

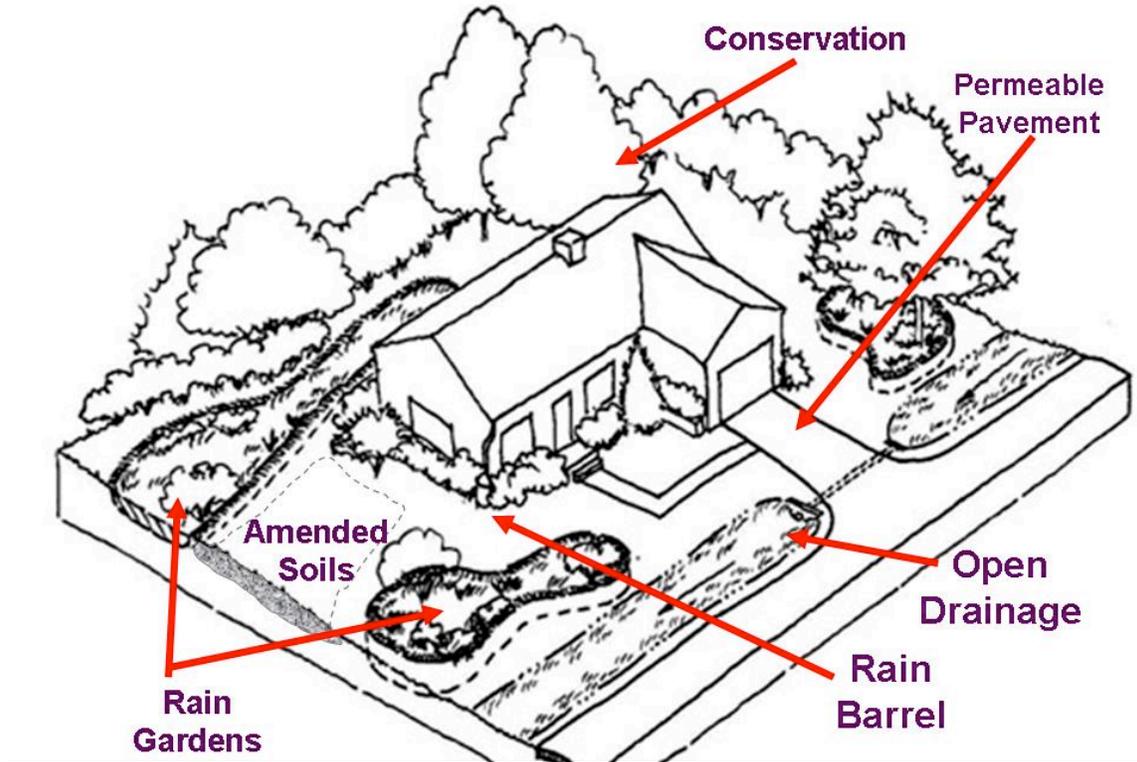
Stormwater BMP Guide For Single Family Homes

These practices are necessary to satisfy the water quantity and water quality criteria of the Rappahannock County Stormwater Management Ordinance. These practices maintain dispersed flows and prevent environmental damage due to erosion and increased runoff from development. These practices may be used for in-lieu-of agreements or residential site plan submissions.

The practices listed here are not comprehensive, and alternative practices may be appropriate for the site. Consult the Virginia Stormwater BMP Clearinghouse or the County for additional design options.

<http://vwrrc.vt.edu/swc/StandardsSpecs.html>

Figure 1: Typical House Lot Layout



House lot practices:

- ❖ 1.1 Rooftop Disconnection
- ❖ 1.2 Mulched Landscape Beds
- ❖ 1.3 Rainwater Harvesting System
- ❖ 1.4 Rain Garden
- ❖ 1.5 Dry Well
- ❖ 1.6 Infiltration Trench
- ❖ 1.7 Grass Channel
- ❖ 1.8 Sheet Flow to Conservation Area

Instructions:

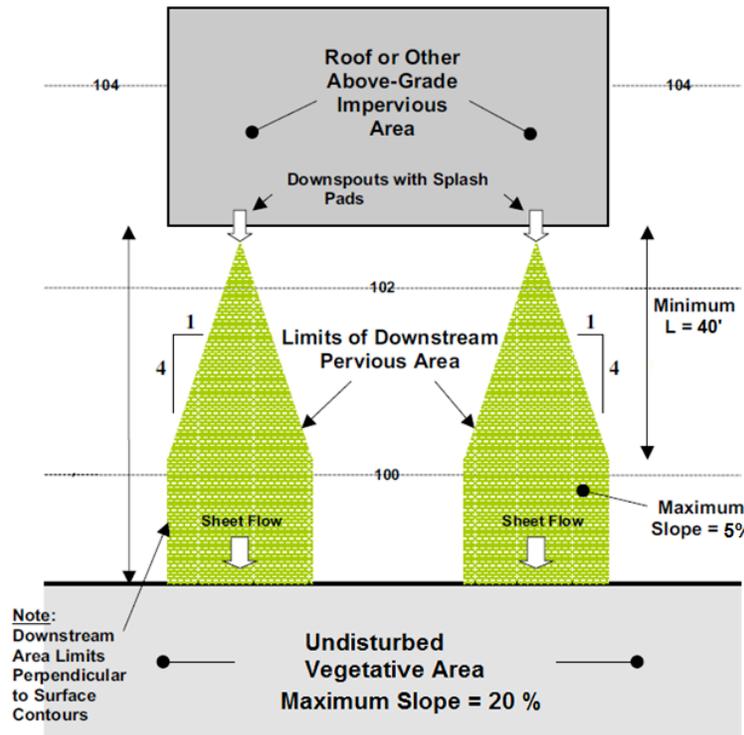
Choose one or more BMP to treat each square-foot of impervious surface associated with a single family home. Maintenance agreement is to be submitted for each permanent structure (e.g. 1.3, 1.4, 1.5, 1.6, and 1.7).

Example:

Typical 2,800 square foot home on a site with slopes from 2-10 percent; given the site constraints a combination of BMPs are used.

- | | |
|--|-----------------------|
| • Simple Rooftop Disconnection (1.1) | 1,000 sq. ft. of roof |
| • 2,000 sq. ft. of Mulched Landscaping (1.2) | 400 sq. ft. of roof |
| • 250 gallon Cistern (1.3) | 400 sq. ft. of roof |
| • 25 sq. ft. Rain Garden (1.4) | 500 sq. ft. roof |
| • 25 sq. ft. Dry Well (1.5) 4 feet deep | 500 sq. ft. roof |

1.1 Rooftop Disconnection



Description: Rooftop disconnection (RD) is one of the simplest means of reducing stormwater from residential lots. RD takes roof runoff that has been collected in gutters and piped directly to storm drains and streams, and redirects it away from impervious surfaces to landscaped areas.

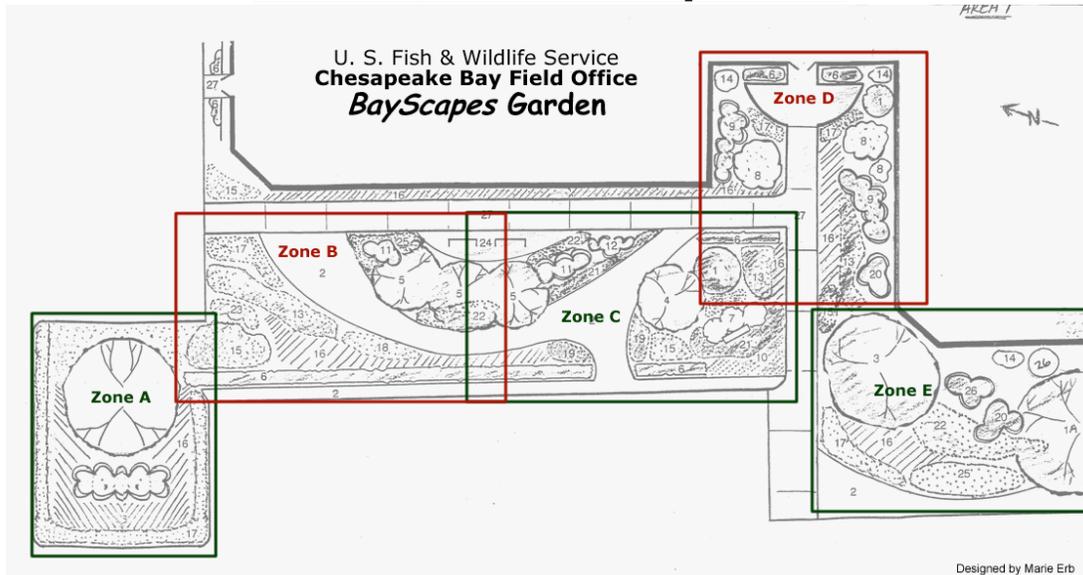
Limitations: Slope, Flow Length and the location of other structures.

Material Specifications: BMP Clearinghouse #1; VESCH 3.18, 3.32, and 3.36

Design Standard:

- Maximum roof area per downspout is 1,000 square feet
- Must discharge to a well-vegetated area that is at least 40 feet long with a slope less than 5 percent
- If flow length is less than 40 feet or slope is greater than 5 percent, an alternative practice is preferred (e.g. Rain Garden, Dry Well, etc.)
- Slopes less than 2 percent should be seeded and mulched in accordance with VESCH 3.32 and 3.30.
- Slopes greater than 2 percent shall be stabilized with temporary matting in accordance with VESCH 3.36.
- Install splash block or gravel apron at end of downspout to aid in dispersion. Extend the downspout at least 5 feet from building foundation if the grade is less than 1 percent.

1.2 Mulched Landscape Beds



Description: Use of native plants with a wood mulch groundcover that reduces the time and expense of mowing, watering, fertilizing, and treating lawn and garden areas. Landscape beds can address areas with existing problems such as erosion, poor soils, steep slopes and poor drainage.

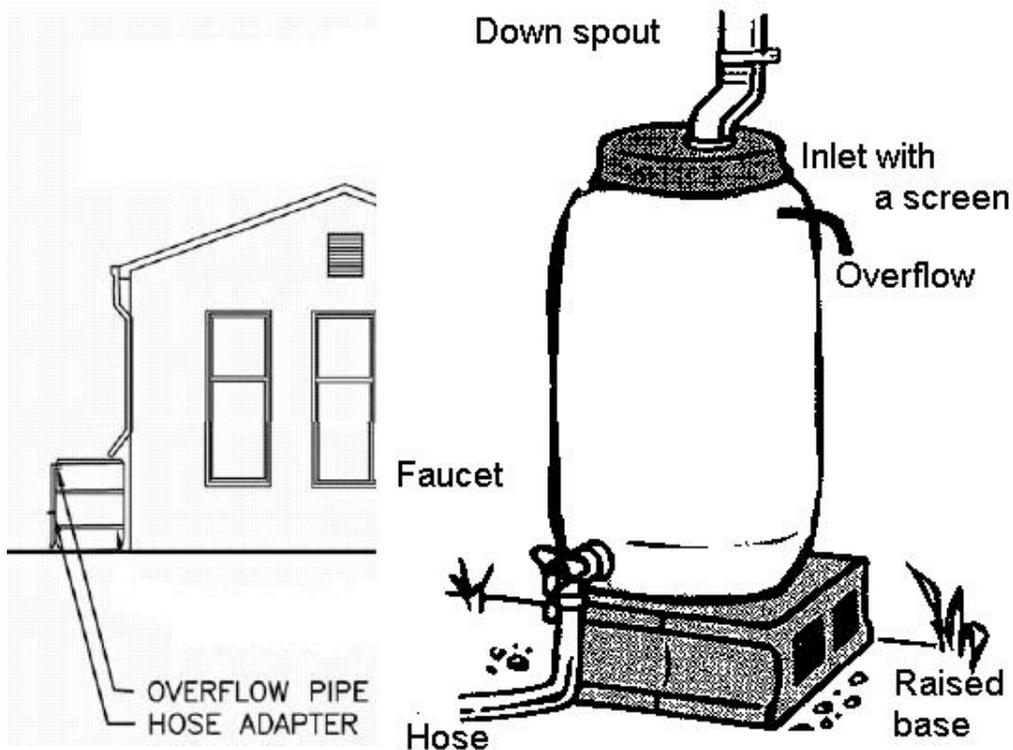
Limitations: Slope, foundation depth

Material Specifications: 4-inches Double Shredded Mulch; 3-year Weed Barrier; Plants: Plugs, Container, and/or Burlap stocks

Design Standards:

- Minimum size shall be 5 times the treated roof area
- Landscaping shall be contiguous wood mulch cover with a mixture of trees, shrubs and perennials.
- Shall be located in areas that were disturbed, have existing turf lawns or existing tilled garden areas. May be installed as a transitional area between managed lawn and undisturbed forest.
- All vegetation shall be native as defined by the Virginia Natural Heritage. http://www.dcr.virginia.gov/natural_heritage/nativeplants.shtml
- All vegetation should be planted in the appropriate season, and at the proper spacing and density to survive the first two growing seasons.
- Wood mulch and/or weed barrier shall be used until vegetation is fully established. Weed barrier or herbicides shall be used when planted on existing turf lawns.
- Shall not conflict with any applicable local, state or federal permits such as building, VDOT entrances, or zoning.

1.3 Rainwater Harvesting System



Description: Rainwater harvesting systems intercept, divert, store, and release rainfall for future use.

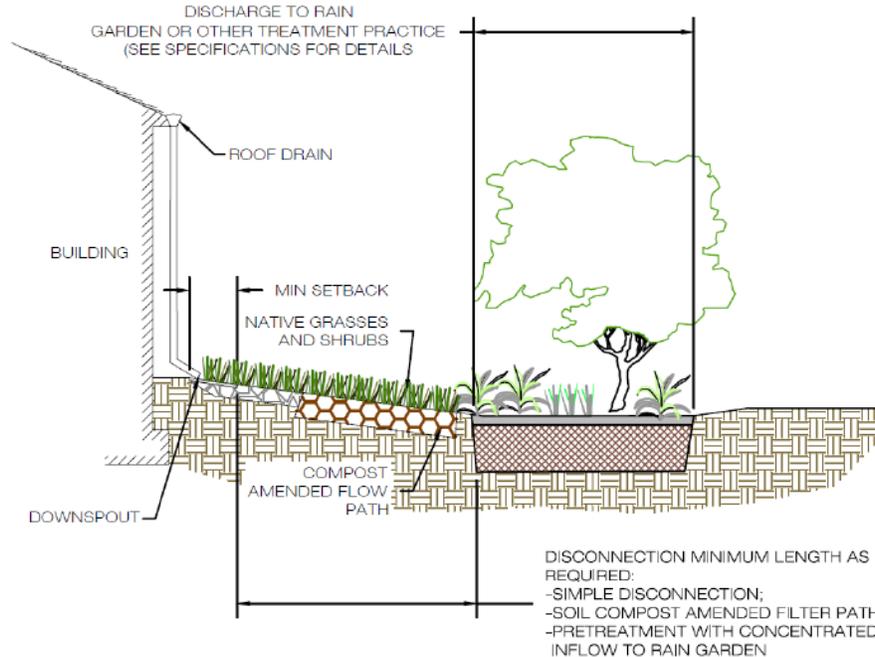
Limitations: Elevation and Storage capacity

Material Specifications: BMP Clearinghouse #5; Va. Rainwater Harvesting Manual

Design Standards:

- Minimum size shall be 250 gallons per 400 square feet of rooftop.
- Cisterns must be installed in accordance with manufacturer specifications.
- Above ground systems shall be elevated at least 2 feet for gravity flow.
- Provide a filter or diverter box on the downspout to aid in reducing debris within the cistern.
- Provide an adequate overflow. Ensure that the overflow will not scour the foundation of the structure or erode the adjacent yard. A splash block or routing the overflow hose into another practice can reduce the flow velocity.
- All applicable federal, state and local permits must be obtained prior to constructions. Local Building Officials and Health Department Officials should be consulted prior to installation of rainwater harvesting systems designed for indoor uses. The cistern shall be sized to meet at least the 5-day water demand.

1.4 Rain Garden



Description: The use of a graded or natural depression that can be improved with soil amendments and native plants.

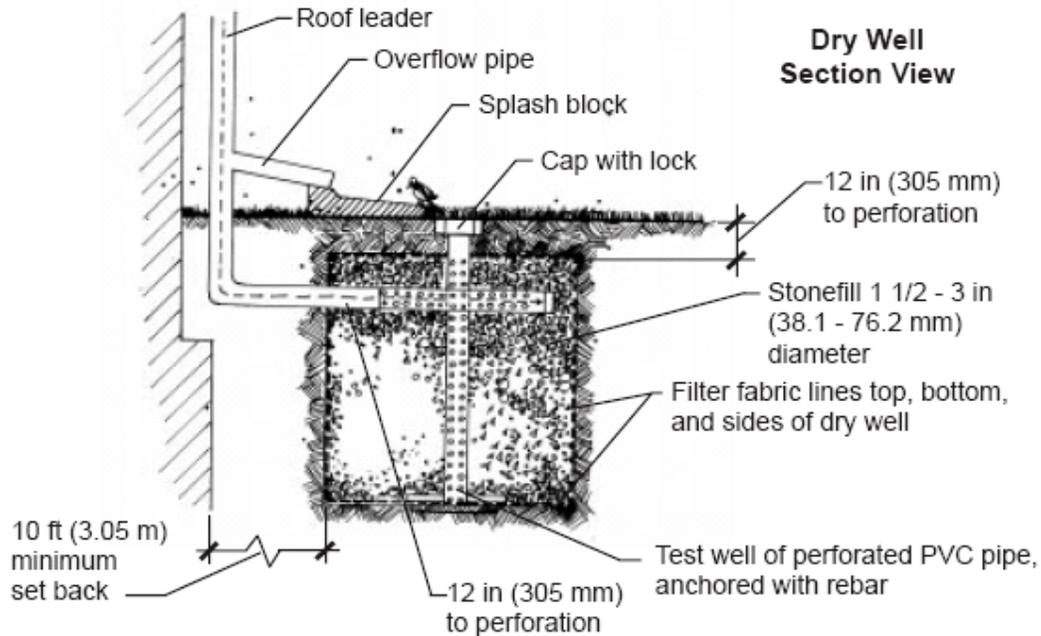
Limitations: Slope, Water Table and Bedrock depth, and subsoil compaction. Distance to septic fields, wells and structures.

Material Specifications: 4-inches Double Shredded Mulch; Weed Barrier; Plants: Plugs, Container, and/or Burlap stocks; BMP Clearinghouse #4

Design Standards:

- Maximum roof area per downspout shall be 1,000 square feet
- Surface area of planting bed shall be at least 5 percent of the roof area.
- Slopes should be less than 7 percent. This practice shall have a 30-foot setback from the top of slopes steeper than 15 percent.
- Minimum setback from building foundation is 10 feet down gradient or 25 feet up gradient. Minimum setback from septic field and well is 50 feet.
- An earthen berm may be necessary to maintain a temporary ponding depth of 6 inches. The berm shall be 9-12 inches above the planting bed. The limits of the ponding area shall not encroach on foundations.
- Compaction shall be prevented within the ponding area.
- Scarify the planting bed and incorporate compost amendments into the native soil at a rate of 1 part compost to 2 parts soil.
- Weed barrier or herbicides shall be used when planted on existing turf lawns.

1.5 Dry Well



Description: An underground pit filled with open-graded gravel and wrapped with nonwoven geotextile fabric. The dry well accepts runoff from roof downspouts and other stormwater pipes.

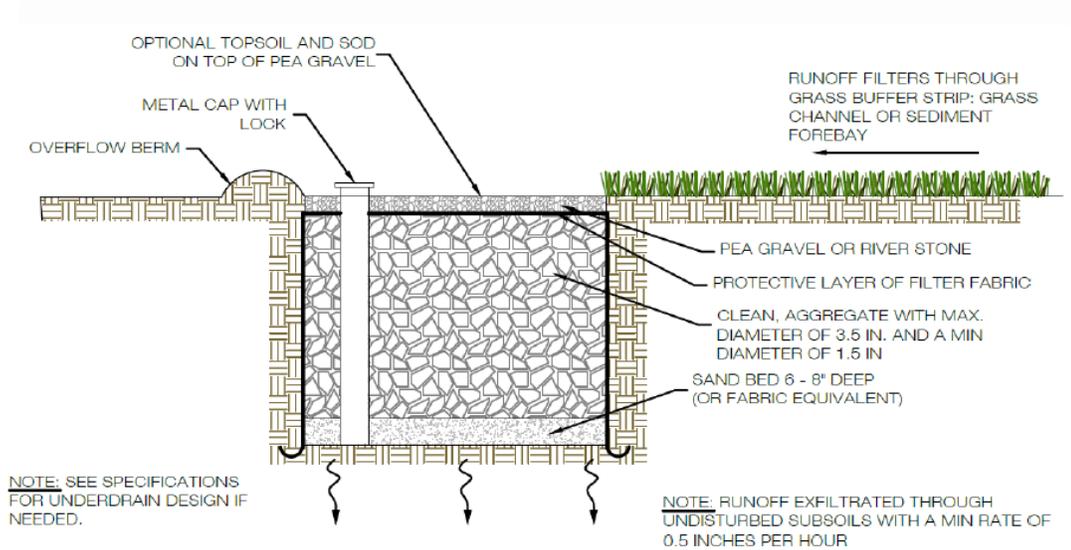
Limitations: Slope, Water Table and Bedrock depth, and subsoil compaction. Distance to septic fields, wells and structures.

Material Specifications: BMP Clearinghouse #8; VESCH 3.28

Design Standards:

- Maximum roof area treated shall be 2,500 square feet
- Depth, $d = 9.5 / (48 SA\%)$; where SA% is the dry well surface area divided by roof area treated.
- Maximum depth shall be within 2 feet of bedrock and the water table
- Slopes should be less than 7 percent. This practice shall have a 30-foot setback from the top of slopes steeper than 15 percent.
- Minimum setback from building foundation is 10 feet down gradient or 25 feet up gradient. Minimum setback from septic field is 50 feet and well is 100 feet.
- Install an overflow mechanism for higher storm events.
- Screen the downspout inlets to reduce debris and mosquitoes.
- Sod covers the top of the gravel pit.

1.6 Infiltration Trench



Description: An excavated trench filled with layers of open-graded aggregate stone that provides temporary runoff storage and groundwater recharge.

Limitations: Slope, Water Table and Bedrock depth, and subsoil compaction. Distance to septic fields, wells and structures.

Material Specifications: BMP Clearinghouse #8, BMP Clearinghouse App. A, B, and C

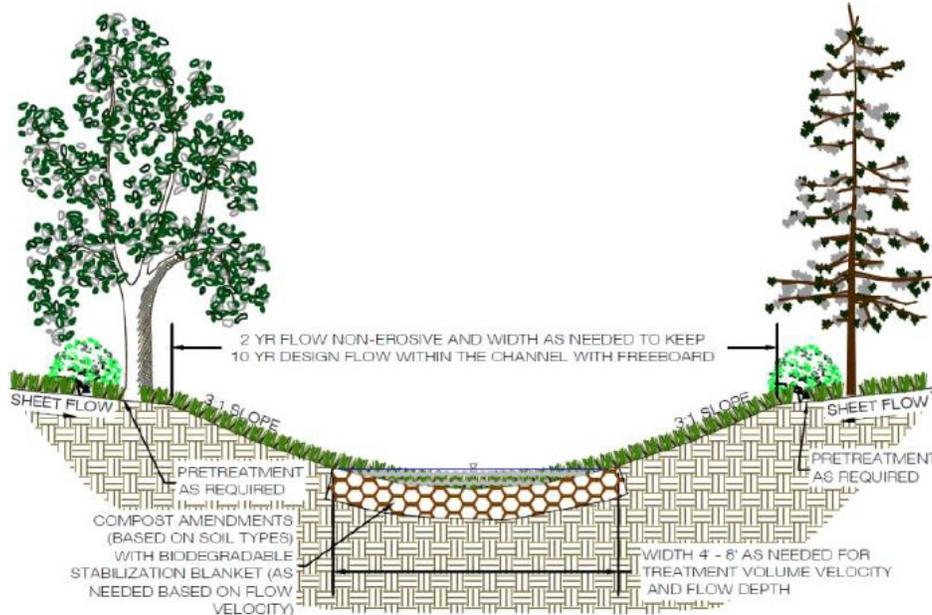
Design Standards:

- Maximum contributing drainage area treated shall be 2 acres
- Minimum surface area should be 5 percent of drainage area.
- Trench should be a minimum of 2 feet wide and a minimum of 1 foot deep.
- Depth, $d = 10 R_v / (48 SA\%)$; where SA% is the trench surface area divided by drainage area; and R_v is a composite runoff factor.

Rv Coefficients	A soils	B Soils	C Soils	D Soils
Forest/Meadow/Mulched Landscaping	0.02	0.03	0.04	0.05
Managed Turf Lawn	0.15	0.20	0.22	0.25
Impervious Cover	0.95	0.95	0.95	0.95

- Maximum depth shall be within 2 feet of bedrock and the water table.
- Slopes should be less than 7 percent. This practice shall have a 30-foot setback from the top of slopes steeper than 15 percent.
- This is a linear practice installed along the perimeter of driveways or buildings and may be incorporated into a grass channel, see 1.7.
- Minimum setback from building foundation is 10 feet down gradient or 25 feet up gradient. Minimum setback from septic field is 50 feet and well is 100 feet.

1.7 Grass Channel



Description: Grass channels are wide, gently sloping, open channels with grass sides used as a stormwater conveyance system.

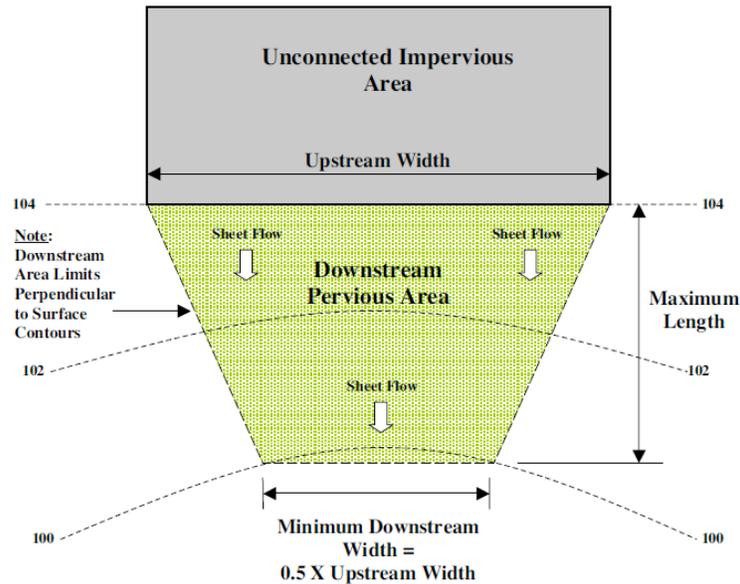
Limitations: Steep Slopes; Setbacks; Side Slopes

Material Specifications: BMP Clearinghouse #3; VESCH 3.17, 3.20, 3.32, and 3.36

Design Standards:

- Maximum contributing drainage area is 5 acres
- Bottom width of channel shall be at least 4 feet. Side slopes of channel shall be 3:1 or flatter
- Longitudinal Slopes of less than 2 percent. Slopes greater than 2 percent require permanent check dams. Slopes greater than 4 percent shall incorporate additional practices. Slopes greater than 10 percent are not suitable for this practice.
- Must discharge to a well-vegetated area that has a slope less than 15 percent. A gravel diaphragm, rip rap apron or engineered level spreader may be needed at the outlet.
- Slopes less than 2 percent should be seeded and mulched in accordance with VESCH 3.32 and 3.30. Slopes greater than 2 percent shall be stabilized with temporary matting in accordance with VESCH 3.36.
- The channel shall have the capacity to carrying the 10-year design storm. Requires a minimum of 6 inches of freeboard when the channel follows a roadway.
- The channel shall have a 2-year flow velocity that is non-erosive.

1.8 Sheet Flow to Conservation Area



Note: In determining maximum length and effective size of downstream pervious area, downstream area width cannot be less than one half of upstream width regardless of distance to downstream conveyance system.

Description: This practice incorporates a group of best management practices (BMPs) designed to preserve natural areas and disperse concentrated runoff to sheet flow.

Limitations: Steep Slope; Concentrated Flow

Material Specifications: BMP Clearinghouse #2; VESCH 3.18, and 3.38

Design Standards:

- Maximum impervious surface shall be 5,000 square feet or 20 percent impervious cover of contributing drainage area.
- Minimum size of receiving area shall be 10,000 square feet of contiguous undisturbed vegetation.
- Minimum length of receiving area shall be 35 feet for slopes less than 3 percent and 50 feet for slopes less than 6 percent.
- Longest flow length across impervious surface shall be 75 feet. Gravel diaphragms or permeable berms must be used if flow length is longer.
- Longest flow length across turf lawns shall be 150 feet.
- Concentrated flows shall use an engineered level spreader
- Disturbance of a stream buffer to achieve this design is not recommended.

Stormwater BMP Guide For Private Driveways and Roads

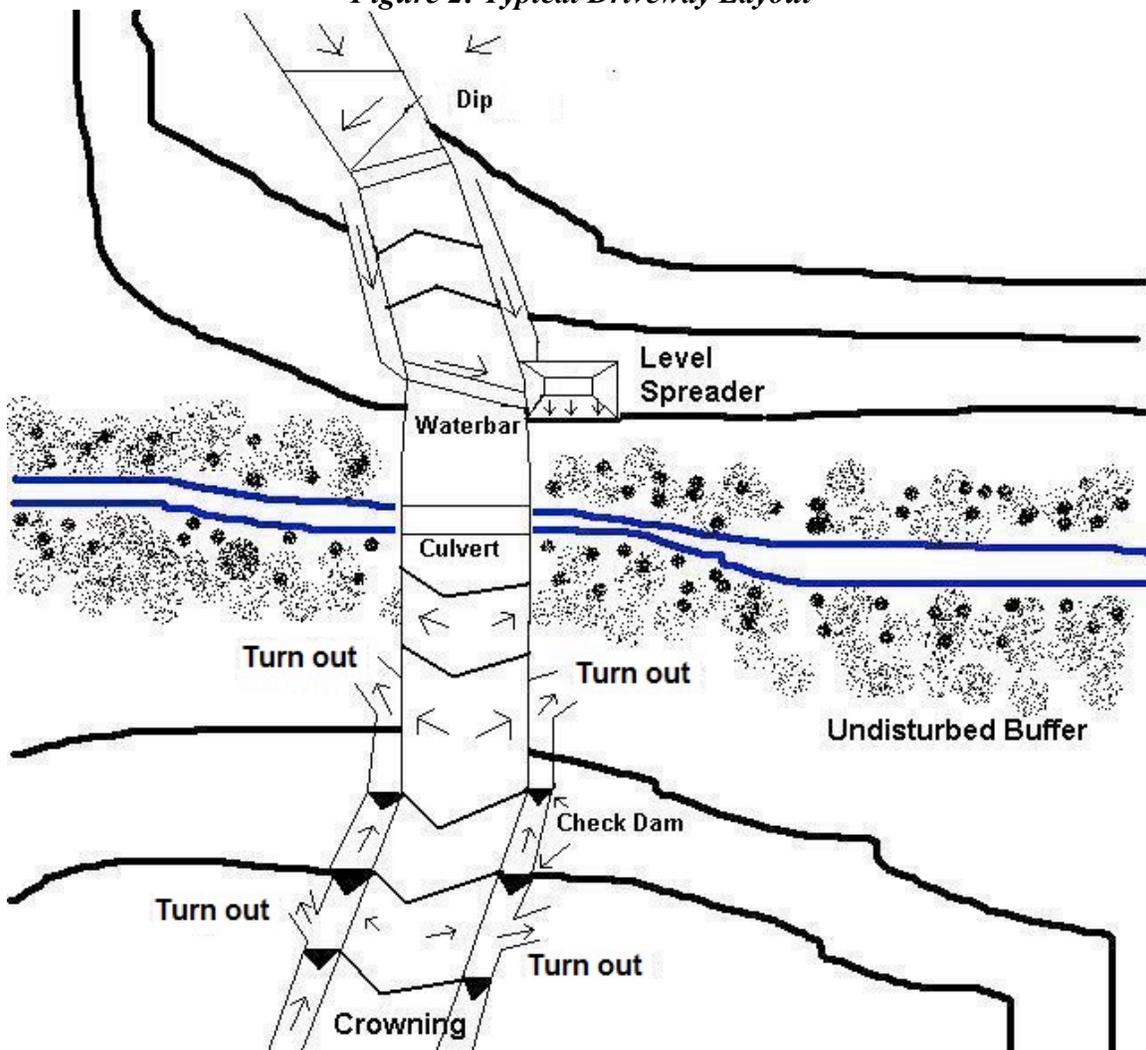
These practices are necessary to satisfy the water quantity and water quality criteria of the Rappahannock Stormwater Ordinance. These practices maintain dispersed flows and prevent environmental damage due to erosion and increased runoff from development. These practices may be used for in-lieu-of agreements or residential site plan submissions.

The practices listed here are not comprehensive, and alternative practices may be appropriate for the site. Consult the Virginia Stormwater BMP Clearinghouse or the County for additional design options.

<http://vwrrc.vt.edu/swc/StandardsSpecs.html>

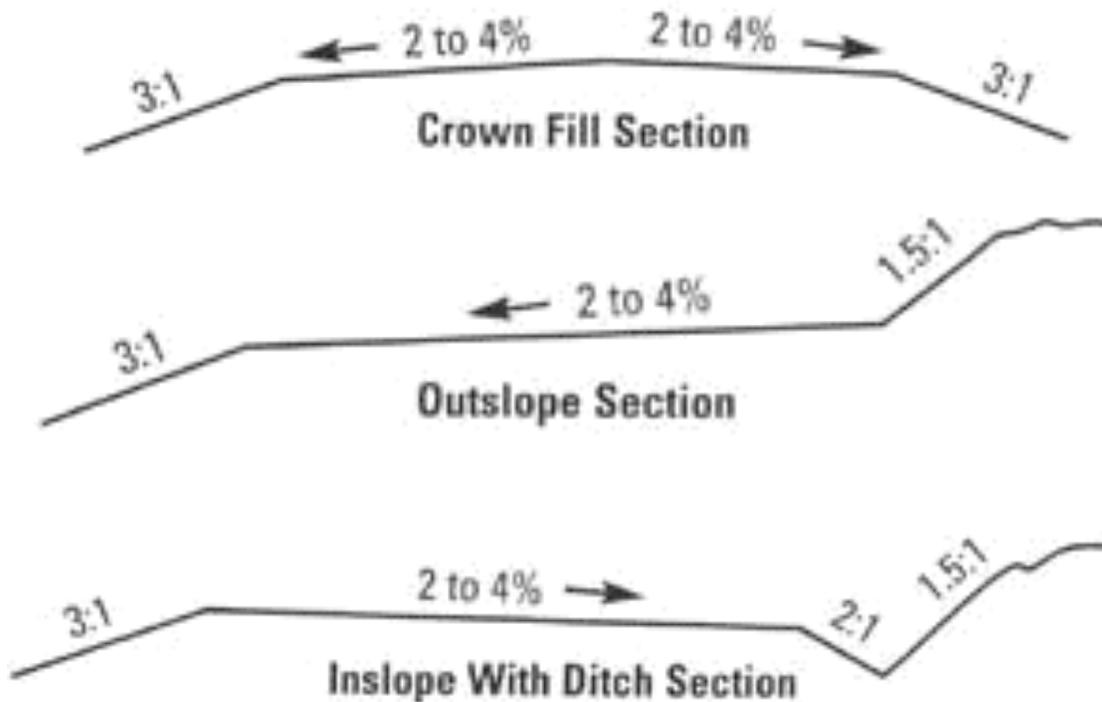
And Consult the Center for Dirt and Gravel Road Studies, Penn State University

<http://www.dirtandgravel.psu.edu/>

Figure 2: Typical Driveway Layout**Driveway practices:**

- ❖ 2.1 Crown and Cross-Slope
- ❖ 2.2 Dips
- ❖ 2.3 Waterbar
- ❖ 2.4 Grass Channel
- ❖ 2.5 Wing Ditches
- ❖ 2.6 Engineered Level Spreaders
- ❖ 2.7 Cross Culvert
- ❖ 2.8 Clearwater Crossing
- ❖ 2.9 French Matress
- ❖ 2.10 Ford and Culvert Crossings

2.1 Crown and Cross-Slope



Description: Crown describes the cross-sectional shape of a road surface. Cross-sloping, either *in*-sloped or *out*-sloped, of the road is the slope angle of the road cross-section. The purpose of surface drainage is to cause the water to leave the road as shallow, non-erosive sheet flow in a direction and pattern chosen to suit various combinations of road material, slope, and terrain.

Limitations: Bedrock depth, Slope, Soil drainage, and length of flow.

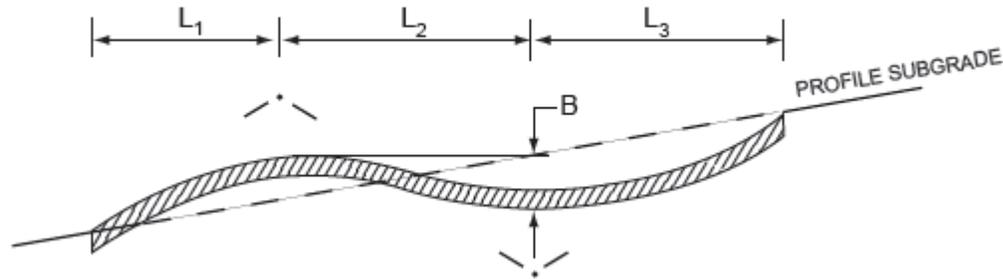
Specifications:

Design Standards:

- Crowning is a surface configuration that sheds water to both sides of the road. Crowning can be used where there is adequate drainage away from either side of the roadbed; such as ridges and floodplains.
- Out-sloped road surfaces drain water from the entire width of the road toward the fill-bank or down-slope side. The road is shaped to avoid collection or concentration of water in a ditch. Minor overland sheet flow is allowed to flow across the road (2). Out-sloping is useful on roads where concerns about winter icing are minimal or side-slopes are gentle.
- In-Sloping is a surface configuration that drains water from the entire width of the road toward the cut bank or up-slope side. Commonly used on steep side-hills, and can be useful to direct ditch water to better discharge points. Integration of cross-drains, water bars, and dips can be effective to disperse the concentrated ditch runoff.
- Unpaved roads shall have a cross slope of 4 percent.

2.2 Dips

Dip Profile



Description: Dips are designed and constructed to divert water off the road surface, disperse surface water flows, and reduce erosion. The road profile (vertical alignment) is changed by simultaneously constructing a dip and raising the grade by placing fill material in the road below the dip. The slightly skewed dip turns surface flows and disperses runoff away from the road surface.

Limitations: Bedrock depth, slope of outfall, and traffic.

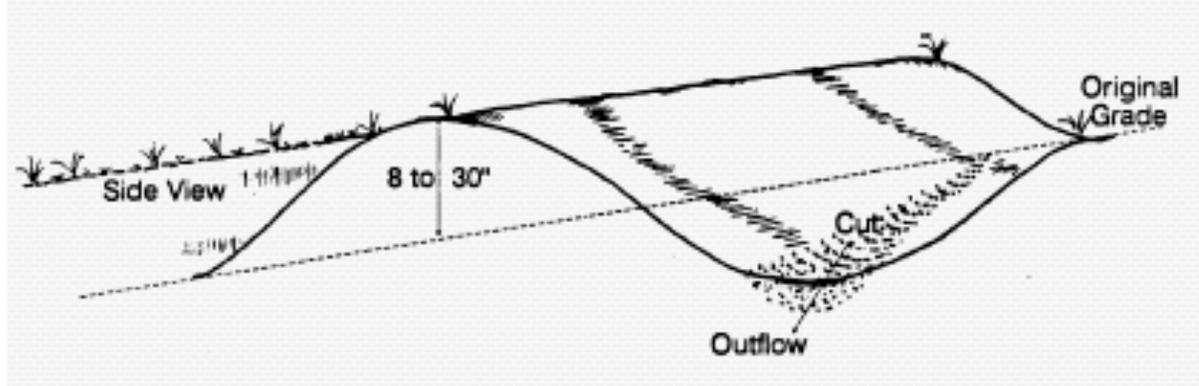
Specifications: U.S. Forest Service Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads; VESCH 3.11 and 3.18

Design Standards:

- Maximum slope of road shall be 10 percent.
- Depth, B of the dip shall be 8 inches.
- Approaching length, L₃ shall be between 10 and 25 feet
- May be used to replace or supplement a cross-culvert
- Not to be used to divert spring or stream flows.
- Angle the dip across the road in the direction of flow between 20 and 40 degrees. Slope the dip 3 percent across the bottom toward the outlet.
- The berm shall have a reverse grade between 2 and 8 percent.
- The outlet shall be stabilized with a stone apron in accordance with VESCH 3.18.
- Dips shall be spaced; as measured from the toe of the berm, in accordance with the following equation:

$$X = (0.68S + 1) (100/S); \text{ where } S \text{ is the road slope in percent } (\%)$$

2.3 Water Bar



Description: Water bar is a diversion berm built across the roadbed which acts as a dip. Suitable where traffic is low and slopes are steeper than 10 percent.

Limitations: Bedrock depth, slope of outfall, and traffic. High vehicle traffic can damage these structures.

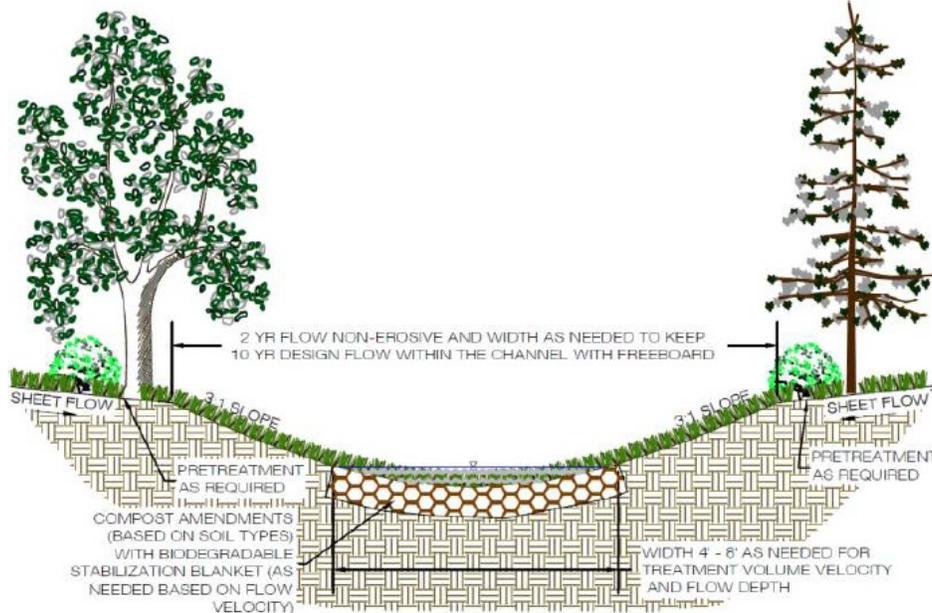
Specification: VESCH 3.11, VESCH 3.18

Design Standard:

- Minimum height shall be 8 inches and no more than 18 inches.
- Side slopes shall be 2:1 or flatter
- Minimum base width shall be 3 feet
- The berm shall be composed of non-erodible materials.
- Angle the berm across the roadbed in the down-gradient direction. An angle between 20 and 40 degrees is most effective. Slope the cut 3 percent across the bottom toward the outlet.
- The outlet shall be stabilized with a stone apron in accordance with VESCH 3.18.
- Bars shall be spaced; as measured from the toe of the berm, in accordance with the following equation:

$$X = (0.68S + 1) (100/S); \text{ where } S \text{ is the road slope in percent } (\%)$$

2.4 Grass Channel



Description: Grass channels are wide, gently sloping, open channels with grass sides used as a stormwater conveyance system.

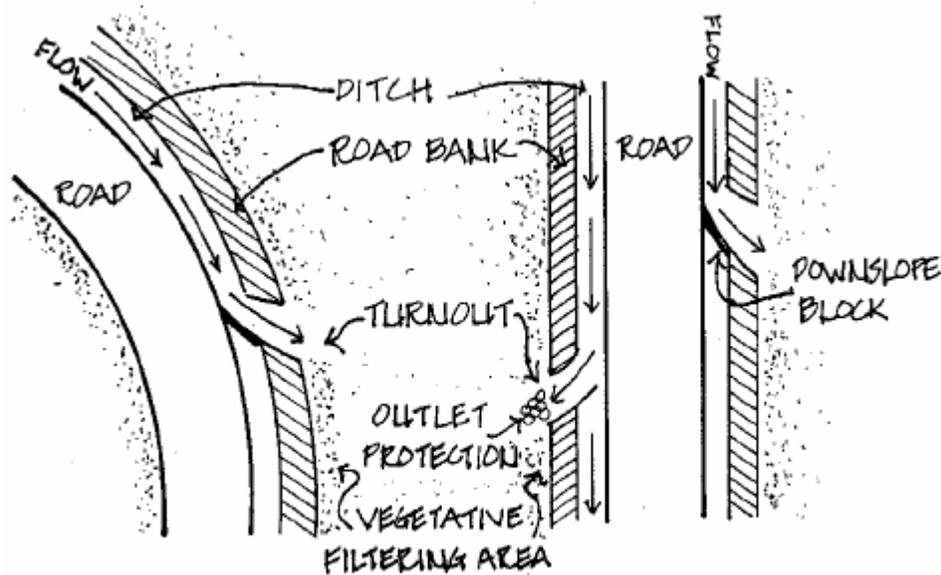
Limitations: Steep Slopes; Setbacks; Side Slopes

Material Specifications: BMP Clearinghouse #3; VESCH 3.17, 3.20, 3.32, and 3.36

Design Standards:

- Maximum contributing drainage area is 5 acres
- Bottom width of channel shall be at least 4 feet. Side slopes of channel shall be 3:1 or flatter
- Longitudinal Slopes of less than 2 percent. Slopes greater than 2 percent require permanent check dams. Slopes greater than 4 percent shall incorporate additional practices. Slopes greater than 10 percent are not suitable for this practice.
- Must discharge to a well-vegetated area that has a slope less than 15 percent. A gravel diaphragm, rip rap apron or engineered level spreader may be needed at the outlet.
- Slopes less than 2 percent should be seeded and mulched in accordance with VESCH 3.32 and 3.30. Slopes greater than 2 percent shall be stabilized with temporary matting in accordance with VESCH 3.36.
- The channel shall have the capacity to carrying the 10-year design storm. Requires a minimum of 6 inches of freeboard when the channel follows a roadway.
- The channel shall have a 2-year flow velocity that is non-erosive.

2.5 Ditch Turnout



DETAIL - TURNOUTS

Description: A ditch turnout consists of a stable ditch, a turnout berm and level spreader outlet. Turnouts disperse concentrated ditch flows by reducing the length of flow into more manageable and less erosive dispersal areas.

Limitations: Bedrock depth, Slope, and adequate dispersal areas.

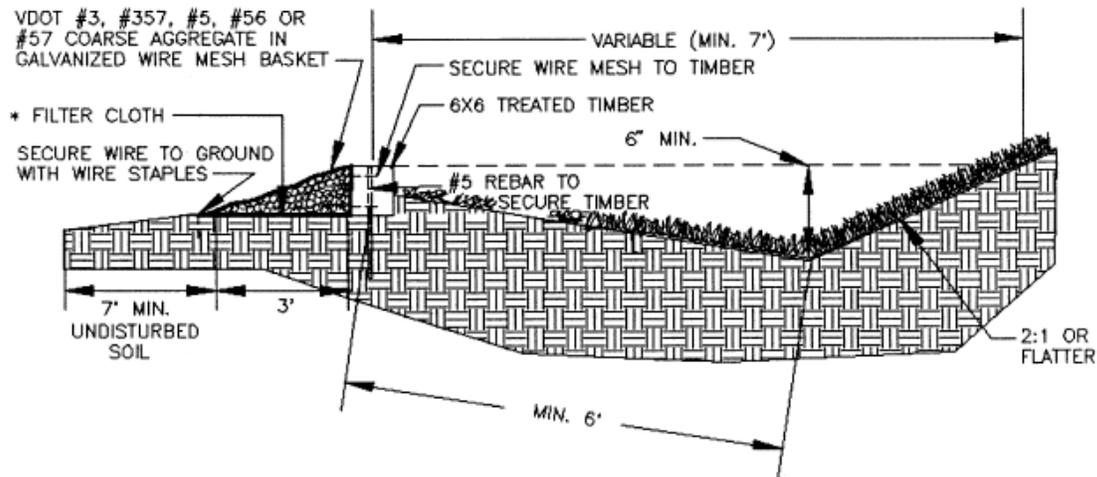
Specifications: VESCH 3.18, and 3.21; BMP Clearinghouse #2

Design Standard:

- Maximum drainage areas shall be 2 acres
- Obtain an easement for flows that will cross an adjoining property before being intercepted by an adequate channel.
- The receiving area must maintain the natural contour across the slope and shall have uniform and mature vegetation that can inhibit erosion.
- Ditch must be stabilized with either vegetation or riprap.
- The turnout should be at least 3 times the width of the ditch.
- Avoid building turnouts directly into streams. If possible provide a vegetated buffer between the outfall and stream channel.
- Angle the turnout at 20 to 40 degrees with a slope of 3 percent.
- The outlet shall be stabilized with a stone apron in accordance with VESCH 3.18. Turnouts can be integrated with Water bars, Dips and engineered level spreaders to provide a stable outlet.

2.6 Engineered Level Spreader

LEVEL SPREADER WITH RIGID LIP



Description: A graded shallow depression with a long overflow weir. The level spreader is a dispersion technique that reduces flow velocity and allows sedimentation to occur.

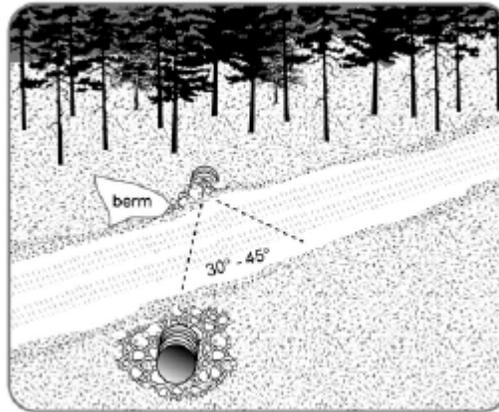
Limitations: Bedrock depth; Flow Rate

Specifications: VESCH 3.21, 3.32, 3.35, and 3.36; BMP Clearinghouse #2

Design Standards:

- A rigid weir should be used where the receiving areas slope is greater than 15 percent. The weir may be concrete, wood, or pre-fabricated metal with well-anchored footer, or other non-erodible materials.
- A vegetated weir may be used where the receiving areas have uniform, mature vegetation that will inhibit erosion and have a slope less than 15 percent.
- Length of the weir shall be 13 feet per 1 cfs of inflow with a minimum width of 13 feet.
- The width of the level spreader channel on the up-stream side of the weir should be three times the ditch width or pipe diameter. The depth should be 9 inches or $\frac{1}{2}$ the pipe diameter; whichever is greater.
- The level spreader should be contoured to match existing slopes to avoid scouring.
- The level spreader should be placed 3 to 6 inches above the downstream grade. A 3-foot long section of VDOT #3 stone underlain by class 3 nonwoven geotextile fabric.
- Slopes less than 2 percent should be seeded and mulched in accordance with VESCH 3.32 and 3.35. Slopes greater than 2 percent shall be stabilized with temporary matting in accordance with VESCH 3.36.

2.7 Cross Culvert



Description: A culvert pipe placed in a ditch or dry swale. Cross-ditch culvert diverts inside ditches to an adequate outfall. These culverts shorten ditch flow lengths and reduce runoff accumulation.

Limitations: Bedrock depth, width of road, fill cover depth, and width of inside ditch. The culvert design and installation is different for draining springs/seep or crossing live (constantly flowing) water, these culverts need to be perpendicular and sized appropriately.

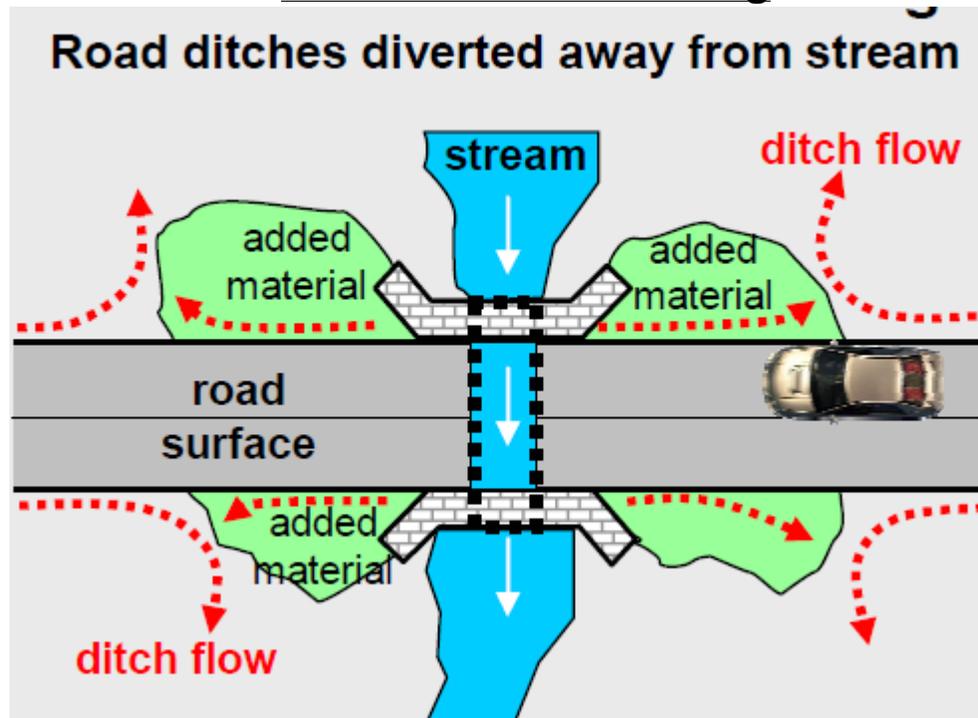
Specifications: VESCH 3.08, 3.18, and 3.19

Design Standard:

- Cross-ditch culverts should be installed at an angle of 20 to 40 degrees with the direction of flow.
- Install the culvert at a minimum of 0.5 percent and maximum of 2 percent slope.
- Place a minimum of one foot of cover. Make pipe length adequate to extend the full width including side slopes, plus one foot on each side. Additional cover may be needed for buoyancy protection.
- Provide a stabilized outlet. Use rip rap underlined with filter fabric or another structure such as a level spreader to disperse runoff and reduce flow velocities.
- Provide inlet protection measures during construction to prevent clogging.
- A berm can be used to prevent flow from bypassing the structure. An overflow mechanism may be needed in the berm for larger storm events.
- Cross-Culverts and drains shall be spaced in accordance with the following equation:

$$X = (0.68S + 1) (100/S); \text{ where } S \text{ is the road slope in percent } (\%)$$

2.8 Clearwater Crossing



Description: Clearwater crossings disconnect and disperse concentrated ditch runoff to reduce flow velocities prior to entering an undisturbed buffer or stream channel.

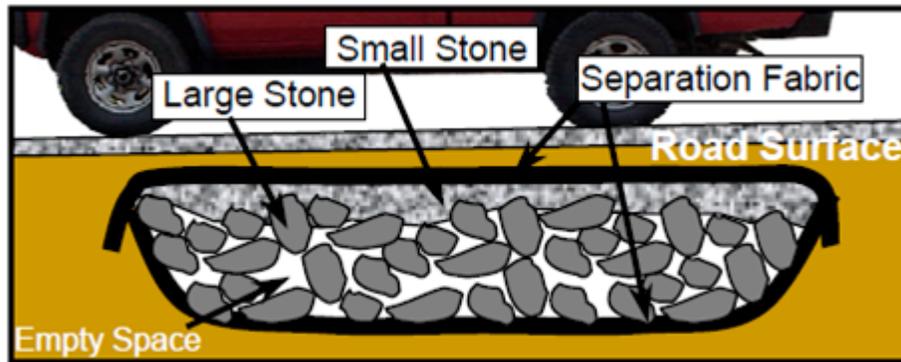
Limitations: Available Floodplain Width; Slope

Specifications: U.S. Forest Service Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads;

Design Standard:

- Contributing drainage area per ditch outfall shall be minimized with upslope diversion measures
- Area receiving dispersed flows shall have established vegetation that is uniform, mature enough to survive and will inhibit erosion.
- Eliminate ditches where possible through berm removal and filling the road profile.
- Locate drainage outlets away from streams and into vegetation when possible.
- Grade ditches in wide flood plains to drain away from stream crossings.
- Cross slope the road before stream crossings to disperse surface flows.
- Incorporates Dips, Water Bars, Turnouts, and Engineered Level Spreaders where needed.
- Disturbance of a stream buffer to achieve this design is not recommended.

2.9 French Mattress



Description: A structure under a road consisting of clean coarse rock wrapped in geotextile fabric through which water can pass freely. French mattresses are used in extremely wet areas, such as wetlands, to support the roadbed while allowing unrestricted water movement.

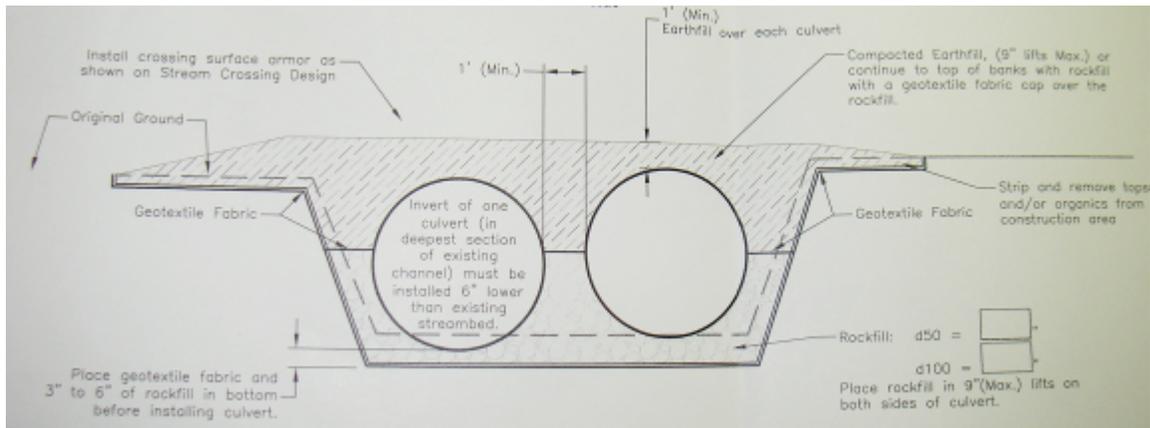
Limitations: Bedrock; Steep Slopes

Specifications: U.S. Forest Service Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads; VESCH 3.28; BMP Clearinghouse #1

Design Standard:

- May be used in low-lying areas near streams or wetlands where installing cross drains would be difficult due to lack of grade or vegetation; areas where the road acts as a dam by cutting off the natural flow of subsurface water; or areas with a high water table.
- Not to be used for concentrated flows such as small streams or ditches.
- Width and depth of mattress is flexible.
- French mattresses should be installed to match the slope of the land. In some wetland situations, this slope may be minimal. In sloped areas a 1- to 2-percent slope should be used to aid drainage.
- Covered with at least 8 inches of fill
- Class 2 Woven geotextile fabric shall be used to wrap the drainage stone.
- All large stone shall be clean aggregate 3-4 inches in diameter. The small stone shall be sized to provide a suitable base for the road bed.

2.10 Stream Crossing (Culverts)



Description: A stabilized area (Ford) or structure (Bridge or Culvert) constructed across a stream channel.

Limitations: Bedrock, adequate slope, stream size, and stream pattern.

Specifications: VDOT Drainage Manual Chapter 8; FHWA-HEC 14

Design Standard:

- Stream crossing method should minimize habitat fragmentation and minimize barriers to aquatic organism movement
- Do not use culverts where large flows of sediment or large woody debris are expected or where the stream gradient is greater than 4 percent.
- Crossings must accommodate out-of-bank flows by safely bypassing without damaging the structure or eroding the stream bank or fill material.
- At least one culvert pipe shall be placed 6 inches below the existing stream bed. Additional culverts may be used at various elevations to maintain floodplain hydraulics and water surface elevations.
- Place a minimum of one foot of cover. Make pipe length adequate to extend the full width including side slopes, plus one foot on each side. Additional cover may be needed for buoyancy protection.
- Earthen fill sides slopes shall be no steeper than 2:1. Rock fill side slopes shall be no steeper than 1.5:1.
- Use Class 3 non-woven geotextile fabric between rock fill and earth fill.
- RCP and HDPE materials are preferred over CMP due to the high risk of corrosion.

Location:

- Stream crossing shall be placed in an area where stream bed is stable or where it can be stabilized
- Crossings should be perpendicular to the stream flow and at a riffle. Not appropriate where channel grade or alignment changes abruptly.
- Stable approach is needed no steeper than 6:1.
- Length of culvert shall be at least 12 feet, but not more than 30 feet as measured from the upstream invert to the downstream