MINIMUM DESIGN STANDARDS

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MINIMUM DESIGN STANDARD 9.01
ENERGY DISSIPATOR

Definition

An energy dissipator is a device that is used to convert concentrated stormwater runoff to sheet flow and is constructed at the end of all storm sewers or channels that outfall into a buffer.

Purpose

The purpose of an energy dissipator is to introduce storm flows into the buffer at a slower rate and spread the flow over a larger area than would normally occur with a storm sewer outfall. The energy dissipator allows for more efficient use of the buffer by spreading the storm flow over a wider area of the buffer.

Design Criteria

Energy dissipators are required at the end of all storm sewers and constructed/altered channels that outfall into Stream Protection Areas. The energy dissipators must be designed and constructed according to the following design criteria. All appropriate details must be included in the approved plans.

- As indicated in the following table, either Design A or Design B (refer to sketches) will be provided based on the pipe size and discharge (10-year storm) or the channel's discharge (10-year storm).

Pipe Diameter (in)	10-Year Peak Discharge (cfs)									
	10	20	30	40	50	60	70	80	90	100
15	A	A								
18	A	A	A	A						
21		A	A	A	B					
24			A	A	B	B	B	B		
27			A	A	A	B	B	B	B	B
30				A	A	A	B	B	B	B
36						A	A	B	B	B
42									A	B

- The sides and bottom of the plunge pool excavation shall be lined with filter fabric underlining and Class AI rip rap in accordance with the Virginia Erosion and Sediment Control Handbook, Third Edition, 1992, State Minimum Standards and Specifications Number 3.19.

- The spreader weir section shall be constructed by excavating a trench to the depth and configuration shown, laying down hardware cloth and backfilling with VDOT No. 3 aggregate. The hardware cloth shall be galvanized steel, ½ inch mesh, 19 gauge. The hardware cloth shall be wrapped around the aggregate and timber as shown and the edges stapled to the top of the timber every 12" with ¾ inch galvanized steel staples.

- The 6" x 6" treated timber shall be level.

- Special considerations shall be made where a cross slope exists in the area of construction and outfall, and where there is a possibility that storm water may flow around and bypass the spreader weir. The contractor shall construct an additional timber and aggregate weir section as shown that ties back into existing grade.

- A minimum of clearing and grading may be required downstream of the spreader weir section to insure free overflow of storm water over the weir. Generally, all clearing and grading shall be kept to a minimum, but where required, the disturbed area shall be planted with sod in accordance with the Virginia Erosion and Sediment Control Handbook, Third Edition, 1992, State Minimum Standards and Specifications Number 3.33. The sod shall be secured with netting and staples in accordance with Plate 3.33-2.

- If installed at the end of county maintained storm sewer, the drainage easement must encompass the entire energy dissipator (dissipation section, plunge pool section, and spreader weir section) and provide an area 10 feet wide around the entire energy dissipator to provide for maintenance.

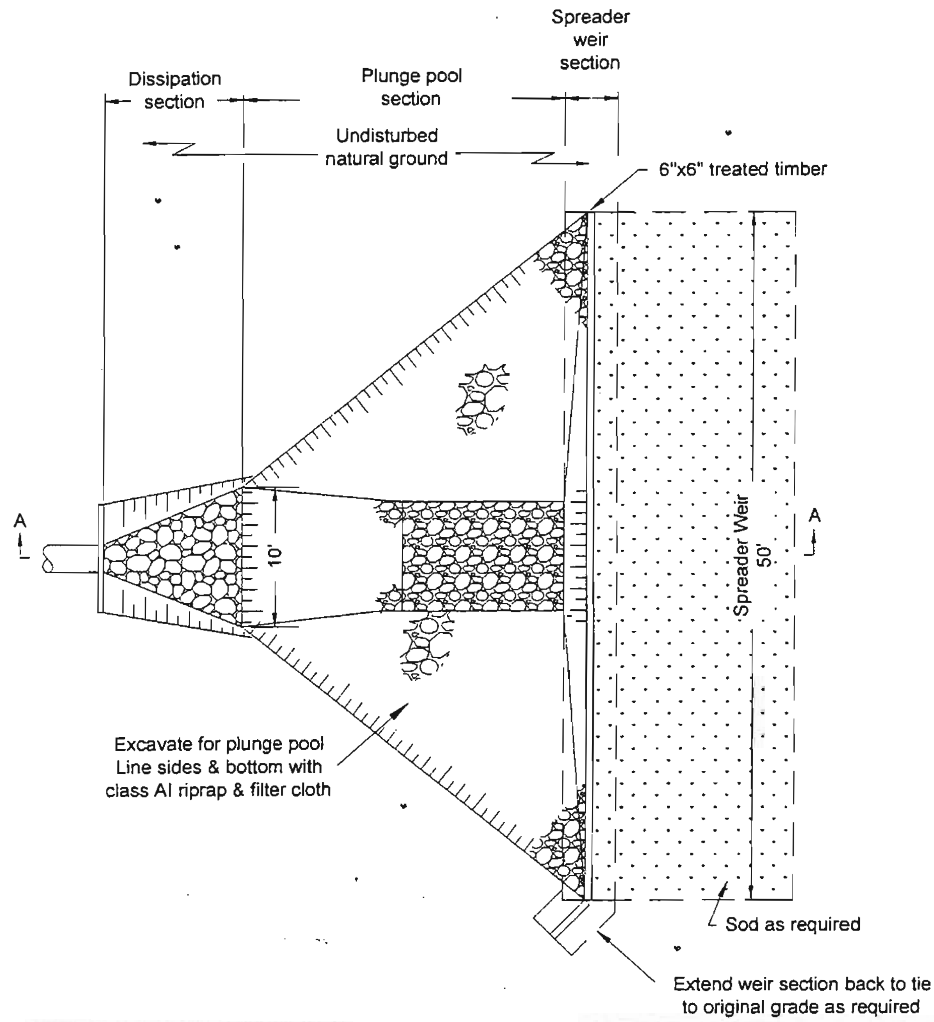
- As indicated in the details, the dissipation section of the energy dissipator is outside the Stream Protection Area (SPA). The remaining components (plunge pool section and spreader weir section) of the energy dissipator will be in the upper twenty (20) feet of the SPA unless site constraints dictate otherwise and the Department of Public Works concurs.

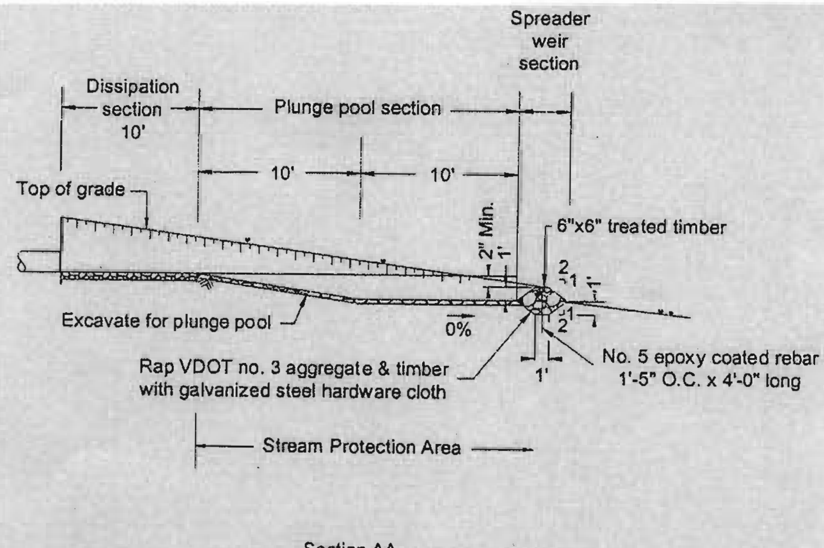
Pollutant Removal

Each energy dissipator that is installed in conjunction with the SPA is assumed to result in 0.10 pound of pollutant removal.

Environmental Fund Contribution Adjustment

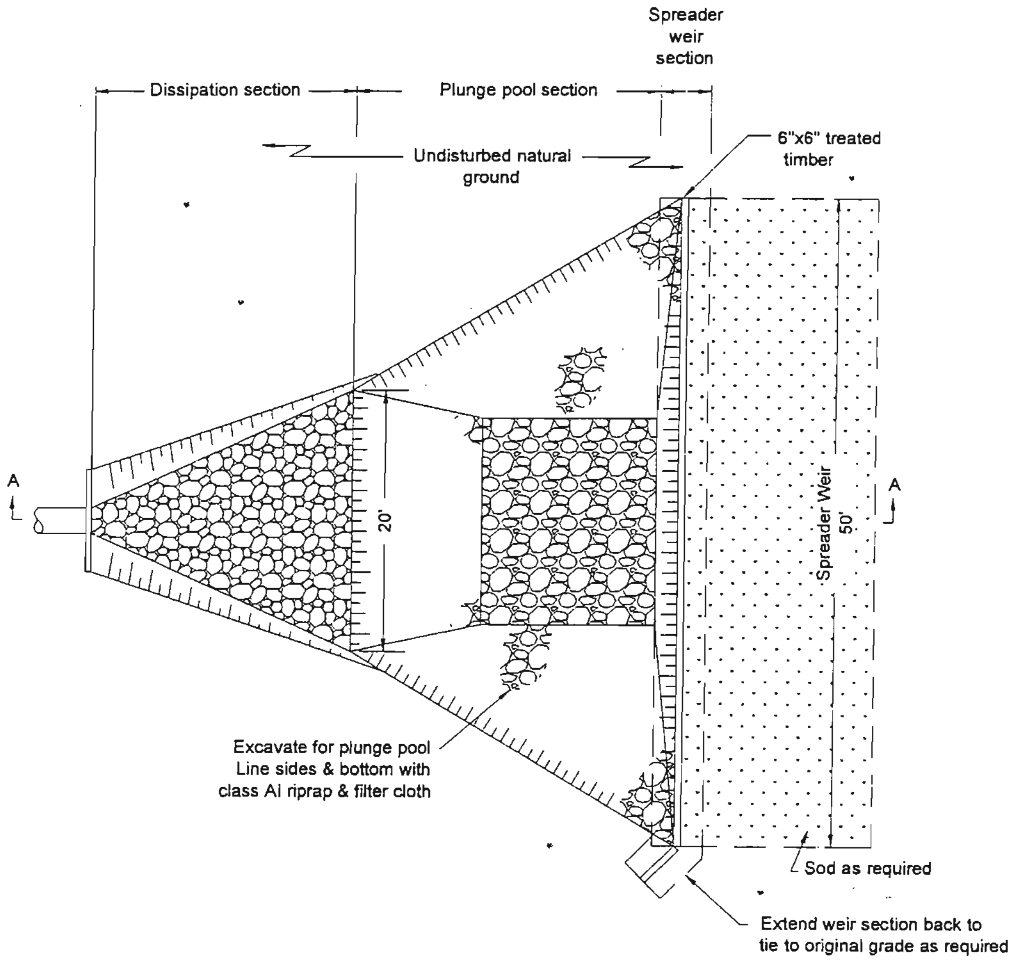
Each energy dissipator that is installed in conjunction with the Stream Protection Area yields an $800.00 Environmental Fund contribution adjustment.

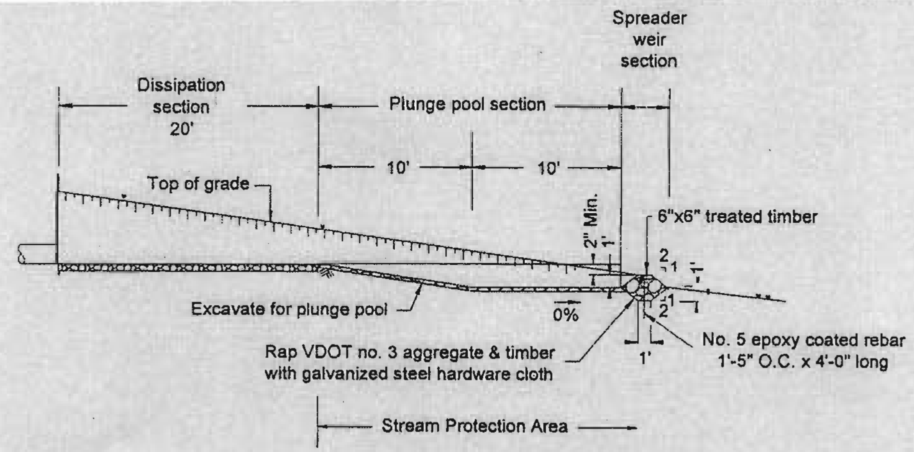




Section AA

Storm Water Outflow Spreader Device
Design A
N.T.S.





Section AA

Storm Water Outflow Spreader Device
Design B
N.T.S.

MINIMUM DESIGN STANDARD 9.02
GRASSED SWALE

Definition

A grassed swale is a broad and shallow earthen vegetated channel with erosion resistant and flood tolerant grasses designed for stormwater quality treatment.

Purpose

Grassed swales are used to achieve pollutant removal while conveying stormwater. Swales have a limited capacity to accept runoff from large design storms, and often must lead into storm drain inlets to prevent large, concentrated flows from gullying/eroding the swale. Check dams are placed across the flow path to provide some stormwater management for small design storms by infiltration and flow attenuation. In most cases however, swales must be used in combination with other BMPs downstream to meet stormwater management requirements.

Design Criteria

Grassed swales must be constructed according to the following design criteria:

- The flow velocity must not exceed 1.5 feet per second.
- Swale slope shall be between two (2) and four (4) percent.
- Side-slopes of the swale shall not be steeper than 3:1.
- The check dams must be installed, sized, and spaced to store the water quality volume. Ponded water depth must not exceed 18".
- The check dams must be permanent and made of non-erodible materials. Creosote treated materials are not acceptable. Stone check dams are unacceptable because they do not provide a controlled detention time. The overflow must occur over the non-erodible material and not be allowed to scour around the area where the check dam meets the swale side slopes.
- The check dams must have water quality perforations designed to provide a detention time of 12 hours.
- Wire mesh and stone shall be placed in front of the water quality perforations.

Maintenance

- Grassed swale maintenance is largely aimed at keeping the grass cover dense and vigorous and the accumulated sediment removed.
- When mowing, the minimum grass height will be 3".
- When sediments accumulate and clog the outlet, resulting in excessive detention times, the stone shall be cleaned and the wire mesh replaced.

Pollutant Removal

Grassed swales have a removal efficiency of 20%.

GRASSED SWALE
MINIMUM DESIGN STANDARD 9.02

The swale must detain the Water Quality Volume (WQV) for a period of twelve (12) hours. If off-site credits are to be taken, the swale must be sized to accommodate the entire contributing drainage area.

VOLUME: V_{SWALE} = Volume of runoff detained by basin

V_{SWALE} = Water Quality Volume (WQV)

WQV = The volume produced by ½ inch of runoff per impervious acre of contributing drainage area.

= A_{IMP} x 43,560 x 0.0417

= 1816 x A_{IMP}

A_{IMP} = The area of impervious surface on the contributing watershed in acres.

43,560 is the number of square feet in an acre.

0.0417 is the first half-inch of runoff.

WQV = 1816 x ___________ (acres)

WQV = ___________ cubic feet

Check dams may be a maximum of eighteen (18) inches high, and the placement is determined based on the slope of the swale. A series of check dams may be needed to provide the required water quality volume.

Number of check dams required = V_{SWALE} / volume provided behind each check dam.

DETENTION: Q_{AVG} = the average outflow rate for the desired detention time (cfs).

= V_{SWALE} / (T x 3600)

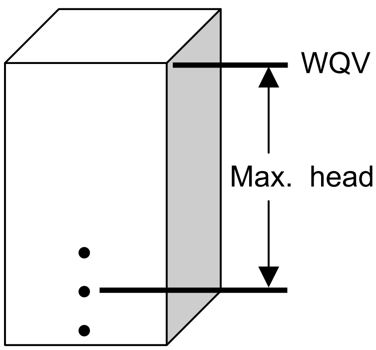
T = detention time (hrs.) = 12 hours

3600 = conversion factor (sec/hr)

Q_{AVG} = ___________ / (12 x 3600) = ___________ cfs

A_P = Q_{AVG} / [0.6 x (64.4 x H_{AVG})$^{1/2}$] = total perforation area (ft^2)

H_{AVG} = 0.5 x [maximum head (in feet)]



A_P = _______ / [0.6 x (64.4 x _____)$^{1/2}$] = _________ ft^2

N = the number of perforations

N = A_P / A_H

A_H = the area of each perforation (ft^2)

Perforation Diameter	A_H
0.5 inch	0.0014
0.75 inch	0.0031
1.0 inch	0.0055

N = _____ / ______ = ____ _____ inch diameter perforations

The perforations must be evenly spaced and shall begin at the basin floor elevation.
The perforation area of the riser must be covered with wire mesh and a gravel cone (#3 stone).

NOTE: The maximum acceptable perforation diameter is one inch.

The number of perforations must be rounded **down** to the nearest whole number.

CONSTRUCTION PLANS SHALL INCLUDE THE FINAL DETAILED BMP DESIGN

MINIMUM DESIGN STANDARD 9.03
EXTENDED DETENTION (DRY) POND

Definition

An extended detention (dry) pond is a basin constructed at the outfall location of a project. These basins will fill with stormwater during a rainfall event but will drain dry within a specified design period.

Purpose

Residential, commercial, and industrial development often increases the volume and rate of stormwater runoff in urban settings. Without proper stormwater controls, adverse downstream effects, including channel erosion and increased flooding can occur. In some situations, runoff is not increased by development, but can become polluted as it flows over construction and later impervious surfaces picking up soil particles and pollutants.

Extended detention ponds are often used to control the quantity and quality of stormwater leaving an urban site. Designed to capture and slowly release stormwater runoff, dry ponds rely almost exclusively on gravitational settling to remove pollutants. The pollutant removal effectiveness of the extended detention pond is based on the volume of runoff that can be stored and the release rate of the impounded water.

Design Criteria

Extended detention (dry) ponds must be constructed according to the following design criteria:

- The 10-year post-development flow must be passed by the principal outlet structure and contained within the basin.
- The 100-year post-development flow must be passed through the basin by either the principal outlet structure, an emergency spillway, or a combination of both. Basins that will be constructed as a cut rather than a fill will be handled on a case by case basis.
- A minimum of one foot (twelve inches) of freeboard is required between the 100-year water surface elevation and the top of the basin.
- A minimum of 0.5 feet (six inches) of freeboard is required between the 10-year water surface elevation and the emergency spillway elevation.
- Emergency spillways located in fill sections must be lined with rip rap (per the Virginia Erosion and Sediment Control Handbook).

- When dry ponds are utilized for 50-10 detention purposes, up to 50 percent of the water quality volume may be used for 50-10 storage. 50-10 structures can be set no lower than the Water Quality Volume elevation.
- Inlet(s) and outlet(s) must be designed so that short circuiting does not occur (too close together to allow for settling).
- "Low flow" channels are not allowed in BMP basins. This would allow the "first flush" of runoff to short circuit the basin.
- Basin side slopes must be 4:1 (horizontal to vertical) or flatter for subdivisions to allow better maintenance. 3:1 side slopes are permissible for BMPs located in non-residential and multi-family developments.
- Landscaping of the basin slopes that requires mulching, spraying, etc. must be limited to the areas above the elevation of the top of the principal outlet structure elevation and must be done in such a manner so that the basin maintenance access will not be prohibited.
- Outlet structure, materials, joint connections, trash control, clogging, anti-vortex device, structural strength, and stability must be addressed by the consulting engineer on the plans.
- Unless otherwise specified in this document, all designs shall be in accordance with the Virginia Erosion and Sediment Control Handbook.
- All County maintained basins must have outlet structures constructed of reinforced concrete pipe (RCP) – Class III or better (minimum 15" diameter).
- All basins require wire mesh in lieu of filter fabric in front of all water quality perforations. The stone should not be installed until the BMP is stabilized.
- All efforts will be made during basin design and construction to ensure that the basin functions as a "dry" basin. At a minimum, the following should be incorporated into the design:
    1. The basin bottom will have a minimum one percent slope from the inlet(s) to the outlet <u>or</u> a trench drain will be provided that drains into the outlet structure.
    2. The basin bottom will have a two percent slope from the edge to the center of he basin, with a one percent slope along the resulting channel to the outlet structure.

<u>Maintenance</u>

- The elevation of the sediment cleanout level must be calculated and clearly indicated on both the plans and the riser/outfall structure (25% of the water quality volume).

- All extended detention outlet control structures must be surrounded by a filter cone of #3 stone and wire mesh. The stone should not be installed until the BMP is stabilized.
- Maintenance access should never cross the emergency spillway, unless the spillway has been designed for that purpose and has been properly stabilized.
- Debris and litter will accumulate near the outlet control device and should be removed during mowing operations.
- Care should be taken during the grading phase to ensure that no low pockets develop. This should make mowing operations easier.

Pollutant Removal

The efficiency ratings for Extended Detention (Dry) ponds are as follows:

WQV detained 12 hours	20%	(w/ additional vol. in forebay - 25%)
2.0 x WQV detained 30 hours	30%	(w/ additional vol. in forebay - 35%)
2.0 x WQV detained 30 hours (shallow marsh)	50%	(w/ additional vol. in forebay - 55%)
2.0 x WQV detained 40 hours	35%	(w/ additional vol. in forebay - 40%)

EXTENDED DETENTION BASIN
DESIGN 1
MINIMUM DESIGN STANDARD 9.03

The basin must detain the Water Quality Volume (WQV) for a period of twelve (12) hours. If off-site credits are to be taken, the basin must be sized to accommodate the entire contributing drainage area.

VOLUME: V_{BASIN} = Volume of runoff detained by basin

V_{BASIN} = Water Quality Volume (WQV)

WQV = The volume produced by ½ inch of runoff per impervious acre of contributing drainage area.

= A_{IMP} x 43,560 x 0.0417

= 1816 x A_{IMP}

A_{IMP} = The area of impervious surface on the contributing watershed in acres.

43,560 is the number of square feet in an acre.

0.0417 is the first half-inch of runoff.

WQV = 1816 x ___________ (acres)

WQV = ___________ cubic feet

DETENTION: Q_{AVG} = the average outflow rate for the desired detention time (cfs).

= V_{BASIN} / (T x 3600)

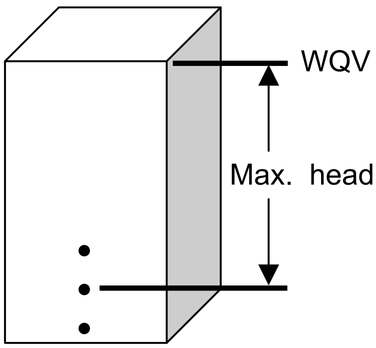
T = detention time (hrs.) = 12 hours

3600 = conversion factor (sec/hr)

Q_{AVG} = ___________ / (__12__ x 3600) = ___________ cfs

A_P = $Q_{AVG} / [0.6 \times (64.4 \times H_{AVG})^{1/2}]$ = total perforation area (ft^2)

H_{AVG} = 0.5 x [maximum head (in feet)]



A_P = _______ / [0.6 x (64.4 x _____)$^{1/2}$] = _________ ft^2

N = the number of perforations

N = A_P / A_H

A_H = the area of each perforation (ft^2)

Perforation Diameter	A_H
0.5 inch	0.0014
0.75 inch	0.0031
1.0 inch	0.0055

N = _____ / ______ = ____ _____ inch diameter perforations

The perforations must be evenly spaced and shall begin at the basin floor elevation.
The perforation area of the riser must be covered with wire mesh and a gravel cone (#3 stone).

NOTE: The maximum acceptable perforation diameter is one inch.

The number of perforations must be rounded **down** to the nearest whole number.

CONSTRUCTION PLANS SHALL INCLUDE THE FINAL DETAILED BMP DESIGN

EXTENDED DETENTION BASIN
DESIGN 2
MINIMUM DESIGN STANDARD 9.03

The basin must detain a volume equal to twice the water quality volume (2xWQV) for a period of thirty (30) hours. If off-site credits are to be taken, the basin must be sized to accommodate the entire contributing drainage area.

VOLUME:

V_{BASIN} = Volume of runoff detained by basin

V_{BASIN} = 2 x Water Quality Volume (WQV)

WQV = The volume produced by ½ inch of runoff per impervious acre of contributing drainage area.

= A_{IMP} x 43,560 x 0.0417

= 1816 x A_{IMP}

A_{IMP} = The area of impervious surface on the contributing watershed in acres.

43,560 is the number of square feet in an acre.

0.0417 is the first half-inch of runoff.

V_{BASIN} = 2 x 1816 x ________ (acres)

V_{BASIN} = ___________ cubic feet

DETENTION:

Q_{AVG} = the average outflow rate for the desired detention time (cfs).

= V_{BASIN} / (T x 3600)

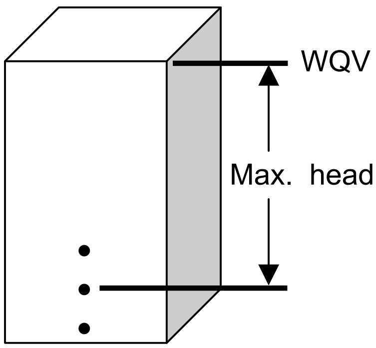
T = detention time (hrs.) = 30 hours

3600 = conversion factor (sec/hr)

Q_{AVG} = ___________ / (30 x 3600) = ___________ cfs

A_P = Q_{AVG} / $[0.6 \times (64.4 \times H_{AVG})^{1/2}]$ = total perforation area (ft^2)

H_{AVG} = 0.5 x [maximum head (in feet)]



A_P = _______ / [0.6 x (64.4 x _____)$^{1/2}$] = _________ ft^2

N = the number of perforations

N = A_P / A_H

A_H = the area of each perforation (ft^2)

Perforation Diameter	A_H
0.5 inch	0.0014
0.75 inch	0.0031
1.0 inch	0.0055

N = ______ / ______ = ____ _____ inch diameter perforations

The perforations must be evenly spaced and shall begin at the basin floor elevation.
The perforation area of the riser must be covered with wire mesh and a gravel cone (#3 stone).

NOTE: The maximum acceptable perforation diameter is one inch.

The number of perforations must be rounded **down** to the nearest whole number.

CONSTRUCTION PLANS SHALL INCLUDE THE FINAL DETAILED BMP DESIGN

EXTENDED DETENTION BASIN
DESIGN 3
MINIMUM DESIGN STANDARD 9.03

The basin must detain a volume equal to twice the water quality volume (2xWQV) for a period of forty (40) hours. If off-site credits are to be taken, the basin must be sized to accommodate the entire contributing drainage area.

VOLUME: V_{BASIN} = Volume of runoff detained by basin

V_{BASIN} = 2 x Water Quality Volume (WQV)

WQV = The volume produced by ½ inch of runoff per impervious acre of contributing drainage area.

= A_{IMP} x 43,560 x 0.0417

= 1816 x A_{IMP}

A_{IMP} = The area of impervious surface on the contributing watershed in acres.

43,560 is the number of square feet in an acre.

0.0417 is the first half-inch of runoff.

V_{BASIN} = 2 x 1816 x ________ (acres)

V_{BASIN} = ___________ cubic feet

DETENTION: Q_{AVG} = the average outflow rate for the desired detention time (cfs).

= V_{BASIN} / (T x 3600)

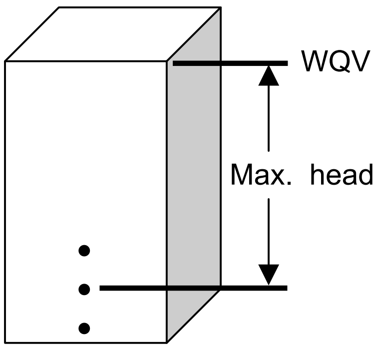
T = detention time (hrs.) = 40 hours

3600 = conversion factor (sec/hr)

Q_{AVG} = ___________ / (__40__ x 3600) = ___________ cfs

A_P = $Q_{AVG} / [0.6 \times (64.4 \times H_{AVG})^{1/2}]$ = total perforation area (ft^2)

H_{AVG} = 0.5 x [maximum head (in feet)]



A_P = _______ / [0.6 x (64.4 x ______)$^{1/2}$] = _________ ft^2

N = the number of perforations

N = A_P / A_H

A_H = the area of each perforation (ft^2)

Perforation Diameter	A_H
0.5 inch	0.0014
0.75 inch	0.0031
1.0 inch	0.0055

N = ______ / ______ = ____ _____ inch diameter perforations

The perforations must be evenly spaced and shall begin at the basin floor elevation.
The perforation area of the riser must be covered with wire mesh and a gravel cone (#3 stone).

NOTE: The maximum acceptable perforation diameter is one inch.

The number of perforations must be rounded **down** to the nearest whole number.

CONSTRUCTION PLANS SHALL INCLUDE THE FINAL DETAILED BMP DESIGN

MINIMUM DESIGN STANDARD 9.04
EXTENDED DETENTION WITH SHALLOW MARSH

Definition

An extended detention pond with a shallow marsh performs like a standard extended detention pond, but there is a one-foot deep permanent pool of water that is planted with wetland vegetation.

Purpose

Wetland vegetation is a reliable non-point source pollution control measure. Hydraulic resistance provided by wetland vegetation reduces stormwater runoff velocities and promotes settling of particulate matter. Using a process of assimilation, emergent and aquatic vegetation can effectively remove nutrients and pollutants from the water column and settle particulate. Additionally, the root network of emergent plants helps to stabilize and reduce the re-suspension of sediment. Design engineers have recognized the capability and efficiency of a wetland to remove pollutants. By combining wetland vegetative systems with extended detention basins, the designer is able to achieve higher pollutant removal capabilities without having to utilize greater land area.

As the amount of impervious area in a watershed increases due to the construction of buildings and roadways, so does the volume and rate of runoff and the amount of pollutants in stormwater. Groundwater recharge decreases as impervious surfaces reduce the infiltration of surface water into the soil. Natural wetlands provide ecological services that are particularly beneficial in urban areas such as stormwater retention, groundwater recharge, and the removal of sediment, nutrients, and pollutants. The goal of constructing a shallow marsh wetland stormwater basin is to provide several of these important ecological services. When properly designed and constructed, an extended detention shallow marsh basin can assist in maintaining, and potentially enhancing, the quality of water in Henrico County and the State of Virginia.

Design Criteria

Extended detention basins with shallow marsh must be constructed in accordance with the following design criteria:

- The 10-year post-development flow must be passed by the principal outlet structure and contained within the basin.
- The 100-year post-development flow must be passed through the basin by either the principal outlet structure, an emergency spillway, or a combination of both. Basins that will be constructed as a cut rather than a fill will be handled on a case by case basis.

- A minimum of one foot (twelve inches) of freeboard is required between the 100-year water surface elevation and the top of the basin.
- A minimum of 0.5 feet (six inches) of freeboard is required between the 10-year water surface elevation and the emergency spillway elevation.
- Emergency spillways located in fill sections must be lined with rip rap (per the Virginia Erosion and Sediment Control Handbook).
- When shallow marsh ponds are utilized for 50-10 detention purposes, up to 50 percent of the water quality (detention) volume may be used for 50-10 storage. No portion of the permanent marsh volume may be used for 50-10 storage. 50-10 structures can be set no lower than the Water Quality Volume elevation.
- Inlet(s) and outlet(s) must be designed so that short-circuiting does not occur (too close together to allow for settling).
- “Low flow” channels are not allowed in BMP basins. This would allow the “first flush” of runoff to short circuit the basin.
- Basin side slopes must be 4:1 (horizontal to vertical) or flatter for subdivisions to allow better maintenance. 3:1 side slopes are permissible for BMPs located in non-residential and multi-family developments.
- Landscaping of the basin slopes that requires mulching, spraying, etc. must be limited to the areas above the elevation of the top of the principal outlet structure elevation and must be done in such a manner so that the basin maintenance access will not be prohibited.
- Outlet structure, materials, joint connections, trash control, clogging, anti-vortex device, structural strength, and stability must be addressed by the consulting engineer on the plans.
- Unless otherwise specified in this document, all designs shall be in accordance with the Virginia Erosion and Sediment Control Handbook.
- All County maintained basins must have outlet structures constructed of reinforced concrete pipe (RCP) – Class III or better (minimum 15” diameter).
- All basins require wire mesh in lieu of filter fabric in front of all water quality perforations. The stone should not be installed until the BMP is stabilized.
- A minimum drainage area of 10 acres is required for the shallow marsh extended detention basin. Evidence of groundwater interception or another supply of water that will effectively sustain wetland plants may be provided for qualification review.
- Two (2) planting zones, a high marsh (6” max. inundation – ref. Zone 2) and a low marsh (12” max. inundation – ref. Zone 3) are required for shallow marsh extended detention basins. Reference pages 9.04-5 and 9.04-6 for plant lists.

- Two-thirds (2/3) of the total shallow marsh volume will be contained in the low marsh, and the remaining one-third (1/3) in the high marsh.
- A planting plan that details the requirements of this section shall be submitted as part of the POD or subdivision construction plans and also as part of the landscape plan.

Wetland Vegetation Establishment

Various hydrologic and biological pathways are available in natural wetland systems to transport seeds of wetland plants. Over time, seeds are buried in the soil and provide a bank of vegetative diversity. A newly created stormwater basin does not contain a buried seed bank and has a fixed boundary that cannot provide wetland seed transportation opportunities found in natural systems.

The most reliable method for establishment of a wetland plant community in the basin is by planting nursery grown or transplanted wetland plants. Several plants with strong vegetative cover potential, hence pollutant removal capability, are listed at the end of this section for Planting Zone 2 (high marsh) and Planting Zone 3 (low marsh).

- To support the establishment and growth of the planted wetland plant species, a minimum of three (3) inches of topsoil will be applied to the surface of the basin prior to plant installation. The three (3) inches of topsoil is not to be included in the volume requirement.
- At least two different wetland plant species will be planted in each zone. No one wetland plant species can exceed 75% cover of any planting zone. A survival rate of 80% of vegetative cover is required the first full growing season after planting.
- Herbaceous (i.e. emergent and aquatic) species will be planted on two (2) feet centers and shrub species on four (4) feet centers.
- Dormant underground plant parts (i.e. rhizomes or tubers) or whole plants will be used during the dormant season, from November to March and actively growing plant material (i.e. bare root or potted) from April to October.
- The basin can be temporarily stabilized with annual rye grass (lolium multiflorum), winter rye (secale cereale), or german millet (setaria italica). All varieties of fescue are prohibited for use in the shallow marsh planting zones.

Longevity/Maintenance

Stormwater shallow marsh basins require the greatest maintenance during the first three years. This is largely due to the lack of established vegetative cover in areas still under construction (i.e. fill lots) within the drainage area of the basin. With a forebay in place, the created shallow marsh area should function for approximately 10 years before requiring major sediment removal or other rehabilitation work.

Additional Benefits

In addition to the water quality benefits associated with the establishment of a shallow marsh wetland stormwater basin, wildlife habitat will be created. Creative basin designs that include small islands or peninsulas will help to attract various waterfowl for feeding and nesting. These basins can be aesthetically pleasing, particularly when various plants flower throughout the year. The general flower description and flowering period is provided for plants listed at the end of this section.

Pollutant Removal

The efficiency ratings for Extended Detention basins with shallow marsh are as follows:

2.0 x WQV detained 30 hours	50%
2.0 x WQV detained 30 hours	55% (with additional volume in forebay)

SHALLOW MARSH PLANT LIST

ZONE 1 - *BANKS/SHORES* - TOLERATES SATURATED SOIL CONDITIONS

Scientific Name	Common Name	Flowering Period	Flowers
Aster puniceus	Swamp Aster	August-November	Purple-blue/panicle
Caltha palustris	Marsh Marigold	April-June	Shiny yellow
Carex lurida	Lurid Sedge	June-October	Spikelet
Impatiens capensis	Jewelweed	June-September	Orange-yellow/spurred
Lobelia cardinalis	Cardinal Flower	July-October	Bright red/tubular
**Panicum virgatum*	Switchgrass	July-September	Spikelet
Phalaris arundinacea	Reed Canary Grass	June-August	Spikelet
**Scirpus pungens*	Three Squared Rush	June-September	Inconspicuous
Veronia noveboracensis	New York Ironweed	August-October	Purple-brown

ZONE 2 - *HIGH MARSH* - 6" INUNDATION MAXIMUM BELOW NORMAL POOL

Scientific Name	Common Name	Flowering Period	Flowers
Acorus calamus	Sweet Flag	May-August	Yellow-brown/spathe
Decodon verticilatus	Swamp Loosetrife	July-September	Pink/bell shaped
*Elodea Canadensis	Common Waterweed	July-September	Small white/spathe
Hibiscus moscheutos	Rose Mallow	July-September	Large pink or white
Iris versicolor	Blue Flag	May-July	Large blue or purple
Iris pseudocorus	Yello Flag	May-July	Large yellow or cream
Leersia oryzoides	Rice Cutgrass	June-October	Spikelet
Orontium aquaticum	Golden Club	April-June	Small yellow/spathe
Saururus ceruus	Lizards Tail	June-September	Smallwhite/stalked

SHALLOW MARSH PLANT LIST

ZONE 3 - *LOW MARSH* - 12" INUMDATION MAXIMUM BELOW NORMAL POOL

Scientific Name	Common Name	Flowering Period	Flowers
Peltandra virginica	Arrow-arum	May-July	Green/spathe
Polygonum pennsylvanicum	Pennsylvania Smartweed	May-October	Small pink/stalked
Polygonum punctatum	Water Smartweed	July-October	Small green/stalked
Polygonum sagittatum	Tearthumb	June-September	Small green/pink
Pontederia cordata	Pickerel Weed	June-November	Small violet-blue
Sagittaria latifolia	Arrow-head	July-September	Small white/yellow
**Scirpus validus*	Soft Stemmed Bulrush	June-September	Inconspicuous
**Typha latifolia*	Broad Leaved Cattail	May-July	Inconspicuous
Zizania aquatica	Wild Rice	June-September	Spikelet

ZONE 4 - *DEEP POOL* - 3' INUNDATION BELOW NORMAL POOL

Scientific Name	Common Name	Flowering Period	Flowering form/color
Cephalanthus occidentalis	Buttonbush	May-August	Small white/balled
**Elodea canadensis*	Common waterweed	July-September	Small white/spathe
**Nuphar luteum*	Spatterdock	June-September	Yellow
**Nymphaea odorata*	Water lilly	June-September	Large white
**Potamogeton pectinatus*	Pondweed	Summer	Stalked
**Spirodela polyrhiza*	Greater duckweed	Summer	Inconspicuous
Vallisneria Americana	Wild celery	July-October	Small white/stalked

**** plants known to be particularly good at pollutant removal***

EXTENDED DETENTION BASIN WITH SHALLOW MARSH
MINIMUM DESIGN STANDARD 9.04

The basin must detain a volume equal to twice the water quality volume (2xWQV) for a period of thirty (30) hours. In addition, the basin must contain a shallow marsh in the bottom stage with a volume equal to the water quality volume (WQV). If off-site credits are to be taken, the basin must be sized to accommodate the entire contributing drainage area.

VOLUME: V_{BASIN} = Volume of runoff detained by basin

V_{BASIN} = 2 x Water Quality Volume (WQV)

WQV = The volume produced by ½ inch of runoff per impervious acre of contributing drainage area.

= A_{IMP} x 43,560 x 0.0417

= 1816 x A_{IMP}

A_{IMP} = The area of impervious surface on the contributing watershed in acres.

43,560 is the number of square feet in an acre.

0.0417 is the first half-inch of runoff.

V_{BASIN} = 2 x 1816 x ________ (acres)

V_{BASIN} = ___________ cubic feet

V_{MARSH}= The volume of the shallow marsh = WQV

V_{MARSH}= 1816 x A_{IMP}

V_{MARSH}= 1816 x ___________ = ___________ ft^3

Total Volume = V_{BASIN} + V_{MARSH}

= ___________ + _________

Total Volume = ___________ ft^3

Calculate the volume of the High (6”) Marsh:

V_{HIGH} = (1/3) x V_{MARSH}

= (1/3) x ___________

V_{HIGH} = ___________ cubic feet

Calculate the volume of the Low (12”) Marsh:

V_{LOW} = (2/3) x V_{MARSH}

= (2/3) x ___________

V_{LOW} = ___________ cubic feet

DETENTION: Q_{AVG} = the average outflow rate for the desired detention time (cfs).

= V_{BASIN} / (T x 3600)

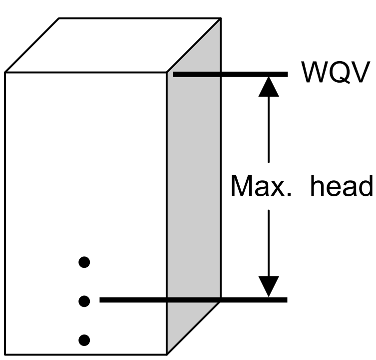
T = detention time (hrs.) = 30 hours

3600 = conversion factor (sec/hr)

Q_{AVG} = ___________ / (_30_ x 3600) = ___________ cfs

A_P = $Q_{AVG} / [0.6 \times (64.4 \times H_{AVG})^{1/2}]$ = total perforation area (ft^2)

H_{AVG} = 0.5 x [maximum head (in feet)]



A_P = _______ / [0.6 x (64.4 x ______)$^{1/2}$] = __________ ft^2

N = the number of perforations

N = A_P / A_H

A_H = the area of each perforation (ft^2)

Perforation Diameter	A_H
0.5 inch	0.0014
0.75 inch	0.0031
1.0 inch	0.0055

N = ______ / ______ = ____ _____ inch diameter perforations

The perforations must be evenly spaced and shall begin at the top of the shallow marsh elevation.
The perforation area of the riser must be covered with wire mesh and a gravel cone (#3 stone).

NOTE: The maximum acceptable perforation diameter is one inch.

The number of perforations must be rounded **down** to the nearest whole number.

CONSTRUCTION PLANS SHALL INCLUDE THE FINAL DETAILED BMP DESIGN

MINIMUM DESIGN STANDARD 9.05
RETENTION (WET) POND

Definition

A wet pond is a BMP that relies on settling as the primary removal method of removing pollutants from runoff. Wet ponds maintain a permanent water quality volume elevation.

Purpose

Wet ponds, along with extended detention/shallow marsh basins are among the top BMPs in terms of providing water quality and quantity control benefits over a broad range of storm frequencies/sizes, drainage areas, and land use scenarios. Typically, wet ponds are restricted to drainage areas of 10 acres or more.

Wet ponds provide a large, deep permanent pool area, which is generally deep enough to discourage the establishment of wetland plants. The degree of pollutant removal achieved by a wet pond is a function of the size and design of the permanent pool. In theory, the incoming storm runoff displaces the “old water” out of the pond and is stored until the next storm. Suspended pollutants settle out from the water column to the pond sediments. Moreover, the permanent pool acts as a barrier to re-suspension of deposited materials, improving removal performances over that achieved by extended detention.

Wet ponds are not permitted as BMPs in residential development, however, regional wet ponds are allowed in residential development under certain conditions.

Wet Pond/Wetland System

Recent studies have been made regarding a wet pond/shallow marsh system to enhance pollutant removal capabilities. Currently, a design for such a system is illustrated in “Design of Stormwater Wetland Systems”. At this time, Henrico County recognizes a 65% removal efficiency for that design.

Design Criteria

Wet ponds must constructed according to the following design criteria.

- The 10-year post-development flow must be passed by the principal outlet structure and contained within the basin.
- The 100-year post-development flow must be passed through the basin by either the principal outlet structure or an emergency spillway.

- A minimum of one foot (twelve inches) of freeboard is required between the 100-year water surface elevation and the top of the basin.
- Emergency spillways in fill sections must be lined with rip rap (per the Virginia Erosion and Sediment Control Handbook, Third Edition, 1992).
- The inlet(s) and outlet(s) must be designed so that short circuiting does not occur (too close together to allow for settling).
- Forebays are required at each incoming discharge point.
- The outlet structure, materials, joint connections, trash control, clogging, anti-vortex device, structural strength, and stability must be addressed by the consulting engineer on the plans.
- A minimum contributing drainage area of 10 acres is required for a wet pond. Evidence of groundwater interception (or another supply of water) that will effectively sustain the wet pond may be provided for qualification review. The use of a domestic water supply is not acceptable.
- Landscaping of the wet pond which requires mulching, spraying, etc. must be limited to the areas above the top elevation of the principal outlet structure.
- There must be a minimum of 50 feet between any buildable area and the permanent pool elevation.
- All wet ponds must include an aquatic bench. The aquatic bench ranges in depth from 0 inches at the water's edge to 12 inches deep at the outer limit of the aquatic bench. For wet ponds with a permanent pool less than 10 feet in depth, the aquatic bench must be 10 feet in width. For wet ponds with a permanent pool 10 feet or greater in depth, the aquatic bench must be 20 feet in width.
- Side slopes in wet ponds (above and below the aquatic bench) can be no steeper than 4 : 1 (horizontal : vertical).

Pollutant Removal

The efficiency ratings for wet ponds are as follows:

Pond size:	Removal Eff.	Removal Eff. with additional volume in forebay
WQV	35%	40%
2.5xWQV	40%	45%
4.0xWQV	50%	55%
10.0xWQV	65%	
Wet pond/ wetland system	65%	

RETENTION (WET) POND
DESIGN 1
MINIMUM DESIGN STANDARD 9.05

The basin must maintain a volume equal to the Water Quality Volume (WQV). If off-site credits are to be taken, the basin must be sized to accommodate the entire contributing drainage area.

VOLUME: V_{BASIN} = Volume of runoff detained by basin

V_{BASIN} = Water Quality Volume (WQV)

WQV = The volume produced by ½ inch of runoff per impervious acre of contributing drainage area.

= A_{IMP} x 43,560 x 0.0417

= 1816 x A_{IMP}

A_{IMP} = The area of impervious surface on the contributing watershed in acres.

43,560 is the number of square feet in an acre.

0.0417 is the first half-inch of runoff.

WQV = 1816 x __________ (acres)

WQV = __________ cubic feet

Although Q_{IN} may equal Q_{OUT} for this facility, any stormwater management concerns must be addressed. Storage volume for stormwater management purposed begins at the maximum elevation of the permanent pool.

CONSTRUCTION PLANS SHALL INCLUDE THE FINAL DETAILED BMP DESIGN

RETENTION (WET) POND
DESIGN 2
MINIMUM DESIGN STANDARD 9.05

The basin must maintain a volume equal to 2.5 times the Water Quality Volume (2.5xWQV). If off-site credits are to be taken, the basin must be sized to accommodate the entire contributing drainage area.

VOLUME: V_{BASIN} = Volume of runoff detained by basin

V_{BASIN} = 2.5 x Water Quality Volume (WQV)

WQV = The volume produced by ½ inch of runoff per impervious acre of contributing drainage area.

= A_{IMP} x 43,560 x 0.0417

= 1816 x A_{IMP}

A_{IMP} = The area of impervious surface on the contributing watershed in acres.

43,560 is the number of square feet in an acre.

0.0417 is the first half-inch of runoff.

V_{BASIN} = 2.5 x 1816 x ______ (acres)

V_{BASIN} = ___________ cubic feet

Although Q_{IN} may equal Q_{OUT} for this facility, any stormwater management concerns must be addressed. Storage volume for stormwater management purposed begins at the maximum elevation of the permanent pool.

CONSTRUCTION PLANS SHALL INCLUDE THE FINAL DETAILED BMP DESIGN

RETENTION (WET) POND
DESIGN 3
MINIMUM DESIGN STANDARD 9.05

The basin must maintain a volume equal to four times the Water Quality Volume (WQV). If off-site credits are to be taken, the basin must be sized to accommodate the entire contributing drainage area.

VOLUME: V_{BASIN} = Volume of runoff detained by basin

V_{BASIN} = 4 x Water Quality Volume (WQV)

WQV = The volume produced by ½ inch of runoff per impervious acre of contributing drainage area.

= A_{IMP} x 43,560 x 0.0417

= 1816 x A_{IMP}

A_{IMP} = The area of impervious surface on the contributing watershed in acres.

43,560 is the number of square feet in an acre.

0.0417 is the first half-inch of runoff.

V_{BASIN} = 4 x 1816 x ________ (acres)

V_{BASIN} = ___________ cubic feet

Although Q_{IN} may equal Q_{OUT} for this facility, any stormwater management concerns must be addressed. Storage volume for stormwater management purposed begins at the maximum elevation of the permanent pool.

CONSTRUCTION PLANS SHALL INCLUDE THE FINAL DETAILED BMP DESIGN

RETENTION (WET) POND
DESIGN 4
MINIMUM DESIGN STANDARD 9.05

The basin must maintain a volume equal to ten times the Water Quality Volume (10xWQV). If off-site credits are to be taken, the basin must be sized to accommodate the entire contributing drainage area.

VOLUME: V_{BASIN} = Volume of runoff detained by basin

V_{BASIN} = 10 x Water Quality Volume (WQV)

WQV = The volume produced by ½ inch of runoff per impervious acre of contributing drainage area.

= A_{IMP} x 43,560 x 0.0417

= 1816 x A_{IMP}

A_{IMP} = The area of impervious surface on the contributing watershed in acres.

43,560 is the number of square feet in an acre.

0.0417 is the first half-inch of runoff.

V_{BASIN} = 10 x 1816 x _______ (acres)

V_{BASIN} = ___________ cubic feet

Although Q_{IN} may equal Q_{OUT} for this facility, any stormwater management concerns must be addressed. Storage volume for stormwater management purposed begins at the maximum elevation of the permanent pool.

CONSTRUCTION PLANS SHALL INCLUDE THE FINAL DETAILED BMP DESIGN

MINIMUM DESIGN STANDARD 9.06
BIORETENTION

Definition

Bioretention is a method to manage stormwater runoff using native plants and soil conditioning.

Purpose

Bioretention areas are conceived to capture sheet flow from impervious surfaces and will typically be limited to small drainage areas (up to one acre).

Design Criteria

Bioretention basins must be constructed according to the following design criteria:

- Six major design components need to be incorporated: grass buffer strip, ponding area, planting soil, sand bed, organic layer, and plant material.
- The bioretention area shall be sized to meet the following standards:
  - a. Minimum width of 15'.
  - b. Minimum length shall be 40'. For widths equal to or greater than 20', the length of the bioretention area shall be at least twice the width.
  - c. The ponded area shall have a maximum depth of 6 inches.
  - d. The planting soil shall have a minimum depth of 4'.
  - e. The sand bed shall have a depth of 1'.
  - f. The minimum width of the buffer strip shall be 10 feet.
- A one foot wide sand wall shall extend around all sides of the bioretention area that receives surface runoff.
- The design needs to incorporate a bypass to take runoff around the BMP once the ponding area has filled to capacity.
- Filter fabric needs to be placed between the sand and planting soil layers.
- Trees and shrubs shall be provided at a rate of 1,000 total stems per acre of BMP surface area. The total number should be distributed such that for every tree there are 3 shrubs.
- The water table must be at least two feet below the bottom of the BMP.

- The six inch ponding area over the surface area of the BMP must hold the water quality volume.
- Planting Material:
  1. The plant material should be chosen and placed to replicate a forest community structure. The layout should follow two basic guidelines. First, woody plant material should not be placed within the immediate areas of where flow will be entering the BMP. Secondly, trees should be planted primarily on the perimeter of the bioretention area to maximize shading and sheltering.
  2. At installation, trees should be 2.5 inches in caliper, and shrubs 3 to 4 feet in height or 18 to 24 inches in spread. Ground cover may be as seed or, preferably, plugs.
  3. A minimum of 3 species of trees and three species of shrubs should be selected to insure diversity.
  4. A planting plan needs to be submitted and approved with the construction plans and as part of the landscape plan.
- Perforated underdrains shall be provided beneath the bottom sand layer. The underdrains shall be 4" in diameter. In order to provide 2" of cover, they shall be placed in 6" of stone.

Material Specifications

- The planting soil used in the bioretention area must have a composition of at least 10 to 25% clay and shall be of a sandy loam or loamy sand texture. Loamy soils may be used if the composition consists of 35% sand.
- The planting soil shall be of uniform composition, free of stones, stumps, roots or similar objects larger than one inch, brush, or any other material or substance which may be harmful to plant growth, or a hindrance to planting or maintenance operations.
- The planting soil shall be free of plants or plant parts of Bermuda grass, Quack grass, Johnson grass, Mugwort, Nutsedge, Poison Ivy, and Canadian Thistle.
- The planting soil must meet the following criteria:

pH range	5.5 - 6.5
Organic matter	1.5 - 3.0%
Magnesium - Mg	35 lbs./acre
Phosphorus - P_2O_5	100 lbs./acre
Potassium - K_2O	85 lbs./acre
Soluble salts	not to exceed 500 ppm

Maintenance

- Soil testing should be conducted annually so that the accumulation of toxins and heavy metals can be detected or prevented.
- Once contaminated, the soil must be removed. In some cases, removal and disposal of the entire soil base, as well as the plant material, may be required.
- Replacement of mulch layers may be necessary every 2 to 3 years.
- Dead or diseased plant materials must be replaced in a timely manner.
- Areas of soil erosion must be corrected in a timely manner.

Pollutant Removal

A standard bioretention basin (WQV) has a removal efficiency of 50%. A bioretention basin that holds two times the Water Quality Volume has a removal efficiency of 65%.

BIORETENTION BASIN
DESIGN 1
MINIMUM DESIGN STANDARD 9.06

The bioretention area must store the Water Quality Volume (WQV) over a six (6) inch deep area and filter it through a media of sand and soil.

VOLUME: WQV = Volume of runoff detained by basin

WQV = Water Quality Volume (WQV)

WQV = The volume produced by ½ inch of runoff per impervious acre of contributing drainage area.

= A_{IMP} x 43,560 x 0.0417

= 1816 x A_{IMP}

A_{IMP} = The area of impervious surface on the contributing watershed in acres.

43,560 is the number of square feet in an acre.

0.0417 is the first half-inch of runoff.

WQV = 1816 x ___________ (acres)

WQV = ___________ cubic feet

COMPUTE THE VOLUME PROVIDED:

Volume Provided = V_{PROV} = L x W x D

L = Length of the bioretention area = ___________ feet

W = Width of the bioretention area = ____________ feet

D = Ponded depth = 0.50 feet

V_{PROV} = ___________ft. x ________ft. x ________ft.

V_{PROV} = ___________ $ft.^3$

CALCULATE THE NUMBER OF PLANTINGS REQUIRED:

Surface area of bioretention area = L x W

= ___________ft. x ________ft.

Surface area = ___________ $ft.^2$

Number of stems = 1,000 stems/acre x surface area x 1acre/43,560 $ft.^2$

= 1,000 stems/acre x ______ x 1acre/43,560 $ft.^2$

= ___________ stems

Number of trees = number of stems / 4

= ___________ / 4

= ___________ trees (round up to whole number)

Number of shrubs = number of stems – number of trees

= ___________ - __________

= ___________ shrubs

CONSTRUCTION PLANS SHALL INCLUDE THE FINAL DETAILED BMP DESIGN

BIORETENTION BASIN
DESIGN 2
MINIMUM DESIGN STANDARD 9.06

The bioretention area must store the twice the Water Quality Volume (2xWQV) over a six (6) inch deep area and filter it through a media of sand and soil.

VOLUME: WQV = Volume of runoff detained by basin

WQV = Water Quality Volume (WQV)

WQV = The volume produced by ½ inch of runoff per impervious acre of contributing drainage area.

= A_{IMP} x 43,560 x 0.0417

= 1816 x A_{IMP}

A_{IMP} = The area of impervious surface on the contributing watershed in acres.

43,560 is the number of square feet in an acre.

0.0417 is the first half-inch of runoff.

V_{BASIN} = 2 x 1816 x ________ (acres)

V_{BASIN} = ____________ cubic feet

COMPUTE THE VOLUME PROVIDED:

Volume Provided = V_{PROV} = L x W x D

L = Length of the bioretention area = ____________ feet

W = Width of the bioretention area = _____________ feet

D = Ponded depth = 0.50 feet

V_{PROV} = ____________ft. x ________ft. x ________ft.

V_{PROV} = ____________ $ft.^3$

CALCULATE THE NUMBER OF PLANTINGS REQUIRED:

Surface area of bioretention area = L x W

= ___________ft. x ________ft.

Surface area = ___________ $ft.^2$

Number of stems = 1,000 stems/acre x surface area x 1acre/43,560 $ft.^2$

= 1,000 stems/acre x ______ x 1acre/43,560 $ft.^2$

= ___________ stems

Number of trees = number of stems / 4

= ___________ / 4

= ___________ trees (round up to whole number)

Number of shrubs = number of stems – number of trees

= ___________ - __________

= ___________ shrubs

CONSTRUCTION PLANS SHALL INCLUDE THE FINAL DETAILED BMP DESIGN

MINIMUM DESIGN STANDARD 9.07
SAND FILTER

Definition

A sand filter is a device used to remove pollutants by filtering runoff through a bed of sand.

Purpose

Pollutant removal processes at work in Delaware Sand Filters are complex and involve physical, chemical and biological transformations. The most obvious mechanism is physical straining of suspended solids and particulate nutrients. There are two types of sand filter systems; systems that provide partial sedimentation pretreatment and those that provide full sedimentation pretreatment. Systems that provide only internal sedimentation pretreatment are considered partial sedimentation systems. Full sedimentation systems involve the use of a basin that detains the water quality volume for 12 hours immediately up gradient from the Delaware Sand Filter. The sizing criteria varies depending on whether full or partial sedimentation is provided.

Design Criteria

Sand filters must be constructed according to the following design criteria:

- The sand filtration chamber shall contain an 18" layer of sand over a 6" layer of stone.
- Filter fabric shall be placed between the sand and stone layers.
- When the filter length exceeds 20 feet, 4 inch diameter perforated under drains must be placed within the stone layer. Two inches of stone cover must be provided over the under drain. Under drains must be wrapped in filter fabric and spaced 2 feet on center.
- An internal weir, sized to pass the 10-yr post-developed flow, shall be provided between the sedimentation chamber and the clear well.
- The bottom of the sand filter must be sloped towards the clear well at 1%.
- Runoff may enter the sand filter system by a variety of means, including slotted curbs, grate tops, and traditional curb throat openings.
- When the filter will be subjected to traffic loads or significant earth loads, the concrete vault should be designed accordingly.

- Reinforcement specifications must be shown on the plans.
- A layer of filer fabric and a 2" deep layer of rock (#5 or similar) shall be placed on top of the sand.
- Weirs located in the wall between the sedimentation chamber and the sand filtration chamber shall be 3" or 4" in diameter and spread one foot on center.
- Access for inspection and maintenance activities should be provided according to the sketch on Page 9.07-3.
- Trash racks shall be installed over the curb openings into the sand filter.
- Observation wells (with threaded caps) are required in the sand filter chamber and must be located at the access manhole on the upper end of the structure.

Maintenance

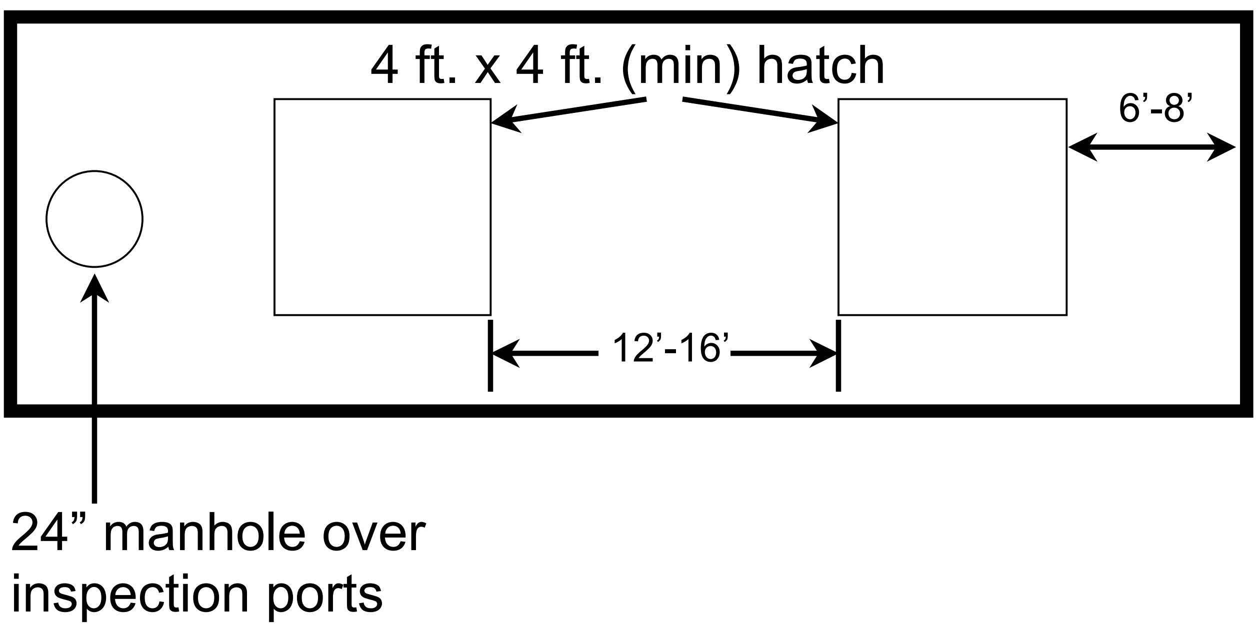
- When accumulation of sediments in the filtration chamber indicate that the filter media is clogging and not performing properly, sediments must be removed along with the top two to three inches of sand. The coloration of the sand will provide a good indication of what depth of removal is required. Clean sand must then be placed in the filter to restore the design depth.
- Trash collected on the grates or trash racks protecting the inlets shall be removed no less frequently than weekly to assure preserving the inflow capacity of the BMP.
- Monitoring manholes, flumes, and other facilities shall be kept clean and ready for use.

Pollutant Removal

Extensive monitoring studies by the City of Alexandria on the Delaware Sand Filter have produced documentation to support a removal efficiency of 65%. Therefore, the County will recognize a removal efficiency of 65% for the Delaware Sand Filter. For other sand filter designs, such as the Austin Sand Filter or the D. C. Sand Filter, the County recognizes a removal efficiency of 40%.

SEDIMENTATION CHAMBER

SAND FILTER CHAMBER



DELAWARE SAND FILTER
DESIGN 1 – NO PRE-TREATMENT
MINIMUM DESIGN STANDARD 9.07

COMPUTE THE WATER QUALITY VOLUME:

WQV = The volume produced by ½ inch of runoff per impervious acre of contributing drainage area.

= A_{IMP} x 43,560 x 0.0417

= 1816 x A_{IMP}

A_{IMP} = The area of impervious surface on the contributing watershed in acres.

43,560 is the number of square feet in an acre.

0.0417 is the first half-inch of runoff.

WQV = 1816 x __________ (acres)

WQV = ___________ cubic feet

COMPUTE THE MINIMUM FILTER CHAMBER AREA(A_{FM}) AND SEDIMENT CHAMBER AREA (A_{SM}):

2h is the difference in elevation between the top of the filter layer and the invert of the 10-year bypass weir.

A.) If 2h is greater than or equal to 2.67 feet, use the formula:

A_{SM} = A_{FM} = 545 A_{IMP} d_f / (d_f + h)

d_f = the depth of the sand layer (1.5 feet)

A_{SM} = A_{FM} = (545 x ___________ x 1.5) / (1.5 + __________)

A_{SM} = A_{FM} = ___________ $ft.^2$

B.) If 2h is less than 2.67 feet, use the formula:

A_{SM} = A_{FM} = 1816 A_{IMP} / (4.1h + 0.9) = WQV / (4.1h + 0.9)

A_{SM} = A_{FM} = ___________ / [(4.1 x _________) + 0.9]

A_{SM} = A_{FM} = ___________ $ft.^2$

INTERNAL WEIR SIZING: If the sand filter is designed as an on-line structure, an internal weir must be provided between the sedimentation chamber and the clearwell. The internal weir must be sized to pass the 10-year post-development flow.

Q = the 10-year post-development flow = ___________ cfs

Using the weir equation $Q = CLH^{3/2}$, where C = 3.1, determine the weir length and head needed to pass the 10-year flow.

IF L IS KNOWN:

$H^{3/2}$ = Q / (C x L)

H = $[Q / (3.1 \times L)]^{2/3}$

H = [___________ / (3.1 x __________)]$^{2/3}$

H = ___________ feet

IF H IS KNOWN:

L = $Q / (C \times H^{3/2})$

= $Q / (3.1 \times H^{3/2})$

= ___________ / [3.1 x (__________)$^{3/2}$]

L = ___________ feet

The 10-year water surface elevation in the sand filter = weir elevation + H

10-year WSE = ___________ + _________

10-year WSE = ___________

CONSTRUCTION PLANS SHALL INCLUDE THE FINAL DETAILED BMP DESIGN

DELAWARE SAND FILTER
DESIGN 2 – WITH PRE-TREATMENT
MINIMUM DESIGN STANDARD 9.07

COMPUTE THE WATER QUALITY VOLUME:

WQV = The volume produced by ½ inch of runoff per impervious acre of contributing drainage area.

= A_{IMP} x 43,560 x 0.0417 = 1816 x A_{IMP}

A_{IMP} = The area of impervious surface on the contributing watershed in acres.

43,560 is the number of square feet in an acre.

0.0417 is the first half-inch of runoff.

WQV = 1816 x __________ (acres)

WQV = __________ cubic feet

COMPUTE THE SEDIMENT CHAMBER VOLUME (V_{SM})

V_{SM} = 10% of the required WQV = 0.10 x WQV (cubic feet)

= 0.10 x ___________ (cubic feet)

V_{SM} = __________ $ft.^3$

The volume of the sediment chamber provided ($V_{SM-PROV}$) is the length and width of the sediment chamber times the depth of stone and sand in the filter chamber , usually 2.17 feet.

$V_{SM-PROV}$ = length x width x depth (usually 2.17')

= __________ x _________ x _________

$V_{SM-PROV}$ = __________ $ft.^3$

COMPUTE THE MINIMUM FILTER CHAMBER AREA(A_{FM}):

In this design, an external bypass is utilized to divert runoff in excess of the WQV when a pre-treatment basin is used. Therefore, 2h is the difference in elevation between the invert of the lowest water quality perforation in the basin and the top of sand elevation.

A_{FM} = $310\ A_{IMP}\ d_f / (d_f + h)$

Where d_f is the depth of the sand layer (1.5 feet)

A_{FM} = [310 x ___________ x 1.5] / [1.5 + ___________]

A_{FM} = ___________ $ft.^2$

SELECT WIDTH AND LENGTH OF FILTER CHAMBER AND SEDIMENTATION CHAMBER:

W_S = Width of sedimentation chamber

W_F = Width of filter chamber

Based on site constraints, select W_S and W_F

W_S = W_F = ___________ feet

Utilizing W_S and W_F selected, and the A_{FM} previously determined, calculate the length of the sedimentation chamber (L_S) and the length of the filter chamber (L_F).

L_S = L_F = A_{FM} / W_F

= ___________ / __________

L_S = L_F = ___________ feet

COMPUTE THE SURFACE AREA PROVIDED:

A_S = A_F = W_F x L_F = ___________ x __________

A_S = A_F = ___________ $ft.^2$

CONSTRUCTION PLANS SHALL INCLUDE THE FINAL DETAILED BMP DESIGN

MINIMUM DESIGN STANDARD 9.08
INFILTRATION TRENCH

Definition

Infiltration trenches are shallow, excavated trenches which are backfilled with 1.5" to 3" clean, washed stone. In general, the first 0.5 inch of runoff from the impervious area is directed into the trench, where it percolates into the underlying soil.

Site Selection

Studies have shown that infiltration trenches have thus far generally proven to have much shorter life spans than expected (2 to 5 years). Slightly over half partially or totally fail within the first five years of construction. The application of trenches, like other infiltration practices, is severely restricted by soils. Because the soils in Henrico County are generally not conducive to infiltration, soil conditions must be carefully investigated.

Site selection is a key factor in the effectiveness of an infiltration trench. Potential sites must be evaluated so that infiltration trenches are located in accordance with the following criteria:

- The contributing drainage areas are limited to a maximum of five acres.
- The minimum acceptable distance from any water supply well shall be 100 feet.
- The minimum acceptable separation from any building foundation shall be 100 feet upgradient and 10 feet downgradient.
- The minimum acceptable separation from any public right-of-way shall be 10 feet.
- In relation to sewage disposal facilities and cut and fill slopes, the soil saturation zones of trenches shall not have any adverse impacts.
- Soil suitability - discharge only into natural soils that are suitable for infiltration as qualified by an acceptable authority.
- Adequate stormwater outfall - all runoff in excess of the Water Quality Volume must be accounted for and managed via an engineered or natural outfall.
- Infiltrations trenches are <u>not permitted in residential areas</u>.

Soil Suitability

Prior to the approval of any infiltration trench, a qualified professional (soil scientist or geotechnical engineer) shall perform a soil investigation of the proposed location. Each potential location must be evaluated to a depth of at least one foot below the seasonal high water table or until a restrictive layer is encountered. There must be at least two sample locations for each trench. If the trench is longer than 100 feet, an additional sample point must be taken for each 50 feet increment above 100 feet. The soil characteristics description shall record the depth and characteristics for each horizon, layer, or strata encountered at each test location.

The investigation shall confirm that the following conditions will be met:

- The bottom of the trench must be located at least four feet above the seasonal high water table.
- The bottom of the trench must be located at least four feet above any restrictive layer of soil or bedrock.
- The soil must have a permeability of at least 0.52 inches per hour.

The investigating soil scientist shall submit a report to the County that contains a complete soil description of each sample point and a map or site plan that shows the location of each boring. Permeability test methods shall be identified and described. The report shall also include the depth, elevation, location, and the identification of the soil horizon or strata represented. The surface topography, depth of bedrock or auger refusal, seasonal high water table, proposed invert elevation of the bottom of the storage reservoir, and the invert elevations of any pipe inlets or overflow risers shall also be included.

Design Criteria

In order for an infiltration trench to function properly, it is important that as much sediment as possible be removed before any runoff reaches the trench. Stormwater must pass through a pretreatment device before entering the trench. Infiltration trenches will be designed to handle the first flush of runoff (1/2" of runoff per impervious acre of contributing drainage area). Based on this design, a 50% phosphorus removal efficiency can be achieved.
Infiltration trenches should be designed based on the following guidelines:

- Infiltration trenches generally have a depth ranging from two feet to eight feet and are filled with coarse stone aggregate.

- Aggregate must be 1.5" to 3" diameter clean, washed stone (30-40% voids).
- Trenches that are designed with a grass covered surface must have at least one foot of seal cover between the top of the stone and the surface.
- Trenches must be designed so that the water quality volume is completely infiltrated within two days (48 hours).
- The slope of the contributing drainage area must not be greater than 5% for surface trenches and 20% for underground trenches.
- The depth of the trench shall not exceed four times the width of the trench.
- The bottom of the trench shall consist of a layer of sand eight inches deep with a layer of filter fabric between the sand and the aggregate.
- The sides and bottom of the trench shall be lined with filter fabric.
- All trenches without grass covered surfaces shall contain a layer of filter gravel along the top of the trench that is lined with filter fabric, to allow the top portion of the trench to be maintained without having to rebuild the entire trench.
- A 20' wide buffer strip shall be provided immediately upgradient from all trenches without grass covered surfaces.
- An infiltration trench shall not be constructed or placed in service until all of the contributing drainage area has been stabilized and approved by the erosion and sediment control inspector for the site.
- Heavy equipment and traffic shall be restricted from travelling over the infiltration areas in order to minimize compaction of the soil.
- Observation wells shall be provided at the rate of at least one well per 50 linear feet of trench. The well shall consist of a 4"-6" diameter perforated PVC pipe with a removable cap. It shall be located in the center of the trench, with the bottom of the pipe resting on a plate. The minimum width of the plate shall be twice the diameter of the pipe.
- Due to heavy equipment restrictions, the infiltration trench area must be flagged prior to the pre-construction meeting in order to prevent compaction.

Maintenance

Due to the fact that even properly designed and constructed infiltration trenches are prone to clogging by sediments, routine inspection and maintenance is critical to prevent failure or replacement of the system.

- Water shall be measured in the trench after a storm event to insure that the trench has drained within two days (48 hours). If the trench is not drained in this time period, it is possible that maintenance will need to be performed.

- Pre-treatment for sediment removal shall be provided for all infiltration trenches.
- Grass filter strips should be mowed at least twice a year to prevent woody growth. The grass should never be mowed to a height of less than three inches or performance of the filter strip could be impaired.
- Eroded ruts shall be repaired and all bare areas shall either be reseeded or sodded.
- Woody vegetation or trees should not be allowed in the immediate vicinity of the device to prevent fallen leaves from clogging the trench and to prevent roots from puncturing the filter fabric which can allow sediment into the trench.
- If surface clogging of the trench occurs, it can be fixed by removing the top layer of vegetation and stone, removing the clogged filter fabric, installing new filter fabric, and cleaning or replacing the top layer of stone.
- If clogging occurs in the underground or bottom layer of the trench at the filter fabric/soil interface, a more serious maintenance procedure becomes necessary. All underground portions of the trench and layers of filter fabric must be removed and cleaned or replaced. Prior to the reconstruction of the trench, the subsoil layer should be tilled to promote better infiltration.

Pollutant Removal

Henrico County recognizes a maximum removal efficiency of **50%** for infiltration trenches.

INFILTRATION TRENCH
MINIMUM DESIGN STANDARD 9.08

The infiltration trench must be designed to hold and exfiltrate the Water Quality Volume (WQV) within two (2) days (48 hours).

VOLUME: V_{BASIN} = Volume of runoff detained by basin

V_{BASIN} = Water Quality Volume (WQV)

WQV = The volume produced by ½ inch of runoff per impervious acre of contributing drainage area.

= A_{IMP} x 43,560 x 0.0417

= 1816 x A_{IMP}

A_{IMP} = The area of impervious surface on the contributing watershed in acres.

43,560 is the number of square feet in an acre.

0.0417 is the first half-inch of runoff.

WQV = 1816 x ____________ (acres)

WQV = ____________ cubic feet

COMPUTE THE DEPTH OF TRENCH:

D = $(F \times T_S) / (R_{VOIDS} \times 12)$

D = Depth of stone reservoir (feet)

F = Infiltration rate of soil (inches/hour)

T_s = Storage time (48 hours)

R_{VOIDS} = The voids ratio of stone aggregate (0.4)

D = (____________ x 48) / (0.4 x 12) = ____________ x 10

D = ____________ feet

CONSTRUCTION PLANS SHALL INCLUDE THE FINAL DETAILED BMP DESIGN

MINIMUM DESIGN STANDARD 9.09
TRASH RACK

Definition

A trash rack is a device that is used to prevent trash and other debris from entering storm sewer inlets while not obstructing the flow of stormwater.

Purpose

Certain land uses have the potential for generating significant quantities of litter that could be conveyed by stormwater runoff. These land uses include, but are not limited to, shopping centers, fast food restaurants, and convenience stores. Curb inlets on these types of projects must be equipped with grates or other device to collect trash and prevent the debris from entering the storm sewer systems.

Design Criteria

Trash racks must be constructed according to the flowing design criteria:

- The trash rack must be constructed of reinforcement steel or similar material and must be epoxy coated or galvanized.
- The trash rack must be constructed to provide a maximum of two inch openings between the rebar or in the grate.
- Trash racks are not allowed on inlets that have the potential to flood a public roadway if the inlets become clogged.

Maintenance

- Trash racks must be cleaned periodically of trash and other debris.
- The collected debris should be disposed of in a proper trash receptacle.
- The source of the trash and debris should be addressed.

MINIMUM DESIGN STANDARD 9.10
STREAM PROTECTION AREA FORESTATION

Definition

Stream Protection Area (SPA) Reforestation is the act of replanting woody species within the riparian corridor in a manner to ensure their future growth into a forest community.

Purpose

The purpose of Stream Protection Area Reforestation is to provide an optimal environmental condition within the riparian zone adjacent to an intermittent stream to allow the uptake of pollutants from stormwater passing over the reforested area and provide other water quality benefits for the stream.

Design Criteria

Stream Protection Area Reforestation is required on all projects with greater than 16% impervious cover whose Stream Protection Area is not currently dominated by woody vegetation at a density of at least 350 stems per acre, with at least 180 being tree species. The Stream Protection Area Reforestation must be accomplished according to the following design criteria.

- Where there are fewer than 350 woody stems per acre and fewer than 180 of those being tree species, within a SPA, forestation shall be accomplished during or immediately following construction activities to achieve at least this number of trees per acre.

- Native species of trees and shrubs shall be planted at 15' On-Center (OC) staggered spacing in accordance with the planting scheme below. This planting scheme will result in the planting of at least 196 trees and 196 shrubs within a one (1) acre area. (Note: greater than 350 woody stems shall be planted due to plant mortality potential.)

- Plant material shall be a minimum of 18" in height (first year seedlings). Plantings shall be protected with tree sapling tubes to prevent predation. Planting shall occur when the plants are dormant; typically the planting window occurs between November and March, however, not when the soil is frozen.

- At least three species of trees and three species of shrubs shall be planted on a site.

- The SPA forestation will be part of the Erosion and Sediment Control (ESC) Plan. Therefore, the ESC Bond will not be released until the SPA has been planted, inspected and 80% survival is achieved after one growing season. In lieu of this one-year inspection, the project proponent may provide a contract/agreement with an established landscape company to plant and/or maintain the SPA for a minimum of one year prior to release of the ESC Bond. Where the SPA occurs on individual residential lots, it must be forested prior to the issuance of building permits for those lots.

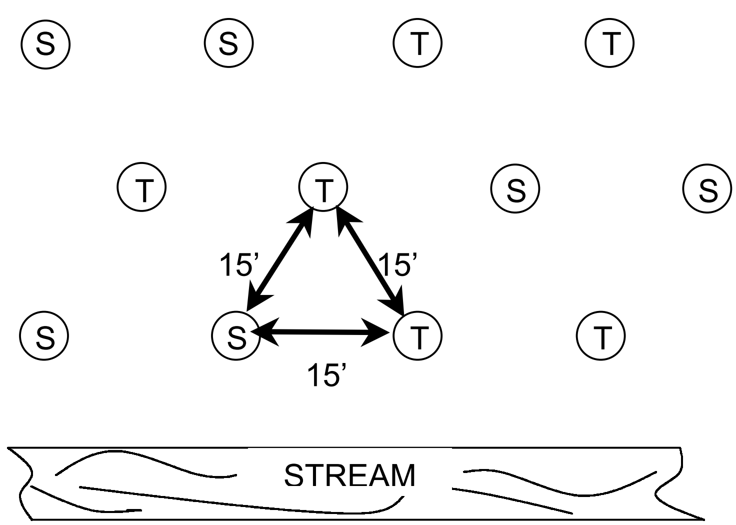
- On residential lots, the SPA will be identified through the placement of "Environmental Protection Area" signs along the landward edge of the buffer. These signs will be provided by the Department of Public Works. The signs will be installed in accordance with the Department of Public Works Environmental Division Sign Spacing, Location, and Installation Guidelines.

Pollutant Removal

Each linear foot of forested SPA provided in conjunction with level spreaders is assumed to result in a 0.00029 pound of pollutant removal.

Environmental Fund Contribution Adjustment

Each linear foot of forested SPA (50 feet wide) provided in conjunction with level spreaders results in a $2.30 reduction in the contribution to the Environmental Fund. This applies whether the SPA is already forested or planted at the time of development.



Native Plants

SHRUBS

Common Name	Scientific Name
Alleghany Blackberry	*Rubus allegheniensis*
Alternate-leaf Dogwood	*Cornus alternifolia*
American Cranberrybush	*Viburnum trilobum*
“Bankers” Dwarf Willow	*Salix cotteti*
Bayberry	*Myrica pennsylvanica*
Bicolor Lespedeza “Natob”	*Lespedeza bicolor*
Black Chokeberry	*Aronia melanocarpa*
Black Haw	*Viburnum prunifolium*
Border Forsythia	*Forsythia intermedia*
Burkwood Viburnum	*Viburnum burkwoodii*
California Privet	*Ligustrum ovalifolium*
Common Alder	*Alnus serrulata*
Common Elderberry	*Sambucus canadensis*
Dahoon Holly	*Ilex cassine*
Drooping Leucothoe	*Leucothoe fontanesiana*
Fetterbush	*Leucothoe racemosa*
Firethorn	*Pyracantha coccinea*
Gray Dogwood	*Cornus racemosa*
Highbush Blueberry	*Vaccinium corymbosum*
Inkberry	*Ilex glabra*
Leatherleaf Viburnum	*Viburnum rhytidophyllum*
Mountain Laurel	*Kalmia latifolia*
October Haw	*Crateagus flava*
Pampas Grass	*Cortaderia selloana*
Paw paw	*Asimina triloba*
Pfitzer Juniper	*Juniperus chinensis “Pfitzerana”*
Possumhaw	*Ilex decidua*
Red chokeberry	*Aronia arbutifolia*
Red Mulberry	*Morus rubra*
Redosier Dogwood	*Cornus stolonifera*
Rosebay Rhododendron	*Rhododendron maximum*
Rugosa Rose	*Rosa rugosa*
Schipka Laurel Cherry	*Prunus laurocerasus “Schipkaensis”*
Scotch Broom	*Cytisus scoparius*
Serviceberry	*Amelanchier arborea, A. canadensis*
Silky Dogwood	*Cornus amomum*
Silky Willow	*Salix sericea*
Shining Sumac	*Rhus copallina*
Shrub Lespedeza	*Lespedeaz thunbergii VA-70*

Smooth Sumac	*Rhus g*labra
Southern Wax Myrtle	*Myrica cerifera*
Spicebush	*Lindera benzoin*
Staghorn Sumac	*Rhus typhina*
Pupleosier Willow	*Salix purpurea*
Swamp Azalea	*Rhododendron viscosum*
Weeping Forsythia	*Forsythia suspensa*
Wild Hydrangea	*Hydrangea arborescens*
Winterberry	*Ilex verticillata*
Winter Jasmine	*Jasminum nudiflorum*

TREES

Common Name	**Scientific Name**
American Beech	*Fagus grandifolia*
American Holly	*Ilex opaca*
American Hornbeam	*Carpinus caroliniana*
American Mountain Ash	*Sorbus americana*
Bald Cypress	*Taxodium distichum*
Basswood	*Tilia americana*
Black Birch	*Betula lenta*
Black Cherry	*Prunus serotina*
Black Gum	*Nyssa sylvatica*
Black Locust	*Robinia pseudoacacia*
Black Walnut	*Juglans nigra*
Black Willow	*Salix nigra*
Canadian Hemlock	*Tsuga canadensis*
Cucumber Tree	*Magnolia acuminata*
Eastern Cottonwood	*Populus deltoides*
Eastern Hop hornbeam	*Ostrya virginiana*
Eastern Red Cedar	*Juniperus virginiana*
European Black Alder	*Alnus glutinosa*
European Mountain Ash	*Sorbus aucuparia*
Flowering Dogwood	*Cornus florida*
Green Ash	*Fraxinus pennsylvanica*
Hackberry	*Celtis occidentalis*
Honey Locust	*Gleditsia triacanthos*
Laurel Oak	*Quercus laurifolia*
Littleleaf Linden	*Tilia cordata*
Loblolly Pine	*Pinus taeda*
Northern Red Oak	*Quercus rubra*
Persimmon	*Diospyros virginiana*
Pin Oak	*Quercus palustris*

Red Maple	*Acer rubrum*
River Birch	*Betula nigra*
Sourwood	*Oxydendrum arboreum*
Southern Red Oak	*Quercus falcata*
Swamp Chestnut Oak	*Quercus michauxii*
Swamp Laurel Oak	*Quercus laurifolia*
Swamp White Oak	*Quercus bicolor*
Sweet Bay	*Magnolia virginiana*
Sweet Gum	*Liquidambar stryaciflua*
Sycamore	*Platanus occidentalis*
Virginia Pine	*Pinus virginiana*
Water Oak	*Quercus nigra*
White Ash	*Fraxinus americana*
White Oak	*Quercus alba*
White Pine	*Pinus strobus*
Willow Oak	*Quercus phellos*
Yellow Poplar	*Liriodendron tulipifera*

MINIMUM DESIGN STANDARD 9.11
WASH RACK

Definition

A wash rack is a device installed near the construction entrance of a land disturbing activity that is used to minimize the amount of soil and debris carried from the site on the tires of the construction traffic.

Site Selection

The initial need for a wash rack will be determined during project review depending on the scope of the project and its location. Wash racks may also be required once construction begins and mud tracking becomes a recurring problem.

Design Criteria

Wash racks must be constructed according to the following design criteria:

- The wash area of the wash rack must be large enough to accommodate the expected construction traffic.
- In addition to the wash area, the wash rack must have an exit ramp such that wash water dripping from construction traffic will be collected.
- A source of wash water must be provided (either a hydrant or a water truck).
- The wash rack must be designed to collect the wash water and discharge it to a properly designed sediment trap, sediment basin or a dewatering device

MINIMUM DESIGN STANDARD 9.12
CONCEPTUAL BMP LANDSCAPE PLAN

Definition

A conceptual BMP landscape plan provides general planting guidelines for BMPs.

Purpose

The purpose of a conceptual BMP landscape plan is to give the plan reviewer an idea of how the proposed BMP landscaping will appear in the field. It is required for those locations where the BMP is deemed to be highly visible from the right-of-way or less intense uses of adjacent properties.

Design Criteria

Conceptual BMP landscape plans are required for all highly visible BMPs and must be in accordance with the following criteria:

- A detailed planting plan is not required at this stage.
- The plan must show how the proposed BMP can be screened from the right-of-way and/or less intense uses of adjacent properties.
- Acceptable methods of screening include landscaping, hedges, and fencing, or a combination of these items.

MINIMUM DESIGN STANDARD 9.13
ENVIRONMENTAL PROTECTION AREA SIGN

Definition

Environmental Protection Area signage is the act of erecting signs along the boundary of sensitive environmental features within residential subdivisions to alert citizens to their presence and the need for good environmental stewardship in these areas.

Purpose

The purpose of Environmental Protection Area signage is to protect sensitive environmental features from secondary impacts after completion of construction activities. Waters of the U. S., including wetlands, Resource Protection Areas, and Stream Protection Areas should be maintained only as natural areas, with minimal alterations, in order that they may function properly within the watershed.

Design Criteria

- **Spacing:** Generally, the signs will be located on the lot lines at the intersection of the landward edge of the wetlands, RPA buffer, or 50-foot stream protection buffer, and at other locations which will approximately delineate the wetland/RPA boundary/stream protection buffer boundary. Additional signs will be located as necessary such that the spacing between two consecutive signs does not exceed 100 feet. Signs will be equally spaced between the signs on the lot lines.

- **Location:** As noted, the signs will be located on the lot lines at the intersection of the landward edge of the wetlands, RPA, or stream protection buffer and at other locations which will approximately delineate the wetland, RPA, or stream protection buffer boundary. Any additional signs required to meet the spacing requirements must be located on the wetland, RPA, or stream protection buffer delineation line.

- **Installation:** Where possible, the signs will be mounted to a tree larger than three (3) inches in diameter at breast height. The signs must be mounted between four (4) and six (6) feet above the ground surface. Where it is not possible to mount the sign to a tree, a treated wood 4 by 4 or a metal signpost must be installed. The post must extend below the ground surface at least 24 inches. Again, the signs will be mounted between four (4) and six (6) feet above the ground surface.

MINIMUM DESIGN STANDARD 9.14
OIL WATER SEPARATOR

Definition

An oil water separator is a device that is installed in conjunction with fueling stations to remove hydrocarbon fuels and lubricants from stormwater and washwater.

Purpose

The purpose of an oil water separator is to remove fuels and lubricants in stormwater and washwater that would otherwise be flushed into the storm sewer system or receiving channels.

Design Criteria

- The Oil / Water Separator (OWS) must be designed according to the American Petroleum Institute (API) standards.
- If the OWS will be designed by the engineer, the design calculations and details must be submitted for review.
- If a pre-manufactured OWS will be used, the following information must be submitted for review:
    - The design calculations for sizing the OWS.

$$Q = A \times I$$

where: Q is the design flow to the OWS
A is the area draining to the OWS
I is the amount of rainfall = 1.6 in/hr/ft^2 under the canopy
= 2.8 in/hr/ft^2 outside of canopy

- A statement from the manufacturer indicating that the OWS is designed per the API standards.

- A detail drawing of the OWS must be shown on the plans.

- A trench drain system must be installed to divert the wastewater to the OWS.

- The trench drain must fully encompass the area that produces wastewater.

- The area that produces wastewater must be covered. The canopy must be labeled and the trench drain should be inside the drip edge of the canopy.

- The area that produces wastewater must be graded so the runoff from the surrounding area will not enter the trench drain. Spot grades around the fueling pad must be shown on the plans.

- IF THE WASTEWATER WILL BE DIVERTED TO THE SANITARY SEWER SYSTEM:

  - The OWS must be approved by the Department of Public Utilities. (The Department of Public Works will not review the OWS).

  - A trench drain system must be installed to divert the wastewater to the OWS.

  - The trench drain must fully encompass the area that produces wastewater.

Pollutant Removal

There is no additional pollutant removal efficiency associated with level oil water separators.

OIL WATER SEPARATOR
MINIMUM DESIGN STANDARD 9.14

Project:____________________________ Date:___________________

IF THE WASTEWATER WILL BE DIVERTED TO THE STORM SEWER SYSTEM:
Checked items must be addressed

- ❑ The Oil / Water Separator (OWS) must be designed according to the American Petroleum Institute (API) standards.

- ❑ If the OWS will be designed by the engineer, the design calculations and details must be submitted for review.

- ❑ If a pre-manufactured OWS will be used, the following information must be submitted for review:

  a. The design calculations for sizing the OWS.

  $$Q = A \times I$$

  where: Q is the design flow to the OWS
  A is the area draining to the OWS
  I is the amount of rainfall = 1.6 in/hr/ft^2 under the canopy
  = 2.8 in/hr/ft^2 outside of canopy

  b. A statement from the manufacturer indicating that the OWS is designed per the API standards.
  c. A detail drawing of the OWS must be shown on the plans.

- ❑ A trench drain system must be installed to divert the wastewater to the OWS.

- ❑ The trench drain must fully encompass the area that produces wastewater.

- ❑ The area that produces wastewater must be covered. The canopy must be labeled and the trench drain should be inside the drip edge of the canopy.

- ❑ The area that produces wastewater must be graded so the runoff from the surrounding area will not enter the trench drain. Spot grades around the fueling pad must be shown on the plans.

IF THE WASTEWATER WILL BE DIVERTED TO THE SANITARY SEWER SYSTEM:

- The OWS must be approved by the Department of Public Utilities. (The Department of Public Works will not review the OWS).
- A trench drain system must be installed to divert the wastewater to the OWS.
- The trench drain must fully encompass the area that produces wastewater.

MINIMUM DESIGN STANDARD 9.15
FOREBAY

Definition

A forebay is a storage area provided near an inlet of a BMP to trap incoming sediments.

Purpose

The purpose of a forebay is to provide an area for sediment and debris to settle from incoming stormwater. With heavy sediments and debris confined to the forebay area, maintenance is made simpler and less costly and the longevity of the BMP is extended.

Design Criteria

Henrico County requires forebays on all BMP stormwater basins as part of the overall basin design. Forebays should be constructed according the sketch below and the following design criteria:

- The minimum forebay length shall be 10 feet.
- The minimum length of the forebay shall be twice the width (L = 2W).
- The height of the forebay berm shall be one foot below the 10-year storm elevation.
- The forebay outlet shall be constructed of non-erodible material and the remaining berm shall be constructed of compacted soil (see sketch on Page 32-A). A perforated pipe will also be provided as shown in the sketch. If the entire forebay will be below the normal water surface elevation of the BMP, the forebay should be constructed entirely of non-erodible material and the perforated pipe will not be required.
- In cases where the basin is used as a sediment basin during constuction, the forebay will not be installed until the sediment basin is converted to the BMP. A note stating this will be included in the ESC narrative on the approved plan.

NOTE: **An additional 5% removal efficiency rating can be obtained if the forebay is sized in such a manner that it provides an additional volume that is equal to 10 percent of the required water quality volume. If runoff is delivered to the BMP by more than one pipe, forebays shall be required at the outfall of each pipe. The total forebay volume should be divided between the outfall pipes based on the percentage of pollutants that each pipe delivers to the BMP.**