Category 2
Selected *Emerging Technologies* BMPs

For instructions on seeking approval to use these BMPs, refer to Section 5-3.6, Seeking Authorization for Alternative BMP Options, in Chapter 5 of the *Highway Runoff Manual* (HRM). All BMPs referenced in Category 2, which are not included herein, can be found in Chapter 5, Section 5-4, of the HRM.

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Category 2
Selected *Emerging Technologies* BMPs

The BMPs listed here are part of a wide range of emerging technologies BMPs that have not received a *general use* designation from the Washington State Department of Ecology (Ecology). They are made available here as a potential source of ideas that could be adapted to meet the needs of a specific situation. This is not a complete list and other BMPs or their variations may be more applicable to a particular situation. Ecology's Emerging Technologies web site has additional information about the state of development of some of these technologies.

The design criteria for these BMPs will need further refinement. Their use will require meeting the requirements of the demonstrative approach and completing the Engineering and Economic Feasibility (EFF) Checklist, which can be found in Section 2A-2 in Appendix 2A of the *Highway Runoff Manual* (HRM). The procedure for seeking *pilot, conditional, or general use* designations is provided in Section 5-3.6 in Chapter 5 of the HRM.

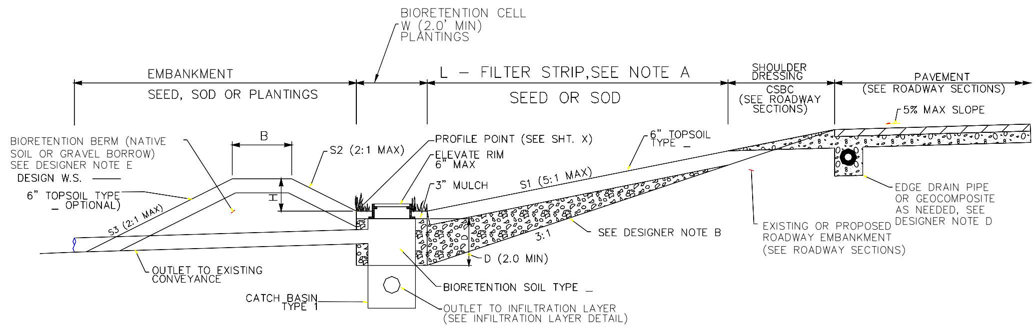
1 Bioretention Area

Introduction

General Description

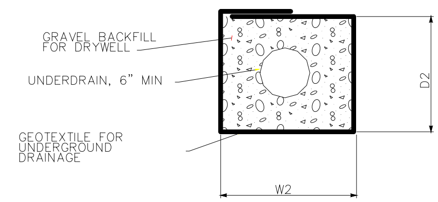
Bioretention areas or rain gardens are characterized as native or amended soils and plantings, engineered to infiltrate stormwater runoff (see Figure 1.1). These facilities or Integrated Management Practices (IMP) are designed to incorporate many of the pollutant-removal mechanisms that are present in forested ecosystems. Bioretention areas are generally located directly adjacent to the pavement being treated in a linear swale configuration or downstream of a conventional stormwater collection system in a cell or pothole design.

Courtesy of Prince George's County, MD Department of Environmental Resources



BIORETENTION WITH UNDERDRAIN NTS

(STA XX TO STA XX)
(FOR PARTIAL INFILTRATION IN HYDROLOGIC SOIL GROUP C)

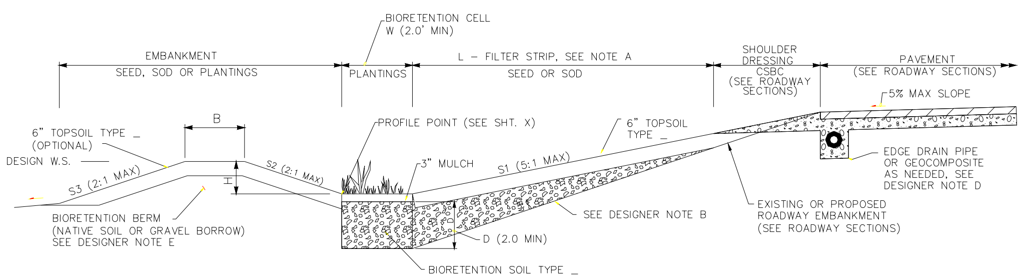


INFILTRATION LAYER DETAIL

(SEE DESIGNER NOTE F)

BIORETENTION CELL DATA

	FEET							__:1		
LOCATION	W	D	H	B	L	W2	D2	S1	S2	S3
STA XX TO XX										
STA XX TO XX										
STA XX TO XX										



BIORETENTION WITHOUT UNDERDRAIN NTS

(STA XX TO STA XX)
(FOR FULL INFILTRATION IN HYDROLOGIC SOIL GROUPS A AND B)

GENERAL NOTES:

1. HEAVY EQUIPMENT AND EROSION CONTROL LIMITATIONS DURING BIORETENTION CONSTRUCTION (SEE SPECIAL PROVISIONS)
2. FOR BIORETENTION CELL, INFILTRATION CELL AND FILTER STRIP DIMENSIONS (W, H, L, D, ETC) , SEE TABLE ON THIS SHEET
3. SEE DRAINAGE DETAILS AND DRAINAGE PROFILES FOR ADDITIONAL INFORMATION.
4. FOR BIORETENTION PLANTINGS, SOIL AND MULCH REQUIREMENTS, SEE SHTS. X AND SPECIAL PROVISIONS

DESIGNER NOTES:

A. SEE VEGETATED FILTER STRIP BMP RT.02 FOR SIZING/DESIGN PROCEDURE.

B. BIORETENTION SOIL UNDER FILTER STRIP OPTIONAL FOR INCREASED INFILTRATION. CONSULT GEOTECH IF MODIFYING ROADWAY EMBANKMENT.

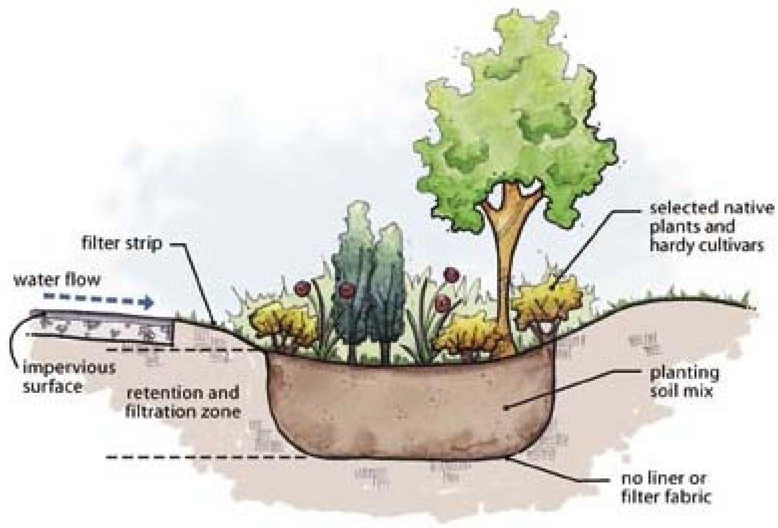
C. PROVIDE STORAGE LAYER AS NEEDED IN SOILS WITH POOR INFILTRATION RATES.

D. PROVIDE EDGE DRAIN OR GEOCOMPOSITE IF ROADWAY SUBGRADE IS LOWER THAN 25 YEAR WATER SURFACE IN BIORETENTION CELL.

E. FOR A REDUCED BERM WIDTH, USE ALTERNATE (SUCH AS MODULE BLOCKS) IF CLEAR ZONE COMPATIBLE.

F. PREFABRICATED INFILTRATION CHAMBERS ARE ALTERNATIVE TO GRAVEL AND PIPE SHOWN.

Figure 1.1. Bioretention configurations.



Courtesy AHBL Engineers
Figure 1.2. Cross section of a basic bioretention cell.

Applications and Limitations

Bioretention areas can be used to meet basic as well as enhanced runoff treatment objectives (see Figure 5.3.2 in the HRM). Bioretention is an alternative for conventional treatment and/or detention facilities where standard end-of-pipe facilities are not necessary, appropriate, or available. Possible areas for its use include the following:

- Roadsides where neither defined flow paths nor conveyance systems are present.
- Areas adjacent to roadways where right-of-way, suitable topography, and maintenance access are available in continuous segments along the shoulder.
- Contributing pavement areas less than or equal to 0.5 acres, or two lanes and shoulder.
- Roadside cross slopes that are approximately 30% (3H:1V) or less. Infiltration and pretreatment using filter strips becomes impractical on steeper slopes. Steeper slopes introduce erosion and/or stability issues related to placing looser, less compacted material over compacted roadway embankments, a condition that could cause slides. This potential condition on steeper slopes should be evaluated for geotechnical feasibility.
- Roadway profile slopes of 2% or less. Steeper slopes generally create problems in maintaining uniform sheet flow into the roadside areas. Steeper slopes also require larger steps/drops in the bioretention cells to maintain a flatter grade than the roadway.

- Roadway cross slopes of 5% or less. Steeper cross slopes, such as those in excessively elevated areas, generally create problems in maintaining uniform sheet flow into the roadside areas.

Bioretention has some limitations and is not recommended for:

- Areas downstream of large drainage areas with concentrated flows.
- Areas with large off-site flows that cannot be bypassed.
- Narrow medians of divided roadways where infiltrated stormwater could be conveyed through the pavement.
- Soils that have been previously compacted.
- Soils with low infiltration (i.e., Type C and D [till] soils) without using suitable supplemental storage.
- Areas with a high groundwater table.

Presettling and/or Pretreatment

Pretreatment refers to features that reduce velocities and settle coarse sediments prior to further treatment. The pretreatment area provides a location where a majority of maintenance is performed and increases the life of the soil bed. Typically, sheet flow from the pavement is initially directed across a filter strip along the length of the shoulder. Flows entering a bioretention area should be less than 1.0 foot/second to reduce erosion potential. Even distribution of flow should be provided and local channeling of flow should be prevented with features such as a gravel base course at the pavement edge. The gravel base at the pavement edge serves as a flow spreader.

Design Flow Elements

Flows to Be Treated

Bioretention areas must be designed to treat the runoff treatment volume discussed in Section 3-3.5, Minimum Requirement 5, in Chapter 3 of the HRM. Hydrologic methods are presented in Sections 4-3 and 4-4 in Chapter 4 of the HRM.

Overflow or Bypass

Conveyance features such as an underdrain system can collect filtered runoff and convey it to a suitable downstream system. The system is generally constructed of perforated pipe and installed along the filter bed to either protect the pavement subgrade or provide more efficient drainage. An overflow structure (see BMP FC.03 in the HRM) serves to convey flow from larger storms not treated by the bioretention area to the downstream conveyance.

Conveyance

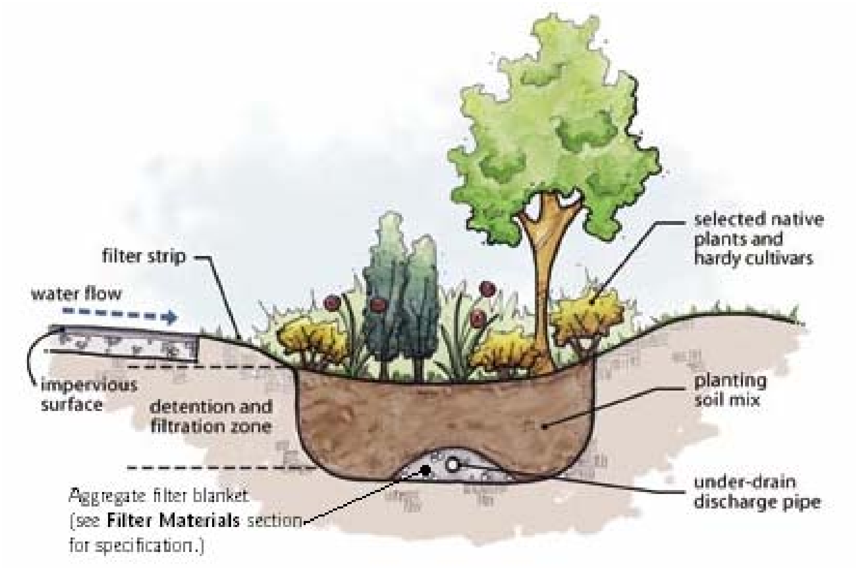
Conveyance components included in the bioretention areas should be sized for anticipated design flows. Structures conveying overflows from bioretention areas (e.g., weirs, catch basins) should be sized for typical roadway conveyance (10-year storm) and water surface elevations checked for potential damage during peak design flows. Underdrains should be closely coordinated with the bioretention design. If they are necessary to protect pavement subgrade, they should be located above the design water surface of the bioretention area.

If a perforated PVC or flexible HDPE pipe underdrain is used:

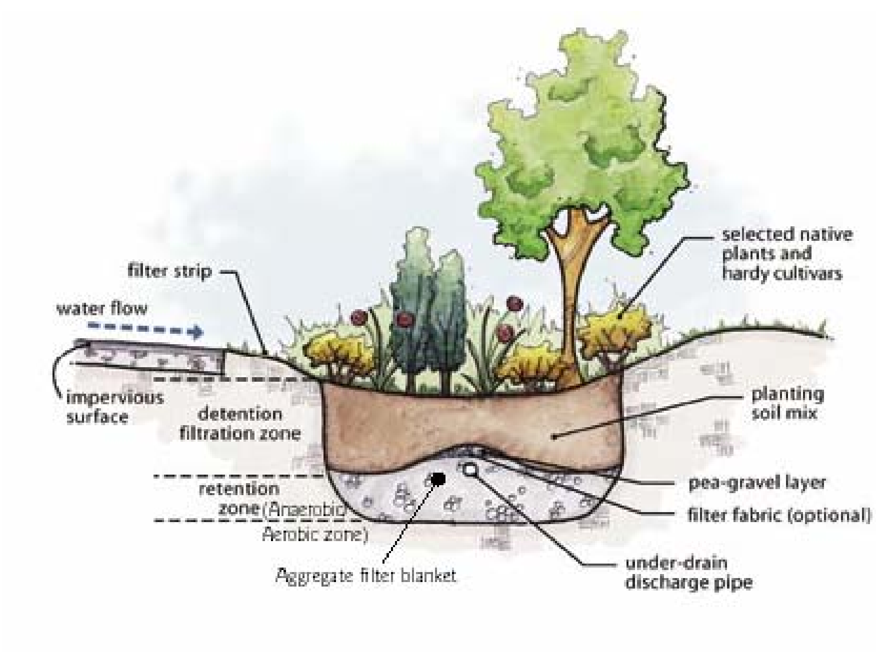
- The underdrain pipe should be placed on a 3-foot-wide bed of ½- to 1½-inch drain rock (ASTM No. 57 aggregate or equivalent) at a minimum thickness of 3 inches, and covered with 6 inches of No. 57 aggregate. Double-washed stone is preferred to reduce suspended solids and the potential for clogging (Low-Impact Development Center, 2004).
- If filter fabric is used, use a nonwoven material placed over the drain rock and extending 2 feet on either side of the underdrain. Wrapping the gravel blanket in filter fabric can cause premature failure due to clogging and is not recommended (Prince George's County, 2002).
- A pea gravel diaphragm (with or without a filter fabric) reduces the likelihood of clogging when used with drain rock. Use ¼- to ½-inch-diameter double-washed gravel (ASTM D 448 or equivalent) placed over the drain rock to a thickness of 3 to 8 inches (Prince George's County, 2002). If filter fabric is used, place between the drain rock and pea gravel extending 2 feet on either side of the underdrain. The strip of filter fabric placed above the underdrain acts as an impediment to direct gravitational flow and causes the water to move laterally and then down toward the underdrain (PSAT, 2005 personal communication, Derek Winogradoff, August 2004).

Flow Control

If flow control is desired, determine the additional storage volume in the bioretention cell needed to infiltrate the design storm. Flow control criteria and analysis methods are discussed in Chapter 4 of the HRM. Similar to runoff treatment, the flow control component can be modeled as a pond with a steady-state infiltration rate (see BMP IN.02 in the HRM). If the available bioretention width is too small to meet flow control requirements, additional width or supplementary subsurface storage should be provided within a storage layer of poorly graded drain rock. A greater depth of surface storage is also an option if hazard depths are not exceeded along the roadside. Alternately, subsurface storage chambers may be used to increase subsurface storage or separate downstream flow control. Released surface flows in excess of the infiltration and surface storage capacity must meet flow control requirements for the project area.



Courtesy AHBL Engineers
Figure 1.3. Bioretention with underdrain.



Courtesy AHBL Engineers
Figure 1.4. Bioretention with elevated underdrain.

Structural Design Considerations

Geometry

The width and depth of the bioretention area vary with the space available and the volume needed for infiltration and detention. Key criteria are widths of contributing pavement and roadside, depth to seasonal high groundwater, and soil infiltration rate (see Figure 1.1).

General Design Criteria

- Bioretention areas function best where soil infiltration is good (i.e., Type A and B [outwash] soils). Where infiltration is poorer (i.e., Type C and D [till] soils), bioretention is not recommended without using suitable supplemental storage such as additional gravel base, infiltration chambers, or downstream flow control.
- Bioretention areas should not receive concentrated flow discharges.
- Clear zone safety elements such as side slopes, maximum ponding depth, and maximum tree sizes should be incorporated into the design.
- The bottom of a storage layer should be 3 feet (desirable) and 2 feet (minimum) above the seasonal high water table.
- Forested areas should not be cleared to accommodate a bioretention area.
- Bioretention areas should be offset from the pavement horizontally and vertically (downgradient) as much as possible to protect the pavement. Where necessary, edge drains should be placed adjacent to pavement to avoid subgrade saturation.
- Observation wells should be installed in the bioretention area to facilitate monitoring and maintenance.
- If the constructed facility's slopes or water depths are considered a hazard within the clear zone, guardrails or another approved system should be provided.

Design Procedure

Once a candidate roadside bioretention site is identified, request that the project geotechnical report include investigation of the site's soil infiltration, soil composition, and depth to water table. The region's Materials Laboratory, with assistance from the Headquarters (HQ) Geotechnical Division (as needed), can determine the number and depth of borings/test pits required and any groundwater monitoring needed to characterize the soil infiltration characteristics of the site. Establish any necessary piezometer boreholes to a depth of 10 feet below the base of the storage layer. Monitor the water table at least monthly throughout the wet season.

For determining a final design-level infiltration rate, refer to the design guidance provided in Section 4-5 in Chapter 4 of the HRM. Note that this guidance applies primarily to infiltration basins and may therefore exclude slower-percolating soils such as loams, which are potentially suitable for bioretention.

Because minimizing soil disturbance is a preferred design approach, native soils should be initially checked to determine if they are suitable to receive flows as-is for both runoff treatment and flow control (i.e., without soil disturbance). Generally, native soils should have an infiltration rate of at least 1 inch per hour.

Runoff Treatment

First, size a filter strip to pretreat runoff into the bioretention area using guidance from BMP RT.02 in the HRM.

Next, size a bioretention filter bed. Currently, Darcy's Law for flow through saturated soils is used (Q=kiA). Calculate the filter bed area after calculating the runoff treatment volume, assuming a filter depth, permeability of the bioretention soil mix (k), an allowable drawdown time, and allowable ponding depth.

A minimum filter layer depth of 2 feet should be used with shallow-rooted plants, while a minimum depth of 2 to 2.5 feet is recommended for deeper-rooted plants. A maximum soil filter depth of 4 feet is allowable due to current studies that indicate a lack of performance in deeper soils.

Ponding Area

If topography allows, a wide depression providing surface storage and further settling of sediment prior to subsurface treatment should be incorporated. A maximum ponding depth of 12 inches is recommended. The maximum 12-inch ponding is recommended in soils with a minimum infiltration rate of 2 inches per hour. The maximum drawdown time for a ponded area is 24 hours.

Dried-out soils will improve hydraulic capacity to receive more flows and maintain infiltration rates. Less saturation will maintain soil oxygen levels for a sustainable biota and vegetation, plus assists with the biodegradation and retention of pollutants.

Sorption/Filter Layer

If native soils are not suitable for treatment of pollutants, an amended *bioretention soil* consisting of sand, compost, and soil of specified gradation should be added below the plantings and mulch layer. This filter layer is intended to sustain plant growth, microbial activity, and infiltration of stormwater (see *Materials* below).

Storage/Infiltration Layer

If supplemental storage of runoff is needed for low infiltration soils, a layer providing additional volume prior to infiltration into native soils should be incorporated.

Materials

Bioretention Soil Requirements

For runoff treatment, native soils with a long-term infiltration rate of at least 1 inch per hour are generally suitable for bioretention. Native soils in the filter layer with lower infiltration rates (i.e., NRCS Type B and C soils typical of the Northwest) should be:

- Amended with sand and compost to attain suitable filtration properties and a higher infiltration rate; or
- Replaced completely with a specified bioretention soil mix with a minimum organic content of 10% per dry weight.

Components of the bioretention soil should be designed to maximize its effectiveness. A pH between 5.5 and 7.0 is recommended. The bioretention soil composition in Table 1.1 is recommended when on-site soils require amending (see Section 5-4.3.2 in Chapter 5 of the HRM for information on soil amendments). A minimum permeability (k) for the installed bioretention soil is specified as 3 inches per hour, and design values between 1 and 3 inches per hour should be considered reasonable based on expected long-term maintenance and loadings.

Table 1.1. Bioretention soil composition.

Medium	Composition of Medium in Filter Layer (%)	Minimum Infiltration Rate (inches/hour)
Sand	50–60	8
Topsoil*	20–30	0.5
Compost	20–30	8
Total (loamy sand)	100	~5 (use 2.5)

* Topsoil should have less than 5% maximum clay content.

Liners

If the seasonal high water table is less than 3 feet below the bottom of the bioretention area storage layer, a liner may be warranted. (See the following section on groundwater limitations for further details.) Current bioretention areas with low-permeability liners have demonstrated good pollutant removal. (See Section 5-4.3.3 in Chapter 5 of the HRM for further information on liner designs.)

Groundwater Limitations

- A minimum of 3 feet of clearance is necessary between the lowest elevation of the bioretention soil, or any underlying gravel layer, and the seasonal high groundwater elevation or other impermeable layer, if the area tributary to the rain garden meets or exceeds any of the following limitations:
  - 5,000 square feet of pollution-generating impervious surface; or

  - 10,000 square feet of impervious area; or
  - ¾ acre of lawn and landscape.
- If the tributary area to an individual bioretention area does not exceed the limitations above, a minimum of 1 foot of clearance is adequate between the lowest elevation of the bioretention soil (or any underlying gravel layer) and the seasonal high groundwater elevation or other impermeable layer. (PSAT, 2005)

Site Design Elements

Landscaping (Planting Considerations)

Consult a biologist, landscape architect (the region's Landscape Architect or the HQ Roadside & Site Development Unit), or horticulturist early in the project. Selection of plant species should be based on roadside conditions and ecological factors. Plants typically are limited to grass and shrub species to meet clear zone requirements. Trees may be used outside the clear zone. Select species to ensure diversity, differing rates of transpiration, and a more constant rate of evapotranspiration and nutrient and pollutant uptake throughout the growing season. Species that require regular maintenance should be avoided or restricted. Emphasis should be placed on the use of native species, which drop leaves to improve cation exchange capacity (CEC) and regenerate organic matter for soil biota.

Designers should contact the region's Landscape Architect or the HQ Roadside & Site Development Unit for help developing a location-specific planting schedule list appropriate for the bioretention area(s).

Plantings and Mulch Layer

The plantings and mulch layer (bark or wood chips) provide biological uptake of pollutants and pathways for infiltration, evapotranspiration, and some erosion control. Plantings should be compatible with roadside management plans developed for the area and consist typically of low shrubs and grasses. It is preferred that native vegetation be used where possible. Plants should be selected that can tolerate the hydrologic regime they will experience (i.e., plants that tolerate both wet and dry conditions). It is best to select a combination of trees, shrubs, and herbaceous materials. Trees that reach a diameter greater than 4 inches at 6 inches above the ground are classified as a hazard and should not be used in the clear zone. An organic layer of bark or wood chips provides a medium to control weeds, retain soil moisture, remove some metals, and decompose plant material.

Construction and Maintenance Criteria

Unlike traditional BMPs, bioretention areas should be constructed after other portions of the roadway project are completed. This is necessary because they should not receive flows from unstabilized construction sites, nor be used as temporary sedimentation facilities during construction. However, it may be desirable to construct a bioretention area early in the project to establish vegetation prior to exposure to highway runoff. The bioretention area could be protected from disturbance during construction through a variety of project-specific measures. Identify the need for staging such operations. It is very important to avoid compacting subsurface soils during construction. On-site mixing and/or placement bioretention media should not be performed if soil is saturated. (PSAT, 2005)

Bioretention requires seasonal work to establish plants. In many cases, bioretention areas require higher maintenance initially to establish plants, but less maintenance over the long term. Bioretention basin plants should be inspected on a monthly basis until they are established, and more frequently if a large storm occurs between the monthly inspections. Once it is determined that the basin is functioning in a satisfactory manner and that there are no potential sediment problems, inspection can be reduced to a semiannual basis, with additional inspections following a large storm.

The facility should be observed after storms to ensure adequate drainage. Water standing longer than 1 day will severely limit the growth of most plants. Mosquitoes and other insects may start to breed as well. The microbial processes of the planting soil, which remove nutrients, will not work as well if the facility becomes waterlogged and anaerobic.

Plants provide enhanced environmental benefits over time as root systems and leaf canopies increase in size and as pollutant uptake and removal efficiencies increase. Soils, however, begin filtering pollutants immediately and can lose their ability to function in this capacity over time. Therefore, evaluation of soil fertility is important in maintaining an effective bioretention system. Substances in runoff such as nutrients and metals may eventually disrupt normal soil functions by lowering the CEC. The CEC is the soil’s ability to adsorb pollutant particles through ion attraction and it decreases over time. It is expected that remulching of the planting zone should be performed every two to three years. However, once plants are established, it is recommended that soils in the planting zone be periodically tested to determine when CEC is lost and to establish an appropriate soil amendment schedule.

Trees and shrubs should be inspected twice per year. Any dead or severely diseased vegetation should be removed. Prune and weed to maintain the bioretention area’s appearance. Spot mulch when bare spots appear. Every two to three years, the entire area should be remulched. Once or twice a year, limestone should be applied to counteract soil acidity resulting from the treated runoff.

Soil should be tested annually to detect toxic concentrations of pollutants. As toxins accumulate, they may impair plant growth and bioretention effectiveness, and soil replacement may be required.

The primary concern in maintaining the continued effectiveness of a bioretention area is to prevent the layers from clogging with fine sediments. Maintenance levels generally vary depending on the potential likelihood of fine sediments clogging the surface. Locations with a higher risk of clogging include unmaintained sites with high traffic volumes.

Roadside Bioretention Design Example

This design example sizes a roadside bioretention cell based on existing methods of soil infiltration principles (i.e., Darcy's Law). Other refined methods using revised low-impact development (LID) hydrology model input parameters are possible. Such a model would require input file revisions for continuous runoff models and is currently being investigated by the WSDOT *Highway Runoff Manual* team.

The location of the design example is the SR 5 off-ramp in central Snohomish County.

1. **Size bioretention facility.** After evaluating and determining that site characteristics are suitable for bioretention (soils, slopes, maintenance commitment), the following data are used to size a bioretention facility:
   - Roadway characteristics: 300-foot roadway length; two 12-foot lanes; 6-foot shoulder; 30-foot roadside available.
   - Tributary area: 0.21-acre pavement, 0.21-acre roadside; total = 0.42 acres.
   - Native soil: Alderwood (NRCS Type C).
   - Roadway profile slope 1.0%; cross slope 2.0%.
   - Existing drainage system: roadside ditch.
2. **Determine water quality requirements for project area.** Because the example project is in western Washington, runoff treatment volume associated with 91% of the average annual runoff from the tributary area must be treated.
3. **Compute runoff treatment volume.** Compute from continuous runoff model the runoff treatment volume required for the bioretention area. For this project location, this is the volume associated with 91% of the runoff. With the above project data, runoff treatment flow and volume are computed from the software model:

   On-line facility volume: 0.026 acre-feet

   On-line facility target flow: 0.03 cubic feet per second (cfs)

   Adjusted for 15-minute time step: 0.03 cfs

   Off-line facility volume: 0.033 acre-feet

   Off-line facility target flow: 0.01 cfs

   Adjusted for 15-minute time step: 0.02 cfs

   The runoff treatment volume of 0.026 acre-feet (1,133 cf) is to be treated and infiltrated in the bioretention area. Use on-line volume because all flows are conveyed to bioretention area.

4. **Size bioretention area and filter bed.** The filter bed is sized assuming Darcy's Law:

$$Q = [KA_f(H_t - H_h)]/L$$

where: Q = flow rate into the soil

K = conductivity (coefficient of permeability) of filter bed soil

A_f = surface area of filter bed normal to flow

$H_t - H_h$ = difference in hydraulic head

L = depth of filter medium to saturation.

Since: $Q = Vol_{WQ}/T_{drain}$

$(H_t - H_h)/L$ = hydraulic gradient = $D/(H_f + D)$

where: Vol_{WQ} = runoff treatment volume

T_{drain} = time to drain (drawdown time) = 24 hours for runoff treatment storm selected

D = filter bed depth (2 ft min. recommended)

H_f = average ponding depth above filter bed (6 inches recommended/2 = 3 inches)

K = 3.0 in/hr minimum specified for soil mix; 1.0 in/hr selected for design

Solve for surface area of ponding/filter area:

$A_f = [(Vol_{WQ}/T_{drain})*(D)]/ K(H_f+D)$

= [(1,133/24)x 2.0]/[(1.0/12) x (3/12 + 2.0)]

= 506 sf

506 sf/300 ft = 1.7 ft ~ 2.0-ft-wide filter area.

A filter bed with 506 square feet of surface area is needed to filter and drain the runoff treatment storm volume in 24 hours. Filter bed = 300 feet long x 2.0 feet deep x 2.0 feet wide.

Check overtopping: Route runoff treatment storm through the facility using native infiltration rates (tested) to check storage capacity of filter bed and 6-inch storage pool. Adjust width and depth as needed to contain runoff treatment storm in filter bed and storage pool.

5. **Size pretreatment vegetated filter strip.** The filter strip length is calculated using the method described in BMP RT.02 in the HRM. The required residence time is 9 min:

$$Q_{WQ} = \frac{1.49}{n} W d_f^{5/3} s^{1/2}$$

where: Q_{WQ} = runoff treatment design flow (cfs)

n = Manning's roughness coefficient for grass

d_f = design flow depth, also assumed to be the hydraulic radius = 1.0 inch maximum = 0.083 foot

W = width of the filter strip perpendicular to the pavement edge (ft)

s = slope of the filter strip

then:

$$d_f = \left[\frac{nQ_{WQ}}{1.49Ws^{1/2}}\right]^{3/5}$$

$$V_{WQ} = \frac{Q_{WQ}}{Wd_f}$$

where: V_{WQ} = design flow velocity (ft/sec)

$$L = T_{event}V_{WQ} = 540V_{WQ}$$

where: L = filter strip length (ft)

T_{event} = residence time (t = 9 minutes = 540 seconds)

Solve for d_f, V_{WQ}, and L, where:

Q_{WQ} = 0.03 cfs

W = 300 ft

n = 0.20 (0.35–0.45 allowed; 0.20 selected if lower maintenance is expected)

s = 0.2 (20%, 5H:1V)

d_f = $[2.5(0.03)(0.20)/1.49(300)(0.20)^{1/2}]^{3/5}$

= 0.00335

V_{WQ} = 0.03/[300(0.0035)]

= 0.0298 ft/sec

L = 540(0.0298)

= 16.1 ft

This calculated filter strip length fits in an available roadside width of 30 feet. Also, check the design for a narrow filter strip BMP (Volume V of Ecology's SMMWW, BMP T9.50, pages 9-27 to 9-28, for roadsides with limited space:

Flow path = 12 + 12 + 6 = 30 feet

Slope = 0.2 (20%)

L = 18 feet (which exceeds the computed length above); therefore, a 16-foot-long filter strip is used

6. **Compute flow control volume.** If flow control is required, calculate required storage volume for peak flow attenuation using guidance in Section 3-3.6, Minimum Requirement 6, in Chapter 3 of the HRM. Because the example project is in western Washington, limit durations of postdeveloped peak flows to predeveloped durations for flows between 50% of the 2-year and the 50-year storm events. Route developed flows from design storms through a facility sized for runoff treatment to verify adequate peak storage using infiltrated flows only. If inadequate, then:

   - Increase bioretention bed width and/or depth.
   - Provide additional subsurface storage layer in bioretention area.
   - Provide individual downstream flow control.

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2 Modified Biofiltration Swale

Introduction

General Description

The *modified biofiltration swale* is an experimental runoff treatment BMP that has been developed to target the removal of dissolved metals within highway runoff (see Figure 2.1).

This BMP occupies the same area as a basic biofiltration swale (see BMP RT.04 in the HRM) and includes the addition of three filter systems along the length of the swale: a rock roughing filter, a compost filter berm, and a polishing filter berm. The primary pollutant-removal mechanisms include biofiltration, filtration, ion exchange, and adsorption.

Applications and Limitations

The BMPs in Category 2 have not received approval for use by Ecology and are still under development. The design criteria for these BMPs will need further refinement and will also be subject to Ecology's evaluation process (see Section 5-3.6 in Chapter 5 of the HRM) before actual project application can be permitted to meet applicable Minimum Requirements. These BMPs may be considered for use on a “pilot” scale if Ecology accepts the design proposal. Provisional approval from the region and HQ Hydraulics and Environmental Services Water Quality offices must be obtained prior to considering these BMPs for project use.

Design Flow Elements

Flows to Be Treated

Flows to be treated by modified biofiltration swales are the same as those for basic biofiltration swales (see BMP RT.04 in the HRM).

Flow Spreaders

Flow spreaders must be placed approximately 10 feet from the upstream face of the rock filter berm and 10 feet upstream from the polishing filter berm.

Structural Design Considerations

Geometry

Sizing Procedure

1. Determine the runoff treatment design flow rate Q_{WQ} (see Chapter 4 of the HRM).

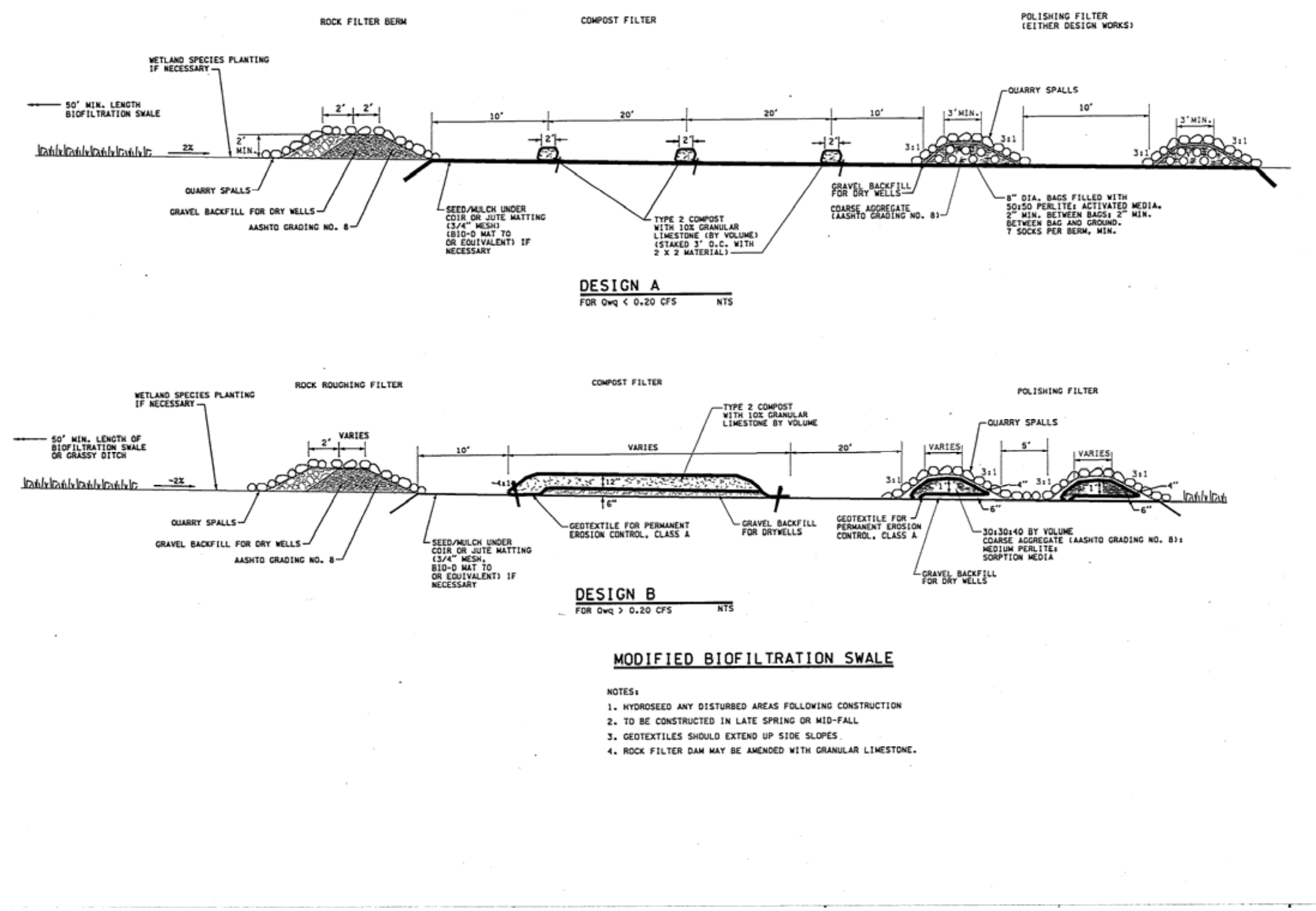

Figure 2.1. Modified biofiltration swale.

2. Size surface area of the upstream face of the **rock roughing filter** so that:

$Q_{WQ} / A_{rockfilter} < 0.02$ **(2-2.1)**

where: Q_{WQ} = the runoff treatment design flow rate (cfs)

$A_{rockfilter}$ = the surface area of the upstream face plus one-half of the top area of the rock roughing filter (sf)

Notes:

1. Do not include the surface area of the coarse rock (gravel backfill for drywells) on the upstream face of the rock roughing filter when calculating $A_{rockfilter}$.
2. Equation 2-2.1 is based on the assumption that the peak horizontal flow rate per square foot of rock filter is 0.02 cfs. The rock filter meets the gradation criteria for AASHTO Grading No. 8 (WSDOT Standard Specification 9-03.1(4)).

3. The **compost filter berm** consists of several compost-wrapped berms or a compost filter bed:

a) For $Q_{WQ} \leq 0.20$ cfs, use three 2-foot-long (top length) geotextile-wrapped compost berms. Set these compost berms 20 feet apart.

b) For $Q_{WQ} > 0.20$ cfs, design compost filter bed based on 220 sf of coarse compost filter per 1 cfs of highway runoff.

To determine bed area use:

$$Q_{WQ} \text{ x } 220 = A_{bcf} \quad \textbf{(2-2.2)}$$

To determine the bed length use:

$$A_{bcf} / W_{bcf} = L_{bcf} \quad \textbf{(2-2.3)}$$

$$W_{bcf} = W_{bed} + (2\ h_{bcf}\ z) \quad \textbf{(2-2.4)}$$

where: A_{bcf} = area at bottom of compost layer (sf)

W_{bcf} = width of bed at bottom of compost filter layer (ft)

L_{bcf} = length of bed at bottom of compost filter layer (ft)

W_{bed} = width of swale bed (ft)

h_{bcf} = distance from swale bed to bottom of compost filter layer (ft)

z = side slope (ft/ft) (H:V)

4. The **polishing filter** consists of two rock-enclosed berms filled with a mix of mineral aggregate, coarse perlite, and/or activated media. (See Figure 2.1 for design options.) If $Q_{WQ} > 0.20$ cfs, then use the following sizing procedure:

$$Q_{WQ} / A_{polish} = 0.01 \quad \textbf{(2-2.5)}$$

where: A_{polish} = the minimum required surface area of the upstream face plus one-half of the top area of the polishing filter (sf).

Notes:

1. A_{polish} must include the surface area of the two separate polishing filters.
2. Equation 2-2.5 is based on the assumption that the peak horizontal flow rate per square foot of polishing filter surface area is 0.01 cfs. This assumes that the polishing filter consists of a media mix of which 90% or more is retained on the No. 16 (or larger) sieves, by weight.

Berms, baffles, and slopes: unsupported side slopes of berms must be designed with a maximum slope of 3H**:**1V.

Site Design Elements

Construction Criteria

Same as for the basic biofiltration swale (see BMP RT.04 in the HRM), except for the following:

- Runoff from construction areas must be prevented from entering modified biofiltration swales
- Bed and wetted side slopes of modified biofiltration swales shall be covered with matting to ensure stability of topsoil during vegetation establishment period

3 Enhanced Swale Rating Matrix

> *Note: This will be a similar rating system to that listed in the following section on Pond Modifications for Enhanced or Phosphorus Treatment.*

Meets two of the following four characteristics:

- Physical geometry
- Soils/plantings
- Treatment features
- Upstream/downstream features

4 Pond Modifications for Enhanced or Phosphorus Treatment

The BMPs in Category 2 have not received approval for use by Ecology and are still under development. The design criteria for these BMPs will need further refinement and will also be subject to Ecology's evaluation process (see Section 5-3.6 in Chapter 5 of the HRM) before actual project application can be permitted to meet applicable Minimum Requirements. These BMPs may be considered for use on a "pilot" scale if Ecology accepts the design proposal. Provisional approval from the region and the HQ Hydraulics and Environmental Services Water Quality offices must be obtained prior to considering these BMPs for project use.

Following are recommended design features and site characteristics for basic wet ponds to qualify as stand-alone enhanced or phosphorus stormwater treatment BMPs (see Table 4.1).

Table 4.1. Proposed rating system for basic wet pond to meet enhanced or phosphorus treatment criteria.

Feature Group	Requisite Score to Qualify for Enhanced Treatment	Requisite Score to Qualify for Phosphorus Treatment
1	2	2
2	2	2
3 to 7 (total)	6	6 (Enhancement 4C required)

Feature Group 1: Pretreatment and Source Control

- 1A – Floatable and spill control[1] (1)
- 1B – Aggressive sweeping and catch basin maintenance program (2)
- 1C – Oil/water separator with settling chamber (2)
- 1D – Sheet flow runoff through grassy vegetation and/or compost-amended soils (2)
- 1E – Alternative deicing agents (1)
- 1F – Substitute materials (1)
- 1G – Water introduced via sheet flow through compost-amended, grassy embankment (2)

Feature Group 2: Posttreatment (Polishing)

- 2A – Constructed stormwater wetland[2] (2)
- 2B – Submerged gravel biofilter (2)
- 2C – Basic BMP with amended soils: vegetated filter strip, biofiltration swale, engineered dispersion area, or natural dispersion area (2)

Feature Group 3: Receiving Body and Runoff Characteristics

- 3A – Runoff of limited toxicity risk: low traffic volume, low truck volume, low accident rate, and low vehicle wear area (flat grade, constant speed, no intersections, excellent sight distance, and good winter conditions) (1)
- 3B – Receiving body without presence of sensitive organisms (1)
- 3C – Discharge into closed depression or isolated wetland (1)
- 3D – Contributing basin less than 0.5% of receiving body basin at outfall location (1)

Feature Group 4: Vegetation

- 4A – Shading (1)
- 4B – Emergents (2)
- 4C – Waterfowl control (1)

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[1] Numbers in parentheses denote points applicable to the score.

[2] Meets the requirements of BMP RT.13 (in the HRM) with two exceptions: (1) no forebay is required, and (2) wet pond volume is 25% to 35% of total required wet pond volume of the contributing drainage basin.

Feature Group 5: Geometry and Orientation

- 5A – Oriented in alignment with prevailing summer winds (1/2)
- 5B – Depths of 2 to 6 feet (shallower depths may incur resuspension of settled solids and are prone to summer temperature increases; greater depths may result in reduced dissolved oxygen and stratification and water table interception) (1)
- 5C – Teardrop or sinusoidal shape (1)
- 5D – Length-to-width ratio exceeding 5:1 (2)

Feature Group 6: Other

- 6A – Internal aeration (2)
- 6B – Discharge aeration (1)
- 6C – Small amount of base flow (1)
- 6D – Maintenance: vegetation management (2)
- 6E – Maintenance: no fertilizer following initial vegetation installation (1)

Feature Group 7: Proposed Experimental Modifications for Enhanced Treatment (each modification in Group 7 scores a 2):

- 7A – Permeable earthen berms (basic, enhanced, and phosphorus control)
  - For use in ponds with three or more cells. Installation of these features requires designing a pond that can fully drain. Second and subsequent berms can be modified to include windows or catch basins for placement of exchange media.
- 7B – Sorptive media berms (basic, enhanced, and phosphorus control)
  - Various combinations of filtration and sorption media on top or within downstream berms.
- 7C – Shallow flow berms (basic and enhanced)
  - Berm between second and third cell to provide treatment via shallow overland flow through amended soils and vegetation on the gently sloped top surface of dividing berm.
- 7D – Engineered treatment liners (basic, enhanced, and phosphorus control)
  - Runoff treatment to be provided by draining through bed and/or embankments of basin. In areas with poor infiltration and seasonally high water table 4 feet below pond bed, a drainage layer can be constructed to collect effluent from an engineered treatment liner.

Alternative Design Where Prolonged Standing Water Is a Concern:

This facility has two cells consisting of a standing pool within the first cell (forebay) and a second cell (dry bay). The first cell comprises 25% of the total wet pool volume and is a straight-walled structure at least 4 feet deep, preferably covered or shaded to reduce increased temperatures. Flows enter the second cell by spilling out of the first cell and trickling down a well-vegetated embankment with a minimum slope of 4H:1V. The outlet structure is designed like the basic wet pond. An inclined sand filter window, treatment liner + underdrain system, or floating discharge pipe could be used to slowly draw down water in the second cell.

Additional design details are under development.

5 Permeable Earthen Berm

Permeable earthen berms can be used to improve the pollutant-removal efficiency of wet ponds. Filtration of suspended materials via permeable earthen berms improves the removal efficiency of ponds that rely on gravity settling alone. (These pond modifications were installed in the Northwest Region in 2003. Preliminary flow and water quality information should be currently available.)

Three key components of ponds utilizing permeable earthen berms are as follows:

Low-Permeability Liner

- The entire pond must be lined with a low-permeability liner to prevent solid soils uplift (use of soils meeting the low-permeability criteria are not acceptable).
- Liner must be placed in the first two cells, at a minimum.
- If a geomembrane liner is used, then the liner must include surface roughness to increase surface friction and allow for soils to adhere on slopes.

Berm Design

- The permeable berm must be keyed in on top of and along the side slopes of the low-permeability liner.
- The top of the berm must be a minimum of 6.0 feet wide with 3H:1V side slopes.
- The permeable berm must be covered with a 1-foot depth of quarry spalls.
- Two overflow structures, such as a catch basin or grate inlet with discharge pipe, must be installed in each berm unit. The outlet pipes must pass though the berm and discharge at the protected downstream toe of the berm.
- The overflow inlet elevation must have a minimum distance of 3.0 feet from the bottom of the pond to the top of the overflow inlet.
- The catch basin or grate inlet must include a 0.5-foot-wide by 0.5-foot-deep lip of concrete at the base and a 2.0-foot-high open riser at the top to ensure stability. If less than 75% of the overflow structure is embedded in the berm, a pipe collar for the outlet pipe must be included in the design.
- The top of the berm must maintain 1.0 foot of clearance from the top of the pond.
- Pond lengths over 150 feet must include multiple cells.
- The bottom of the pond must be covered with 1.0 foot of compost-amended soil.
- The second or final berm of the system must include removal media such as the ecology mix or engineered filter media. Particle sizes must be a ¼-inch nominal diameter (or greater) to maintain flow within the system. Contact your WSDOT water quality engineer for more information regarding media use.

Pond Geometrics

- The pond bottom must have a continuous minimum slope of 2.0% across the length of the pond.
- A level spreader that allows inlet water to flow over the full width of each cell must be included.
- The outlet control structures must have a 10-foot by 10-foot energy-dissipating pad and concrete or coir log flow spreader encompassing the flow spreader area.

6 Pond Filter Berms

Introduction

General Description

Pond filter berms are experimental designs intended to remove dissolved metals and organic compounds within highway runoff at a significantly higher rate than basic wet pond facilities. Pond filter berms are modifications to the earthen dividing berms within stormwater wet ponds. The earthen berm is topped with a series of media-filled bags through which the runoff passes as it moves from cell to cell within the pond (see Figure 6.1). Particulate and dissolved heavy metal removal relies on filtration (by perlite) and ion exchange (by zeolite). Removal of soluble organic compounds is via adsorption (by granular activated carbon). Alternatively, the berm can be topped with compost-amended topsoil and seeded with a fine, herbaceous seed mix to provide treatment ("shallow flow berms" to be developed).

Applications and Limitations

The BMPs in Category 2 have not received approval for use by Ecology and are still under development. The design criteria for these BMPs will need further refinement and will also be subject to Ecology's evaluation process (see Section 5-3.6 in Chapter 5 of the HRM) before actual project application can be permitted to meet applicable Minimum Requirements. These BMPs may be considered for use on a "pilot" scale if Ecology accepts the design proposal. Provisional approval from the region and HQ Hydraulics and Environmental Services Water Quality offices must be obtained prior to considering these BMPs for project use.

Design Flow Elements

Flows to Be Treated

The minimum wet pool volume is the same as that of a basic wet pond (see BMP RT.12 in the HRM).

Structural Design Considerations

Geometry

The same as for the wet pond (see BMP RT.12 in the HRM), except for the following:

- Wet pool facilities with filter berms must have a minimum of three cells.
- At a minimum, filter berms must be placed between the second and third cell.
- The top width of the earthen berm must exceed the combined width of the filter berm media bags by a minimum of 4 feet.

The elevation of the runoff treatment design water surface must be set at the bottom of the highest media bag.

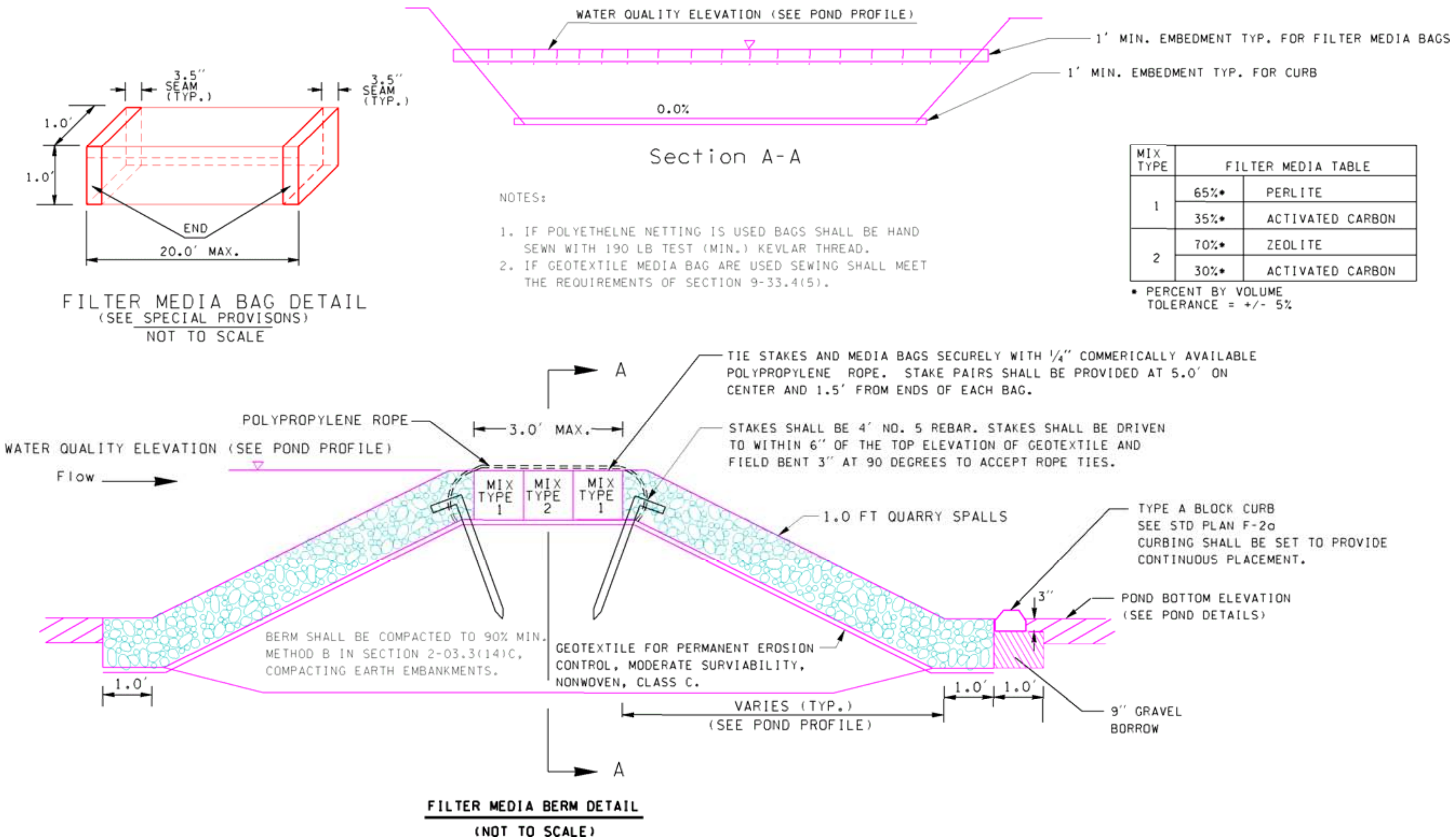

Figure 6.1. Pond filter berm media details.

Site Design Elements

Construction Criteria

The same as for the wet pond (see BMP RT.12 in the HRM), except for the following:

- Filter berm media bags must not be exposed to construction runoff. Site must be stabilized before filter berm media bags are placed.
- Filter berm media bags must be installed tightly against the geotextile wrapping the earthen berm.

7 Submerged Gravel Biofilter

Introduction

General Description

The *submerged gravel biofilter* consists of one or more treatment cells that are filled with an alkalinity-generating pea gravel media (ecology mix) designed to allow stormwater to flow through the subsurface root zone of vegetation established in an uppermost soil/compost confining layer. These units are also commonly known as subsurface horizontal flow wetlands, rock media polishing filters, rock-reed filters, vegetated submerged bed wetlands, and shallow horizontal flow wetlands. These units all apply the same basic plant species: maidencane, giant bulrush, and fireflag. The submerged gravel biofilter is intended for use as a secondary or tertiary polishing step for runoff discharged from a wet pond or other runoff treatment BMPs. The outlet from each cell is set at an elevation to keep the rock or gravel submerged. In this environment, wetland plants are rooted in the media, where they can directly uptake some pollutants. In addition, filimentaceous algae (epilithic periphyton) thrive on the surface area of the submerged gravel media, which has the capacity to encapsulate and transform many pollutants.

Although widely used for wastewater treatment in recent years, only a few submerged gravel biofilters have been designed for stormwater treatment. Laboratory testing in Canada indicated that biofilters just three days old provided suspended solids and dissolved heavy metals removal in excess of 90%. Overall, given the variable nature of stormwater runoff quality, it is anticipated that the pollutant-removal efficiency of submerged gravel biofilters is similar to that of a typical treatment wetland. An additional benefit of using submerged gravel biofilters is their capability of reducing temperatures of pond effluent on those rare occasions when summertime storms exceed the holding capacity of the pond.

Applications and Limitations

The BMPs in this appendix have not received approval for use by Ecology and are still under development. The design criteria for these BMPs will need further refinement and will also be subject to Ecology's evaluation process (see Section 5-3.6 in Chapter 5 of the HRM) before actual project application can be permitted to meet applicable Minimum Requirements. These BMPs may be considered for use on a “pilot” scale if Ecology accepts the design proposal. Provisional approval from the region and HQ Hydraulics and Environmental Services Water Quality offices must be obtained prior to considering these BMPs for project use.

The submerged gravel biofilter should be used only as a post-treatment process following a wet pond (see BMP RT.12 in the HRM) to remove residual concentrations of heavy metals and solids. The submerged gravel biofilter can also be designed as an additional treatment cell in a wet pond. In this application, it can be used in lieu of sand filters, constructed surface wetlands, or other BMPs designed to provide enhanced treatment for dissolved metals. As a primary treatment device, it is likely that sedimentation and media saturation would result in intensive routine maintenance. With a majority of the coarse solids removed as a result of sedimentation in the wet pond, it is likely that maintenance of the biofilter would be on a 5- to 15-year cycle to maintain its designed hydraulic and runoff treatment performance.

Structural Design Considerations

Geometry

- The local slope should be relatively flat (<2%). While there is no minimum slope requirement, there does need to be enough available head from the inlet to the outlet to ensure that hydraulic conveyance by gravity feed is feasible (generally >2.5 feet).
- All submerged gravel biofilters should receive effluent from a wet pond (preferably) or other sediment control BMP.
- Unless it receives runoff from a high-use intersection, submerged gravel biofilters can intersect the local water table.
- The media bed should be covered by a minimum of 4 inches of soil or compost to aid plant establishment.
- The ecology mix should be a minimum of 24 inches deep, including the section on top of the underdrain trench. The surface area of the submerged gravel biofilter should have at least a 2:1 length-to-width ratio to minimize the chances of short-circuiting within the biofilter.

Sizing

For runoff treatment, sizing a submerged gravel biofilter is based on the requirement that the runoff treatment flow rate $Q_{Highway}$ needs to be less than the long-term infiltration capacity of the submerged gravel biofilter $Q_{Infiltration}$:

$$Q_{Highway} < Q_{Infiltration}$$

$$(WQI_{Highway}) < (LTIR_{EM} * Area_{SGB})$$

Solving for the surface area of the submerged gravel biofilter:

$$Area_{SGB} > \frac{(WQI_{Highway})}{LTIR_{EM}}$$

where: $WQI_{Highway}$ = runoff treatment design storm or maximum pond release rate (cfs)
$LTIR_{EM}$ = long-term infiltration rate of the ecology mix (use 14 inches per hour for design purposes)
$Area_{SGB}$ = width of the submerged gravel biofilter (ft)

Inlet Control

Same as for constructed stormwater treatment wetlands (see BMP RT.13 in the HRM).

Outlet

Same as for constructed stormwater treatment wetlands (see BMP RT.13 in the HRM).

Materials

Ecology Mix Media Bed: the ecology mix is a mixture of pea gravel, dolomite, gypsum, and perlite. The pea gravel provides the basic matrix of the media; the dolomite and gypsum add alkalinity and ion exchange capacity to promote the precipitation and exchange of heavy metals; and the perlite promotes moisture retention to promote the formation of biomass within the media bed. The combination of physical filtering, precipitation, ion exchange, and biofiltration provides the water treatment capacity of the mix. The ecology mix has an estimated initial infiltration rate of 50 inches per hour, a long-term infiltration rate of 28 inches per hour, and a design infiltration rate of 14 inches per hour.

The ecology mix to be used in the construction of the submerged gravel biofilter consists of the components shown in Table 7.1.

Table 7.1. Ecology mix.

Soil Amendment	Quantity
Mineral aggregate Crushed screenings 3/8 inch to #10 sieve	3 cubic yards
Perlite Horticultural grade: >70% larger than 18 mesh (1 mm)	1 cubic yard for 3 cubic yards of mineral aggregate
Dolomite (calcium magnesium carbonate) #0, gradation #16 sieve	10 pounds per cubic yard of perlite
Gypsum (calcium sulfate) #0, gradation #8 to #16 sieve	1.5 pounds per cubic yard of perlite

Gravel backfill for pipe bedding should conform to Section 9-03.12(3) of the Standard Specifications.

Berms, Baffles, and Slopes

Slopes should generally be no steeper than 2%. Lateral slopes should be less than 3H:1V unless slopes are permanently stabilized using methods identified in Section 2-03 of the Standard Specifications. A minimum freeboard of 1 foot above the soil surface covering the submerged gravel biofilter is needed.

Site Design Elements

Setback Requirements

Same as for constructed stormwater treatment wetlands (see BMP RT.13 in the HRM).

Landscaping (Planting Considerations)

Same as for constructed stormwater treatment wetlands (see BMP RT.13 in the HRM).

Signage

- Signage must be provided according to the requirements for detention ponds (see BMP FC.03 in the HRM).
- If the submerged gravel biofilter is in a critical aquifer recharge area for drinking water supplies, signage prohibiting the use of pesticides or herbicides should be provided.

Maintenance Access Roads (Access Requirements)

Same as for constructed stormwater treatment wetlands (see BMP RT.13 in the HRM).

8 Amended Sand Filter

> *WSDOT does not recognize this BMP as a viable highway application for basic or enhanced treatment due to cost and performance considerations associated with maintaining this treatment option.*

To meet the performance goals of an enhanced treatment BMP, the following modifications to BMPs RT.14, RT.15, and RT.16 in Category 1 BMPs are recommended for the *amended sand filter*:

- The top 12 inches (80% to 95%) of the sand filter bed should consist of sand (see Table RT.14.1 in Category 1 BMPs) and compost Type 2 (5% to 20%), by volume. Granular calcitic limestone should be added at a rate of 3 to 15 pounds per cubic yard of the sand/compost mix.
- The next 6 to 12 inches should consist of sand alone (see Table RT.14.1 in Category 1 BMPs) or a 70:30 mix of sand exchange media, by volume. Experimental exchange media may consist of zeolite or activated soybean hulls. For phosphorus removal, consider the use of iron-infused sand. Do not use processed steel fiber in the sand filter.
- Herbaceous vegetation should be seeded on top of the sand filter to maintain bed permeability, shade bed surface, and limit extent of invasive vegetation establishment.

The water quality and hydraulic characteristics of a sand filter with the preceding elements will be monitored at a facility near Monroe, Washington. Preliminary findings should be available in 2006.

General Sand Filter Recommendations/Modifications

Pretreatment and Source Control

- Consider upsizing pretreatment BMPs (see Proprietary Presettling Devices in Section 12) above the minimum requirements of this manual. This can improve sediment capture upstream of sand filter.
- Introduce flows to sand filter level spreader as sheet flow through dense, herbaceous vegetation or compost filter berms. As sheet flow passes through dense grass or compost, nonsettleable solids are trapped, which can significantly reduce sediment loading to the sand filter.
- Establish an aggressive maintenance schedule to clean roadway, drainage, and pretreatment facilities upstream of sand filter.
- Provide effective temporary erosion and sediment control (TESC) measures to ensure that turbid runoff from construction areas does not reach sand filter bed.

Maintenance

- Routinely inspect pretreatment facility to evaluate need for sediment and floatables removal.
- Maintain sand filter vegetation (and surrounding landscaping) to limit weed establishment and litter accumulation and to increase stem density on sand filter bed.
- Periodically rejuvenate sand filter bed via thatching or aeration if surface is vegetated. Bare beds can be rototilled or scraped to remove upper layer of sand filter bed if clogging occurs.
- Periodically inspect sand filter during large storm events to evaluate whether it is operating as designed and is treating water effectively.

Other

- Provide adjustable weirs within flow splitter to allow modifications if flows are not directed as originally designed.

9 Continuous Inlet Protection

WSDOT does not recognize this BMP as a viable highway application for basic or enhanced treatment due to cost and performance considerations associated with maintaining this treatment option.

Introduction

General Description

Continuous inlet protection, or catch basin inserts (CBIs), are devices installed under a storm drain grate to provide runoff treatment through filtration, settling, or adsorption. CBIs are proprietary products generally configured to remove one or more of the following contaminants: course sediment, oil, grease, litter, and debris. CBIs typically consist of the following components:

- A structure (e.g., screen box, brackets) that contains a pollutant-removal medium
- A means of suspending the structure in a catch basin
- A filter medium such as sand, carbon, or fabric
- A primary inlet and outlet for the stormwater
- A secondary outlet for bypassing flows that exceed design flows

Examples of proprietary CBIs and more detailed information can be found at the Region 1 – U.S. Environmental Protection Agency's S*torm Water Virtual Trade Show* at:
http://epa.gov/boston/assistance/ceitts/stormwater/index.html

Applications and Limitations

CBIs have been found to be nominally effective in removing fine (silt and clay) sediment, trace metals, and total petroleum hydrocarbons (TPH). Possible locations for CBIs include parking lots, bridges, and roadways. CBIs provide little if any spill prevention and do not meet spill-containment requirements unless the catch basin in which they are installed has a tee section.

The use of CBIs may be limited by drainage area, available space inside the catch basin, availability of maintenance, and access. Absorbent media CBIs are not recommended as a substitute for basic approved BMPs. CBIs can cause floods when plugged. Plugging problems may be compounded by street sanding and other activities.

Presettling and/or Pretreatment

While no pretreatment is required with CBIs, the use of source control BMPs on the site decreases maintenance needs.

Design Flow Elements

Flows to Be Treated

The total maximum tributary area runoff should be 5,000 square feet (465 square meters ±5%) per CBI. This flow is approximately 19 gallons per minute (gpm) for the runoff treatment design flow. This limit is based on treating 90% of the runoff volume.

Structural Design Considerations

Design Parameters

The CBI should be located such that it is accessible as needed for maintenance and not limited by continuous vehicle parking. A CBI should be designed to fit with a standard grate. If the insert is installed in an existing catch basin, the insert should be demonstrated to fit properly so that there is a positive seal around the grate to prevent low-flow bypass. The maximum height of the grate above the top of the frame, with the insert installed, should not exceed 3/16 inch, and the grate should be nonrocking. The maximum height of 3/16 inch adds a passive perimeter berm to capture low-flow suspended solids prior to discharge through the CBI.

The bottom of the filter media (oil-absorbent/absorbent material) must be above the level of normal low flows. If the media is above the crown of the outlet pipe, it is assumed to be above the normal low flows. An alternative method to demonstrate that the media material is above the normal low flow is to show by backwater analysis method that the bottom of the media is above the water surface elevation corresponding to the runoff treatment design flow.

Site Design Elements

Maintenance

CBIs fitted with oil-absorbent/absorbent filter media should be inspected monthly and changed whenever the filter media surface is covered with sediment. In addition, the catch basin sump should be examined for sediment accumulations during the monthly inspections. Sediment should be removed if the depth in the sump is greater than 0.5 feet or as indicated in the manufacturer's maintenance manual. Inspections are especially important during the wet season. Information on manufacturers' recommendations regarding maintenance frequency can be found at the Region 1 – U.S. Environmental Protection Agency's S*torm Water Virtual Trade Show* at:
🖱 http://epa.gov/boston/assistance/ceitts/stormwater/index.html

10 Experimental Design Options for Enhancing Dissolved Metals Removal in Conventional Stormwater BMPs

Introduction

There are optional design features that can be incorporated into stormwater treatment systems to promote the capture efficiency of dissolved metals from highway runoff. Dissolved heavy metals can be removed from wastewaters by direct *precipitation*, *sorption*, *ion exchange*, or *bioaccumulation*. Precipitation of metals has long been the primary method of treating metal-laden industrial wastewaters. Metals precipitation from contaminated water involves the conversion of soluble heavy metal salts to insoluble salts that precipitate. The precipitate can then be removed from the treated water by physical methods such as clarification (settling) and/or filtration. The process usually uses pH adjustment through the addition of a chemical precipitant, such as limestone, dolomite, or hydrated lime. Typically, metals coprecipitate from the solution as hydroxides, sulfides, or carbonates.

Detention ponds with permanent wet pools are particularly good candidates for use in conjunction with precipitation methods because the quiescent flow conditions in the pond can promote settling of metal precipitants. Complexation of carbonates, hydroxides, and sulfides with soluble metals can be induced with passive treatment methods pioneered in acid mine drainage remediation, aquaculture, process wastewater treatment, and aquarium water treatment. Sorption and ion exchange using vegetated compost, agricultural byproducts, or engineered fabric filters can be adapted for use on filter strips, biofiltration swales, infiltration/exfiltration facilities, or other conventional stormwater BMPs that were originally designed for removing suspended solids. Gravel biofilters can be designed to maintain wet, aerobic conditions that promote the development of filimentaceous algae biomass (epilithic periphyton), which has been demonstrated in pilot tests in Canada to remove soluble metals from stormwater with great efficiency.

Chemistry of Metals in Highway Runoff

Highway stormwater runoff has several distinctive properties that are significant for BMP design that optimizes dissolved metals removal. All rainfall and highway runoff is acidic and has low alkalinity due to (natural) carbonic and (induced) sulfuric acids in the atmosphere and short times of concentration that are typical of highway drainage systems. As a result, when highway stormwater runoff enters a runoff treatment BMP, heavy metals such as zinc, copper, lead, and cadmium are found in a stable, dissolved aqueous form and are unable to form solids.

Precipitation

Hydroxide Precipitation

Hydroxide precipitation converts soluble heavy metal ions to relatively insoluble metal-hydroxide precipitates by adding an alkali-precipitating agent that increases pH. Hydroxide precipitation can be passively induced using open limestone channels, anoxic limestone drains, or vertical flow reactors; techniques pioneered in acid mine drainage treatment. Theoretically, the solubility of copper hydroxide can be reduced by more than 300% by increasing runoff pH from 5.0 (fairly typical for highway runoff) to 7.0. Ideally, hydroxide precipitation (as with all precipitation methods) should be induced to the runoff prior to discharge to a wet pond or other sediment retention BMP, where the metal-hydroxide compounds can precipitate and settle out per Stokes' law. The advantages of hydroxide precipitation include the following:

- It is a well-proven, accepted technique in industry and for acid mine drainage treatment
- It is a relatively simple, low-maintenance operation
- It can be passively induced without pumps, controllers, or other sophisticated, maintenance-intensive equipment
- The precipitant (limestone, oyster shells) is low cost, widely available, and easy to specify

The disadvantages of hydroxide precipitation include the following:

- Little hydroxide precipitation occurs at $pH<6$
- Minimum solubilities of different hydroxide-metal compounds occur at different pH conditions
- The presence of chelates (cyanide, EDTA) has adverse effects on metals removal
- Hydroxide sludge quantities can be substantial and difficult to dewater
- The minimum theoretical solubilities of hydroxide-metal compounds may not be low enough to meet Washington State water quality standards

Carbonate Precipitation

Dissolved heavy metals can also be removed from stormwater runoff by direct precipitation using carbonate precipitation. Carbonate precipitation is often preferred over hydroxide precipitation for the removal of cadmium, lead, and nickel. The solubilities of metal-carbonate compounds are intermediate between hydroxide and sulfide-metal compounds. The advantages of carbonate precipitation are the following:

- Carbonate reagents are inexpensive, widely available, and easy to handle.
- An alkalinity-producing process (such as open limestone channels) as pretreatment can create both metal-carbonate and metal-hydroxide compounds, which can be advantageous for treatment of multiple metals
- Calcium carbonate forms easily settleable or filterable precipitates
- Optimum treatment occurs at lower pH than with hydroxide precipitation

The disadvantages of carbonate precipitation are the following:

- Carbonates can evolve carbon dioxide, which can reduce reaction times
- The metal-carbonate sludge can be difficult to precipitate without subsequent flocculation by inorganic salts or polymers
- Carbonate sludge accumulated in detention ponds may have to be tested for compliance with hazardous waste regulations prior to disposal

Sulfide Precipitation

Sulfide precipitation works under the same basic principal as hydroxide precipitation. Sulfide-metal compounds tend to have very low solubilities relative to metal-hydroxide and metal-carbonate compounds. Sulfide compounds can be passively generated in anoxic conditions with a nutrient source, where bacteria reduce sulfates to sulfides, which in turn form metal-sulfide compounds. The advantages of sulfide precipitation are the following:

- Attainment of a high degree of soluble metal removal over a wide range of pH values (2 to 12) is possible
- Increases in the sulfide ion concentration directly cause more metals to be precipitated
- Metal-sulfide precipitates tend to be dense, easily settleable, and filterable
- Good metals removal is possible even with weak chelating agents present

The disadvantages of sulfide precipitation are the following:

- Generation of sulfides can result in small emissions of hydrogen sulfide
- Sulfide sludge accumulated in detention ponds may have to be tested for compliance with hazardous waste regulations prior to disposal

Pretreatment Methods to Induce Metals Precipitation

Open Limestone Channels

Open limestone channels are the simplest passive pretreatment method to induce precipitation. A drainage channel is excavated and filled with limestone rocks (light riprap). The channel receives runoff and the dissolution of limestone adds alkalinity to the runoff and raises its pH from acidic to neutral or mildly alkaline. The runoff is then routed to a wet pond to allow the precipitates to settle out by gravity/Stokes' law. Open limestone channels are designed using standard engineering practice and Manning's equation. The design objective is to have the water level remain within the coarse limestone matrix (AASHTO 57 gradation) and not show surface ponding or flow for the runoff treatment design storm. Open limestone channel design criteria:

- Cross section – trapezoidal
- Maximum flow velocity – 1.2 meter/sec

- Manning's n – 0.040
- Porosity of the limestone bed –
- Minimum bottom width – 2 feet
- Minimum detention time – 7 minutes
- Minimum freeboard – 0.5 feet

Anoxic Limestone Drains

An anoxic limestone drain (ALD) is a bed of limestone buried under a layer of soil or compost and constructed to intercept runoff and prevent contact with atmospheric oxygen. The advantage of ALDs over open limestone channels is the opportunity to induce sulfide precipitation of metals through bacterial reduction of sulfates in the anoxic zone. Additionally, the process of limestone dissolution provides alkalinity, carbonates, and hydroxides that could lead to metals oxidation and coprecipitation in the subsequent wet pond. ALDs are sized based on the assumption that the drain produces 275 to 300 mg/L of alkalinity over 14 hours (this has been derived empirically from acid mine drainage treatment projects; see http://www.dep.state.pa.us/dep/deputate/minres/bamr/amd/science_of_amd.htm). The overall equation to calculate the mass of limestone needed for an ALD is as follows:

$$M = \left(\frac{Q\rho_b t_d}{V_v}\right) + \left(\frac{QCT}{x}\right)$$

where: M = mass of limestone in tons

Q = runoff treatment design flow (m^3/day)

ρ_b = bulk density of the limestone in tons per cubic meter

t_d = retention time in days

V_v = bulk void ratio expressed as a decimal (0.30)

C = effluent alkalinity concentration in tons per cubic meter

T = design life of the drain in days, typically 7,300 days (20 years)

X = $CaCO_3$ content of the limestone expressed as a decimal (0.85)

Vertical-Flow Reactors

Vertical-flow reactors (VFRs), also referred to as successive alkalinity producing systems or vertical flow wetlands, are passive pretreatment devices that are able to neutralize acidity and promote metals precipitation in space-confined treatment situations. Due to the active mixing of runoff with the limestone, acid neutralization is more rapid in vertical-flow systems than in limestone channels or ALDs, so vertical-flow systems require shorter residence times and smaller surface areas. These systems are not stand-alone; they require the addition of a wet pond at the effluent point to allow for the settling and storage of the metals precipitants from solution. The VFR consists of one underground treatment cell lined with a limestone base and topped with a layer of organic substrate; typically a coarse-textured compost. The water flows vertically through the compost and limestone and is collected and discharged through a system of pipes. The VFR increases alkalinity by limestone dissolution and bacterial sulfate reduction. The VFR should be designed to promote the transport of fine solids through the system and into the subsequent wet pond for settling. VFRs that retain fine solids are likely to require intensive maintenance. The removal of such metals prior to vertical-flow treatment lengthens the system's useful life and reduces necessary maintenance by limiting the accumulation of aluminum or iron-hydroxide precipitants on the organic matter surface. A pretreatment system for removal of gross solids and floatables (Vortechs, CDS, and many others—see Section 12, Proprietary Presettling Devices) should also precede the system to prevent fouling or clogging in the reactor.

The three major system elements are the drainage system, an organic-mulch layer, and a limestone layer. The system is constructed within a watertight excavated basin, with the drainage system constructed with a standpipe to ensure that the organic and limestone layers remain continuously submerged. As the stormwater runoff flows downward through the organic layer, two essential functions are performed: dissolved oxygen is removed from the waters by aerobic bacteria, and sulfate-reducing bacteria in the anaerobic zone of the mulch layer generate alkalinity. Low dissolved oxygen concentrations, biodegradable carbon, and the presence of dissolved sulfate are necessary for sulfate reduction to take place. If metals that form insoluble sulfides, such as Cu, are present in the stormwater runoff, they can combine with the sulfides generated by the sulfate-reducing bacteria and remain within the mulch layer. In the limestone layer, $CaCO_3$ is dissolved by the anoxic waters moving toward the drainage system, producing additional alkalinity. The final effluent is discharged from the drainage system standpipe into a settling pond to allow acid neutralization and metal precipitation to take place prior to ultimate discharge.

Current practices include a limestone layer of 0.60 to 0.90 meters (2 to 3 feet) in depth, an organic layer of 0.15 to 0.45 meters (0.5 to 1.5 feet) in depth, and a standpipe and basin capable of maintaining a body of water 0.90 to 1.5 meters (3 to 5 feet) deep above the organic layer. Building systems with 3 feet or more of standing water over the mulch layer provides sufficient head pressure, which aids flushing. VFRs are sized by using the runoff treatment design storm and providing a detention time of ______ to achieve a mean alkalinity of 150 mg/L.

Sorption and Ion Exchange Using Vegetated Compost, Agricultural Byproducts, or Engineered Fabric Filters for Incorporation Into Primary BMP Designs

Compost and Humic Filters

This treatment option uses the sorptive capacity of agricultural and yard waste products to remove dissolved metals from stormwater. StormFilter™ is a commercially available product that uses processed deciduous tree leaves and should be considered an option for dissolved metals treatment if used as a tertiary polishing step to avoid repeated clogging from sediments blinding off the media. Two other prime options would be (1) composted yard wastes, or (2) activated soybean hulls (a product developed by the USDA that has been successfully tested in pilot tests at SeaTac Airport). It is likely that humic/compost filters can be installed as components of other primary BMPs, such as compost-amended vegetative filter strips, biofiltration swales, or effluent from a detention pond.

Engineered Fabric Filters

Several products are on the market and, although most are designed to absorb hydrophobic or emulsified hydrocarbons, some products (fuzzy filter, xextex, and many others) have been shown to be effective for treating dissolved metals. One advantage of fabric filters over media filters is that they can have up to 85% void space, which results in low head loss due to clogging.

11 Partial Infiltration Systems (Open and Closed)

Any use of this BMP will require approval from Ecology. The following text ***does not*** *describe how such a system would be appropriately sized using MGSFlood or WWHM to fully achieve or partially achieve the flow control requirement. Any partial proposals would have to include a way to track the water that is not infiltrated in hourly time steps so that the flow duration curve can be produced and a downstream detention facility sized. Also, the same procedures that are used to estimate long-term infiltration rates for ponds and trenches apply.*

Introduction

This discussion covers closed systems only. This BMP will be further detailed to discuss open systems.

Source: Association of Rainwater Storage and Infiltration (Japan)

General Description

Partial infiltration systems are stormwater conveyance systems that leak into the surrounding storage area similar to an infiltration trench. These systems at a minimum can be composed of perforated pipe, wash rock reservoir, and filter lining between control structures. A permanent installation in Japan has used permeable control structure in conjunction with perforated conveyance pipe for the last 20 years with good results.

Applications and Limitations

Information to be added here to help determine when this could be a practical application. Suggest that Section 5.6, Subsurface Infiltration, of Ecology's SMMWW be reviewed and used as a reference to fill in the gaps.

The attractive aspect of this BMP is the minimal right-of-way needed for effective performance. The trench element of the partial infiltration system allows this BMP an efficient use of space; it is relatively easy to fit into the median, perimeter, and other less used areas of developed sites, making it particularly suitable for retrofitting. Impermeable cross culverts could be used in conjunction with this BMP to spread the flows.

Appropriate soil conditions and the protection of groundwater are the most important considerations limiting the use of this BMP. Because partial infiltrations are part conveyance and part infiltration, the loss of treated stormwater is based on the soil type, preferably SCS type A, B, or C, and the volume of rock reservoir storage. Other soil conditions that do not support the use of a partial infiltration system include the following:

- Soils with more than 40% clay content (subject to frost heave)
- Fill soils (unless the fill material is specially designed to accommodate the facility)

Presettling and/or Pretreatment

Partial infiltration systems should always be preceded by a pretreatment BMP to remove sediments that could clog the infiltration system.

Design Flow Elements

Discussion to be added here on how this system is typically connected to a flow control BMP at the outlet and how that BMP is reduced in size since flows are partially infiltrated within the system.

Flows to Be Infiltrated

Flows to be treated by a partial infiltration system could be the same as those for infiltration ponds (see BMP IN.02 in the HRM) if permeable control structures are used.

Overflow or Bypass

Since partial infiltration systems use at a minimum perforated pipe for conveyance with the infiltration element, an overflow or bypass should not be necessary.

Structural Design Considerations

Geometry

Consult the WSDOT *Design Manual* M 22-01 for underdrain and storm sewer geometry design guidance.

Materials

Consult the WSDOT *Hydraulics Manual* M 23-03 for underdrain and storm sewer material guidance. For further design clarifications, see the backfill material and liner information provided for the infiltration trench (see BMP IN.03 in the HRM).

Berms, Baffles, and Slopes

Steep slopes (>25%) can contribute to slope failures.

Liners

Liners should be used as a separation layer between native and rock reservoir to prevent migration of fine soil particles into the designed dispersion area. Additional water quality filtration can be achieved through the liner as well. (See Section 5-4.3.3 in Chapter 5 of the HRM for information on facility liners.)

Groundwater Issues

If the minimum depth to groundwater is equal to or greater than 5 feet from the proposed bottom of the rock reservoir, and the soil conditions are appropriate, infiltration can be used. If the depth to the water table is shallower, there is an increased risk of groundwater contamination.

Vadose Zone Requirements

To be determined.

Aquifers

As with any type of infiltration BMP, these facilities should not be used in areas with shallow aquifers.

Seeps

To be determined.

Springs

To be determined.

Site Design Elements

Setback Requirements

For further design guidance, see the setback requirements defined for the infiltration trench (see BMP IN.03 in the HRM).

Right-of-Way

Due to the compact feature of this BMP, existing right-of-way could be used to reduce additional right-of-way purchases.

Landscaping (Planting Considerations)

Depends on project design.

Signage

Signage would be encouraged to provide public education regarding this innovative BMP.

Maintenance Access Roads (Access Requirements)

Depends on project design.

Construction of Access Roads

Depends on project design.

12 Proprietary Presettling Devices

Introduction

General Description

A *proprietary presettling device* can provide pretreatment of runoff to remove suspended solids, which can impact other primary treatment BMPs. Examples of proprietary presettling structures and more detailed information can be found at the Region 1 – U.S. Environmental Protection Agency's S*torm Water Virtual Trade Show* at:
http://epa.gov/boston/assistance/ceitts/stormwater/index.html

Applications and Limitations

Since proprietary presettling devices are the first nodes in a treatment train, approvals of these BMPs are not required. These devices can be installed in a confined space application. Presettling devices remove debris, sediment, and large oil droplets. Runoff treated by a presettling structure may not be directly discharged to receiving water; it must be further treated by a basic or enhanced treatment BMP.

Certain presettling structures have been recognized with a use designation through the Technology Assessment Protocol Ecology (TAPE) program. For more information on the use designation documents, see Ecology's web site:
http://www.ecy.wa.gov/programs/wq/stormwater/newtech/vortex_enhanced_sedimentation.html

Design Flow Elements

Flows to Be Treated

A proprietary presettling device must be designed to treat 30% of the total volume of runoff from the 6-month, 24-hour storm event.

Overflows or Bypass

A proprietary presettling device design must take overflows into consideration. An overflow section should be designed to allow flows to exit during the 6-month, 24-hour storm event.

Site Design Elements

Setback Requirements

- All facilities must be a minimum of 5 feet from any property line and vegetative buffer. This distance may be increased based on permit conditions required by the local government.
- All facilities must be 100 feet from any septic tank/drainage field (except wet vaults, which must be a minimum of 20 feet).

- All facilities must be a minimum of 50 feet from any steep (greater than 15%) slope.

Maintenance

Information on manufacturer's recommendation regarding maintenance frequency can be found at the Region 1 – U.S. Environmental Protection Agency's *Storm Water Virtual Trade Show* at: http://epa.gov/boston/assistance/ceitts/stormwater/index.html

13 Reactive Infiltration Barriers

Introduction

General Description

Reactive infiltration barriers (RIBs) are layers of water quality treatment media that are added to the surface of an infiltration pond, trench, or drywell to improve water quality prior to discharge to groundwater. Reactive infiltration barriers have historically been used to prevent ground-water contamination in hazardous waste site remediation projects. Two types of media are used as reactive infiltration barriers on highway projects: sand (as specified in Table 13.1) and the stormwater-permeable reactive infiltration barrier (SPRIB) medium, a sand/clay/mulch mixture developed by the USGS and Washington State University, designed specifically to improve the capture of dissolved-phase heavy metals in areas with sensitive groundwater resources. The sand and SPRIB media have been extensively tested in bench-scale simulations, so the water quality and infiltration characteristics are very well known.

Applications and Limitations

The *advantages* of using reactive infiltration barriers for water quality treatment prior to disposal to an infiltration facility are the following:

- A single facility can accommodate both water quality treatment for the protection of groundwater resources and flow control by infiltrating runoff to the water table, which has additional environmental benefits by increasing base flows and hyporheic recharge. A smaller footprint will likely save the cost of acquiring right-of-way.
- The RIB has lower maintenance requirements relative to an on-line sand filtration system followed by infiltration. This is because a reactive barrier on top of an infiltration facility will have lower surface loading rates than an accurately-sized sand filter, resulting in less frequent need for routine maintenance.

The *limitations* of using reactive infiltration barriers are the following:

- In highly permeable soils, the reactive barriers will become a limiting factor in infiltration pond design since they have a lower long-term infiltration rate than the underlying soils.
- In marginally acceptable soils for infiltration, the volume of treatment media needed to cover the surface of the infiltration facility may be excessively large.

Site Suitability Criteria

Generally, the suitable site for using RIBs is the same as for BMP IN.02 in the HRM. Reactive infiltration barriers are most suitable for use in areas that have high hydraulic conductivities and relatively deep water tables that make infiltration BMPs feasible. In very high permeability soils, such as glacial outwash deposits and Lake Missoula flood deposits, the reactive infiltration barriers will likely be the limiting factor inhibiting the infiltration of water into the subsoils. In these cases, the long-term infiltration rate of the applicable treatment media should be used to calculate the size of the infiltration facility instead of the measured or calculated long-term infiltration rate of the native soils (as determined by the same method used in Section 4-5.2.2, Simplified Approach to Determining Infiltration Rates, in Chapter 4 of the HRM).

Presettling and/or Pretreatment

In some instances, an oil or spill control BMP may be required by local governments or by a specific environmental permit issued by a local, state, or federal government. In these cases, consult with the HQ Hydraulics Office for feasible options or use a BMP identified in Section 5-2.2.5, Oil Control BMPs, in the HRM.

Treatment Performance

As a result of bench testing at the Washington State University Hydraulics Laboratory and pilot testing on SR 90 in Spokane (Research Report WA-RD #559.1, "An Evaluation of Stormwater Permeable Rapid Infiltration Barriers for Use in Class V Stormwater Injection Wells"), the performance specifications that can be expected from the RIB media under optimal conditions are described in Table 13.1.

Table 13.1. RIB media performance.

Medium	TSS Reduction	Metals Concentration Reduction					
		Copper		Lead		Zinc	
		Dissolved	Total	Dissolved	Total	Dissolved	Total
Sand	96%	61%	97%	79%	97%	76%	97%
SPRIB	86%	91%	99%	98%	99+%	98%	99%

Design Flow Elements

Flows to Be Treated/Infiltrated

The flows to be treated are the same as for BMP IN.02, Infiltration Pond, in the HRM.

Outlet Control Structure

Outlet control guidance is provided in BMP FC.03, Detention Pond, in the HRM.

Flow Splitters

When the infiltration pond is to be used as an off-line facility, use the information for flow splitter design in Section 5-4.3.4 in Chapter 5 of the HRM.

Inlets

The inlet flows to the RIB-amended infiltration pond can be achieved either by sheet flow, channel flow, or pipes. A 4- to 8-inch quarry spall rock pad should be located directly below the invert of the inlet pipe to the pond to prevent scour and erosion into the RIB media.

Emergency Overflow Spillway

A nonerodible outlet or spillway with an established elevation should be constructed to discharge overflow to the downstream conveyance system, as described in BMP FC.03 in the HRM. Ponding depth, drawdown time, and storage volume are calculated from the overflow elevation.

Structural Design Considerations

Refer to Section 4-5 in Chapter 4 of the HRM for detailed guidance on sizing infiltration facilities. In general, a long-term infiltration rate for the native soils needs to be estimated and compared to the long-term infiltration rate of the RIB media. If the native soils have a higher infiltration rate than the RIB media, then the media will be the limiting factor affecting infiltration rates, and the long-term infiltration rate should be used to size the infiltration facility. If the native soils have a lower infiltration rate than the specified RIB media, then the infiltration characteristics of the native soils should be used.

Geometry

Same as BMP IN.02, Infiltration Pond, in the HRM.

Embankments

Requirements for infiltration pond embankments are the same as for BMP FC.03 in the HRM, with the following exception:

- An impervious liner to prevent infiltration of ponded runoff into the side slopes, possibly bypassing water around the RIB treatment media layer, should cover the side slopes of the RIB-amended infiltration pond. Specifications and design criteria for impervious liners are located in Section 5-4.3.3 in Chapter 5 of the HRM.

Depth and Liners

The RIB consists of a minimum of 18 inches of treatment media placed on the surface of the excavated infiltration pond. This corresponds directly to the media bed depth. Compaction should be kept to a minimum to retain the RIB's infiltration capacity. A pervious woven geotextile can be used as separation between the RIB and the native soil (see Underground Drainage Geotextiles in Section 9-33 of the Standard Specifications).

Vegetation

RIB-amended infiltration ponds can be vegetated with turf grasses to reduce maintenance cycles and improve aesthetics, if desired. Planting herbaceous shrubs or trees in RIB-amended infiltration ponds is not recommended because deep root penetration may cause macropore development within the RIB media, increasing infiltration rates and increasing the risk of short-circuiting through the media. Consult with the region or the HQ Roadside & Site Development Unit for selection of suitable plants and soil amendments.

Material Selection and Specifications

The preferred RIB medium that should be specified at each project location depends on the sensitivity of the local groundwater resources, as described in Table 13.2.

Site Design Elements

Maintenance Access Roads (Access Requirements)

Access should be provided at the upper edge of all filter strips to enable maintenance of the gravel flow spreader and allow access for mowing.

Table 13.2. RIB media selection and composition.

Media	Suitable Areas for Use	Composition	Long-Term Infiltration Rate
Sand	All, except for the areas described below	As per Table RT.14.1, Sand Medium Specification, in Category 1 BMPs	18.0 inches/hour
SPRIB	Critical aquifer recharge areas Designated sole-source aquifer areas Wellhead protection zones Whenever the proposed infiltration facility is within 150 feet of a freshwater receiving system	90% sand by dry weight (same specification as above) 5% clay by dry weight >1.0 mm: <0.5% 0.5-1.0 mm: <0.5% 0.25-0.5 mm: <0.5% 0.125-0.25 mm: <2.0% 0.05-0.125 mm: <15.0% 0.02-0.05 mm: 40–50% <0.02 mm: 35–40% 5% compost by dry weight Type 1 compost, the Standard Specifications	10.0 inches/hour