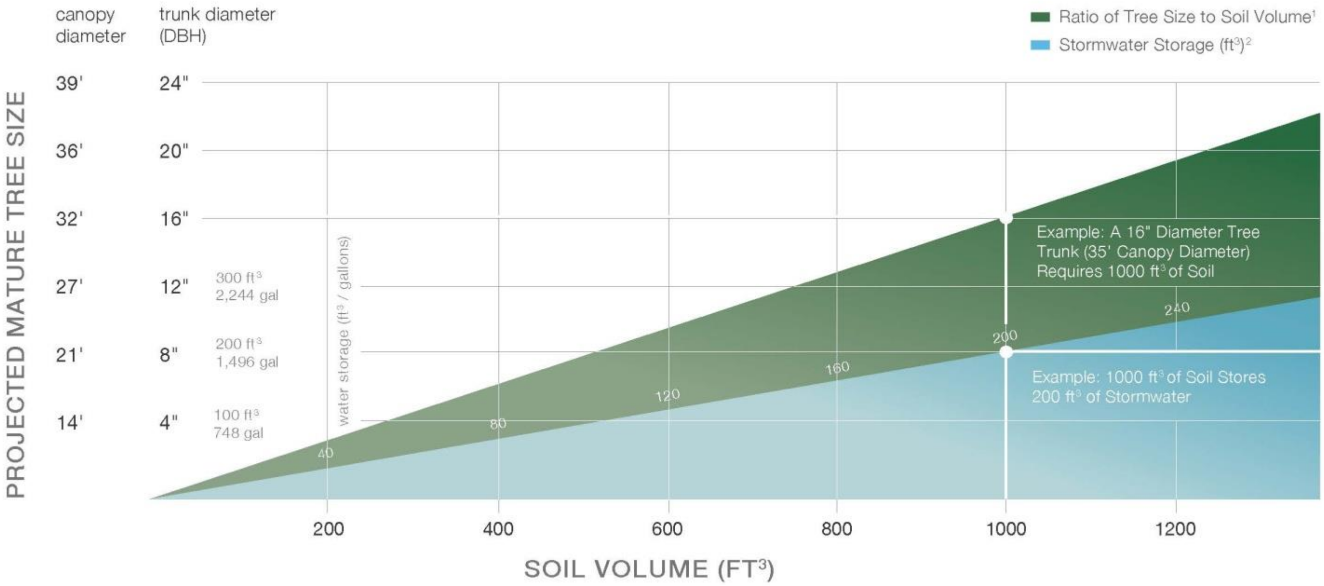
October, 2015

Trees contribute to the management stormwater runoff in several ways:

- Capturing and holding precipitation in the foliage (interception);
- Conveying water in the soil through the tree to the atmosphere (transpiration); and
- Building soil structure through root growth, increasing absorption of water in the root zone (infiltration).
- Trees also take up nutrients and trace amounts of chemicals, including metals, organic compounds, fuels, and solvents from the soil along with water (pollutant removal).

Trees also provide many benefits beyond stormwater mitigation, including improved air quality, carbon sequestration, reduced heat island effect, pollutant removal, and habitat preservation or formation.

When implemented in accordance with the criteria in this section, retained and newly planted trees can receive credit toward meeting the performance goal of the LID/GSI Model Bylaw. The degree of stormwater management provided by a tree depends on the tree type (evergreen or deciduous), its canopy area, and whether or not the tree canopy overhangs impervious surfaces. Big trees with large, dense canopies manage the most stormwater – and designing tree plantings to accommodate the largest size tree possible will increase their stormwater utility function (see figure below).



Comparison of uncompacted soil volume to projected mature tree size (trunk and canopy diameter), with estimates of stormwater storage per tree. Source: Deep Root Partners 2011.

Location

The tree(s) must be on the development site and within 20 feet of new and/or replaced ground level impervious surfaces (e.g., driveway, patio, or parking lot). Distance from the impervious surfaces should be measured from the edge of the surface to the center of the tree at ground level.

Use caution when considering tree retention or planting in combination with the use of permeable pavers. Fallen leaves and other material from trees can contribute to the premature clogging and failure of the pavers' infiltration capacity.

The soils in the area where trees are to be retained or planted must meet the Post-Construction Soil Depth and Quality requirements.

Ideally, a minimum of 1,000 cubic feet of rootable soil volume should be provided per tree, whether retained or newly planted. In planting arrangements that allow for shared rooting space amongst multiple trees, a minimum of 750 cubic feet of rootable soil volume should be provided for each tree. (Rootable soil volume means that the soil must be within 3 feet of the ground surface).

Trees planted in bioretention areas or bioswales within or next to parking lots are eligible for the credit.

The total tree credit for retained and newly planted trees cannot exceed 25 percent of the impervious area that requires stormwater management.

Design and Sizing

In order for the tree credits to be applicable, the following requirements must be met for both retained and newly planted trees.

- Trees must be retained, maintained, and protected on the site after construction and for the life of the development, or until any approved redevelopment occurs in the future.

- Trees that are removed or die must be replaced with like species during the next planting season (typically in fall). If any pruning is required, the trees should be pruned according to industry standards.
- The total tree credit for retained and newly planted trees cannot exceed 25 percent of the impervious surface area requiring stormwater management.

Requirements for retained trees include the following:

- Trees must be viable for long-term retention on the site (in good health and compatible with proposed construction activities).
- Retained trees must have a minimum 6 inches diameter at breast height (DBH). DBH is defined as the outside bark diameter at 4.5 feet above the ground on the uphill side of a tree. For existing trees smaller than this size that are retained, the newly planted tree credit may be applied instead.
- The retained tree canopy area is measured at the time of permit application, as the area within the tree drip line. The drip line is the line encircling the base of a tree that is delineated by a vertical line extending from the outer limit of a tree's branch tips down to the ground. If the trees are clustered, overlapping canopies cannot be double counted.
- The existing tree roots, trunk, and canopy must be fenced off and carefully protected during construction activities to avoid damage to the tree and compaction of the soils.

Protecting trees to be retained from damage and disturbance during construction activities is critically important for the trees' long-term health and performance.

For each retained tree that meets the criteria above, an applicant can subtract a portion of the retained tree's canopy area from the total ground-level impervious surface that needs stormwater management, as shown in the design table below.

BMP	**Tree Type**	**Impervious Area Reduction Credit**
Retained Tree	Evergreen	20% canopy area (min. 100 ft² / tree)
	Deciduous	10% canopy area (min. 50 ft² / tree)
Newly Planted Tree	Evergreen	50 ft² / tree
	Deciduous	20 ft² / tree

Requirements for newly planted trees include:

New deciduous trees must be at least 1.5 inches in diameter, measured 6 inches above the ground. New evergreen trees must be at least 4 feet tall.

- Tree species selection should be appropriate to the site, the soils, and the surrounding environmental conditions. Use of the Vermont Urban and Community Forestry Program's Community Forestry Library tree planting references (http://www.vtcommunityforestry.org/resources/tree-care/tree-planting) and the accompanying Tree Selection Tool (http://www.vtcommunityforestry.org/resources/tree-selection) are both highly recommended.
- Mature tree height, size, and rooting depth must be considered to ensure that the tree location is appropriate given adjacent and above- and below-ground infrastructure.
- New trees shall be planted following appropriate procedures (see Construction/Installation).
- Planting must only be performed when weather and soil conditions are suitable for planting.
- To help ensure tree survival and canopy coverage, the minimum tree spacing for newly planted trees must accommodate mature tree spread (see Tree Selection Tool at the link above). Credit for newly planted trees will not be given for new tree densities that exceed 10 feet on center spacing.
- Provisions must be made for supplemental irrigation during the first three growing seasons after installation to help ensure tree survival.

For each newly planted tree that meets the criteria, an applicant can subtract a defined amount of surface area from the total ground-level impervious surface that needs stormwater management, as shown in the design table above.

VEGETATION AND LANDSCAPING

For newly planted trees, 2 to 4 inches of organic mulch must be spread over the soil surface out to the drip line of the tree. Slow-decomposing organic mulches, such as shredded bark, compost, leaf mulch, or wood chips, are recommended. Mulch should never be applied right next to the tree trunk; a mulch-free area, 2- to 3-inches wide at the base of the tree, must be provided to avoid moist bark conditions and prevent decay.

If staking is necessary for support, two stakes used in conjunction with a wide flexible tie material will hold the tree upright, provide flexibility, and minimize injury. Stakes should be placed in undisturbed soil beyond the outer edges of the root ball. Staking material must be removed within 1 year of planting.

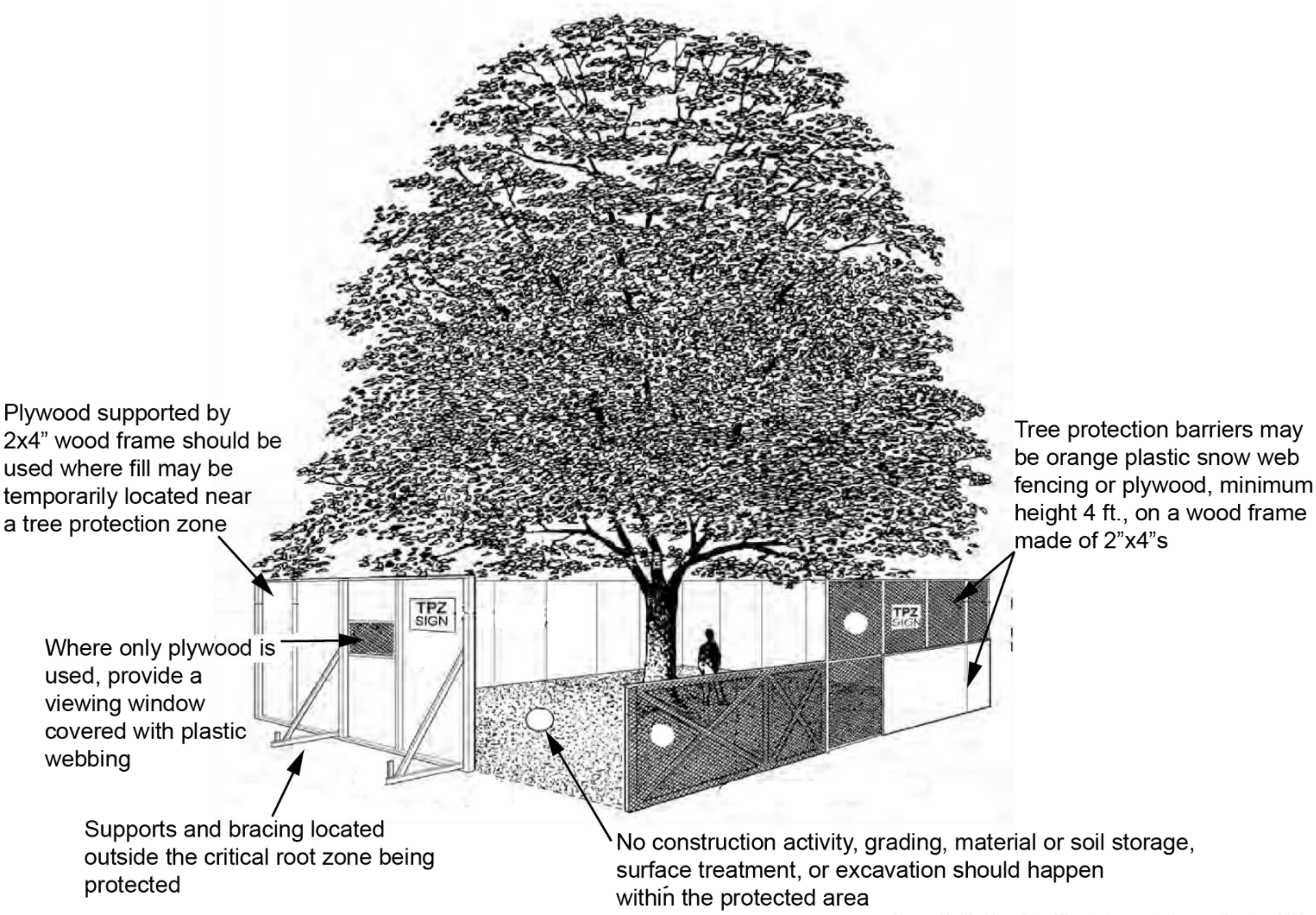
MAINTENANCE

Trees must be retained, maintained and protected on the site after construction and for the life of the development, or until any approved redevelopment occurs in the future. Trees that are removed or die must be replaced with like species during the next planting season (typically in fall).

Newly planted trees must be watered regularly (at least once a week) during the first growing season. Water less frequently (about once a month) during the next two growing seasons, and after that, watering is only needed during drought.

Newly planted trees should get 1 inch of rainfall per week during the growing season—this means at least 25 gallons of water a week. Water deeply and slowly near the roots. Soaker hoses and drip irrigation work best for deep watering; if these are not feasible, slow leak watering bags or tree buckets can be installed to make watering easier while remaining quite effective. Watering should continue until mid-fall (end of September), tapering off as temperatures get cooler.

Pruning is usually not needed for newly planted trees. If necessary, prune only dead, diseased, broken or crossing branches at planting. As the tree grows, lower branches may be pruned to provide clearance or to remove dead or damaged limbs.



Source: Modified from City of Toronto tree protection specifications, 2008

TYPICAL COMPONENTS

CONSTRUCTION STEPS - RETAINED TREES:

1. Review existing tree locations with respect to overall site layout. Tree trunks must be 20 feet or less from existing or proposed ground-level impervious surfaces. Note overhead and buried utilities and avoid conflicts.
2. Measure the area within the tree trip line for any retained trees, and determine the appropriate credit. The drip line is the line encircling the base of a tree that is delineated by a vertical line extending from the outer limit of a tree's branch tips down to the ground. Overlapping canopies cannot be double counted.
3. Lay out the area to be protected and install protective fence (4' tall orange construction fence) before any site disturbance or construction activity begins. This area should include the entire area below the tree's drip line.
   - If construction disturbance includes areas within the drip line, at minimum, the critical root zone of the retained tree must be protected (a distance of 1 foot of tree protection for every inch in tree diameter—so a tree with a 12-inch DBH or caliper at breast height requires 12 feet of protection on every side as measured from the base of the tree.
   - No equipment, trailers, or material can be placed within 20 feet or within the drip lines of any tree to be saved, whichever is greater.
4. Perform construction operations with the goal of preventing trunk, crown, and root damage to existing trees.
5. Remove protective fencing once construction is complete and any temporary erosion control measures (such as straw or matting) have been installed in surrounding areas.

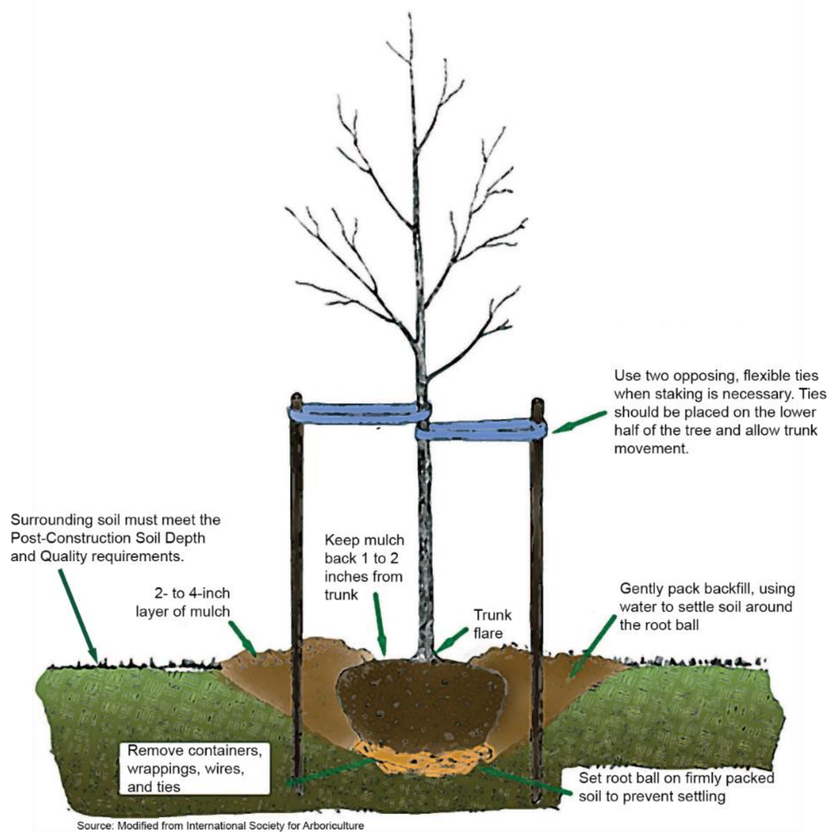
Construction Steps - Newly Planted Trees:

1. Review proposed tree locations with respect to overall site layout. Tree trunks must be 20 feet or less from existing or proposed ground-level impervious surfaces. Note overhead and buried utilities and avoid conflicts.
2. Determine the appropriate credit based on the number of proposed new trees that are eligible for the credit and the type of tree proposed (evergreen or deciduous).
3. If possible, protect the area where trees are to be planted from compaction during construction activities by laying out the area to be protected and installing protective fence (4' tall orange construction fence) before any site disturbance or construction activity begins.
4. Any soil restoration activity (rototilling, topsoil replacement or amendment, etc.) needed within the tree planting area to meet the Post-Construction Soil Depth and Quality requirements must be completed before trees are planted. Topsoil and/or compost amendments should be incorporated evenly across the, stabilized with seed, and protected by biodegradable erosion control matting or blankets.
5. New trees must be planted following appropriate procedures, and only when weather and soil conditions are suitable for planting. See the International Society of Arboriculture's Planting New Trees for more on the following steps:

    1. Identify the trunk flare.
    2. Dig a shallow, broad planting hole.
    3. Remove the containers or cut away the wire basket.
    4. Place the tree at the proper height.
    5. Straighten the tree in the hole.
    6. Fill the hole gently, but firmly.
    7. Stake the tree only if necessary.
    8. Mulch the base of the tree (2- to 4-inches, out to the drip line, not within 2-3 inches of the tree trunk).
    9. Provide follow-up care, especially watering through the end of the growing season.

    Additional planting details for trees and shrubs under a variety of site conditions are available from the International Society of Arboriculture at http://www.isa-arbor.com/education/onlineResources/cadplanningspecifications.aspx#Planting

6. Remove protective fencing once construction is complete and any temporary erosion control measures (such as straw or matting) have been installed in surrounding areas.



Typical Components

Sketch Layout

Provide plan view showing ground level impervious cover, locations and canopy areas of trees to be retained for credit, protection zones for retained trees, and the locations of trees to be planted for credit.

Credit Calculation:

BMP	Tree Type	Impervious Area Reduction Credit
Retained Tree	Evergreen	20% canopy area (min. 100 ft² / tree)
	Deciduous	10% canopy area (min. 50 ft² / tree)
Newly Planted Tree	Evergreen	50 ft² / tree
	Deciduous	20 ft² / tree

Total Ground Level Impervious Cover: ____________sq. ft.

Retained Trees:

Total evergreen canopy area: ___________square feet

Evergreen canopy area × 0.2 = ___________ sq. ft. credit (min. 100)

Total deciduous canopy area: ___________square feet

Deciduous canopy area × 0.1 = ___________ sq. ft. credit (min. 50)

Newly Planted Trees:

Total new evergreen trees meeting requirements: __________

# of new evergreen trees × 50 = ___________ sq. ft. credit (min. 50)

Total new deciduous trees meeting requirements: ___________

# of new deciduous trees × 20 = ___________ sq. ft. credit (min. 20)

Total Credit: ___________sq. ft (max 25% of proposed impervious cover)

Maintenance:

1. Trees must be retained, maintained, and protected for the life of the development.
2. Trees that are removed or die must be replaced with like species during the next planting season.
3. Water newly planted trees regularly (at least once a week) during the first growing season. Target watering depth is 1 inch of rainfall per week during the growing season—this means at least 25 gallons of water a week. Water deeply and slowly near the roots through the end of the growing season.
4. Remove stakes no more than 1 year after planting.
5. Water less frequently (about once a month) during the next two growing seasons.
6. Prune only dead, diseased, broken or crossing branches at planting. As trees grow, lower branches may be pruned to provide clearance or to remove dead or damaged limbs.

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VERMONT GREEN STORMWATER INFRASTRUCTURE (GSI) SIMPLIFIED SIZING TOOL FOR SMALL PROJECTS

Fact Sheet No. 4: Cisterns and Rain Barrels

October, 2015

Cisterns are green stormwater infrastructure practices that store rainwater for later use, rather than primarily for infiltration or release into a waterway. Rain is collected from a rooftop downspout system, screened to remove trash and leaves, and conveyed to a storage container for subsequent use. Water stored in cisterns is only for non-potable water use, unless an additional filtration system is used. Properly sized cisterns can provide significant reductions in stormwater runoff rates, volumes, and pollutant loads from small sites. Rain barrels may also be used, but unless the rooftop area is very small, rain barrels by themselves do not store enough runoff to meet the standards in the LID/GSI Bylaw.

Cistern storing water on a residential property.

LOCATION

The size of the rooftop's contributing drainage area, as well as expected water use needs, should be used to determine how large a storage tank is needed.

Pick a location, considering the following factors: (1) ease in connecting downspouts or roof drains, (2) overflow to adequately sized and stabilized downslope areas, (3) level area for placement and bearing capacity of the soil, (4) proximity to steep slopes, (5) location relative to intended water uses, (6) utility conflicts, (7) electrical connections if applicable, (8) emergency ingress/egress, (9) leaf screening options, (10) location of hoses or other distribution components, (11) ability to drain system between storms and to prevent freezing, and (12) aesthetic considerations.

DESIGN AND SIZING

To fully meet the LID/GSI Bylaw performance standard, cistern capacity must be designed for a 1 inch storm. During a 1-inch storm, each square foot of rooftop will produce about 0.6 gallons of runoff. This means that a 100-square-foot roof surface will fill a 55 gallon barrel.

Cisterns come in sizes from a 55 gallon rain barrel to a 1,500 gallon or larger cistern. If the cistern cannot hold the full inch from a rooftop area, multiple cisterns can be linked together, or the overflow can be diverted to another practice such as a rooftop disconnection area, swale, or rain garden.

Measure contributing roof area width from the drip line of the overhang to the roof peak (ignoring the slope), and the length. The goal is to measure the rooftop area, not just the portion of the building footprint that the roof covers. The width times the length in feet is the drainage area. Multiply that by 0.6 gallons and that is the size of the cistern you need to fully meet the one-inch rainfall standard.

Example of an in-line leaf screen.

All holding tanks should be opaque to prevent algae growth.

Pretreatment of water entering the cistern using filters or screens removes debris, dust, leaves, and other material. The pre-treatment can be installed either in the gutter or downspout, or at the inlet to the storage tank. Pretreatment options are illustrated on the specification sheet. One or more options should be chosen.

Mosquito screening (1 mm mesh size) should be installed at openings to prevent mosquitos from entering the storage tank.

The cistern should have an overflow pipe so that when the tank reaches capacity, the rainwater will be directed away from adjacent buildings. Multiple cisterns can be linked together to increase storage capacity.

Drainage system components leading to the cistern should have a minimum slope of 0.5-1% for gravity drainage to the cistern.

Gravity feed drip irrigation kits are widely available, as well as complete instructions on how to design an irrigation system for the low pressure of a cistern system without a pump. These systems can be used to draw down the water in a cistern between storm events.

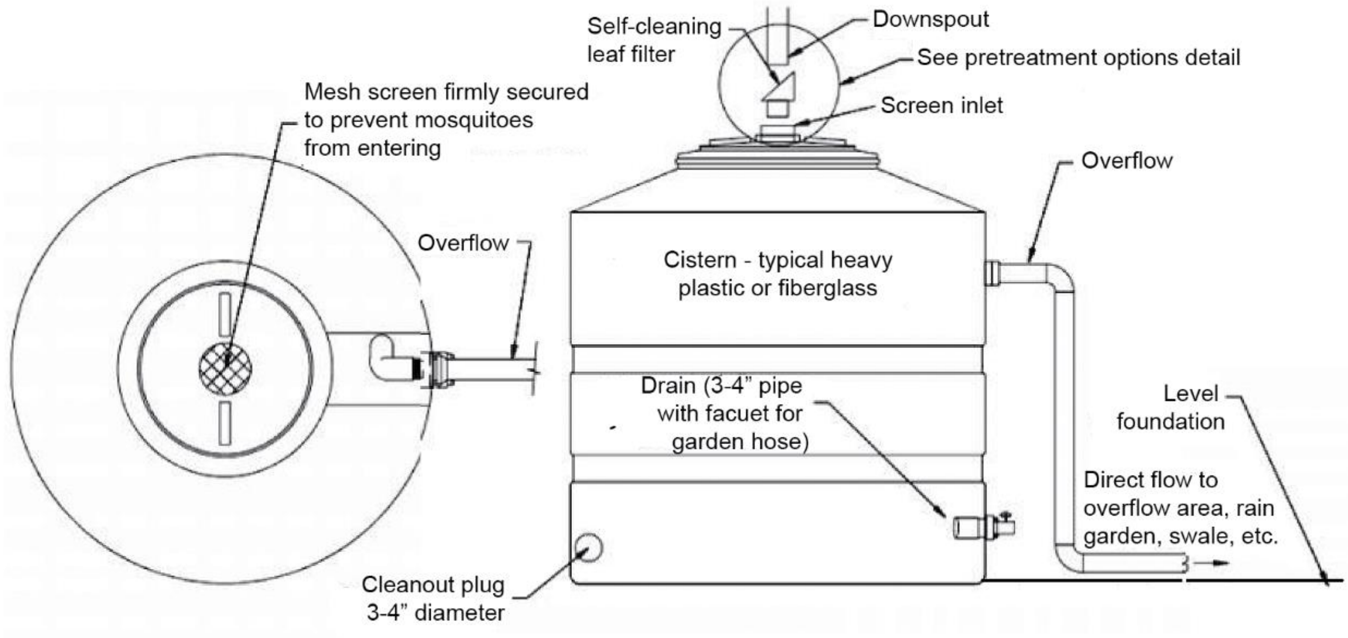
MAINTENANCE

To maintain the storage capacity of the cistern, rainwater should be used regularly and a draw down plan in place for use after each storm.

Routine checks of the intake and leaf screening components should be done once in the spring and periodically during the fall if leaves fall on the contributing roof area.

Ensure mosquito screen is tight.

Inspect and if necessary clean out tank annually by scrubbing and letting water drain through low flow plug. Check connections for leaks; and inspect overflow for erosion.

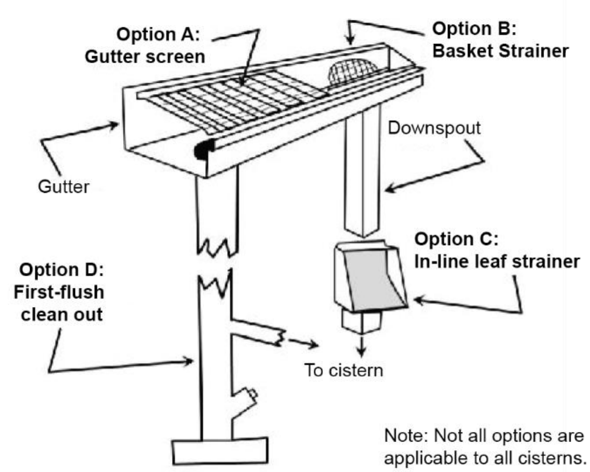


TYPICAL COMPONENTS (ATTACH MANUFACTURER'S SPECIFICATIONS)

CONSTRUCTION STEPS:

1. Locate cistern for: (1) ease in connecting downspouts or roof drains, (2) overflow to adequately sized and stabilized downslope areas, (3) level area for placement and bearing capacity of the soil, (4) proximity to steep slopes, (5) location relative to intended water uses, (6) utility conflicts, (7) electrical connections if applicable, (8) emergency ingress/egress, (9) leaf screening options, (10) location of hoses or other distribution components, (11) ability to drain system between storms and to prevent freezing, and (12) aesthetic considerations.
2. Depending on expected water use, review and follow applicable plumbing code.
3. Provide a level foundation of compacted earth, blocks, gravel, or other hard and durable surface.
4. Properly install the tank accounting for site stability, slope and soil bearing capacity, and accounting for the level of the water table and frost line for below-ground tanks. Review connections for layout and sizing.
5. Install water outlet connections, including pumps if applicable. Follow manufacturer's specifications for connections and fittings including inlet, overflow, and clean-out.
6. Extend overflow to a non-eroding discharge point (well-established lawn area, gravel splash pad, etc.), at least 10 feet away from buildings and property boundaries.
7. Cut and route downspouts or other rainwater delivery components, leaf screen option(s) chosen (see Pretreatment Options Detail), and mosquito screen for any openings. Strap and support downspouts and pretreatment as needed.
8. Test the cistern by filling with water and testing all components in turn – including spraying water on the roof and observing flow.
9. Consider appearance and final landscaping and screening. Complete construction and landscaping.

CIRCLE ONE OR MORE OPTIONS USED: A B C D



PRETREATMENT OPTIONS DETAILS

Sketch Layout

Provide plan and elevation views of cistern or rain barrels and structure, showing roof area directed to cistern, key dimensions and connections, and overflow area.

Notes:

1. **Attach manufacturer's specifications and other details**

Sizing Calculation:

Cistern volume = 0.56 gallons × sq. ft. rooftop area directed to cistern

Roof area directed to cistern: ______________ sq. ft.

Cistern size = ________________ gallons

Type of Cistern / Manufacturer:

____

____

Maintenance:

1. To maintain the storage capacity of the cistern, rainwater should be used regularly.
2. Routine checks of the intake and leaf screening components should be done once in the spring, and periodically during the fall if leaves fall on the contributing roof area.
3. Inspect and if necessary clean out tank annually by scrubbing and letting water drain through low flow plug. Check connections for leaks and inspect overflow for erosion.
4. Ensure mosquito screen is tight.

VERMONT GREEN STORMWATER INFRASTRUCTURE (GSI) SIMPLIFIED SIZING TOOL FOR SMALL PROJECTS

Fact Sheet No. 5: Rooftop Disconnection

October, 2015

Rooftop disconnection involves directing flow from residential or small commercial rooftops to uniformly graded vegetated areas (usually grass lawns), where rainwater can soak into or filter over the ground. These vegetated areas can reduce both runoff volume and pollutants delivered to receiving waters. Rooftop disconnection requires only minimal pre-treatment, due to the low pollutant loadings originating from these surfaces.

Downspout disconnection to a residential lawn, with gravel bed to evenly distribute runoff.

Design approaches that combine rooftop disconnection with an additional practice can enhance infiltration and can use less space on sloping or compact sites. Applicable practices can include cisterns (with cistern overflow directed to the disconnection's receiving area), rain gardens or bioretention areas, infiltration trenches, or dry wells.

LOCATION

Take note of drainage patterns to determine the best location for a rooftop disconnection. Assess the drainage area flow paths on your property, and the slope of the drainage area. Ideal locations are places where there is a gentle, uniform slope away from the structure, the area is relatively flat, and where flow can be spread evenly along the top of the filter area.

The ideal slope of the receiving area is between 1 and 8%. Greater slopes encourage the formation of concentrated flow and erosion, while lesser slopes encourage unplanned ponding. If the slope is between 8% and 15%, terraces, berms, or similar grade controls must be placed every 20 feet along the flow path.

Disconnecting rooftop runoff over utilities is acceptable, but care should be taken where soil amendments are being incorporated. Utility locations should be noted and care taken in completing soil amendment actions. Rooftop runoff should not be directed over a septic system.

The soils in the receiving area must meet the Post-Construction Soil Depth and Quality requirements, and be densely vegetated to prevent erosion.

The length of the receiving area should be no less than 35 feet. Natural meadow or forested areas on site can be counted in the total length. If the soil in the disconnection area is less permeable (infiltration rate lower than 0.5 inches/hour), or if the slope is steeper than 8%, a longer receiving area is needed.

The rooftop area draining to any one downspout or other discharge location cannot exceed 1,000 square feet.

Design and Sizing

Level Spreader

A level spreader must be used at the uphill end of practice to evenly distribute stormwater runoff across the top of the receiving area. The level spreader can be a small trench filled with pea gravel or river stone installed along a level contour, a splash pad, or other flow spreading device installed at the downspout outlet.

Downspouts must be at least 10 feet away from the nearest ground-level impervious surface, to prevent runoff from re-connecting to the stormwater drainage system.

Where a gutter/downspout system is not used, runoff should drain either as sheetflow from the contributing surface or into an infiltration trench.

Down-slope overflow points should be protected from erosion and not blocked by vegetation.

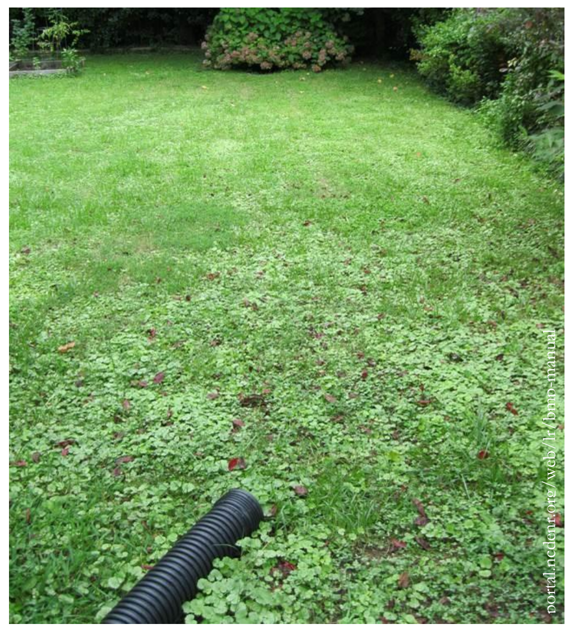
Receiving Area

This practice is critically dependent on several site conditions--especially down-slope flow path length, soils, slopes, and vegetative cover--in order to function properly.

Measure the rooftop area that is going to be directed to the receiving area. If the rooftop area draining to any one downspout is more than 1,000 square feet, the rooftop disconnection must be paired with another practice like a rain garden.

The flow from each downspout must be spread over a minimum 12-foot wide receiving area flow path extending down-slope from the structure.

The length of the flow path extending down-slope varies based on the soil's infiltration rate and the slope of the receiving area. From the design table below, select the flow path length based on your area's infiltration rate and slope. In order to qualify for the shorter receiving area flow path lengths, the soils need to be able to absorb least 0.5 inches of water per hour (see Appendix for testing method). Low-permeability soils require a longer flow path and careful attention to grading in order to maintain sheetflow.



Even distribution of rooftop runoff and a vigorous, healthy vegetative cover are keys to the success of rooftop disconnection to lawn.

Design Table - Rooftop disconnection receiving area lengths (in direction of flow) by infiltration rate and slope class

HSG of soil in receiving area	Receiving Area Slope	
	Less than 8%	8-15%
A/B or infiltration rate >=0.5 in./hr	35 feet	50 feet
C/D or infiltration rate < 0.5 in./hr	65 feet	85 feet

Vegetation and Landscaping

A dense, healthy vegetative cover must be established over the whole length of the receiving area. Turf grass is the most common groundcover. Native or appropriate, non-invasive trees and shrubs, as well as other herbaceous plants, will enhance infiltration and evapotranspiration of runoff.

Choose grasses and other vegetation that will be able to tolerate the stormwater runoff rates and volumes that will pass through the area. The vegetation should be able to tolerate both wet and dry conditions.

Maintenance

Maintain the level spreader and receiving area so that this practice will continue to provide stormwater management benefits over time.

- Keeping a healthy and dense vegetative cover over the entire receiving area is vitally important. Water as needed to promote plant growth and survival, especially in the first two seasons.
- Provide normal turf or garden maintenance - mow, prune, and trim as needed.
- Inspect the receiving area following rainfall events, and fix any erosion issues immediately.
- Remove accumulated leaves, sediment, and other debris from the receiving area as needed.

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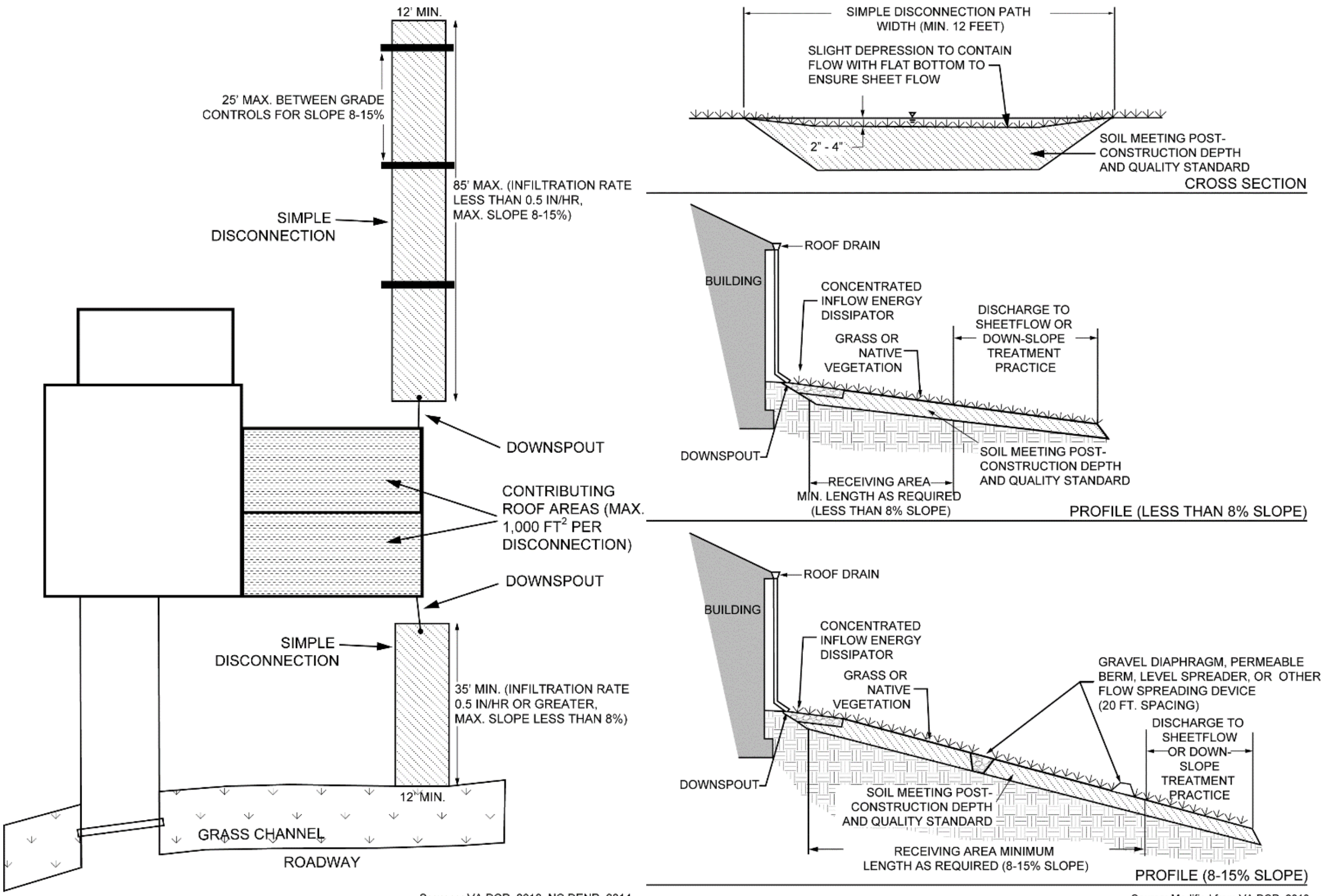

Sources: VA DCR, 2013; NC DENR, 2014

Source: Modified from VA DCR, 2013

TYPICAL COMPONENTS

CONSTRUCTION STEPS:

1. Review potential receiving areas and overall site layout. Receiving areas should slope between 1% and 15% away from the structure and should not be located above any septic system components. Placing a receiving area over utilities is acceptable, but ensure utility locations are noted and that care is taken when placing and incorporating soil amendments.
2. Measure the rooftop proposed to drain to the receiving area, and determine the receiving area's required minimum length from the design table. Determine the desired flow spreader option.
3. Prepare soil and inspect graded area as needed to meet the Post-Construction Soil Depth and Quality requirements.
4. Lay out and mark the receiving area and flow spreader line (if using a gravel trench).
5. Construct the down-slope receiving area. Ensure that the receiving area is uniformly graded with no gullies, low spots, or lateral slopes. Install grade controls every 20 feet if the area has an 8-15% slope. Avoid compaction of receiving areas.
6. Install dispersion measures (level spreader, gravel trench, splash block, etc.).
7. Install temporary erosion control at the flow entrance.
8. Install sod plant grass seed, or plant dense vegetation according to plan. Ensure that a watering plan is in place.
9. Install temporary erosion control measures (such as straw or matting) and leave them in place until vegetation is well established.

Sketch Layout

Provide plan and elevation views of disconnection area and house showing roof area directed to disconnection, key dimensions and connections, and overflow

Sizing Calculation:

HSG of soil in receiving area	Receiving Area Slope	
	Less than 8%	8-15%
A/B or infiltration rate >=0.5 in./hr	35 feet	50 feet
C/D or infiltration rate < 0.5 in./hr	65 feet	85 feet

Measure rooftop area, slope, and infiltration rate.
Read Receiving area length from table.

Measured rooftop area: ______________sq. ft (max. 1,000)

Slope of the receiving area: _______________%

Infiltration rate: __________________inches / hour

Receiving Area Width (across slope, on contour): 12 feet

Receiving Area Length (down-slope):_______________feet

Grade controls every 20 feet REQUIRED on 8-15% slopes

Maintenance:

1. Keeping a healthy and dense vegetative cover over the entire receiving area is vitally important. Water as needed to promote plant growth and survival, especially in the first two seasons.
2. Provide normal turf or garden maintenance - mow, prune, and trim as needed. Re-seed the receiving area as necessary to maintain a dense and robust ground cover.
3. Inspect the receiving area following rainfall events, and fix any erosion issues immediately.
4. Remove accumulated leaves, sediment, and other debris from the receiving area as needed.

VERMONT GREEN STORMWATER INFRASTRUCTURE (GSI) SIMPLIFIED SIZING TOOL FOR SMALL PROJECTS

Fact Sheet No. 6: Non-Rooftop Disconnection to Filter Strips

October, 2015

Filter strips are uniformly graded, vegetated areas of land designed to receive rainfall as sheet flow from adjacent ground-level impervious surfaces like driveways and parking lots. They allow runoff to be slowed and filtered by plants and soil and to infiltrate into the ground, and thus provide reductions in runoff volume and pollutant loads. Dense vegetative cover, long disconnection lengths, and low surface slopes provide the most effective vegetated filters. Design approaches that combine a filter strip with an additional practice, like bioretention or a vegetated swale, can enhance infiltration and can use less space on sloping or compact sites.

Grass filter strips, like this one along a road in a residential development, are a simple and effective way to treat runoff on gently sloping sites.

LOCATION

Take note of drainage patterns to determine the best location for non-rooftop disconnection. Assess the drainage area flow paths on your property, and the slope of the drainage area. Ideal locations are places where there is a gentle, uniform slope away from the impervious surface, the area is relatively flat, and where flow can be spread evenly along the top of the filter area.

The ideal slope of the filter strip area is between 1 and 8%. Greater slopes encourage the formation of concentrated flow and erosion, while lesser slopes encourage unplanned ponding.

The maximum contributing impervious flow path length to a filter strip (measured from the uphill side of the impervious surface to the downhill edge closest to the filter strip) is 75 feet.

Disconnecting non-rooftop runoff over utilities is acceptable, but care should be taken where soil amendments are being incorporated. Utility locations should be noted and care taken in completing soil amendment actions. Non-rooftop runoff should not be directed over a septic system.

The soils in the filter strip area must meet the Post-Construction Soil Depth and Quality requirements.

The length of the filter strip measured along the downhill flow path should be at least 35 feet. Natural meadow or forested areas on site can be counted in the total length. If the soil in the filter strip area is less permeable, or if the slope is steeper than 4%, a longer disconnection area is needed.

The impervious area draining to any one filter strip cannot exceed 5,000 square feet.

Design and Sizing

Level Spreader

When runoff enters the practice along a linear edge (such as at the edge of a road or parking lot) and drains down-slope across the filter strip, a gravel diaphragm(½ to 1 ½ inch diameter clean aggregate) or similar pre-treatment practice serves as a non-erosive transition between the impervious surface and the filter strip.

The gravel diaphragm is created by excavating a 2-foot wide and 1-foot deep trench that runs on the same contour at the top of the filter strip.

Stormwater flow travels over the impervious area and to the practice as sheet flow, and then drops at least 2 inches onto the gravel diaphragm.

A layer of filter fabric should be placed in the trench between the gravel and the underlying soil.

A gravel diaphragm catches runoff and distributes it as sheet flow to the filter strip, settling out sediment and preventing erosion.

If the contributing drainage area is steep (6% slope or greater), use larger-diameter stone (clean bank-run gravel) in the diaphragm.

Small areas of impervious cover (less than 1,000 square feet) or with contributing impervious flow path lengths of 20 feet or less do not require a gravel diaphragm, as long as sheetflow can be maintained into the filter strip.

Down-slope overflow points should be protected from erosion and not blocked by vegetation.

Receiving Area

Filter strips are critically dependent on several site conditions--especially down-slope flow path length, soils, slopes, and vegetative cover--in order to function properly.

Measure the impervious area that is going to be directed to the filter strip. Filter strips can be next to each other, but the maximum area that can drain to any one filter strip is 5,000 square feet.

The flow from each impervious surface must be spread along the entire width extending down-slope from the impervious cover.

Filter strips need to be uniformly graded to less than 8% slope, have a uniform transverse slope, meet the Post-Construction Soil Depth and Quality requirements, and be densely vegetated.

The length of the filter strip extending down-slope varies based on size of the impervious area, the soil's infiltration rate, and the slope of the filter strip. From the design table below, select the flow path length based on your area's characteristics.

In order to qualify for the shorter filter strip flow path lengths, the soils need to be able to absorb least 0.5 inches of water per hour (see Appendix for testing method). Low-permeability soils require a longer flow path and careful attention to grading in order to maintain sheetflow.

Design Table – Non-Rooftop Disconnection Lengths (in direction of flow) by impervious area size, infiltration rate, and slope class

Impervious Area Geometry			**Disconnection Area Slope**		
Contributing flow path length (feet)	**Total impervious surface area (square feet)**	**Infiltration rate for filter strip**	**Less than 4%**	**4-6%**	**6-8%**
1 -35	Less than 1,000	Infiltration rate >=0.5 in./hr	Flow path length × 1.0 (up to 35 feet)		
		Infiltration rate < 0.5 in./hr	Flow path length × 1.9 (up to 65 feet)		
35-75	1,000-5,000	Infiltration rate >=0.5 in./hr	35 feet	50 feet	65 feet
		Infiltration rate < 0.5 in./hr	65 feet	85 feet	105 feet

Vegetation and Landscaping

A dense, healthy vegetative cover must be established over the whole length of the disconnection area. The filter strip vegetation may include turf grasses, meadow grasses, and native or appropriate non-invasive trees, shrubs, or other herbaceous plants, as long as at least 90% coverage with grasses or other herbaceous plants is achieved after the second growing season.

Choose grasses and other vegetation that will be able to tolerate the stormwater runoff rates and volumes that will pass through the area. The vegetation should be able to tolerate both wet and dry conditions and be salt tolerant.

For filter strips planted in turf grass, seeding is recommended over sodding. Seeding develops a better root system, and sod may be grown on muck soils that inhibit infiltration.

Maintenance

Maintain the level spreader and filter strip so that this practice will continue to provide stormwater management benefits over time.

- Keeping a healthy and dense vegetative cover over the entire filter strip is vitally important. Water as needed to promote plant growth and survival, especially in the first two seasons.
- Provide normal turf or garden maintenance - mow, prune, and trim as needed.
- Inspect the gravel diaphragm and filter strip following rainfall events, and fix any erosion issues immediately.
- Check periodically to make sure that foot or vehicular traffic does not compromise the gravel diaphragm.
- Remove accumulated leaves, sediment, and other debris from the gravel diaphragm and filter strip as needed. Make sure that debris and sediment do not build up at the top of the filter strip.
- Consider periodic sweeping of impervious areas, especially in the spring if sand is used as part of winter operations.

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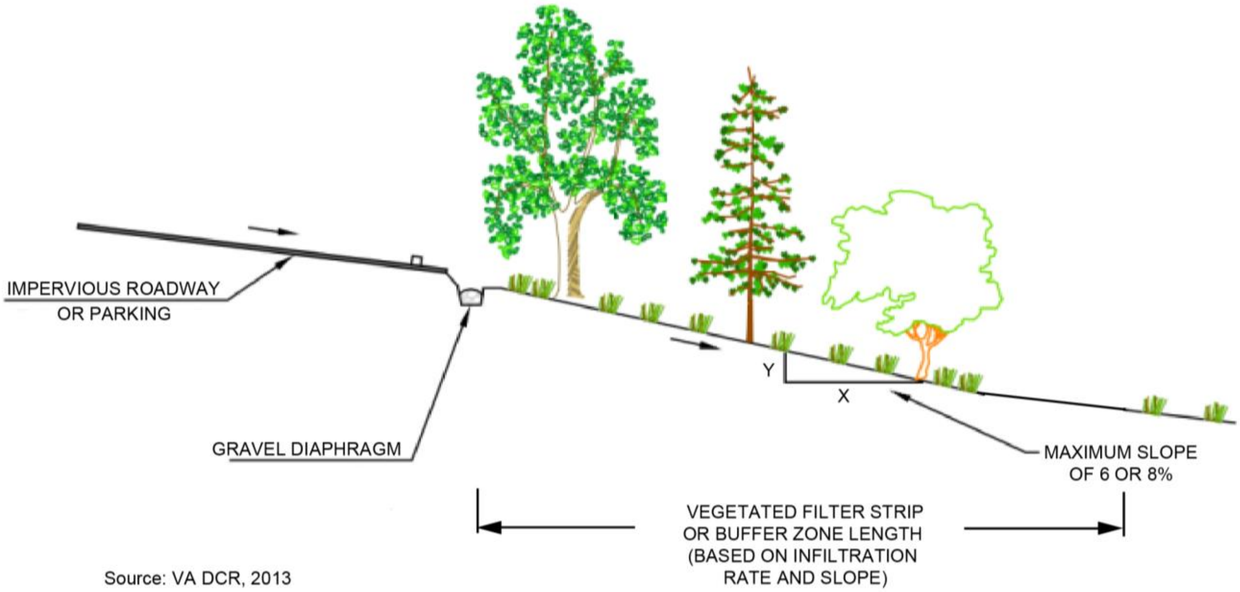
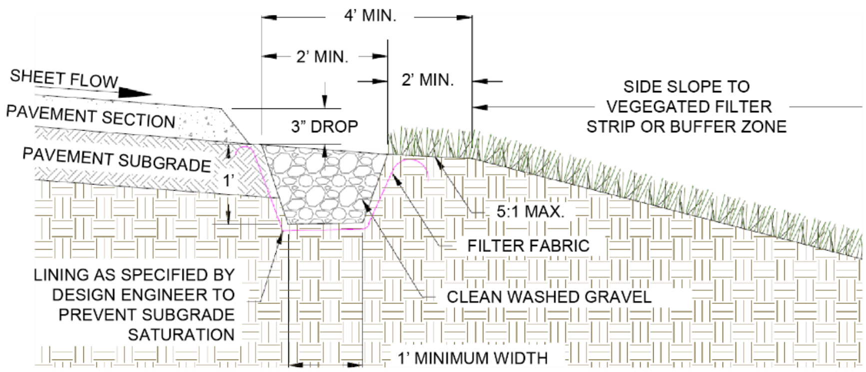


Source: VA DCR, 2013



Source: VA DCR, 2013

TYPICAL COMPONENTS

CONSTRUCTION STEPS:

1. Review potential receiving areas and overall site layout. Filter strips should slope between 1% and 8% away from the impervious cover and should not be located above any septic system components. Placing a filter strip over utilities is acceptable, but ensure utility locations are noted and that care is taken when placing and incorporating soil amendments.
2. Measure the impervious area proposed to drain to the filter strip, and determine its required minimum length from the design table. Determine whether a gravel diaphragm is required.
3. Before site work begins, clearly mark the filter strip boundaries. Only vehicular traffic used for filter strip construction shall be allowed within 10 feet of the area.
4. Prepare soil and inspect graded area as needed to meet the Post-Construction Soil Depth and Quality requirements.
5. Lay out and mark the filter strip area and the gravel diaphragm (if required).
6. Vegetated filter strips typically require light grading to achieve desired elevations and slopes. Complete the grading using tracked vehicles to minimize compaction. Incorporate topsoil and/or compost amendments evenly across the filter strip area, stabilize with seed or other dense vegetation, and protect using biodegradable erosion control matting or blankets. Ensure that a watering plan is in place.
7. Install gravel diaphragm dispersion measure using ½ -1 ½ inch diameter clean aggregate (if required).
8. Ensure that temporary erosion control measures (such as straw or matting) are installed and leave them in place until vegetation is well established.

Sketch Layout

Provide plan and elevation views of impervious surface and filter strip area and house impervious area directed to filter strip, key dimensions and connections, and overflow

Sizing Calculation:

Measure impervious area dimensions, filter strip slope, and soil infiltration rate. Read filter strip length from table in guidance or use calculator.

Contributing impervious flow path length: _______ ft (max. 75)

Filter Strip Design Criteria

Width of the contributing impervious area: _____________ft.

Length of the contributing impervious area: _____________ft.

Total impervious area draining to filter strip: __________sq. ft. (max 5,000 sq. ft.)

Infiltration rate: _________________inches / hour

Slope of the filter strip area: ______________% (max 8%)

Filter Strip Width (across slope, on contour): ____________feet (same as width of contributing impervious area)

Filter Strip Length (down-slope):______________feet (read from table or use calculator)

Maintenance:

1. Water as needed to promote plant growth and survival, especially in the first two seasons.
2. Provide normal turf or garden maintenance - mow, prune, and trim as needed.
3. Inspect the gravel diaphragm and filter strip following rainfall events. Fix any erosion issues immediately.
4. Check periodically to make sure that foot or vehicular traffic does not compromise the gravel diaphragm.
5. Remove accumulated leaves, sediment, and other debris from the gravel diaphragm and filter strip as needed. Make sure that debris and sediment do not build up at the top of the filter strip.
6. Consider periodic sweeping of impervious areas, especially in spring if sand is used in winter operations.

VERMONT GREEN STORMWATER INFRASTRUCTURE (GSI) SIMPLIFIED SIZING TOOL FOR SMALL PROJECTS

Fact Sheet No. 7: Drywells

October, 2015

Dry wells are manufactured, perforated concrete forms or tanks set in the ground and surrounded with stone that are designed to intercept and temporarily store stormwater runoff until it infiltrates into the soil. Alternately, drywells can be made by filling an excavation with stone, with water entering through a perforated pipe with a perforated standpipe in place of a tank. Drywells are a form of infiltration practice that can provide significant stormwater volume reductions and pollutant treatment, and they are especially well-suited to manage rooftop runoff where soils are well-drained. This practice is not appropriate in areas with poorly drained soils or shallow groundwater.

Drywells can be a practically invisible part of a lawn, or they can become attractive landscape elements.

LOCATION

Drywells must be located at least 10 feet from building foundations.

Drywells should be located in a lawn or other pervious (unpaved) area and should be designed so that the top of the dry well is located as close to the surface as possible. They should not be hydraulically connected to structure foundations or pavement, to avoid seepage and frost heaving concerns.

Drywells should not be located beneath any paved or otherwise impervious surface, above an area with a water table or bedrock less than two feet below the drywell bottom, over utility lines, or above any septic system components.

Infiltration practices cannot be located on areas with natural slopes greater than 15%.

To use this practice, your soil infiltration needs to be 0.50 inches per hour (in/hr) or greater. It is highly recommended that you complete an infiltration test as shown in Appendix A.

The height of the tank or depth of excavation cannot exceed 48 inches.

The impervious area draining to any one drywell (or series of drywells) cannot exceed 1,000 square feet.

Design and Sizing

To reduce the chance of clogging, drywells should only be used to treat water from rooftops. The runoff must be pre-treated with at least one device designed to remove leaves, debris, and larger particles (see spec sheet).

Consider the drainage area size and the soil infiltration rate when determining the size of the drywell. As a general rule, about 18 cubic feet of stone will be needed to provide adequate storage volume for one inch of runoff from 100 square feet of rooftop area. If a hollow manufactured tank-style drywell is used, about 8 cubic feet of storage is needed to provide adequate volume to capture one inch of runoff from 100 square feet of rooftop area.

The design table below provides the total rooftop area that can be treated, given a variety of drywell diameters and tank heights or excavation depths, and based on a soil infiltration rate of 0.5 inches/hour. The calculator tool can be used to adjust drywell geometry and the soil infiltration rate for your project.

Design Table –Contributing rooftop area treated by type of drywell (gravel filled excavation or manufactured tank), drywell diameter, and drywell depth

Gravel Jacket Depth (inches)	Tank Height (inches)	Tank Inside Diameter (inches)				
		24	30	36	42	48
		Contributing Rooftop Area Captured (square feet)				
12	**30**	254	342	445	561	693
12	**36**	294	396	515	652	805
12	**48**	373	504	657	832	1029

Hole Depth (inches)	6-inch Perforated Standpipe Gravel Filled Hole Diameter (inches)				
	24	30	36	42	48
	Contributing Rooftop Area Captured (square feet)				
24	29	46	66	90	118
30	36	56	81	110	144
36	43	67	96	130	170
42	49	77	111	150	197
48	56	87	125	171	223

Drywell gravel or hollow chamber depths should be no more than 48 inches. The total excavation depth should leave at least 4-6 inches between the top of the drywell gravel and the ground surface. If a manufactured tank is used, the drywell hole should be excavated 1 foot deeper and 2 feet larger in diameter than the well to allow installation of a 12 inch stone-filled "gravel jacket" layer.

The bottom of the drywell excavation should be flat, so that runoff will be able to infiltrate through the entire surface.

Installation of a drywell, including a manufactured tank, gravel jacket, and filter fabric.

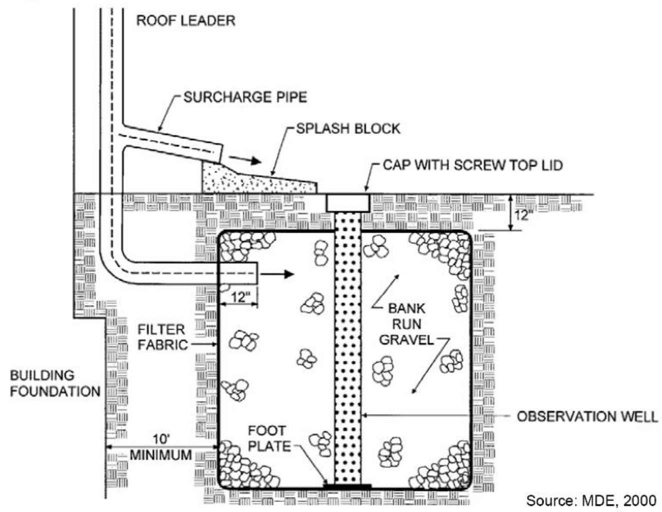
The sides of and top of the drywell (but not the bottoms!) should be lined with filter fabric to prevent soil piping. The sides of the excavation should be trimmed of roots to ease filter fabric installation.

Gravel aggregate used to fill the drywell or to form a stone "jacket" around a manufactured drywell should be clean, washed #57 stone (this stone should average ½ inch to 1 ½ inches in diameter). There should be very few stones smaller than this size in the mix, and the gravel should not look dusty or contain any fines.

6-inch diameter PVC pipe should be used to convey runoff from the downspout to the drywell. If a manufactured tank is used, the pipe should be solid. Perforated pipe should be used within the drywell for the horizontal and vertical pipes if the gravel-filled excavation option is chosen (see schematic at right).

The top gravel surface of the drywell should be covered with permeable landscape fabric to keep soil or pea gravel from filling the pore spaces. The drywell can be covered with topsoil and grass, or with pea gravel or other decorative stone.

An overflow area, like a filter strip or grass channel, should be used to convey the runoff from larger storm events safely away from the drywell.



Source: MDE, 2000

VEGETATION AND LANDSCAPING

The area above the surface of a drywell should be covered with pea gravel (or larger-diameter river stone or other decorative stone) when water enters the drywell through surface flow rather than through a pipe. The pea gravel provides sediment removal and additional pre-treatment upstream of the dry well and can be easily removed and replaced when it becomes clogged.

Alternatively, the drywell may be covered with topsoil, and planted with turf or other herbaceous vegetation.

MAINTENANCE

Regular maintenance is important to ensure that the drywells continue to provide stormwater management benefits over time.

- Inspect gutters/downspouts in the spring and after leaves drop in the fall. Remove any accumulated leaves and debris and clean leaf removal systems.
- Check the drywell following large rainfall events to insure pre-treatment is not clogged, and that the overflow is operating and flow is not causing problems.
- Mow or trim vegetation (if any) as needed.
- Inspect the top layer of filter fabric for sediment accumulation, and remove and replace the filter fabric if it becomes clogged.

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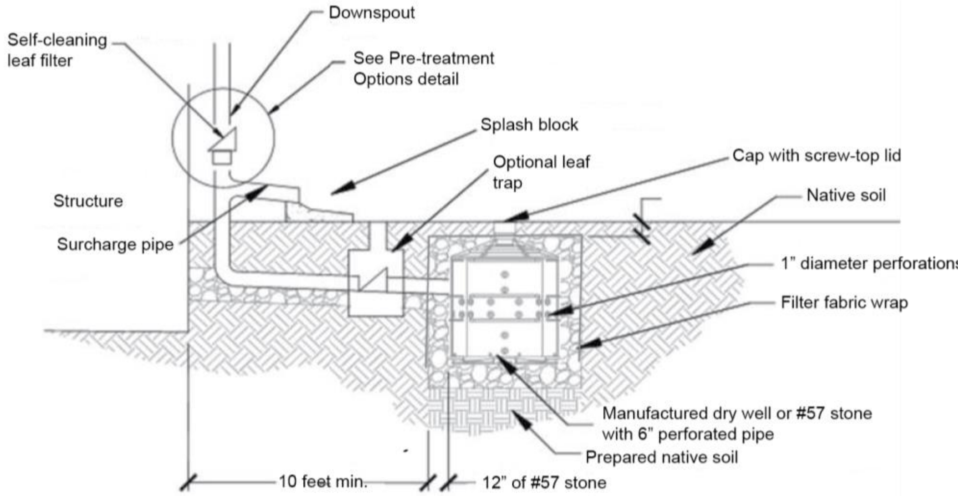
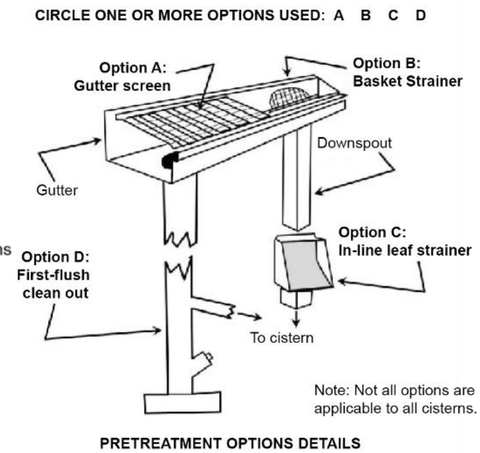


Source: Modified from City of Atlanta, GA 2013



TYPICAL COMPONENTS (ATTACH MANUFACTURER'S SPECIFICATIONS)

CONSTRUCTION STEPS:

1. Identify the potential drywell areas and layout on your plan. Drywells should not be located beneath any paved or otherwise impervious surface, above an area with a water table or bedrock less than two feet below the drywell bottom, over utility lines, or above any septic system components.
2. Measure the rooftop area draining to the drywell.
3. Perform an infiltration test in the area planned for the drywell according to the instructions in Appendix A. If the rate is less than 0.5 in/hr, this method cannot be used. If the infiltration rate is more than 0.5 in/hr, the size or number of drywells may be adjusted.
4. Determine the drywell dimensions and number of drywells needed to capture runoff from the rooftop area from the table on the next page using—or use the calculator to adjust drywell dimensions based on site conditions.
5. Measure elevations, and lay out the drywell excavation's required dimensions. The location of the drywells must be marked off before the start of construction, in order to prevent compaction.
6. Remove sod (if lawn is already established in the drywell area). Excavate the hole to the required dimensions. If using the manufactured tank and gravel jacket option, the hole must be excavated 12 inches deeper and 24 inches wider than the tank dimensions. For both options, add at least six inches of depth to accommodate topsoil or pea gravel. Do not compact soils in the bottom of the excavation. Level the bottom to maximize infiltration area, then roughen the bottom (scarify or till) to a depth of at least 3-4 inches and trim any tree roots.
7. Place non-woven filter fabric (Mirafi 180n or similar) around the side walls of the excavation. Use a filter fabric width that is wide enough to cover perimeter irregularities and overlap back onto the ground surface, leaving enough to fold over the top of the gravel below the soil and turf or pea gravel. Stones or other anchoring objects can be placed on the fabric at the edge of the excavation to secure it temporarily.
8. Place 12 inches of #57 gravel on the excavation bottom, and tamp it firmly to settle. If installing a manufactured tank, pea gravel can be substituted for leveling purposes in the upper three inch layer below the tank.
9. Place and level tank and install piping. Bond top of tank in place. If using the 6-inch perforated standpipe option, install standpipe and associated piping.
10. Route downspouts or other runoff delivery components, and install at least one leaf screening device.
11. Create a safe overflow and ensure it is protected from erosion.
12. Test connections with water flow.
13. Fill the remaining excavation depth (to 6 inches below ground surface) with #57 gravel in lifts of no more than 12 inches, tamping each lift to settle. Place permeable filter fabric on top of the gravel.
14. Place topsoil and sod/seed, pea gravel, or other decorative stone to the same elevation as the surrounding ground surface.

Sketch Layout

Provide plan and elevation views of Drywell(s) and structure, showing roof area directed to drywell(s), key dimensions and connections, and overflow

Sizing Calculation:

Measure contributing rooftop area, and read area for given media depth and drywell design option from table in guidance. The calculator can also be used to determine number and dimensions of drywells.

Contributing rooftop area: __________ sq. ft. (max. 1,000 per downspout)

Infiltration rate: _______________ inches / hour (min. 0.5)

Manufactured Tank and Gravel Jacket Option:

Tank inside diameter: _______________ inches (24-48)
Tank inside depth: _________________ inches (30-48)
Gravel jacket depth: 12 inches
Total number of drywells: _______________

Gravel Filled Hole with 6" Perforated Pipe Option:

Gravel filled hole diameter: ___________ inches (24-48)
Gravel filled hole depth: ______________ inches (24-48)
Total number of drywells: _______________

Maintenance:

1. Inspect gutters/downspouts in the spring and after leaves drop in the fall. Remove any accumulated leaves and debris and clean leaf removal systems.
2. Check the drywell following large rainfall events to insure pre-treatment is not clogged, and that the overflow is operating and flow is not causing problems.
3. Mow or trim vegetation (if any) as needed.
4. Inspect the top layer of filter fabric for sediment accumulation, and remove and replace the filter fabric if it becomes clogged.

Vermont Green Stormwater Infrastructure (GSI) Simplified Sizing Tool for Small Projects

Fact Sheet No. 8: Bioretention and Rain Gardens

October, 2015

Bioretention and rain gardens are multi-functional practices that can be easily adapted for new and re-development applications, and for almost any land use. Stormwater runoff is stored temporarily in small, landscaped depressions that are filled with a mix of sand, native soil, and compost, and are planted with trees, shrubs and other garden-like vegetation. The term "bioretention" is often used to refer to larger facilities, while the term "rain garden" is more commonly used to indicate small facilities for the treatment of rooftop runoff. This guidance uses the term "bioretention", regardless of the size of the practice.

A rain garden catching stormwater from a seasonal home on Lake Carmi.

Bioretention provides stormwater volume reduction, water quality treatment, and aesthetic value. It can be applied in many configurations, including as a landscaping element in residential and commercial lawns, concave parking lot islands, terraced slope facilities, residential cul-de-sac islands, and planter boxes. Bioretention facilities are well suited to be used in combination with other disconnection-based practices, like Rooftop Disconnection and Non-Rooftop Disconnection to Filter Strips. Additional guidance can be found in the *Vermont Rain Garden Manual*.

Location

Bioretention should be located to intercept the maximum amount of runoff, and where downspouts or runoff from parking lots or driveways can enter the facility while flowing away from buildings and impervious surfaces.

Swales, berms, or downspout extensions may help to route runoff to the rain garden.

Bioretention should be located at least 5-10 feet away from building foundations, away from buried utilities, not over septic system components, and not near the edge of a steep slope.

Slopes of the areas contributing flow to bioretention should be low to moderate (15% or less). If slopes are greater than 8%, a level-spreading device will be needed leading into the rain garden. The bioretention area's surface should be flat or slightly sloping (0.5% maximum).

The bottom of the soil media in the rain garden must be located above the groundwater table.

The impervious area draining to any one bioretention area cannot exceed 10,000 square feet.

DESIGN AND SIZING

Runoff can enter a bioretention practice directly through downspouts, covered drainage pipes, or catch basins--or it can enter indirectly through swales, stone channels, or depressed curbs or curb cuts.

The entrance should be designed to immediately intercept the inflow and reduce its velocity with stones, dense hardy vegetation, or other means.

Runoff from rooftops can be directed into a bioretention practice without pre-treatment.

Stormwater from driveways, parking lots, and other larger ground-level impervious surfaces contains more sediment and pollutants. Pre-treatment for this runoff can include a grass filter strip below a pea gravel diaphragm or grass channel, or a small sediment forebay (a depression between the impervious surface and the rain garden that catches a portion of the flow and allows coarse sediment to settle out).

Top: Rooftop runoff can flow directly into rain gardens, though you may need a splash pad or some stone to slow the water down. Bottom: Bioretention areas that are larger or treating runoff from areas with higher sediment loads need some pre-treatment (like this "Rain Guardian") to settle out sediment and debris.

The size of the bioretention filter surface varies depending on the impervious surface draining to it and depth of the soil media. Use the table, or the sizing calculation in the spreadsheet tool, to determine the required surface area for the facility. If needed, the surface area of any pre-treatment should be about 10% of the bioretention practice's surface area. Low-permeability soils do not rule out rain gardens, but you may need an underdrain.

Design Table – Bioretention and rain garden surface areas by size of contributing impervious area and planting media depth

Total impervious surface area (square feet)	**Depth of Bioretention Soil Mix (inches)**			
	18	**24**	**30**	**36**
	Bioretention Filter Bed Surface Area (square feet)			
100	8.3	7.2	6.3	5.7
500	40	35	30	25
1000	80	75	65	60
2000	165	145	125	115
3000	250	215	190	170
4000	335	290	250	225
5000	415	360	315	285
7500	625	540	475	425
10000	835	720	635	565

The bioretention area must include an 18-36 inch deep planting soil bed, a hardwood mulch surface layer (or other surface treatment that suppresses weed growth and minimizes exposed soil), and a 6 inch deep surface ponding area.

The planting soil should consist of sand or loamy sand and meet the following graduation: sand 85- 88%, silt 8-12%, clay 0-2%, and organic matter (in the form of compost) 3-5%. For best results, test your soil characteristics as you would for a garden, or contact the UVM Extension Service for help (http://www.uvm.edu/pss/ag_testing/).

A maximum ponding depth of 6 inches is allowed within rain gardens. Bioretention areas generally drain within two days after a storm, which will not create a mosquito problem.

If the sides of the bioretention area are intended to be mowed, they should be designed with side slopes of 3:1 (H:V) or flatter.

A mulch layer of shredded hardwood that is well aged (stockpiled or stored for at least 6 months) should be applied to a depth of 2-3 inches—but good hardwood mulch can be hard to find. Alternatives include mulching only around shrubs and planting a conservation mix elsewhere to create a cover crop that can be mowed or weed-whacked, or planting two or more species of tall grasses and allowing the whole facility to fill in. Whatever surface treatment you use, it should outcompete or suppress weed growth and minimize exposed soil.

Often rain gardens look neater and are easier to maintain if they have defined edges, similar to a normal garden or landscape bed.

The overflow outlet from the downstream end of the bioretention area should be non-eroding. It can consist of a stone-lined channel or an inlet grate set level with the top of the berm. If a grate is used, it should be slanted or domed to prevent clogging by leaves and debris.

VEGETATION AND LANDSCAPING

Vegetation planted in bioretention includes native trees, shrubs, and other herbaceous vegetation. When developing a planting plan, choose vegetation that will be able to stabilize soils and tolerate the stormwater runoff rates and volumes that will pass through the rain garden.

Native plant species are preferred over non-native species, though non-invasive cultivars can also provide the functions needed for a successful bioretention system.

Plantings should be able to tolerate both wet and dry conditions. See *The Vermont Rain Garden Manual* for plant lists and example planting plans. Volume 2, Appendix A of the *Vermont Stormwater Management Manual* also contains a list of plants that are appropriate for use in rain gardens in Vermont.

Recommended planting densities are as follows: One tree per 100 square feet (10 feet on-center) if trees are desired near the perimeter, one shrub per 25 square feet (5 feet on center), and one perennial or other herbaceous plant per 6 square feet (2.5 feet on center).

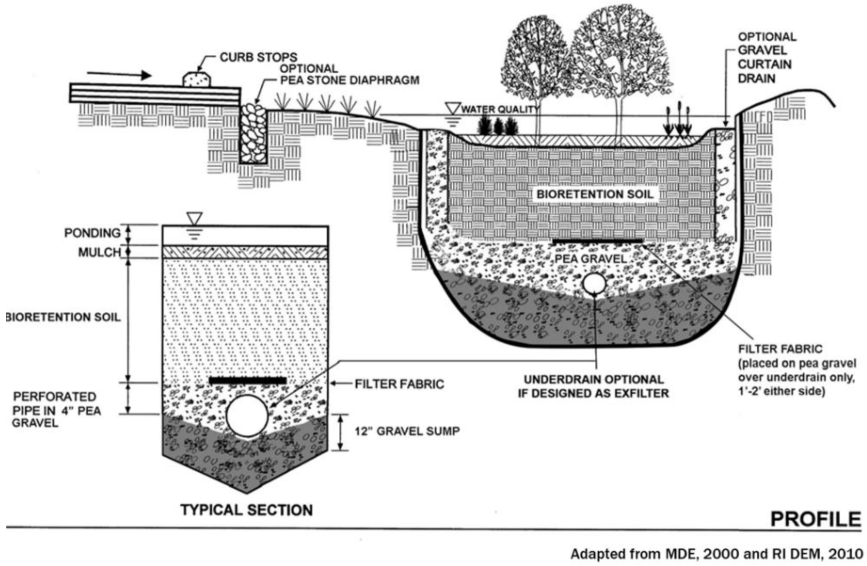
The vegetation may initially require watering to become well established. You may want to plant more densely than you would in a normal garden, to quickly obtain the benefits of soil stabilization and evapotranspiration.

Maintenance

In the first year to two years of operation, watering, weeding and removal of invasive species, removal and replacement of dead plants, and spot re-seeding of bare or eroding areas are especially important for rain garden establishment.

Routine garden maintenance should include weeding, deadheading, replacing dead plants, and replenishing mulch when depleted. Build-ups of sediment, leaves, and debris should be removed from curb cuts, gravel diaphragms, forebays, and other pre-treatment devices annually, or whenever they prevent flow from reaching the rain garden area. Catching and quickly repairing areas of erosion is also important, as is correcting standing water problems.

If standing water persists, and raking the top layer or removing silt from the rain garden surface does not fix the problem, it may be necessary to place a perforated underdrain under the garden that daylights down-slope.



TYPICAL COMPONENTS

CONSTRUCTION STEPS:

1. Construction should only begin after installation of the contributing impervious surfaces has been completed. The bioretention area will fail if large volumes of construction-related sediment flow into it. Ideally, bioretention should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment.
2. Locate rain garden(s) where downspouts or runoff from parking lots or driveways can enter the facility while flowing away from buildings and impervious surfaces. Locate at least 5-10 feet from foundations, away from buried utilities, not over septic system components, and not near the edge of a steep slope.
3. Measure the impervious area draining to the planned bioretention area and determine the required rain garden surface area from the table on the next page, based on your planned ponding depth and excavation depth.
4. Perform infiltration test according to directions in the Appendix. Underdrain is needed if rate is less than 0.5 inches/hour.
5. Measure elevations and stake out the bioretention area dimensions and any needed pre-treatment. Ensure that positive flow will be maintained into the garden, the overflow elevation allows for 6 inches of ponding, and that the outer edge of the garden is higher than the down-slope overflow point. If garden is on a slope, a berm two feet wide can be constructed on the downhill side and/or the garden can be dug into the hillside, taking greater care for erosion control at the garden inlet(s).
6. Remove turf or other vegetation in the area of the rain garden (if any exists). Excavation work should be completed from the sides, to excavate the bioretention area to its appropriate design depth and dimensions. Excavating equipment should never sit inside the rain garden footprint. Level bottom of garden as much as possible to maximize infiltration area.
7. If an underdrain is needed, place at least 3 inches of #57 stone on the bottom, install the perforated underdrain pipe (6" diameter Schedule 40 perforated PVC pipe), pack #57 stone to 3 inches above the underdrain pipe, and add approximately 3 inches of choker stone as a filter between the underdrain and the soil media layer.
8. Mix sand, topsoil, and compost together to make the 'bioretention soil mix'. The soil mix should be mostly sand (85- 88%) with a little silt (8-12%), clay (0-2%), and organic matter in the form of compost (3-5%).
9. Install the soil media in 12-inch lifts until the desired top elevation of the bioretention area is reached. The soil media can be compacted by saturating it with water, or the depth of soil media can be increased by 10% to allow for settling. These lifts should not be mechanically compacted. Leave the surface eight to 12 inches below your highest surrounding surface. Eight inches allows for 6 inches ponding and 2" of mulch. The surface of the rain garden should be as close to level as possible.
10. If needed, build a berm at the downhill edge and sides of the rain garden with the remaining subsoil. The top of the berm needs to be level, and set at the maximum ponding elevation.
11. Create an overflow and ensure it is protected from erosion.
12. Build the inlet feature as appropriate for your application. Examples include a pipe connected to a downspout, a rock lined swale with a gentle slope, a newly constructed or retrofit curb-cut, or a manufactured pre-treatment device like a Rain Guardian. For rain gardens constructed near structures, an impermeable liner under the rocks at the end of the swale near the structure is recommended to keep water from soaking in close to the foundation.
13. Prepare planting holes for any trees or shrubs, and plant the woody vegetation. Plant the rest with a selection of herbaceous plants.
14. Place the surface cover in the rain garden area (hardwood mulch, river stone or turf), depending on the design.
15. Water all plants thoroughly. Regular watering will likely be needed to establish plants, especially during the first growing season.

GREEN STORMWATER INFRASTRUCTURE SIMPLIFIED SIZING TOOL FOR SMALL PROJECTS	NAME/ADDRESS:	BIORETENTION AND RAIN GARDENS SPECIFICATIONS PAGE 1 OF 2

SKETCH LAYOUT

PROVIDE PLAN VIEWS OF BIORETENTION/RAIN GARDEN AND STRUCTURE OR GROUND-LEVEL IMPERVIOUS COVER, SHOWING DRAINAGE AREAS DIRECTED TO BIORETENTION, KEY DIMENSIONS AND CONNECTIONS, AND OVERFLOW

SIZING CALCULATION:

Total impervious surface area (square feet)	Depth of Bioretention Soil Mix (inches)			
	18	24	30	36
	Bioretention Filter Bed Surface Area (square feet)			
100	8.3	7.2	6.3	5.7
500	40	35	30	25
1000	80	75	65	60
2000	165	145	125	115
3000	250	215	190	170
4000	335	290	250	225
5000	415	360	315	285
7500	625	540	475	425
10000	835	720	635	565

MEASURE CONTRIBUTING IMPERVIOUS AREA, AND READ AREA FOR GIVEN MEDIA DEPTH. DESIGN TABLE ASSUMES 6 INCHES OF PONDING AND 0.5 INCHES/HOUR INFILTRATION RATE. USE THE CALCULATOR TO ADJUST MEDIA DEPTH, PONDING DEPTH, & INFILTRATION RATE.

CONTRIBUTING IMPERVIOUS AREA: _________ SQ. FT. (MAX. 10,000)

Infiltration rate: __________________inches / hour (min. 0.5)

Depth of soil media: _______________inches (24-36)

Ponding depth: __________________inches (6-9)

Bioretention filter bed bottom surface area: _______________ sq. ft.

MAINTENANCE:

1. Irrigate vegetation as needed, especially in the first season.
2. Remove weeds and invasive species.
3. Remove and replace unsuccessful plantings.
4. Replenish mulch if used.
5. Stabilize eroded areas and re-seed or replant.
6. Remove sediment and debris from curb cuts, forebays, or other pre-treatment annually or when flow to garden is blocked.
7. Rake clogged surface or remove silt from surface to restore infiltration.
8. Monitor for appropriate drainage; if garden does not drain an underdrain may be necessary.

VERMONT GREEN STORMWATER INFRASTRUCTURE (GSI) SIMPLIFIED SIZING TOOL FOR SMALL PROJECTS

Fact Sheet No. 9: Vegetated Swale

October, 2015

A vegetated swale, often also referred to as a bioswale or dry swale, is essentially bioretention that is shallower, configured as a linear channel, and covered either with mulch and ornamental plants or with turf, river stone, or other surface material. Dry swales rely on a soil media filter below the channel surface. If the native soils are permeable, runoff infiltrates into underlying soils. Vegetated swales provide stormwater volume reduction, water quality treatment, and aesthetic value. They can be applied in many configurations, including as a landscaping element in residential and commercial lawns, along driveways and streets, or in commercial parking lots. Additional guidance can be found in the *Vermont Rain Garden Manual*.

A dry swale in action during a rainstorm on State Street in Montpelier.

LOCATION

Vegetated swales should be located to intercept the maximum amount of runoff, and where downspouts or runoff from parking lots or driveways can enter while flowing away from buildings and impervious surfaces.

Vegetated swale footprints can fit into narrow corridors between utilities, roads, parking areas, or other site constraints—but swale location should also be considered carefully. Swales along roadways may be damaged by off-street parking, and can be susceptible to winter salt applications.

Vegetated swales should be located at least 5-10 feet away from building foundations, away from buried utilities, not over septic system components, and not near the edge of a steep slope.

Slopes of the areas contributing flow to a swale should be low to moderate (15% or less). If slopes are greater than 8%, a level-spreading device will be needed leading into the swale. The swale's surface should be flat or slightly sloping (2% maximum, measured in the direction water will flow). While vegetated swales can work on steeper slopes (up to 6%), check dams, step pools, or other grade controls are needed to reduce the effective slope of the swale to 2% or less. Consult an engineer if you need to use this practice on steeper slopes.

The bottom of the soil media in the vegetated swale must be located above the groundwater table.

The impervious area draining to any one vegetated swale cannot exceed 10,000 square feet.

DESIGN AND SIZING

Runoff can enter a swale directly through downspouts, covered drainage pipes, or catch basins--or it can enter indirectly through swales, stone channels, or depressed curbs or curb cuts.

Wherever runoff enters the swale at a defined point (like a downspout or a curb cut), the entrance should be designed to immediately intercept the inflow and reduce its velocity with stones, dense hardy vegetation, or other means.

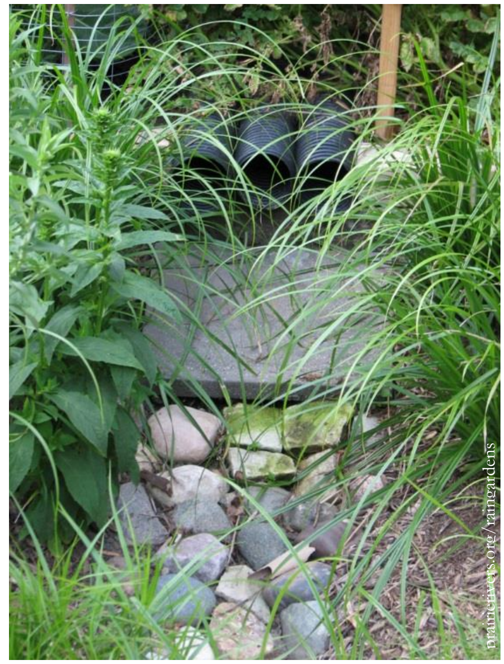
Runoff from rooftops can be directed into a vegetated swale without pre-treatment.

Stormwater from driveways, parking lots, and other larger ground-level impervious surfaces contains more sediment and pollutants. Pre-treatment for this runoff can include a pea gravel diaphragm and a grass filter strip leading to the side-slope of the vegetated swale for sheet flow (for instance, from a portion of a parking lot). Pre-treatment could also be a small sediment forebay (a depression between the impervious surface and the swale that catches a portion of the flow and allows coarse sediment to settle out). Runoff entering a vegetated swale along the length of a roadway can be pre-treated using a grass filter strip, or the storage volume for pre-treatment can be provided by using check-dams to create forebays at pipe inlets or driveway crossings.

A vegetated swale should have a bottom width of between two and eight feet. If a swale will be wider than 8 feet, berms, check dams, level spreaders or multi-level cross-sections need to be included to prevent braiding and erosion of the swale bottom. Consult an engineer if you need to use a vegetated swale with a bottom width of over 8 feet.

The surface area of the vegetated swale filter bed will vary depending on the impervious surface draining to it and the depth of the soil media. Use the table, or the sizing calculation in the spreadsheet tool, to determine the required surface area. If needed, the surface area of any pre-treatment should be about 10% of the swale's surface area. Low-permeability soils do not rule out the use of vegetated swales, but you may need an underdrain.

The vegetated swale area must include an 18-36 inch deep planting soil bed, a surface vegetation or mulch layer, and a 6 inch deep surface ponding area.



Top: Rooftop runoff can flow directly into a vegetated swale, though you may need a splash pad or some stone to slow the water down. Bottom: Swales that are larger or treating runoff from areas with higher sediment loads need some pre-treatment (like this concrete inlet with stone-lined forebay) to settle out sediment and debris.

Design Table – Vegetated swale surface areas by size of contributing impervious area and planting media depth

Total impervious surface area (square feet)	Depth of Vegetated Swale Soil Mix (inches)			
	18	24	30	36
	Vegetated Swale Filter Bed Surface Area (square feet)			
100	8.3	7.2	6.3	5.7
500	40	35	30	25
1000	80	75	65	60
2000	165	145	125	115
3000	250	215	190	170
4000	335	290	250	225
5000	415	360	315	285
7500	625	540	475	425
10000	835	720	635	565

The planting soil should consist of sand or loamy sand and meet the following graduation: sand 85- 88%, silt 8-12%, clay 0-2%, and organic matter (in the form of compost) 3-5%. Whether you are planning turfgrass or vegetation, test your soil characteristics as you would for a garden, or contact the UVM Extension Service for help (http://www.uvm.edu/pss/ag_testing/).

A maximum ponding depth of 6 inches is allowed within the vegetated swale. Swales should generally drain within two days after a storm, which will not create a mosquito problem.

Vegetated swales should include at least 12" of freeboard above the maximum ponding depth, to allow for the safe passage of larger storm volumes.

The sides of the swale should be designed with side slopes of 3:1 (H:V) or flatter.

A pipe outlet structure with a grate (examples at the center of the photo above, and at the bottom of the photo at right) can be used to ensure a safe overflow for your vegetated swale.

The outlet from the downstream end of the vegetated swale should be non-eroding. If overflow from the swale does not flow into a downstream culvert (as may be the case if your swale is separating aisles in a parking lot), your outlet should consist of an inlet grate leading to a catch-basin or pipe, with the inlet set level with the maximum desired ponding elevation in the swale. The grate should be slanted or domed to prevent clogging by leaves and debris.

VEGETATION AND LANDSCAPING

Vegetation planted in vegetated swales can include trees, shrubs, and other herbaceous vegetation. If you are planning to mow the swale, it can be planted in turfgrass. When developing a planting plan, choose vegetation that will be able to stabilize soils and tolerate the stormwater runoff rates and volumes that will pass through the swale.

Native plant species are preferred over non-native species, though non-invasive cultivars can also provide the functions needed for a successful bioretention system.

Plantings should be able to tolerate both wet and dry conditions. See *The Vermont Rain Garden Manual* for plant lists and example planting plans. Volume 2, Appendix A of the *Vermont Stormwater Management Manual* also contains a list of plants that are appropriate for use in Vermont.

Recommended planting densities are as follows: One tree per 100 square feet (10 feet on-center) if trees are desired near the perimeter, one shrub per 25 square feet (5 feet on center), and one perennial or other herbaceous plant per 6 square feet (2.5 feet on center).

The vegetation may initially require watering to become well established. You may want to plant more densely than you would normally, to quickly obtain the benefits of soil stabilization and evapotranspiration.

MAINTENANCE

In the first year to two years of operation, watering, weeding and removal of invasive species, removal and replacement of dead plants, and spot re-seeding of bare or eroding areas are especially important for vegetated swale establishment.

Routine maintenance should include weeding, deadheading, replacing dead plants, and replenishing mulch when depleted. If your vegetated swale is planted in grass, it should be mowed to maintain grass heights in the 4-6 inch range.

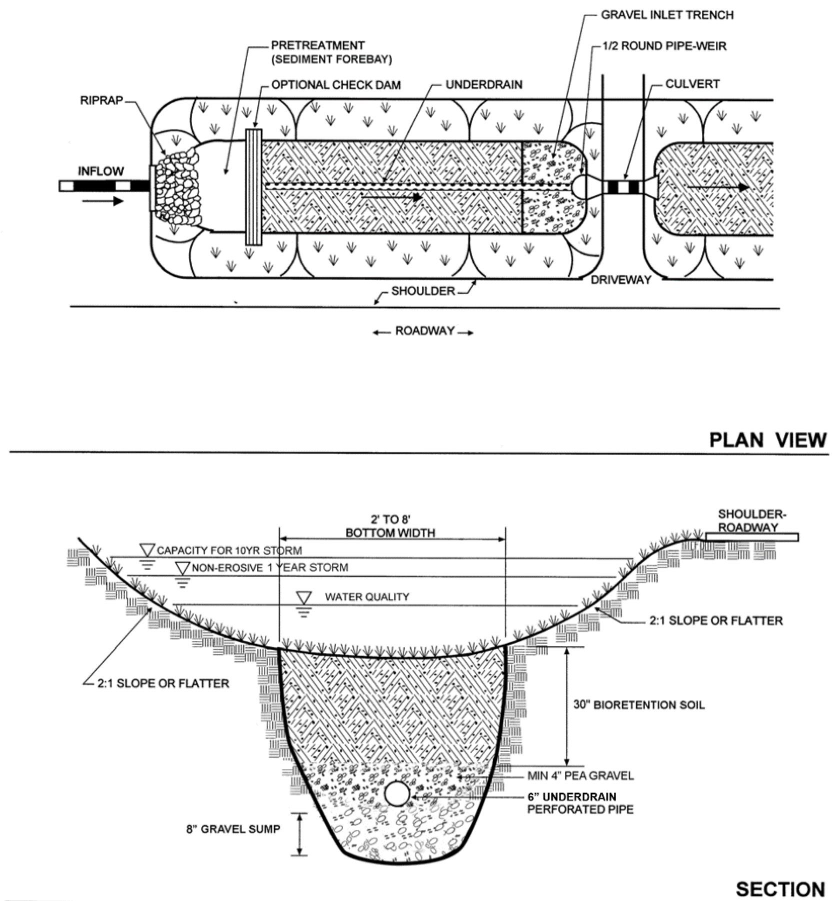
Build-ups of sediment, leaves, and debris should be removed from curb cuts, gravel diaphragms, forebays, check dams, and other pre-treatment devices annually, or whenever they prevent flow from reaching the vegetated swale filter area. Catching and quickly repairing areas of erosion in side slopes or channel bottoms is also important, as is correcting standing water problems.

If the surface of the swale becomes clogged to the point that standing water is observed on the surface more than 48 hours after precipitation events, the bottom should be rototilled or cultivated to break up any hard-packed sediment, and then reseeded or replanted.

If standing water persists, and raking the top layer or removing silt from the filter surface does not fix the problem, it may be necessary to place a perforated underdrain under the swale that daylights down-slope.

CONSTRUCTION STEPS:

1. Construction should only begin after installation of the contributing impervious surfaces has been completed. The vegetated swale will fail if large volumes of construction-related sediment flow into it. Ideally, the swale should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment. Where this is impractical, barriers should be installed at key check dam locations, erosion control fabric should be used to protect the channel, and excavation should stay at least 2 feet above the proposed bottom elevation of the vegetated swale, including any underdrain.
2. Locate swales where downspouts or runoff from parking lots or driveways can enter while flowing away from buildings and impervious surfaces. Locate at least 5-10 feet from foundations, away from buried utilities, not over septic system components, and not near the edge of a steep slope.
3. Measure the impervious area draining to the planned swale and determine the required dimensions and surface area from the table on the next page, based on your planned ponding depth and excavation depth. The bottom of the swale can't be wider than 8 feet.
4. Perform infiltration test according to directions in the Appendix. If the rate is less than 0.5 inches per hour, you will need an underdrain.
5. Measure elevations and stake out the vegetated swale area dimensions and any needed pre-treatment. Ensure that positive flow will be maintained into the swale, the overflow elevation allows for 6 inches of ponding, and that the outer edge of the swale is at least 12" higher than the maximum ponding elevation at the down-slope overflow point.



Adapted from MDE, 2000 and RI DEM, 2010

TYPICAL COMPONENTS

6. Pre-treatment cells should be excavated first to trap sediments before they reach the filter beds.
7. Excavation work should be completed from the sides, to excavate the vegetated swale area and side-slopes to its appropriate design depth and dimensions. Excavating equipment should never sit inside the footprint of the dry swale. Level bottom of swale as much as possible to maximize infiltration area.
8. If an underdrain is needed, place at least 3 inches of #57 stone on the bottom, install the perforated underdrain pipe (6" diameter Schedule 40 perforated PVC pipe), pack #57 stone to 3 inches above the underdrain pipe, and add approximately 3 inches of choker stone as a filter between the underdrain and the soil media layer. If your vegetated swale's overflow outlet structure is an inlet grate leading to a catch-basin or pipe, the outlet structure should also be installed at this stage.
9. Mix sand, topsoil, and compost together to make the 'bioretention soil mix'. The soil mix should be mostly sand (85- 88%) with a little silt (8-12%), clay (0-2%), and organic matter in the form of compost (3-5%).
10. Install the soil media in 12-inch lifts until the desired top elevation of the swale filter is reached. The soil media can be compacted by saturating it with water, or the depth of soil media can be increased by 10% to allow for settling. The surface of the filter bed should be as smooth as possible.
11. Install driveway culverts, internal pre-treatment features, or check dams (if needed), and build inlet features as appropriate for your application. Examples include a rock lined swale with a gentle slope a manufactured pre-treatment device like a Rain Guardian, or a gravel diaphragm at the edge of a parking lot.
12. Prepare planting holes for any trees or shrubs, and plant the woody vegetation. Plant the rest of the swale using a selection of herbaceous plants. Alternately, the swale surface may be seeded with turfgrass. Sod is not recommended in vegetated swales.
13. Place the surface cover in the swale area (mulch, river stone or turf), depending on the design.
14. Water all plants, turfgrass, etc. thoroughly. Watering will likely be needed, especially during the first growing season.

SKETCH LAYOUT

PROVIDE PLAN AND ELEVATION VIEWS OF VEGETATED SWALE AND STRUCTURE OR GROUND-LEVEL IMPERVIOUS COVER, SHOWING DRAINAGE AREAS DIRECTED TO SWALE, KEY DIMENSIONS AND CONNECTIONS, AND OVERFLOW

SIZING CALCULATION:

Total impervious surface area (square feet)	Depth of Bioretention Soil Mix (inches)			
	18	24	30	36
	Bioretention Filter Bed Surface Area (square feet)			
100	8.3	7.2	6.3	5.7
500	40	35	30	25
1000	80	75	65	60
2000	165	145	125	115
3000	250	215	190	170
4000	335	290	250	225
5000	415	360	315	285
7500	625	540	475	425
10000	835	720	635	565

MEASURE CONTRIBUTING IMPERVIOUS AREA, AND READ AREA FOR GIVEN MEDIA DEPTH. THE CALCULATOR CAN ALSO BE USED TO ADJUST MEDIA DEPTH AND INFILTRATION RATE.

CONTRIBUTING IMPERVIOUS AREA: __________ SQ. FT. (MAX. 10,000)

Infiltration rate: __________________inches / hour (min. 0.5)

Depth of soil media: _______________inches (24-36)

Ponding depth: 6 inches

Vegetated Swale Bottom Area (not counting sides): ___________ sq. ft.

MAINTENANCE:

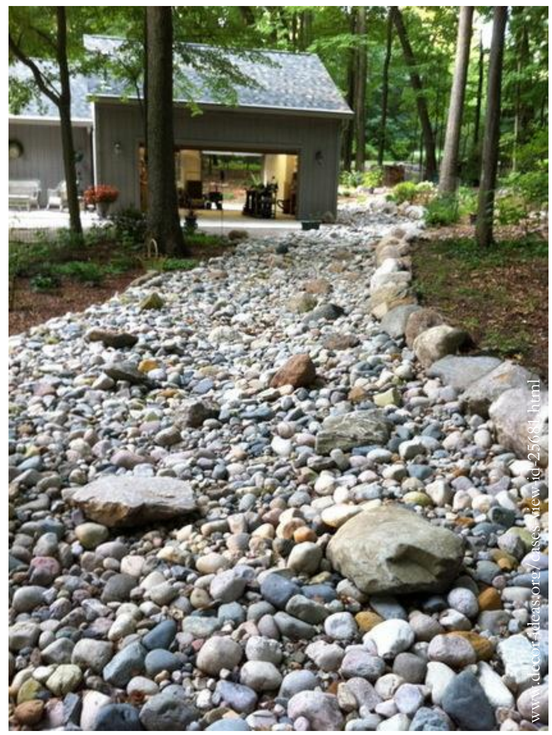
1. Irrigate vegetation as needed, especially in the first season.
2. Remove weeds and invasive species.
3. Remove and replace unsuccessful plantings.
4. Replenish mulch if used.
5. Stabilize eroded areas and re-seed or replant.
6. Remove sediment and debris from curb cuts, forebays, or other pre-treatment annually or when flow to swale is blocked.
7. Rake clogged surface or remove silt from surface to restore infiltration.
8. Monitor for appropriate drainage; if swale does not drain an underdrain may be necessary.

VERMONT GREEN STORMWATER INFRASTRUCTURE (GSI) SIMPLIFIED SIZING TOOL FOR SMALL PROJECTS

Fact Sheet No. 10: Infiltration Trench

October, 2015

Stormwater infiltration trenches are shallow excavations filled with stone that are designed for the express purpose of allowing runoff to infiltrate into the soil. Infiltration practices can provide significant stormwater volume reductions and pollutant treatment, and are especially well-suited to manage rooftop runoff where soils are well-drained. This practice is not appropriate in areas with poorly drained soils or shallow groundwater.



Infiltration trenches can be a practically invisible part of a lawn, or they can be topped with decorative stone as a landscape element.

LOCATION

Infiltration trenches should be located at least 5 feet from building foundations, and 10 feet from buildings with basements. The top end of the infiltration trench can be near a structure to connect to a downspout, but it should be directed away from the structure.

The overall slope of the infiltration trench pipe should be between 0.5% and 6%, and it must slope away from the structure. It can be multi-pronged in construction, as long as the laterals are run parallel to the ground contours and the bottom of each trench excavation is flat. Infiltration practices cannot be located on areas with natural slopes greater than 15%.

Infiltration trenches should be located in a lawn or other pervious (unpaved) area and designed so that the top of the trench is located as close to the ground surface as possible. They should not be hydraulically connected to structure foundations or pavement to avoid seepage and frost heaving concerns.

Infiltration trenches should not be located beneath any paved or otherwise impervious surface, above an area with a water table or bedrock less than two feet below the trench bottom, over utility lines, or above any septic system components.

To use this practice, your soil infiltration needs to be 0.50 inches per hour (in/hr) or greater. It is highly recommended that you complete an infiltration test as shown in Appendix A.

The impervious area draining to any one infiltration trench cannot exceed 10,000 square feet.

DESIGN AND SIZING

To reduce the chance of clogging, infiltration trenches should only be used to treat water from rooftops. The runoff should be pre-treated with at least one device designed to remove leaves, debris, and larger particles (see spec sheet).

Infiltration trench gravel depths should be at least 18 inches and no more than 36 inches. The total excavation depth should leave at least 4-6 inches between the top of the gravel and the ground surface.

As a general rule, about 18 cubic feet of stone will be needed to provide adequate storage volume for runoff from 100 square feet of rooftop area. The design table below provides the total trench length required for different gravel depths, assuming a trench width of 24 inches and a soil infiltration rate of 0.5 inches/hour. The calculator tool can be used to adjust the trench width and the soil infiltration rate. Required lengths can then be adjusted proportionately.

Design Table – Infiltration trench length by size of contributing rooftop area and aggregate depth

Total contributing rooftop area (square feet)	Depth of Gravel In Trench (inches)			
	18	24	30	36
	Required Linear Feet of Trench (feet)			
100	7	5	4	4
500	35	30	25	20
1000	70	55	45	35
2000	135	105	85	75
3000	205	160	130	110
4000	275	215	175	150
5000	340	265	220	185
7500	515	400	325	275
10000	685	535	435	370

The bottom of the stone reservoir in the trench should be flat, so that runoff will be able to infiltrate through the entire surface.

The sides of infiltration trenches (but not the bottoms!) should be lined with filter fabric to prevent soil piping. The sides of the excavation should be trimmed of roots to ease filter fabric installation.

The gravel aggregate used to fill the infiltration trench should be clean, washed #57 stone (this stone should average ½ inch to 1 ½ inches in diameter). There should be very few stones smaller than this size in the mix, and the gravel should not look dusty or contain any fines.

A 6-inch diameter perforated PVC pipe should be embedded in the top of the aggregate, such that the stone covers the top of the pipe. The pipe should have 3/8-inch holes spaced 6 inches on center, and have a minimum slope of 0.5% to ensure positive flow away from the structure.

The perforated pipe should daylight at the down-slope end of the trench, allowing for safe passage of larger storms. An overflow area, like a filter strip or grass channel, should be used to convey the runoff from larger storm events safely out of the downstream end of the trench.

The aggregate and perforated pipe should be covered with permeable landscape fabric to keep soil or pea gravel from working into the gravel trench and filling the pore spaces. The trench can be covered with topsoil and grass, or with pea gravel or other decorative stone.

Vegetation and Landscaping

Infiltration trenches can be covered with topsoil and managed turf, or with native or non-invasive herbaceous vegetation. Woody plantings are discouraged, as the roots may eventually interfere with the function of the perforated pipe.

The area above the surface of an infiltration trench can also be covered with pea gravel (or larger-diameter river stone or other decorative stone) to allow for incidental lateral inflow along the edge of ground level impervious surfaces—for instance, along the edge of a patio or sidewalk.

The down-slope outlet of the perforated pipe must be stabilized, and can also be made into an attractive landscape element.

Maintenance

Inspect gutters/downspouts in the spring and after leaves drop in the fall. Remove any accumulated leaves and debris and clean leaf removal systems.

Check the infiltration trench following large rainfall events to insure pre-treatment is not clogged, and that the overflow is operating and flow is not causing problems.

Mow or trim vegetation as needed.

If water fails to infiltrate 48 hours after the end of the storm as observed at the downstream pipe outlet, the pipe and gravel may need to be replaced.

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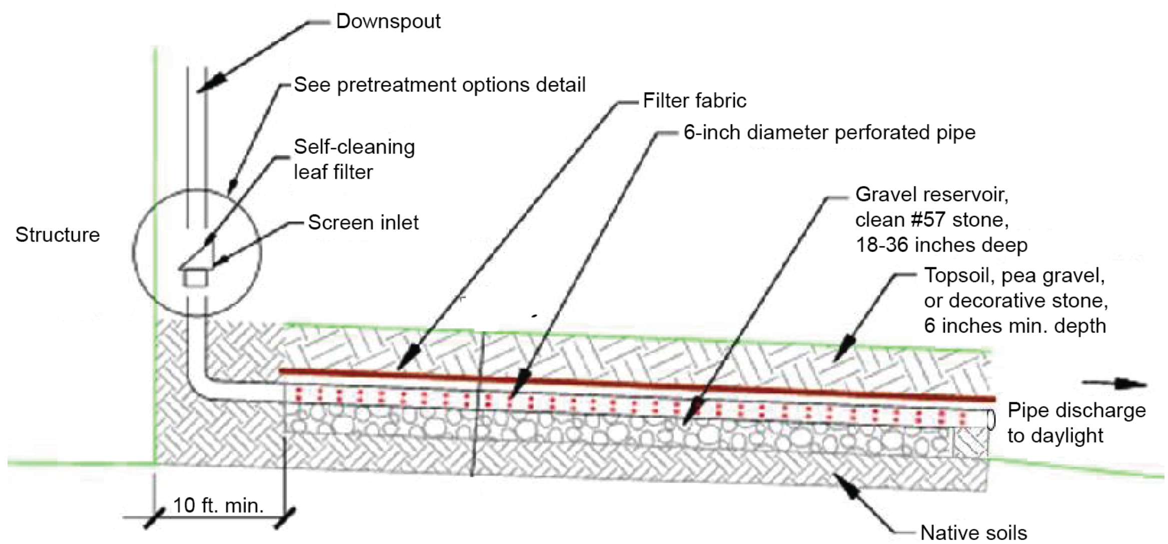
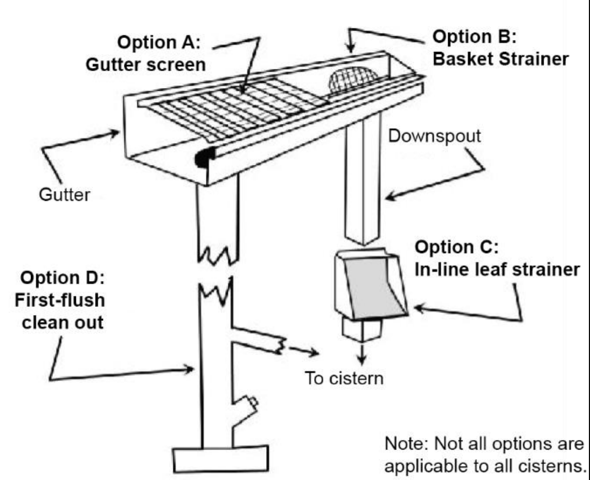


TYPICAL COMPONENTS

CONSTRUCTION STEPS:

1. Lay out the potential infiltration trench area on your plan. The trench or trenches should slope between 0.5% and 6% away from the structure and should not be located beneath any paved or otherwise impervious surface, above an area with a water table or bedrock less than two feet below the trench bottom, over utility lines, or above any septic system components.
2. Measure the rooftop area draining to the infiltration trench.
3. Perform an infiltration test in the area planned for the infiltration trench according to the instructions in Appendix A. If the rate is less than 0.5 in/hr, this method cannot be used. If the infiltration rate is more than 0.5 in/hr, the length of the trench may be adjusted using the calculator.
4. Determine required trench length from the table on the next page using assumed width, gravel depth, and infiltration rate—or use the calculator to adjust trench dimensions based on site conditions.
5. Measure elevations and lay out the infiltration trench to the required dimensions, marking the route and required excavation depths. The location of the infiltration practice must be marked off before the start of construction, in order to prevent compaction of the infiltration area.
6. Remove sod (if lawn is already established in the trench area). Excavate trench to the depth of the gravel, plus six inches for topsoil/pea gravel and three additional inches to accommodate half the pipe depth. Do not compact soils in the bottom of the excavation. Level the trench bottom to maximize infiltration area, then roughen the bottom (scarify or till) to a depth of at least 3-4 inches and trim any tree roots.
7. Place non-woven filter fabric (Mirafi 180n or similar) between the trench side walls and the aggregate stone reservoir. Use a filter fabric width that is wide enough to cover trench perimeter irregularities and overlaps back onto the ground surface at least 6 inches. Stones or other anchoring objects can be placed on fabric at edge of trench to secure it temporarily.
8. Place gravel in the trench in 12-inch lifts, and tamp it firmly to settle. Place the perforated pipe in the center of the trench, three inches deep in the upper portion of the gravel. Place and gently tamp additional gravel until it covers the pipe.
9. Fold the filter fabric over the top of the pipe and aggregate. If filter fabric does not completely cover the aggregate, use another thickness of fabric on top to ensure that smaller stone or soil do not clog trench.
10. Place topsoil and sod/seed, pea gravel, or other decorative stone to the same elevation as the surrounding ground surface.
11. Route downspouts or other runoff delivery components, and install at least one leaf screening device (see options in the Pretreatment Options Detail figure).
12. Create a safe overflow at the downstream end of the perforated pipe and ensure it is protected from erosion.

CIRCLE ONE OR MORE OPTIONS USED: A B C D



PRETREATMENT OPTIONS DETAILS

GREEN STORMWATER INFRASTRUCTURE SIMPLIFIED SIZING TOOL FOR SMALL PROJECTS	**NAME/ADDRESS:**	**INFILTRATION TRENCH SPECIFICATIONS PAGE 1 OF 2**

Sketch Layout

Provide plan and elevation views of infiltration trench and structure, showing rooftop areas directed to infiltration trench, key dimensions and connections, and overflow

Sizing Calculation:

Total contributing rooftop area (square feet)	Depth of Gravel In Trench (inches)			
	18	24	30	36
	Required Linear Feet of Trench (feet)			
100	7	5	4	4
500	35	30	25	20
1000	70	55	45	35
2000	135	105	85	75
3000	205	160	130	110
4000	275	215	175	150
5000	340	265	220	185
7500	515	400	325	275
10000	685	535	435	370

Measure rooftop area, and read trench length area for given gravel depth, assuming 0.5 in/hr infiltration rate and 24-inch-wide trench. Use calculator to adjust gravel depth and infiltration rate.

Contributing rooftop area: ____________ sq. ft. (max. 10,000)

Infiltration rate: _______________inches / hour (min. 0.5)

Depth of gravel in trench: ____________inches (18-36)

Total length of trenches: _____________ feet

Maintenance:

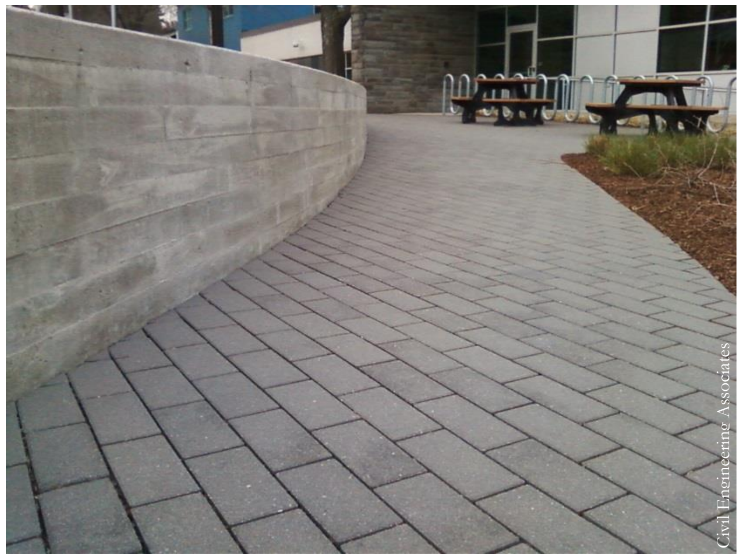
1. Inspect gutters/downspouts in the spring and after leaves drop in the fall. Remove any accumulated leaves and debris and clean leaf removal systems.
2. Check the infiltration trench following large rainfall events to insure pre-treatment is not clogged, and that the overflow is operating and flow is not causing problems.
3. Mow or trim vegetation as needed.
4. If water fails to infiltrate 48 hours after the end of the storm as observed at the downstream pipe outlet, the pipe and gravel may need to be replaced.

VERMONT GREEN STORMWATER INFRASTRUCTURE (GSI) SIMPLIFIED SIZING TOOL FOR SMALL PROJECTS

Fact Sheet No. 11: Permeable Pavers

October, 2015

Permeable pavers are an alternative to impervious asphalt, concrete, or gravel paving surfaces that decrease stormwater runoff. They are best suited to areas of low traffic, such as residential driveways, parking spaces, alleys, sidewalks, bike paths, courtyards, and residential streets. These systems consist of permeable interlocking or grid concrete pavers underlain by a gravel drainage layer. Permeable paver systems allow stormwater runoff to flow between pavers and into a stone reservoir, where it is stored and allowed to infiltrate into the underlying soils. Permeable pavers can provide substantial reductions in stormwater runoff volumes and pollutant loads.



Permeable concrete pavers line a walkway at Dealer.com in Burlington.

LOCATION

Permeable pavers should not be used to collect or treat runoff from other pervious or impervious areas. Drainage from other areas onto the pavers will eventually clog them.

Permeable pavers should not be located above an area with a water table or bedrock less than two feet below the gravel bottom, over utility lines, or above any septic system components.

The soil infiltration rate suitable for a paver system is 0.5 inches per hour (in/hr) or greater. An infiltration test should be completed using the instructions provided in Appendix A. If the rate is less than 0.5 in/hr, an underdrain leading to daylight should be provided—and professional assistance should be obtained.

Permeable paver systems should be installed on slopes less than 5% to insure even distribution of runoff over the infiltration surface, and the paver system should slope away from structures. The bottom of the reservoir course should be designed to be close to 0% slope as possible; terrace the bottom layers as necessary to maintain a maximum slope of 0.5% whenever possible.

Careful consideration should be used before installing permeable pavers on parking lots or other areas where road sanding is expected in the winter, as this can quickly cause the system to clog and fail.

Design and Sizing

Permeable paver systems include several different layers, all of which are necessary for the system's good functioning and long lifespan. Manufacturer's instructions, if they exist, should be followed in addition to these guidelines.

The top course consists of the pavers and a crushed aggregate material swept between the paver joints, such as #8 stone or 1/8" to 3/8" pea gravel. The thickness of this layer varies depending upon the depth of the pavers.

Under the pavers is a bedding course, which consists of 2 to 3 inches of #8 stone or 1/8" to 3/8" pea gravel. The bedding course provides a level bed for setting the pavers evenly.

Under the bedding course is base course or reservoir layer that consists of #57 stone, a minimum of 6 inches. The base course acts as a reservoir to provide stormwater storage capacity and must be compacted. The depth of this layer should be at least 6 inches, with greater gravel depths, if desired, to store runoff from heavy storms for infiltration into soils with finer textures and slower infiltration rates.

The subgrade layer is the layer of native soils below the reservoir layer. The subgrade soil layer should be prepared by scarifying or tilling to a depth of 3 to 4 inches. The subgrade should be as close to flat as possible; and can be terraced as necessary to maintain a maximum slope of 0.5% or less.

A permeable drainage fabric can be used to separate the permeable paver materials from the sides of the excavation. This ensures that side wall contamination of the courses does not occur, and prevents collapse of the sides from soil migrating into the reservoir course and undermining an adjacent sidewalk or slope.

The calculator can be used to determine the reservoir gravel and bedding course gravel volumes that will be needed to construct the paver system.

Vegetation and Landscaping

Areas such as lawns and landscaping near permeable paver systems must not have any areas of bare soil, especially where runoff from nearby landscaping might run on to the permeable paver surface during heavy rains.

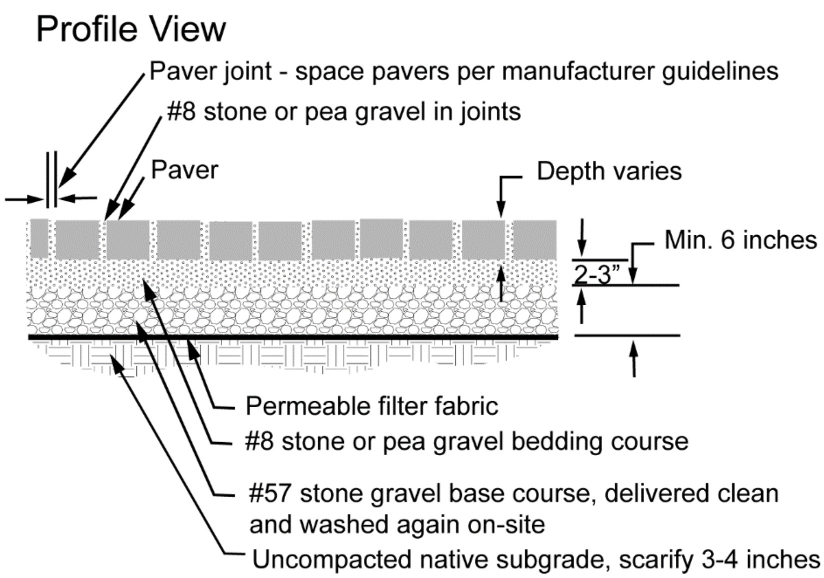
Trees that have the potential to shed leaf litter should not be planted immediately next to permeable pavers, and mature tree drip lines should not overhang permeable pavement surfaces.

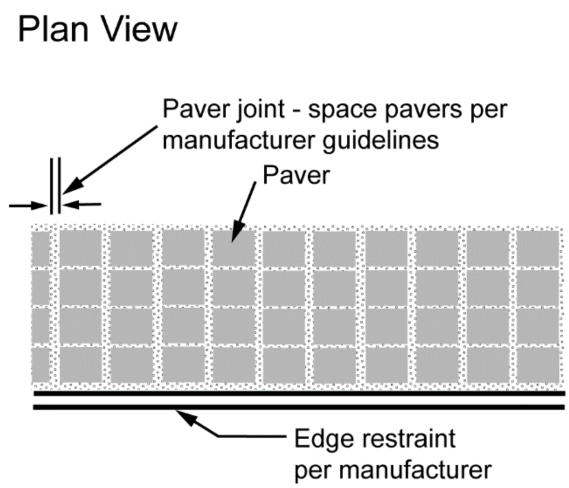
Paver systems planted with grass need mowing, and often need reseeding of bare areas.

Maintenance

Maintenance is very important for permeable paver systems, to prevent clogging and ensure that they continue to perform well and provide stormwater management benefits over time.

- Remove accumulated sediment and debris from joint space monthly.
- Observe the permeable paver system for excessive ponding during storm events and repair as needed.
- Vacuum or hose the permeable paver surface quarterly (or as recommended by paver manufacturer) to keep the surface from clogging. New pea gravel or #8 stone should be swept into the spaces between pavers as needed.
- Minimize the use of salt in winter months. Do not use road sand for de-icing or traction. Attach rollers to the bottoms of snowplows to prevent them from catching on the edges of pavers.
- Inspect permeable paver surface for deterioration annually. Repair or replace any damaged areas as needed.
- Keep adjacent landscape areas well maintained and stabilized (any bare areas quickly re-planted).





TYPICAL COMPONENTS (ATTACH MANUFACTURER'S SPECIFICATIONS)

CONSTRUCTION STEPS:

1. Review potential permeable paver areas and layout. Pavers should slope 5% or less away from structures and should not be located above an area with a water table or bedrock less than two feet below the gravel bottom, over utility lines, or above any septic system components.
2. Perform infiltration test according to Appendix A. If the rate is less than 0.5 in/hr this method cannot be used.
3. Measure the permeable paver area and determine volumes of bedding stone and reservoir gravel needed for construction using the calculator.
4. Protect native soils where permeable pavers are to be installed from compaction during construction. Use temporary erosion and sedimentation controls during construction of the permeable paver areas to divert stormwater away from the area. Do not start construction of permeable pavers until the surrounding area is well-stabilized with grass or other robust vegetation.
5. Excavate permeable paver area to appropriate depth and scarify soil to 3-4". Make sure this bottom surface is as flat as possible. Terrace the bottom if needed to maintain a slope of 0.5% or less.
6. Place non-woven filter fabric (Mirafi 180n or similar) between the excavation side walls and the aggregate stone reservoir. Use a filter fabric width that is wide enough to cover perimeter irregularities and overlaps back onto the ground surface at least 6 inches. Stones or other anchoring objects can be placed on the fabric at the edge of the excavation to secure it temporarily.
7. Place, level and compact gravel to planned depth in no more than 6-inch lifts (six inch minimum depth). Make sure the stone storage layer is properly compacted, improper compaction can result in poor infiltration and early failure of the paver system.
8. Place, level and compact #8 stone or pea gravel bedding layer. Three inch minimum depth (or as specified by manufacturer).
9. Lay pavers one at a time or using mechanical placement, as applicable. Cut pavers at edges to fit.
10. Install edge restraints per manufacturer's specifications.
11. Sweep more #8 stone or pea gravel into stone joints until filled and even.

SKETCH LAYOUT

PROVIDE PLAN AND VIEW OF PERMEABLE PAVERS, SHOWING NEARBY PERVIOUS AND IMPERVIOUS AREAS, AND KEY DIMENSIONS AND CONNECTIONS. ATTACH MANUFACTURER'S SPECIFICATIONS.

SIZING CALCULATION:

THERE IS NO DESIGN TABLE FOR THIS PRACTICE.

USE CALCULATOR TO ADJUST GRAVEL RESERVOIR DEPTH AND INFILTRATION RATE, AND CALCULATE MATERIAL VOLUMES FOR INSTALLATION.

PERMEABLE PAVER AREA: ________________SQ. FT. (MAXIMUM 10,000 SQ. FT.)

SLOPE OF PERMEABLE PAVER AREA:____________% (MAXIMUM 5%)

INFILTRATION RATE: _______________ INCHES/HOUR (MINIMUM 0.5 INCHES/HOUR)

BEDDING COURSE DEPTH: _______________INCHES (MINIMUM 2-3 INCHES OR PER MANUFACTURER'S INSTRUCTIONS)

RESERVOIR COURSE GRAVEL DEPTH: ____________INCHES (MINIMUM 6 INCHES)

MAINTENANCE:

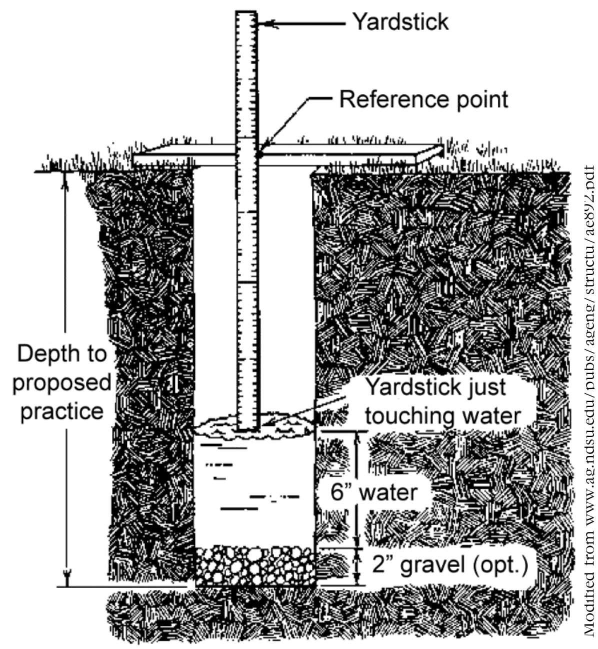
1. Remove accumulated sediment and debris from joint space monthly.
2. Observe the permeable paver system for excessive ponding during storm events and repair as needed.
3. Vacuum or hose the permeable paver surface quarterly (or as recommended by paver manufacturer) to keep the surface from clogging. New pea gravel or #8 stone should be swept into the spaces between pavers as needed.
4. Minimize the use of salt in winter months. Do not use road sand for de-icing or traction. Attach rollers to the bottoms of snowplows to prevent them from catching on the edges of pavers.
5. Inspect permeable paver surface for deterioration annually. Repair or replace any damaged areas as needed.
6. Keep adjacent landscape areas well maintained and stabilized (any bare areas quickly re-planted).

VERMONT GREEN STORMWATER INFRASTRUCTURE (GSI) SIMPLIFIED SIZING TOOL FOR SMALL PROJECTS

Appendix: Simple Infiltration Test

October, 2015

It is assumed that an infiltration rate of at least 0.25 to 0.50 inches per hour exists on sites where infiltration-based practices will be applied using these guidelines. The sizing recommendations in the fact sheets for infiltration-based practices are based on this rate. However, if the soils have a higher infiltration rate, the size of some of the practices could be reduced. The following infiltration test can be conducted, and if it returns a higher infiltration rate than 0.50 inches per hour, reductions in the size of the infiltration-based facilities may be made. See each practice or the calculator for the adjustment procedure.



Infiltration features (rain gardens, bioswales, dry wells, and permeable paver gravel layers) should reliably drain within the recommended time limit. Here is how to test if your soils can handle this type of feature.

1. Locate the approximate center of the area where you expect to build your feature.
2. Dig an access pit down to the bottom of the amended soils or gravel layer in the feature.
3. At that elevation dig a narrow test hole at least eight inches deep. You can optionally place 2” of course gravel in the bottom. The test hole can be excavated with small excavation equipment or by hand using a spade shovel or post-hole digger.
4. If you run into a hard layer that cannot be penetrated with a shovel or, you come across water in the whole, stop. Infiltration features should not be sited over impenetrable rock surfaces or over high water tables, so your site is inappropriate.
5. Place a flat board across the hole to serve as a measuring point (see figure).
6. Fill the hole with water to a depth of six inches. Measure from the flat board to the water surface. Record the exact time you stop filling the hole and the height of the water every 10 minutes for fast draining soils for a minimum of one hour or every 30 minutes for slow draining soils for a minimum of two hours.
7. Refill the hole again and repeat step 5 twice more. The third test will give you the best measure of how quickly your soil absorbs water when it is fully saturated.
8. If on the third test, the water level is dropping at least ½” per hour, the soil will work for the infiltration features.