4-3. Treatment Practices

The following Treatment Practices are presented in this Section:

1. Stormwater Ponds
    - 1.a. Dry Extended Detention Pond With Micropool
    - 1.b. Wet Pond
    - 1.c. Wet Extended Detention Pond
    - 1.d. Multiple Pond System
    - 1.e. Pocket Pond

2. Stormwater Wetlands
    - 2.a. Shallow Wetland
    - 2.b. Extended Detention Wetland
    - 2.c. Pond/Wetland System
    - 2.d. Gravel Wetland

3. Infiltration Practices
    - 3.a. Infiltration Trench & Drip Edge
    - 3.b. Infiltration Basin
    - 3.c. Dry Well
    - 3.d. Permeable Pavement

4. Filtering Practices
    - 4.a. Surface Sand Filter
    - 4.b. Underground Sand Filter
    - 4.c. Bioretention System
    - 4.d. Tree Box Filter
    - 4.e. Permeable Pavement

5. Flow-through Treatment Swale

6. Vegetated Buffer (Vegetated Filter Strip)
    - 6.a. Residential or Small Pervious Area Buffer
    - 6.b. Developed Area Buffer
    - 6.c. Buffer on the Downhill Side of Roadway
    - 6.d. Ditch Turn-out Buffer

1. STORMWATER PONDS

General Description

Stormwater ponds are impoundments designed to collect, detain and release stormwater runoff at a controlled rate. They provide treatment through the use of a permanent pool, which helps settle solids and associated pollutants. Extended detention features can be incorporated into stormwater ponds by combining permanent micropools or other permanent pool storage with an extended drawdown time of the water quality volume.

In addition to water quality benefits, by providing additional storage capacity and a multi-stage outlet structure, stormwater ponds can also be designed to provide flood control. Refer to the Detention Basin description in this Chapter for more information on the design of facilities for controlling peak rates.

The following are examples of Stormwater Ponds:

- Micropool Extended Detention Pond
- Wet Pond
- Wet Extended Detention Pond
- Multiple Pond System
- Pocket Pond

General Requirements Applicable to All Stormwater Ponds

- The pond perimeter should be curvilinear
- Design must include a hydrologic budget to show sufficient water available to maintain permanent pool depth
- A qualified professional must develop a planting plan
- Inlet and outlet should be located as far apart as possible
- Provide a manually controlled drain, if elevations allow, to dewater pond over 24-hour period
- Provide energy dissipation at inlet and outlet for scour prevention
- Stormwater ponds are prohibited in areas of RSA 482-A jurisdiction unless a wetlands permit has been issued
- Provide small trash racks for outlets ≤ 6 inches in diameter or weirs ≤ 6 inches wide
- Additional requirements as listed in Design Criteria for each illustrated BMP

1a. Micropool Extended Detention Pond

An extended detention pond with a micropool temporarily stores and releases the Water Quality Volume over an extended drawdown time. The micropool is typically provided near the outlet, to enhance pollutant removal and to help prevent resuspension of captured sediments. Except for the micropool, the basin is designed to be dry between storms, once the WQV has been discharged. The basin provides pollutant removal by settling of sediments and associated pollutants.

Design Considerations

- Use may be limited by depth to groundwater or bedrock
- May increase water temperature, which may affect use in watersheds of cold water fisheries
- May have a greater risk of sediment re-suspension than do wet ponds, wet extended detention ponds or stormwater wetlands
- May not remove soluble pollutants as effectively as wet ponds, extended detention wet ponds or stormwater wetlands

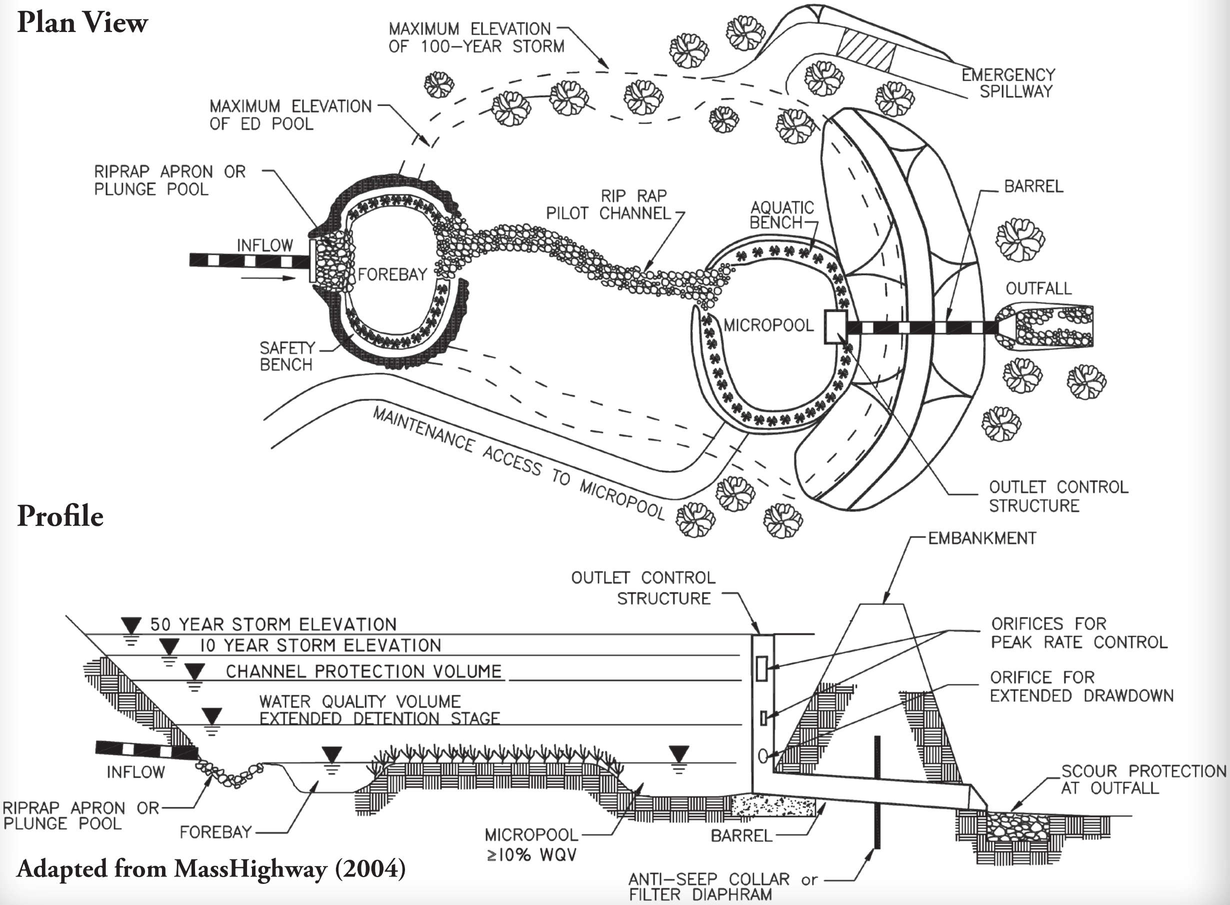
Maintenance Requirements

- Periodic mowing of embankments
- Removal of woody vegetation from fill embankments
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, inlet and outlet structures, and appurtenances

Design References

- Schueler (1987)
- Schueler, et al. (1992)

Example Design



Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Micropool + Extended Detention Volume	≥ WQV
Permanent Pool Depth	Average depth of 3 to 6 feet; no greater than 8 feet
Extended Detention Drawdown	24-hour minimum Size extended detention volume outlet to discharge at a maximum flow rate as follows: $Q_{max} \leq 2*Q_{avg}$; $Q_{avg} = EDV/24$ hours Where EDV = the extended detention volume
Length to Width Ratio	3:1 minimum
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of freeboard should be provided.
Embankment Design	See criteria for Detention Basin
Micropool Volume	Approximately 10% of WQV
Micropool Area	Approximately 5% of surface area of WQV pool

1b. Wet Pond

Wet ponds are designed to maintain a permanent pool of water throughout the year. The pool, located below the outlet invert, allows for pollutant removal through settling and biological uptake or decomposition.

Wet ponds, if properly sized and maintained, can achieve high rates of removal for a number of urban pollutants, including sediment and its associated pollutants: trace metals, hydrocarbons, BOD, nutrients and pesticides. They also provide some treatment of dissolved nutrients through biological processes within the pond.

Where the temperature of receiving waters is a concern, the addition of an underdrained gravel trench in the bench area around the permanent pool allows for slow, extended release of stormwater, which minimizes the risk of the outlet structure clogging and provides effective cooling to avoid thermal impacts to receiving waters.

Design Considerations

- Use may be limited by depth to bedrock
- Use may be limited by soils permeability or groundwater levels, or require special design measures to control exfiltration of retained water or inflow of groundwater
- May increase water temperature, which may affect use in watersheds of cold water fisheries
- Safety issues must be addressed relative to establishing a permanent pool

Maintenance Requirements

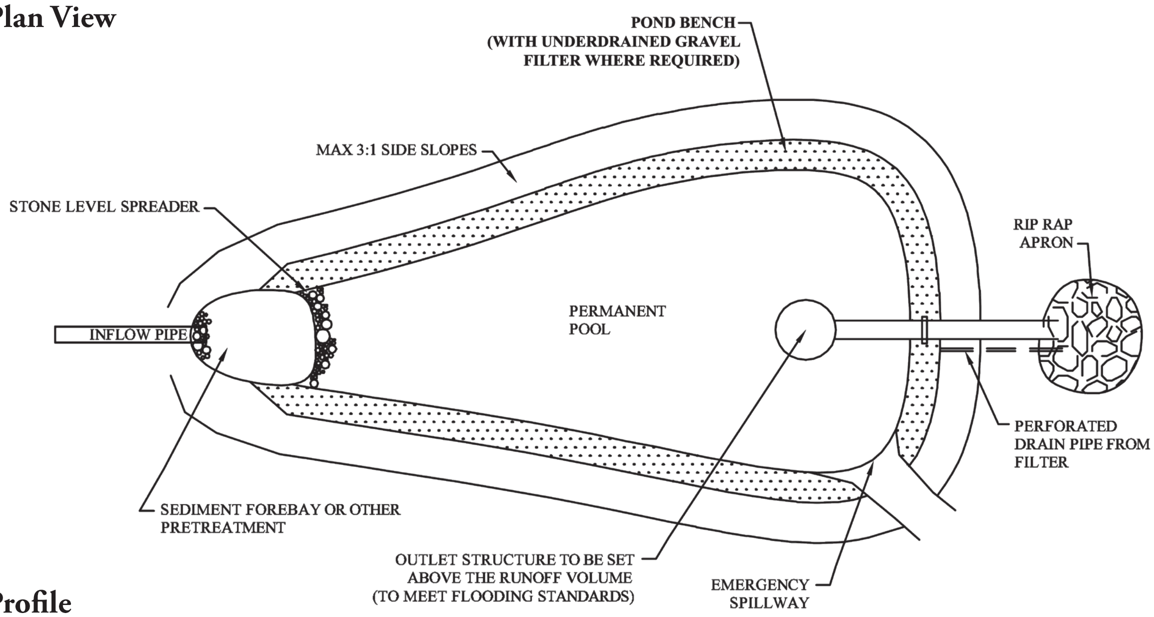
- Periodic mowing of embankments
- Removal of woody vegetation from fill embankments
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, inlet and outlet structures, and appurtenances

Design References

- Schueler (1987)
- Schueler, et al. (1992)
- EPA (1999f)

Example Design

Plan View



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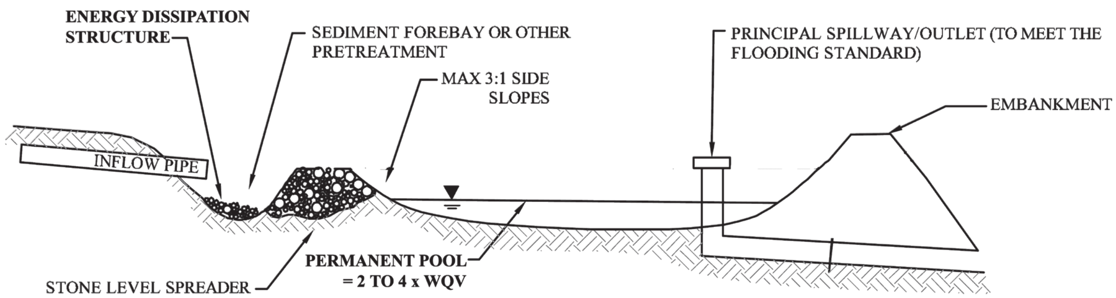


Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Permanent Pool Volume	2 – 4 times the WQV, recommended for enhancing pollutant removal effectiveness
Permanent Pool Depth	Average depth of 3 to 6 feet; no greater than 8 feet
Length to Width Ratio	3:1 minimum
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of freeboard should be provided.
Embankment Design	See criteria for Detention Basin
Recommended Drainage Area	At least 10 acres unless groundwater conditions will sustain permanent pool
Safety Bench	Recommended, > 10 feet width

1c. Wet Extended Detention Pond

Wet extended detention ponds combine the features of wet ponds and extended detention ponds. The combined permanent pool and extended detention volume can be used to treat the Water Quality Volume and meet Channel Protection requirements.

Design Considerations

- Use may be limited by depth to bedrock
- Use may be limited by soils permeability or groundwater levels, or require special design measures to control exfiltration of retained water or inflow of groundwater
- May increase water temperature, which may affect use in watersheds of cold water fisheries
- Safety issues must be addressed relative to establishing a permanent pool

Maintenance Requirements

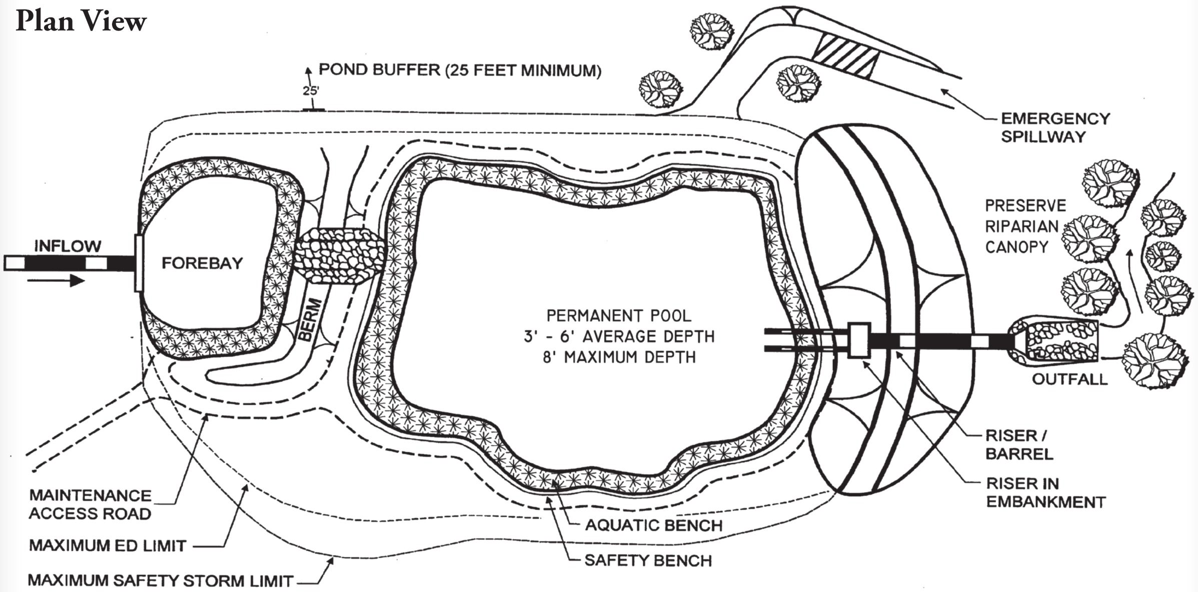
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, inlet and outlet structures, and appurtenances

Design References

- Schueler (1987)
- Schueler, et al. (1992)
- EPA (1999f)

Example Design

Plan View



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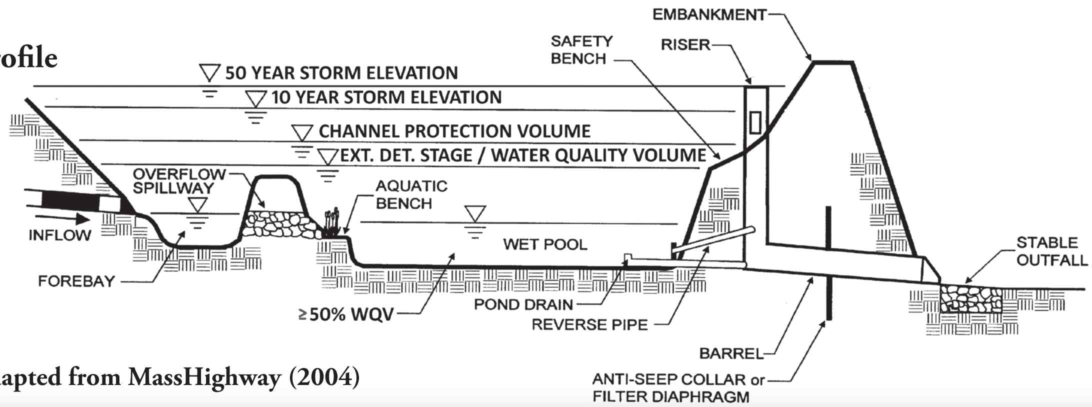


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Combined Volume, Permanent Pool and Extended Detention	≥ WQV
Permanent Pool Depth	≥ 50% of WQV
Length to Width Ratio	3:1 minimum
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of free-board should be provided.
Embankment Design	See criteria for Detention Basin
Recommended Drainage Area	At least 10 acres unless groundwater conditions will sustain permanent pool
Safety Bench	Recommended, > 10 feet width

1d. Multiple Pond System

The multiple pond system is similar to the wet pond, except that the total treatment volume is distributed over two or more pond “cells,” rather than a single pond. This type of design can be useful for adapting the component ponds to fit a particular site layout, provide for a more aesthetic design, or address changes in elevation on a sloping site.

Design

- Use may be limited by depth to bedrock
- Use may be limited by soils permeability or groundwater levels, or require special design measures to control exfiltration of retained water or inflow of groundwater
- May increase water temperature, which may affect use in watersheds of cold water fisheries
- Safety issues must be addressed relative to establishing a permanent pool

Maintenance Requirements

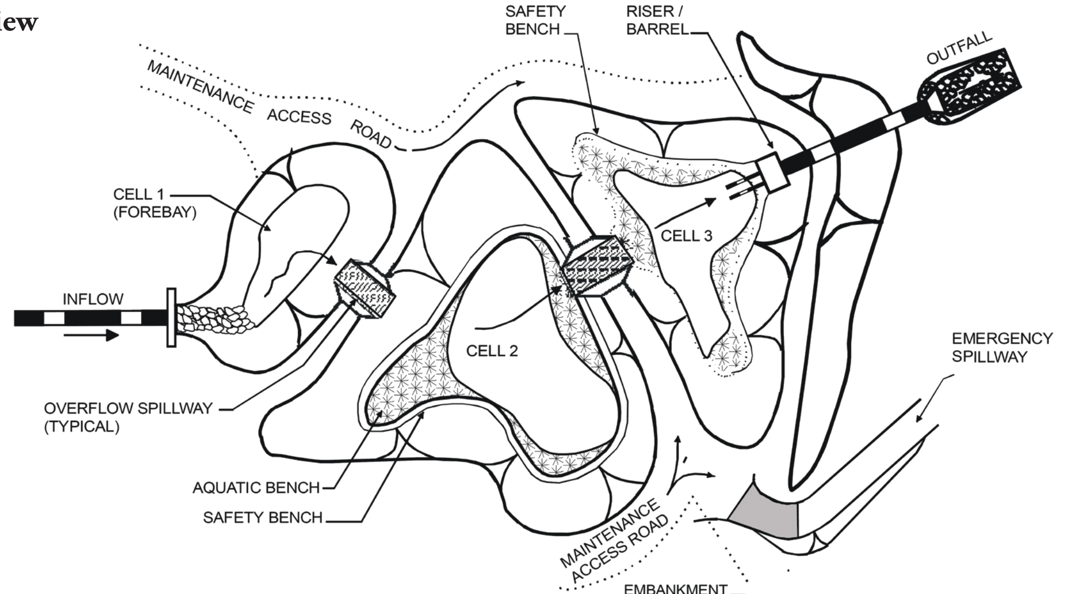
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, outlet structures, and appurtenances

Design References

- Schueler (1987)
- Schueler, et al. (1992)

Example Design

Plan View



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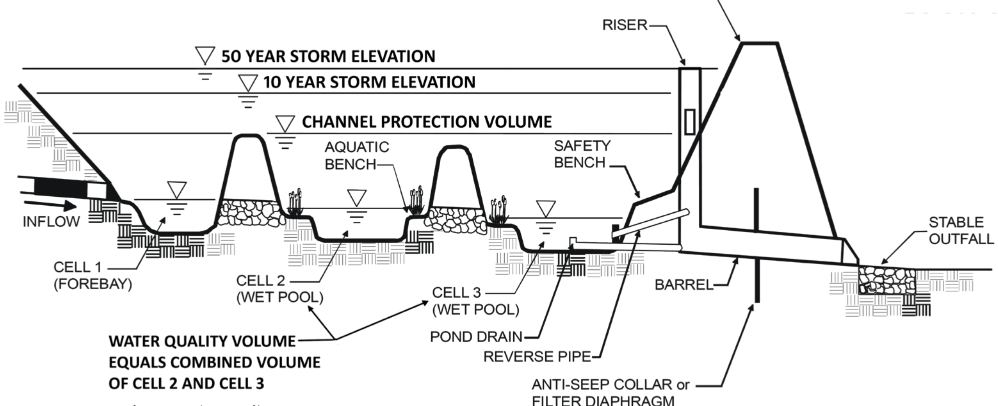


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Permanent Pool Volume	Combined volume of pond cells 2 and 3 ≥ WQV
Permanent Pool Depth	Average depth of 3 to 6 feet; no greater than 8 feet
Length to Width Ratio	3:1 minimum, applicable to each pond cell
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of freeboard should be provided.
Embankment Design	See criteria for Detention Basin
Recommended Drainage Area	At least 10 acres unless groundwater conditions will sustain permanent pool
Safety Bench	Recommended, > 10 feet width

1E. Pocket Pond

The pocket pond is a wet pond or wet extended detention pond designed to serve a small contributing area. While similar to other wet ponds and wet extended detention ponds in design, the water budget for this pond will likely depend on the presence of groundwater, because the smaller contributing watershed would not sustain a permanent pool.

Note that NHDES considers a "wet swale" type of water quality swale to be a "pocket pond."

Design Considerations

- Use may be limited by depth to bedrock
- Use may be limited by soils permeability or groundwater levels, or require special design measures to control exfiltration of retained water or inflow of groundwater
- May increase water temperature, which may affect use in watersheds of cold water fisheries
- Safety issues must be addressed relative to establishing a permanent pool

Maintenance Requirements

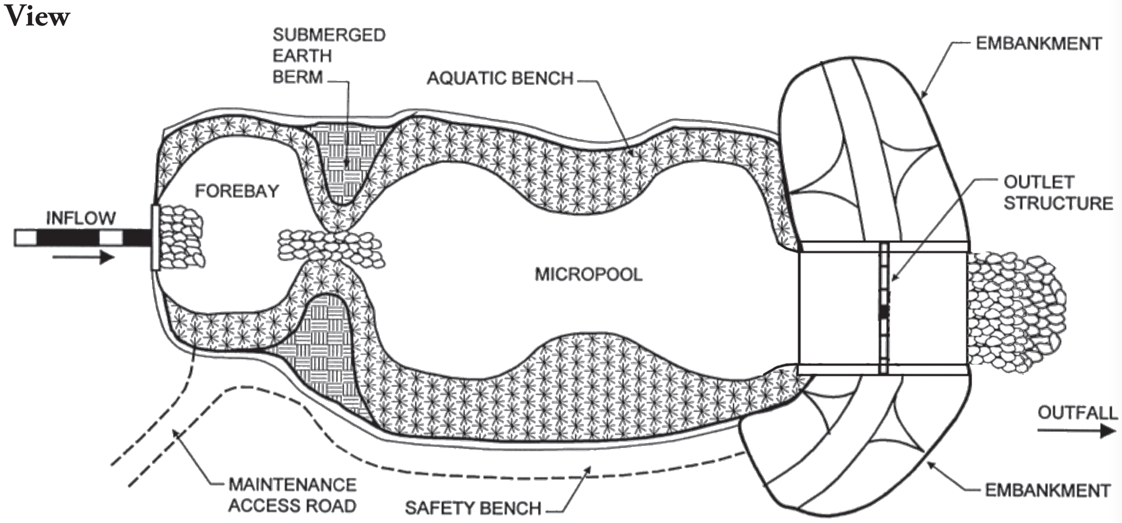
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, outlet structures, and appurtenances

Design References

- Schueler (1987)
- Schueler, et al. (1992)

Example Design

Plan View



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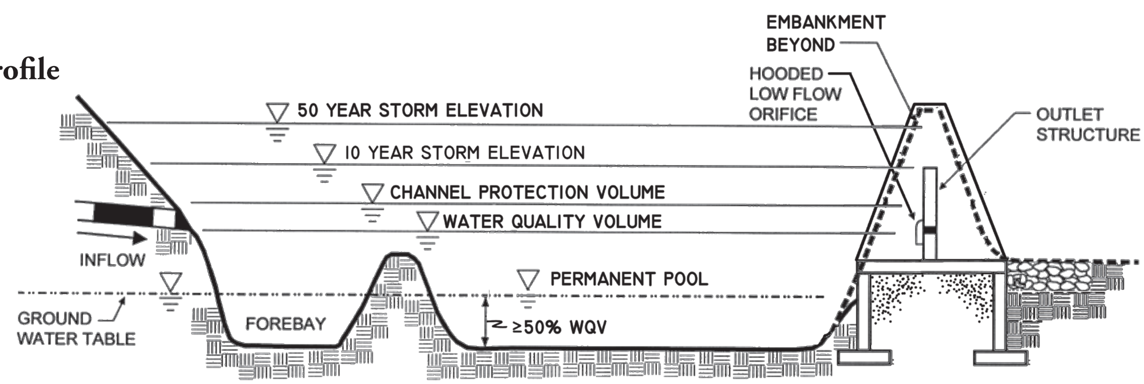


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Combined Volume, Permanent Pool and Extended Detention	≥ WQV
Permanent Pool Volume	≥ 50% of WQV
Permanent Pool Depth	Average depth of 3 to 6 feet; no greater than 8 feet
Length to Width Ratio	3:1 minimum
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of free-board should be provided.
Embankment Design	See criteria for Detention Basin
Groundwater Depth	Groundwater conditions should be present to support maintenance of a micropool
Safety Bench	As warranted by specific site conditions

2. STORMWATER WETLANDS

General Description

Stormwater wetlands are constructed depressions or impoundments designed to function similar to natural wetlands. However, unlike natural wetlands, stormwater wetlands are designed specifically to treat stormwater. Direct discharge of stormwater to natural wetlands is prohibited in New Hampshire due to critical impacts to wetland hydrology and potential habitat degradation.

Stormwater wetlands are similar to stormwater ponds in that the design includes a permanent pool of water. However, the retained pool is designed with varying depths to support a wetland plant community. In addition to the settling processes that occur in the permanent pool, stormwater wetlands provide pollutant removal/uptake by vegetation and by other biological activity supported within the wetland environment. In some stormwater wetlands, such as “gravel wetlands,” the systems provide filtration, as well.

The following are examples of Stormwater Wetlands:

- Shallow wetlands (including “pocket wetlands”)
- Extended detention wetlands
- Pond/wetland systems
- Gravel wetlands

Information is provided in this manual for each of these types of stormwater wetlands. The shallow, extended detention, and pond/wetland systems have a number of similarities, with the basic differences being the relative proportions of open water relative to marsh, and extended detention volume relative to permanent pool. The marsh areas typically include zones with the following depth ranges:

- Deepwater — Greater than 18 inch depth, up to the design maximum depth
- Low Marsh — 6 inch to 18 inch depth below normal pool
- High Marsh — Up to 6 inches depth below normal pool
- Semi-wet — Areas above normal pool that are periodically inundated and expected to support wetland vegetation

Recommended configurations for stormwater wetlands (other than gravel wetlands) are provided in Tables 4-1 and 4-2. Gravel wetlands involve a conceptually different type of design and are discussed separately in the Gravel Wetlands BMP description.

General Requirements Applicable to Stormwater Wetlands

- The wetland perimeter must be curvilinear;
- Design must include a hydrologic budget to show sufficient water available to maintain permanent pool depth;
- A qualified professional must develop a planting plan;
- Inlet and outlet should be located as far apart as possible;
- Provide a manually controlled drain, if elevations allow, to dewater ponds (if included in the design) over 24-hour period;
- Provide energy dissipation at inlet and outlet for scour prevention;
- Stormwater wetlands are prohibited in areas of RSA 482-A jurisdiction unless a wetlands permit has been issued;
- Provide small trash racks for outlets ≤ 6 inches in diameter or weirs ≤ 6 inches wide;
- Additional requirements as listed in Design Criteria for each illustrated BMP

Table 4-1. Recommended Design Criteria for Stormwater Wetlands Designs

Design Criteria	Shallow Wetland	Pond/Wetland	ED Wetland	Pocket Wetland
Wetland/Watershed Area Ratio	≥ 2.0%	≥ 1.0%	≥ 1.0%	≥ 1.0%
Minimum Drainage Area (acres)	≥ 25	≥ 25	≥ 10	1 to 10
Length to Width Ratio (minimum)	≥ 3:1	≥ 3:1	≥ 3:1	≥ 3:1
Extended Detention	no	option	yes	option
Percent Allocation of Treatment Volume (pool/marsh/ED)	30 / 70 / 0	70 / 30 / 0	≥ 20 / ≥30 / ≥50	20 / 80 / 0
Percent Allocation of Surface Area to Wetland Type	Refer to Table 4-2			
Cleanout Frequency (years)	2 to 5	10	2 to 5	10
Outlet Configuration	Reverse-slope pipe or hooded broad crest weir	Reverse-slope pipe or hooded broad crest weir	Reverse-slope pipe or hooded broad crest weir	Hooded broad crest weir

Source: Adapted from Schueler (1992).

Table 4-2. Recommended Allocation of Areas & Volumes for Stormwater Wetlands				
Target Allocations	**Shallow Wetland**	**Pond/ Wetland**	**ED Wetland**	**Pocket Wetland**
% of Surface Area				
Forebay	5	0	5	5
Micropool	5	5	5	5
Deepwater	5	40	0	0
Lo Marsh	40	20	40	45
Hi Marsh	40	25	40	40
Semi-wet	5	5	10	5
% of Treatment Volume				
Forebay	10	0	10	10
Micropool	10	10	10	10
Deepwater	10	60	--	0
Lo Marsh	45	20	20	55
Hi Marsh	25	10	10	25
Semi-wet	0	0	50	0

Definition of terms:

Deepwater	Greater than 18 inch depth, up to the design maximum depth
Low Marsh	6 inch to 18 inch depth below normal pool
High Marsh	Up to 6 inches depth below normal pool
Semi-wet	Areas above normal pool that are periodically inundated and expected to support wetland vegetation

Source: Adapted from EPA (1999d).

2a. Shallow Wetlands

Shallow wetlands for stormwater treatment consist of pools ranging from 6 to 18 inches in depth under normal conditions, with some areas of deepwater pools. They may be configured with a variety of low marsh and high marsh "cells" with sinuous channels to distribute flows to maximize retention time and contact area. Shallow wetland systems are designed with wetland vegetation suitable for these varying depths. The entire Water Quality Volume is provided within the deepwater, low marsh, and high marsh zones.

Design Consdierations

- Requires sufficient contributing area and/or groundwater elevation to maintain permanent pool
- Use may be limited by depth to bedrock
- May increase water temperature, which may affect use in watersheds of cold water fisheries
- May develop mono-culture of invasive plant species over time

Maintenance Requirements

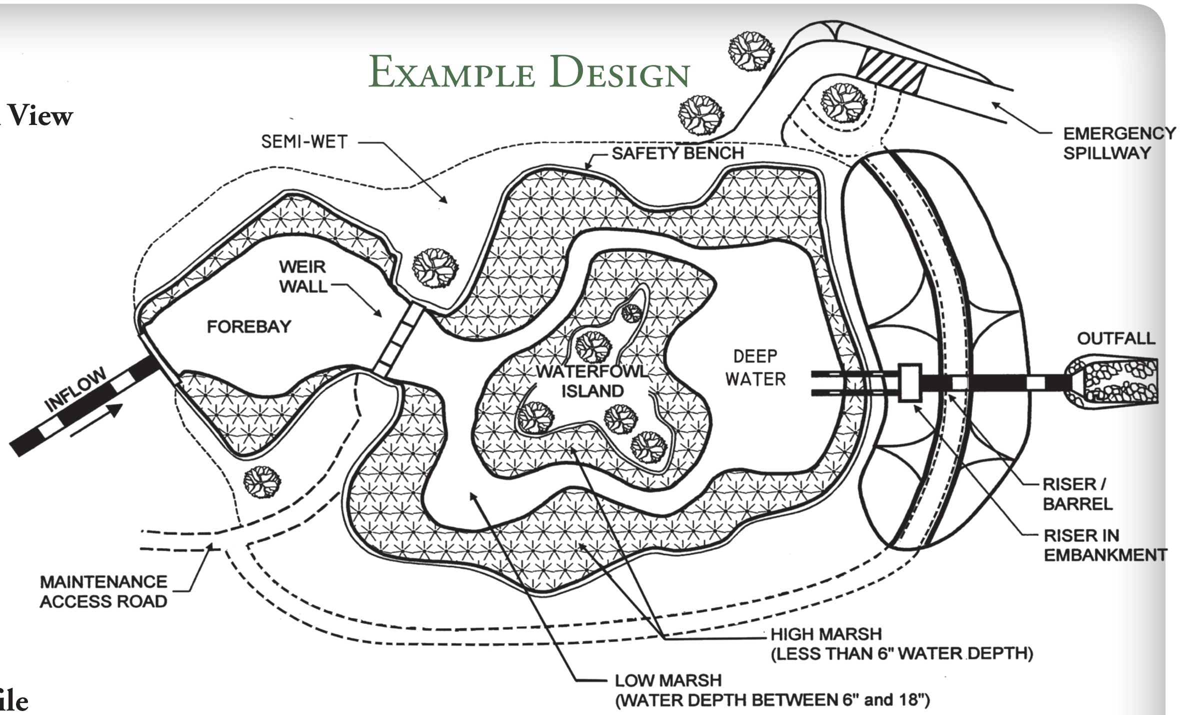
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of invasive species from semi-wet, marsh, and deepwater areas
- Monitoring and replanting, as warranted, of wetland vegetation
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, inlet and outlet structures, and appurtenances

Design References

- Schueler (1992)
- Cappiella, et al. (2008)

Example Design

Plan View



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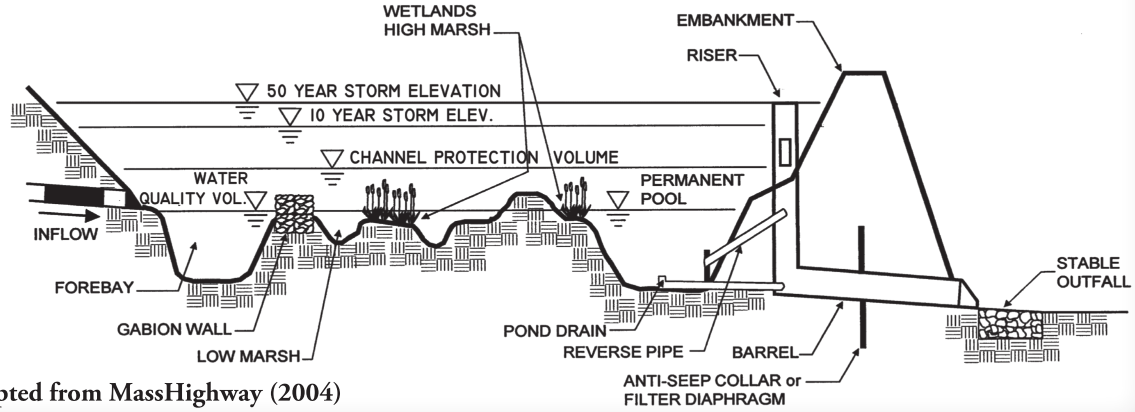


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Permanent Pool Volume	≥ WQV (combined deep water, low marsh, high marsh)
Permanent Pool Depth	≤ 8 feet
Length to Width Ratio	3:1 minimum, applicable to each pond cell
Maximum Temporary Pool Depth	≤ 4 feet above permanent pool
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of freeboard should be provided.
Embankment Design	See criteria for Detention Basin
Marsh/Deepwater Ratios	See Tables 4-1 and 4-2

2b. Extended Detention Wetlands

Extended detention stormwater wetlands typically require less space than shallow wetlands systems, because part of the Water Quality Volume is stored above the level of the permanent pool. Deepwater areas tend to be less extensive and semi-wet areas more extensive than those provided for shallow wetlands. Wetland plants that tolerate both intermittent flooding and dry periods must be selected for the area above the permanent marsh.

Design Consdierations

- Requires sufficient contributing area and/or groundwater elevation to maintain permanent pool
- Use may be limited by depth to bedrock
- May increase water temperature, which may affect use in watersheds of cold water fisheries; because of the smaller area of permanent marsh, this effect may be more moderate than for a shallow wetland or pond/wetland system
- May develop mono-culture of invasive plant species over time

Maintenance Requirements

- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of invasive species from semi-wet, marsh, and deepwater areas
- Monitoring and replanting, as warranted, of wetland vegetation
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, inlet and outlet structures, and appurtenances

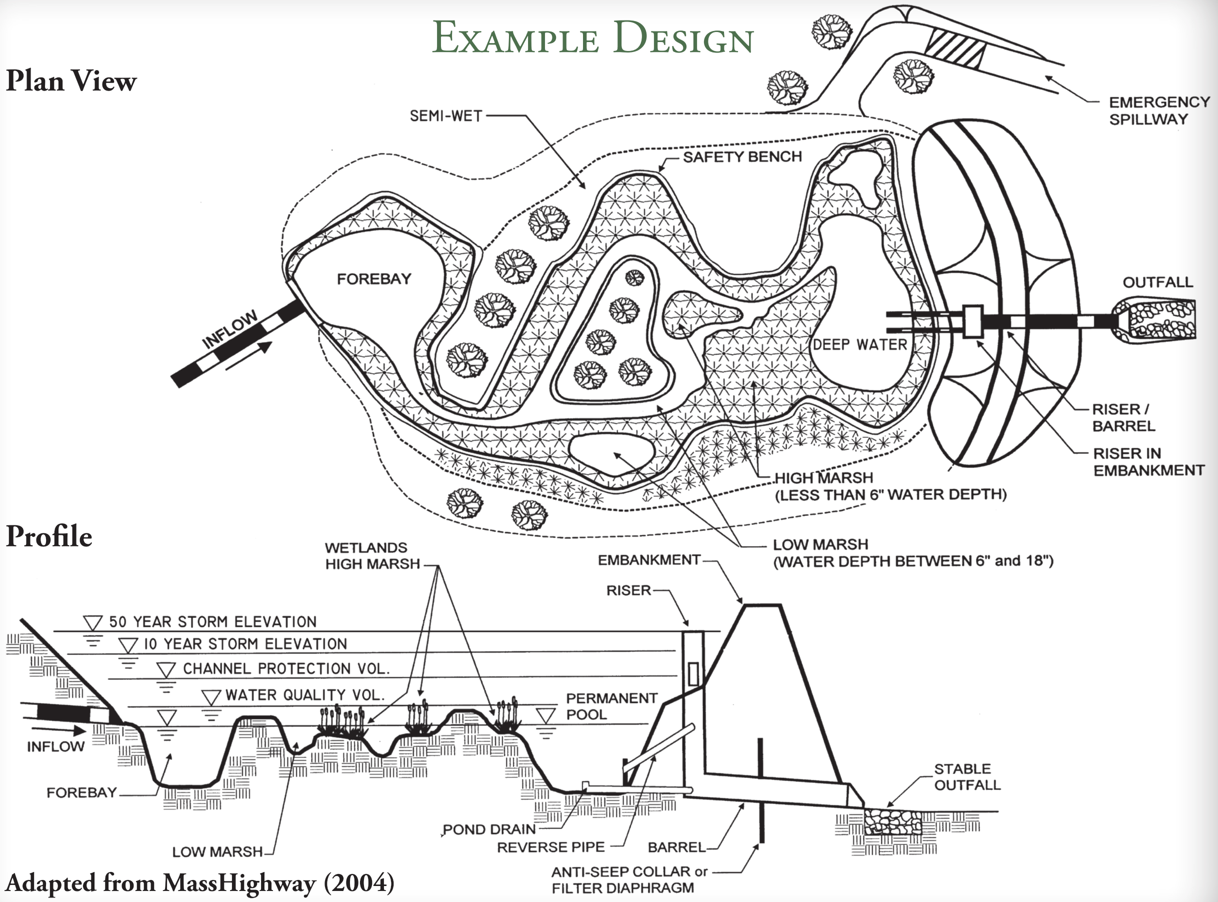
Design References

- Schueler (1992)
- Cappiella, et al. (2008)

Example Design

Plan View

Profile



Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Permanent Pool + Extended Detention Volume	≥ WQV (combined deep water, low marsh, high marsh and extended detention volume)
Extended Detention Volume	≤ 50% of WQV
Extended Detention Drawdown	24-hour minimum
Length to Width Ratio	3:1 minimum, applicable to each pond cell
Permanent Pool Depth	≤ 8 feet
Maximum Temporary Pool Depth	≤ 4 feet above permanent pool
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of freeboard should be provided.
Embankment Design	See criteria for Detention Basin
Marsh/Deepwater Ratios	See Tables 4-1 and 4-2

2c. Pond/Wetland System

The wetlands/pond system for stormwater treatment consists of a series of cells using at least one wet pond in combination with shallow marsh wetlands. The first cell typically comprises the wet pond, which provides initial treatment primarily by settling of particles. The wet pond can also reduce the velocity of runoff entering the system. The shallow marsh provides subsequent additional treatment of the runoff, particularly for soluble pollutants through vegetative uptake and the biological activity associated with the wetland vegetation community. With the deeper pool of the wet pond, these systems can typically require less space than the shallow marsh system.

Design Considerations

- Requires sufficient contributing area and/or groundwater elevation to maintain permanent pool
- Use may be limited by depth to bedrock
- May increase water temperature, which may affect use in watersheds of cold water fisheries
- May develop mono-culture of invasive plant species over time

Maintenance Requirements

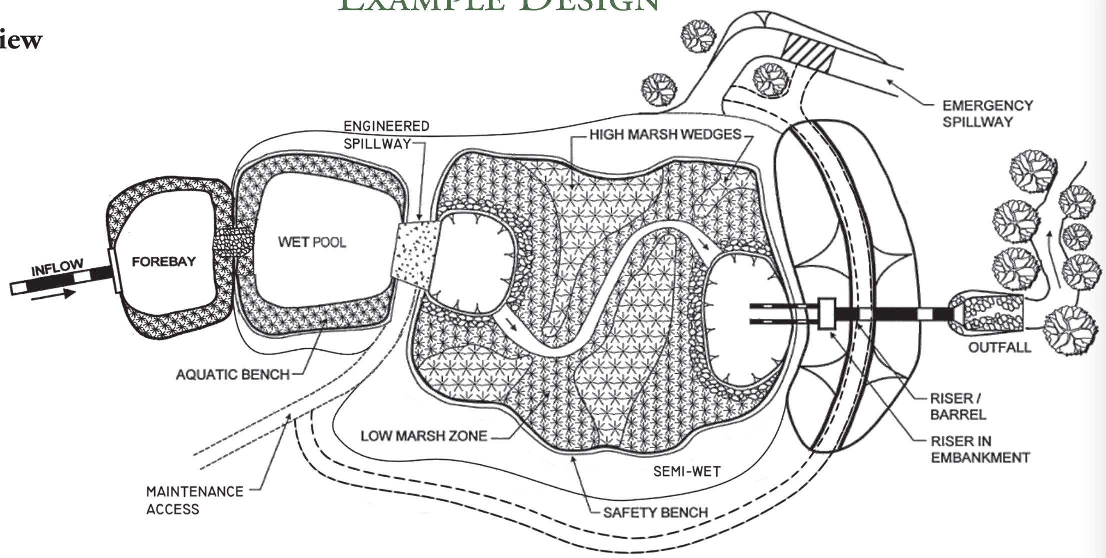
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of invasive species from semi-wet, marsh, and deepwater areas
- Monitoring and replanting, as warranted, of wetland vegetation
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, inlet and outlet structures, and appurtenances

Design References

- Schueler (1992)
- Cappiella, et al. (2008)

Example Design

Plan View



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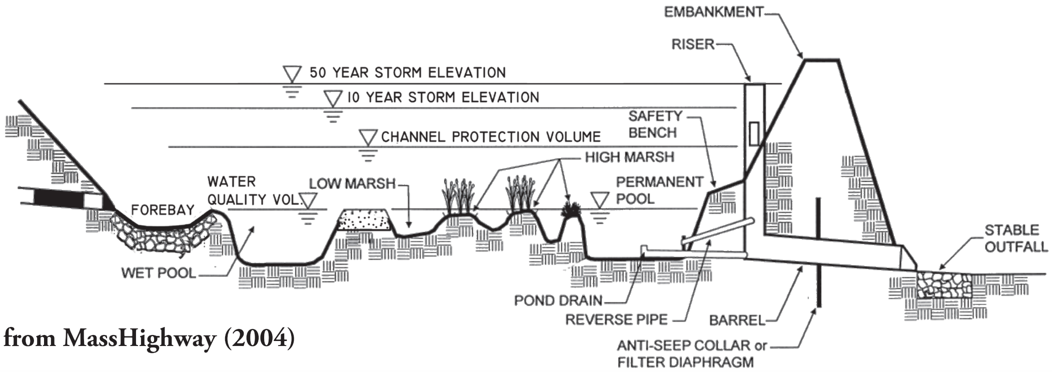


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Permanent Pool Volume	≥ WQV (combined wet pond, micropool (deepwater), low marsh, high marsh)
Extended Detention Volume	≤ 50% of WQV
Length to Width Ratio	3:1 minimum, applicable to each pond cell
Permanent Pool Depth	≤ 8 feet
Maximum Temporary Pool Depth	≤ 4 feet above permanent pool
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of freeboard should be provided.
Embankment Design	See criteria for Detention Basin
Marsh/Deepwater Ratios	See Tables 4-1 and 4-2

2D. Gravel Wetlands

The gravel wetland system consists of one or more flow-through constructed wetland cells, preceded by a forebay. The cells are filled with a gravel media, supporting an organic substrate that is planted with wetland vegetation. During low-flow storm events, the system is designed to promote subsurface horizontal flow through the gravel media, allowing contact with the root zone of the wetland vegetation. The gravel and planting media support a community of soil microorganisms. Water quality treatment occurs through microbial, chemical, and physical processes within this media. Treatment may also be enhanced by vegetative uptake.

To accommodate higher flows, the system is designed to permit inundation of the wetland surface, and the system would function similar to other constructed wetland systems. Overflow from the wetland is provided by an outlet structure designed for this "extended detention" condition. Following such an event, remaining water on the surface of the wetland would infiltrate into the gravel media, and flow horizontally through the media as in the low flow condition.

The outlet of the wetland system is designed to keep the media submerged, to provide the hydrology to support the wetland plant community. The gravel media consists of either crushed rock or processed gravel. An organic soil layer is placed on top of this material, and the wetland plants are rooted in the media where they can directly take up pollutants.

The system can be designed to integrate some stormwater storage, and also to provide infiltration. With these features, the practice would not only remove pollutants, but also contribute to the attenuation of peak rates through temporary storage and reduction in runoff volume through infiltration and evapotranspiration.

Design Considerations

- This BMP is particularly suited to areas with limited available space.
- The BMP requires sufficient contributing area to maintain saturated conditions and support vegetation.
- Unless used to treat runoff from high load areas, gravel wetlands may intersect the groundwater table.
- The bottom of each treatment cell should be lined with an impermeable liner if located on hydrologic group A and B soils.
- Pretreatment measures are essential to prevent clogging of the gravel media and the pipe manifold system.

Maintenance Requirements

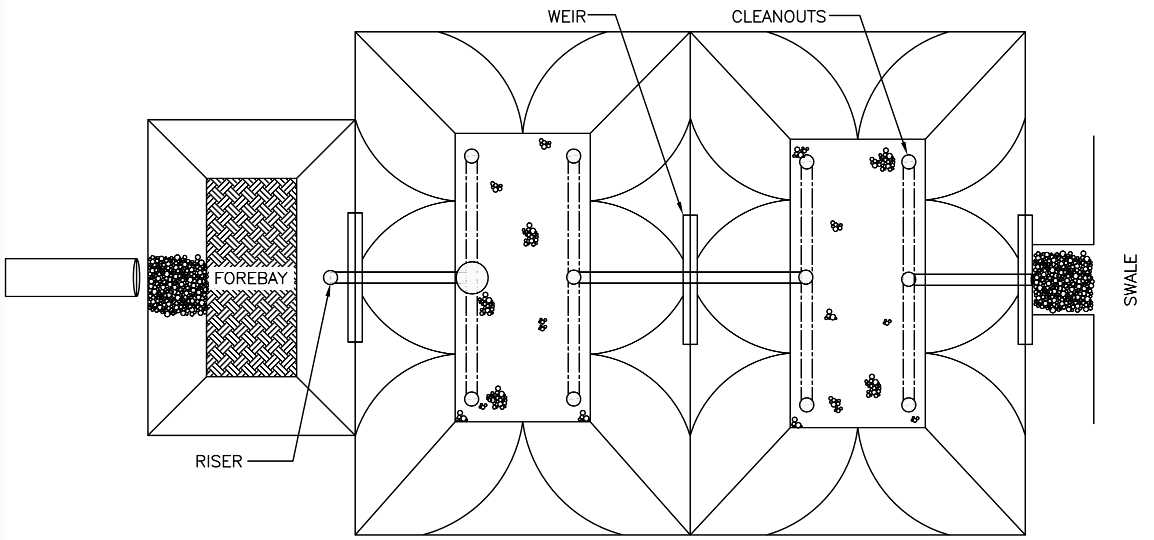
- Monitoring and replanting, as warranted, of wetland vegetation
- Removal of debris from inlet and outlet structures
- Inspection and removal of sediment accumulation in the gravel bed
- Depending on sediment accumulation, bed may require periodic replacement and replanting
- Inspection and repair of containment structure (if applicable), inlet and outlet structures, and appurtenances

Design References

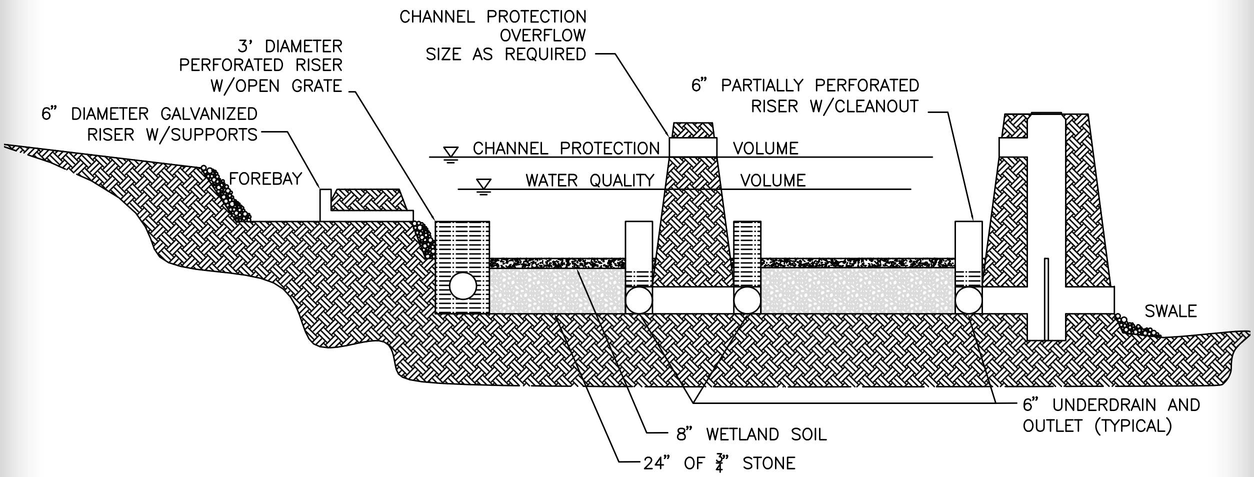
- UNH Stormwater Center

Example Design

Plan View



Profile



Adapted from UNH Stormwater Center (2007)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Permanent Pool + Extended Detention Volume	At a minimum: 10% of the WQV in the sediment forebay and 45% of the WQV in each treatment cell
Extended Detention Volume	≤ 50% of WQV
Extended Detention Drawdown	24 to 48 hours
Length to Width Ratio	3:1 minimum, applicable to each pond cell
Maximum Temporary Pool Depth	≤ 4 feet above permanent pool
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of freeboard should be provided.
Embankment Design	See criteria for Detention Basin

3. INFILTRATION PRACTICES

General Description

Infiltration practices are designed to capture and temporarily store the water quality volume of stormwater while it infiltrates into the soil. Infiltration practices help to recharge groundwater, but must be designed and maintained to avoid clogging and system failure. Pollutants are removed through adsorption of pollutants onto soil particles, and biological and chemical conversion in the soil.

Infiltration practices differ from filtering practices in that stormwater is infiltrated through native soil and allowed to recharge groundwater, while filtration practices typically employ non-native soil materials or other media, and may use underdrains to convey the filtered water to discharge.

Infiltration BMPs can be suitable for treating runoff from drainage areas (ranging up to 50 acres in size for infiltration basins) where subsoils, groundwater conditions, and depth to bedrock are appropriate. Infiltration BMPs can be used for a wide range of land uses, including commercial, residential, industrial, and gravel mining sites. However, some industrial and commercial areas have contaminants that may pose a risk of groundwater contamination. In this case, infiltration should not be used without adequate treatment of runoff prior to entering the device. In some cases, infiltration measures should be avoided in favor of other BMPs.

The following are examples of Infiltration Practices:

- Infiltration trenches
- Drip edges
- Infiltration basins
- Dry wells

Note that “permeable pavements,” discussed under “Filtering Practices,” may also be designed to provide for infiltration.

General Requirements Applicable to Infiltration Practices

- Infiltration is prohibited as follows:
  - Into areas of RSA 482-A jurisdiction unless a wetlands permit has been issued
  - Into groundwater protection areas where the stormwater is from a high-load area (see Chapter 3)
  - Into areas where contaminants occur in groundwater above ambient standards (Env-Or 603.03)
  - Into areas where contaminants occur in soil above site-specific standards (Env-Or 600)
  - Into areas where the soils have infiltration rates < 0.5 inches per hour
  - Into areas where the infiltration rate is too rapid to provide treatment (see Chapter 2 for a listing of these soils), unless treatment is either not necessary or has already been provided. Note, however, as described in Chapter 2, soils may be amended to reduce infiltration rate.
  - Into areas with slopes > 15%, unless calculations show that seepage will not cause slope instability.
  - From areas with soil contaminants above site-specific standards (Env-Or 600).
  - From areas with underground and aboveground storage tanks regulated by RSA 146-C or RSA 146-A, where gasoline is dispensed or otherwise transferred to vehicles.
- Pretreatment must be provided if the infiltration BMP will receive stormwater other than roof runoff.
- Design infiltration rates should be determined in accordance with Chapter 2, Design Criteria.
- BMPs used for to meet stormwater treatment or groundwater recharge objectives should be sized without depending on infiltration that occurs during the design event (static sizing method). However, BMPs used for channel protection or peak flow control may be sized accounting for infiltration during the design event (dynamic sizing method).

3a. Infiltration Trench

An infiltration trench is a stone-filled excavation used to temporarily store runoff and allow it to infiltrate into surrounding, natural soil. Typically, runoff enters the trench as overland flow after pretreatment through a filter strip or vegetated buffer. An infiltration trench is suitable for treating runoff from small drainage areas (less than 10 acres). Installations around the perimeter of parking lots, between residential lots, and along roads are most common. Infiltration trenches can also be incorporated along the center of a vegetated swale to increase its infiltration ability.

An infiltration drip edge is constructed similar to an infiltration trench, except that a drip edge intercepts only roof runoff, and does not require pretreatment.

Design Considerations

- Pretreatment is essential to the long-term function of infiltration systems.
- Preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
    - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to permanent infiltration BMPs.
    - Do not traffic exposed soil surface with construction equipment. If feasible, perform excavations with equipment positioned outside the limits of the infiltration components of the system.
    - After the basin is excavated to the final design elevation, the floor should be deeply tilled with a rotary tiller or disc harrow to restore infiltration rates, followed by a pass with a leveling drag.
    - Do not place infiltration systems into service until the contributing areas have been fully stabilized.
- For any fill required for system construction, use clean, washed, well-sorted aggregate for infiltration media; the porosity of material provided for construction should be verified against the porosity specified by design.

- Drip edges are not recommended adjacent to buildings with foundation drains, as the intercepted runoff may adversely affect performance of the foundation drainage system. Also, if there is a foundation sub-drain beneath the drip edge trench, the sub-drain will likely prevent infiltration from occurring, by intercepting the flow and conveying it to discharge along with other foundation drainage.
- For more guidance on installing monitoring wells, see: Sprecher, S.W. 2008. Installing monitoring wells in soils (Version 1.0). National Soil Survey Center, NRCS, USDA, Lincoln, NE.

Maintenance Requirements

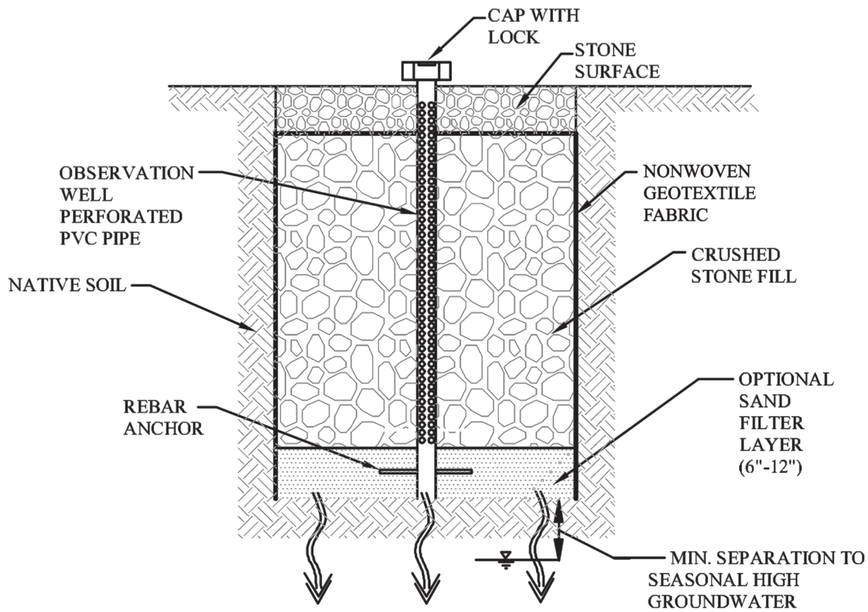
- Systems should be inspected at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Pretreatment measures should be inspected at least twice annually, and cleaned of accumulated sediment as warranted by inspection, but no less than once annually.
- If an infiltration system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore infiltration function, including but not limited to removal of accumulated sediments or reconstruction of the infiltration trench.

Design References

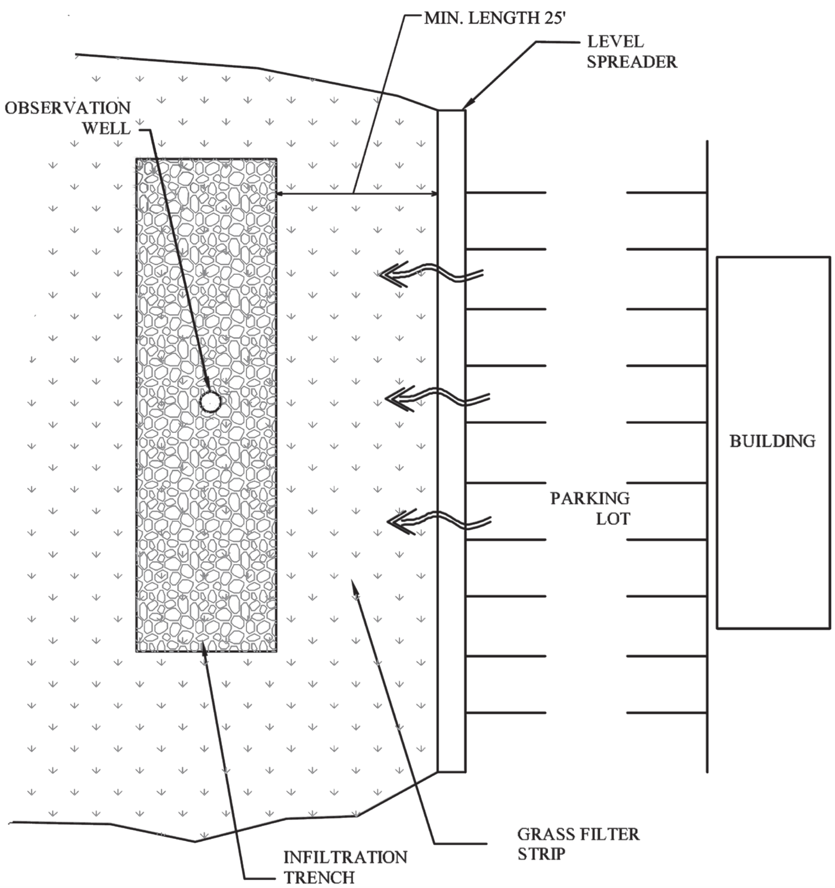
- Schueler (1987)
- Schueler, et al. (1992)
- Ferguson (1994)
- Sprecher (2008)

Example Design

Section



Planview



Design Criteria

Design Parameter	Criteria
Pretreatment	Required (see Section 4-4)
BMP Volume	≥ the larger of WQV or GRV, depending on purpose of BMP excluding sediment forebay capacity, if present, and exclude infiltration occurring during the design event
Minimum trench depth	4 feet
Maximum trench depth	10 feet
Design Infiltration Rate	See Section 2-4 for a discussion on selecting a design infiltration rate
Drain Time	< 72 hours for complete drainage of the water quality volume
Depth to Bedrock and Seasonal High Water Table Elevation	≥ 3 feet from bottom of BMP, except: ≥ 4 feet if within groundwater or water supply intake protection area ≥ 1 foot if runoff has been treated prior to entering the BMP
Overflow Discharge Capacity	10-year, 24-hour storm
Observation Well	Required along trench centerline
Infiltration Media Material	Clean, washed, uniform (well-sorted) aggregate Diameter 1.5 to 3 inches Porosity = 40%

3b. In-Ground Infiltration Basin

Infiltration basins are impoundments designed to temporarily store runoff, allowing all or a portion of the water to infiltrate into the ground. An infiltration basin is designed to completely drain between storm events. An infiltration basin is specifically designed to retain and infiltrate the entire Water Quality Volume. Some infiltration basins may infiltrate additional volumes during larger storm events, but many will be designed to release stormwater exceeding the water quality volume from the larger storms. In a properly sited and designed infiltration basin, water quality treatment is provided by runoff pollutants binding to soil particles beneath the basin as water percolates into the subsurface. Biological and chemical processes occurring in the soil also contribute to the breakdown of pollutants. Infiltrated water is used by plants to support growth or it is recharged to the underlying groundwater.

As with all impoundment BMPs, surface infiltration basins should be designed with an outlet structure to pass peak flows during a range of storm events, as well as with an emergency spillway to pass peak flows around the embankment during extreme storm events that exceed the combined infiltration capacity and outlet structure capacity of the facility.

Design Considerations

- Pretreatment is essential to the long-term function of infiltration systems.
- Preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
    - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to permanent infiltration BMPs.
    - Do not traffic exposed soil surface with construction equipment. If feasible, perform excavations with equipment positioned outside the limits of the infiltration components of the system.
    - After the basin is excavated to the final design elevation, the floor should be deeply tilled with a rotary tiller or disc harrow to restore infiltration rates, followed by a pass with a leveling drag.
    - Vegetation should be established immediately.
    - Do not place infiltration systems into service until the contributing areas have been fully stabilized.

Maintenance Requirements

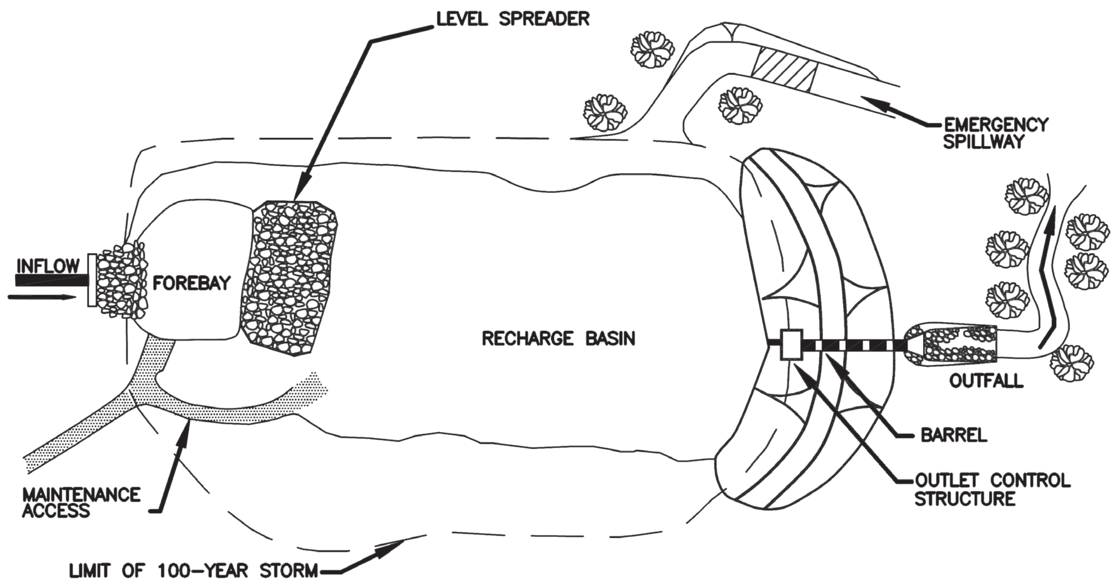
- Removal of debris from inlet and outlet structures
- Removal of accumulated sediment
- Inspection and repair of outlet structures and appurtenances
- Inspection of infiltration components at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Inspection of pretreatment measures at least twice annually, and removal of accumulated sediment as warranted by inspection, but no less than once annually.
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Inspection and repair of embankments and spillways
- If an infiltration system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore infiltration function, including but not limited to removal of accumulated sediments or reconstruction of the infiltration trench.

Design References

- Schueler (1987)
- Schueler, et al. (1992)
- Ferguson (1994)

Example Design

Plan View



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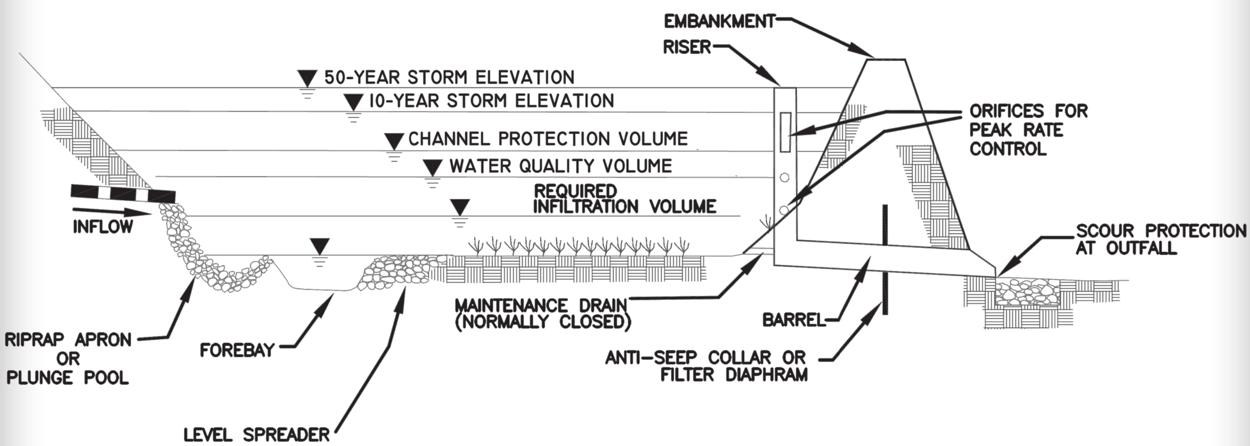


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Pretreatment	Required (see Section 4-4)
BMP Volume	≥ the larger of WQV or GRV, depending on purpose of BMP excluding sediment forebay capacity, if present, and exclude infiltration occurring during the design event
Layout	The pond perimeter should be curvilinear
Maximum Side Slopes	3:1
Minimum Side Slopes	20:1
Slope of Basin Floor	0% (flat)
Design Infiltration Rate	See Section 2-4 for a discussion on selecting a design infiltration rate
Drain Time	< 72 hours for complete drainage of the water quality volume
Depth to Bedrock and to Seasonal High Water Table Elevation	≥ 3 feet from bottom of BMP, except: ≥ 4 feet if within groundwater or water supply intake protection area ≥ 1 foot if runoff has been treated prior to entering the BMP
Basin Floor Preparation	6” layer of coarse sand or 3/8 “ pea gravel; Grass turf that can be inundated for 72+ hrs; or Coarse organic material such as erosion control mix or composted mulch, that is tilled into the soil, soaked, and allowed to dry.
Design Discharge Capacity	50-year, 24-hour storm without overtopping

3c. Underground (Subsurface) Infiltration Basin

Infiltration basins are structures designed to temporarily store runoff, allowing all or a portion of the water to infiltrate into the ground. The structure is designed to completely drain between storm events. An underground infiltration basin is specifically designed to retain and infiltrate the entire Water Quality Volume. Some infiltration basins may infiltrate additional volumes during larger storm events, but many will be designed to release stormwater exceeding the water quality volume from the larger storms. In a properly sited and designed infiltration basin, water quality treatment is provided by runoff pollutants binding to soil particles beneath the basin as water percolates into the subsurface. Biological and chemical processes occurring in the soil also contribute to the breakdown of pollutants. Infiltrated water is recharged to the underlying groundwater.

Subsurface infiltration basins may comprise a subsurface manifold system with associated crushed stone storage bed, or specially-designed chambers (with or without perforations) bedded in or above crushed stone.

Design Considerations

- Pretreatment is essential to the long-term function of infiltration systems.
- Preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
    - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to permanent infiltration BMPs.
    - Do not traffic exposed soil surface with construction equipment. If feasible, perform excavations with equipment positioned outside the limits of the infiltration components of the system.
    - Do not place infiltration systems into service until the contributing areas have been fully stabilized.

Maintenance Requirements

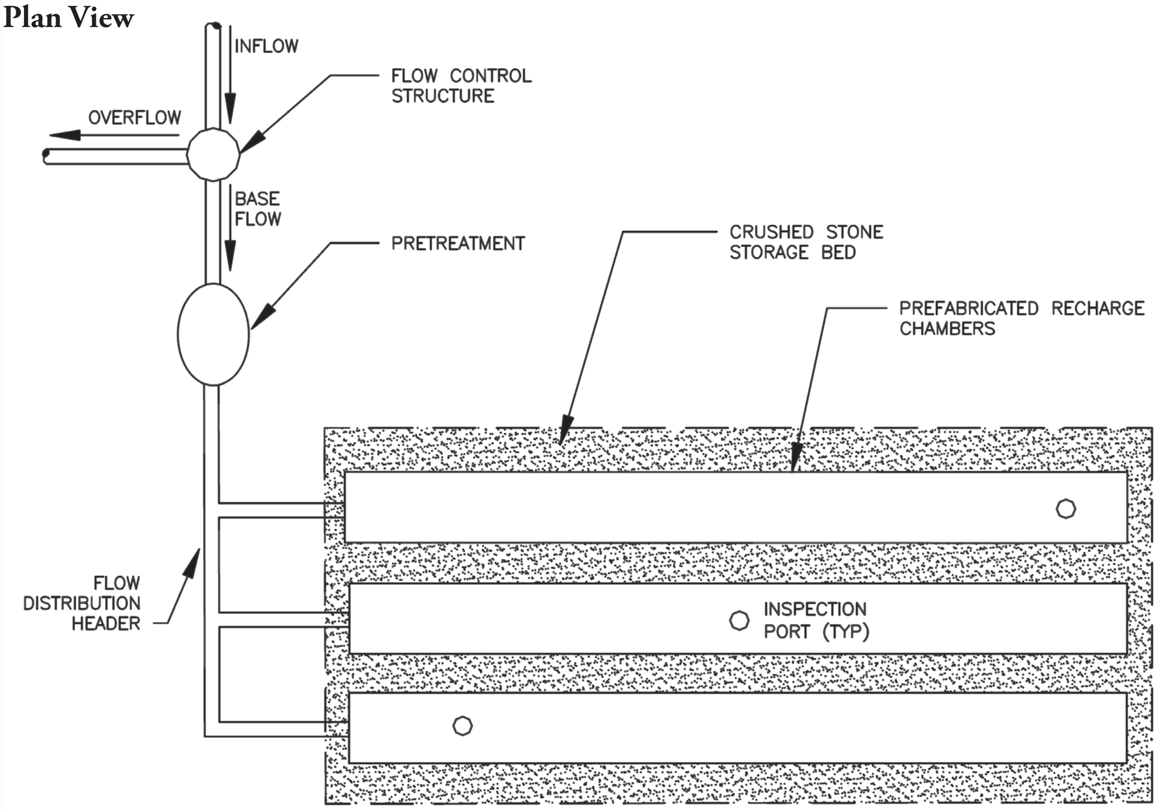
- Removal of debris from inlet and outlet structures
- Removal of accumulated sediment
- Inspection and repair of outlet structures and appurtenances
- Inspection of infiltration components at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Inspection of pretreatment measures at least twice annually, and removal of accumulated sediment as warranted by inspection, but no less than once annually.
- If an infiltration system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore infiltration function, including but not limited to removal of accumulated sediments or reconstruction of the infiltration trench.

Design References

- Schueler (1987)
- Schueler, et al. (1992)
- Ferguson (1994)

Example Design

Plan View



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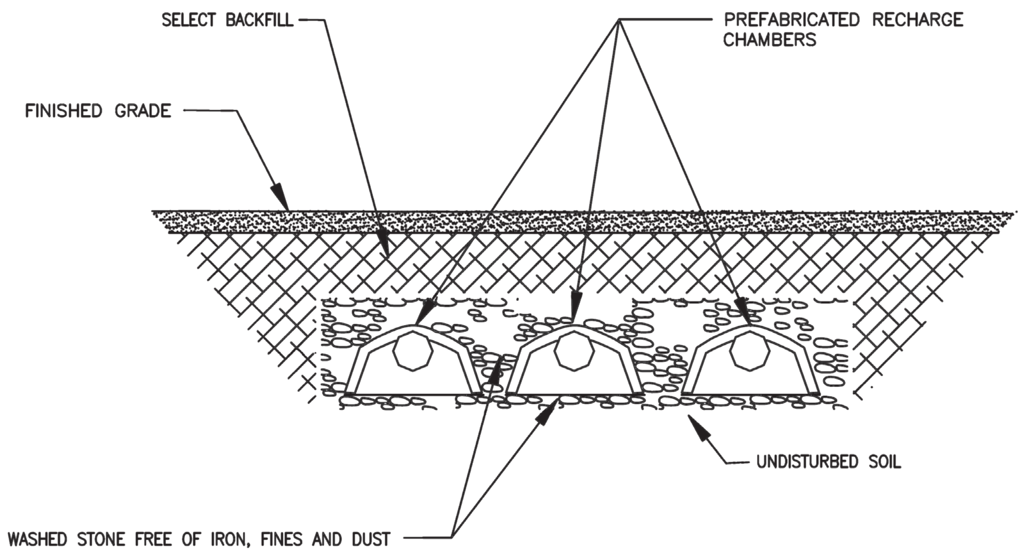


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Pretreatment	Required (see Section 4-4)
BMP Volume	≥ the larger of WQV or GRV, depending on purpose of BMP excluding sediment forebay capacity, if present, and exclude infiltration occurring during the design event
Slope of Basin Floor	0% (flat)
Design Infiltration Rate	See Section 2-4 for a discussion on selecting a design infiltration rate
Drain Time	< 72 hours for complete drainage of the water quality volume
Depth to Bedrock and to Seasonal High Water Table Elevation	≥ 3 feet from bottom of BMP, except: ≥ 4 feet if within groundwater or water supply intake protection area ≥ 1 foot if runoff has been treated prior to entering the BMP
Design Overflow Discharge Capacity (Subsurface Capacity)	10-year, 24 hour storm
Infiltration Media Material (if used for subsurface basin)	Clean, washed, uniform (well-sorted) aggregate Diameter 1.5 to 3 inches Porosity = 40%
Observation Well (subsurface basin)	Well or accessible manhole structure required

3D. Dry Well & Leaching Basin

Dry wells are essentially small subsurface leaching basins. It consists of a small pit filled with stone, or a small structure surrounded by stone, used to temporarily store and infiltrate runoff from a very limited contributing area. Runoff enters the structure through an inflow pipe, inlet grate, or through surface infiltration. The runoff is stored in the structure and/or void spaces in the stone fill. Properly sited and designed dry wells provide treatment of runoff as pollutants become bound to the soils under and adjacent to the well, as the water percolates into the ground. The infiltrated stormwater contributes to recharge of the groundwater table.

Dry wells are well-suited to receive roof runoff via building gutter and downspout systems. With the small size and manageable cost of these BMPs, they are particularly suited for use in subdivisions and for single-family homes. When used for roof drainage, pretreatment of runoff is not typically required.

Leaching basins are dry wells used in well drained soils for the discharge of roadway or parking area runoff. In this case, pretreatment is required prior to discharge to the leaching basin. A typical arrangement is to use a deep sump, hooded catch basin in combination with a leaching basin.

Dry wells, leaching basins, and similar devices should meet the design criteria applicable to subsurface infiltration basins.

Design Considerations

- Pretreatment is essential to the long-term function of infiltration systems.
- Preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
    - o Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to permanent infiltration BMPs.
    - o Do not traffic exposed soil surface with construction equipment. If feasible, perform excavations with equipment positioned outside the limits of the infiltration components of the system.
    - o Do not place infiltration systems into service until the contributing areas have been fully stabilized.

Maintenance Requirements

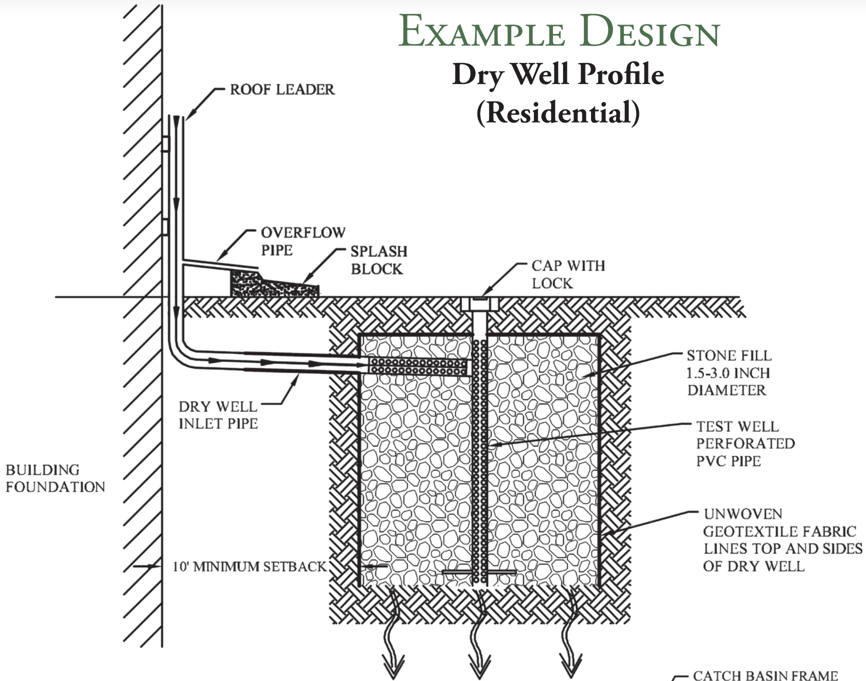
- Removal of debris from inlet and outlet structures
- Removal of accumulated sediment
- Inspection and repair of outlet structures and appurtenances
- Inspection of infiltration components at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- If an infiltration system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore infiltration function, including but not limited to removal of accumulated sediments or reconstruction of the infiltration trench.

Design Criteria

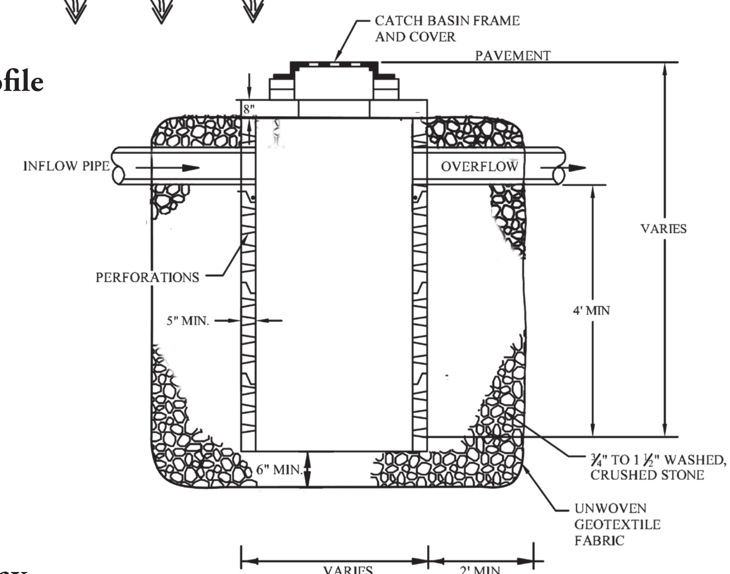
Design Parameter	Criteria
Pretreatment	Required (see Section 4-4)
BMP Volume	≥ the larger of WQV or GRV, depending on purpose of BMP excluding sediment forebay capacity, if present, and exclude infiltration occurring during the design event
Design Infiltration Rate	See Section 2-4 for a discussion on selecting a design infiltration rate
Drain Time	< 72 hours for complete drainage of the water quality volume
Depth to Bedrock and to Seasonal High Water Table Elevation	≥ 3 feet from bottom of BMP, except: ≥ 4 feet if within groundwater or water supply intake protection area ≥ 1 foot if runoff has been treated prior to entering the BMP

Example Design

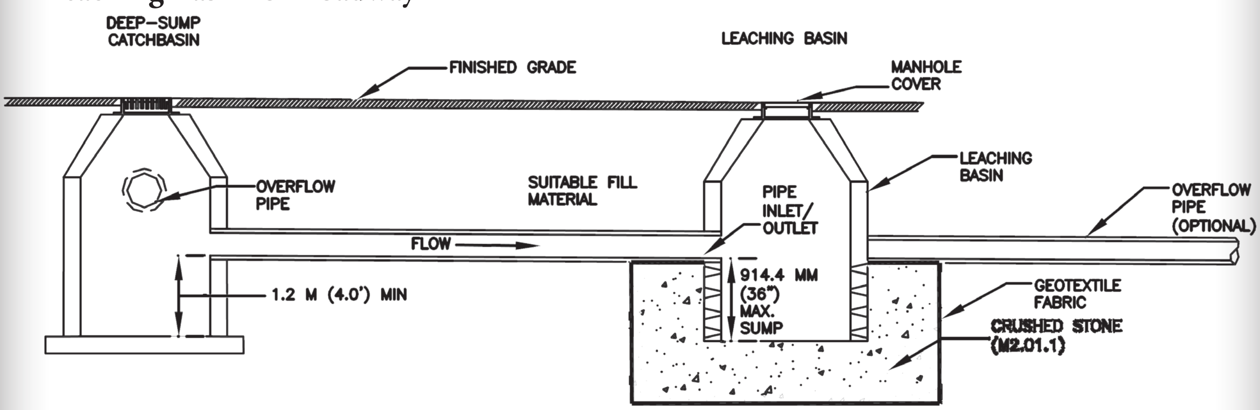
Dry Well Profile (Residential)



Leaching Basin Profile



Leaching Basin for Roadway



Source: MassHighway (2004)

4. FILTERING PRACTICES

General Description

Filtering practices treat stormwater runoff by capturing and passing the water quality volume through a bed of sand, other soil material, or other acceptable treatment media to remove pollutants from the water. Sediments and other pollutants are removed by physical straining and adsorption. Filters can be constructed using common materials, or proprietary systems using various filter media can be employed. Filtration BMPs have shown to be very effective at removing a wide range of pollutants from stormwater runoff, particularly when organic soil filter media have been used.

Filtering practices differ from infiltration practices in that the stormwater filters through an engineered filter media, rather than native soil. However, filtering practices can be constructed in combination with infiltration practices, where the filtered water is discharged into the ground beneath the BMP.

Alternatively, filters can be designed with an underdrain to collect the treated water and convey it to discharge. Underdrained filters can be lined to isolate the filters from the adjacent soil material or underlying groundwater.

The following are examples of filtering practices:

- Surface sand filters
- Underground sand filters
- Bioretention systems
- Tree box filters
- Pervious asphalt and pervious concrete (permeable pavement)

General Requirements Applicable to Filtering Practices

- Filtering practices are prohibited in areas of RSA 482-A jurisdiction unless a wetlands permit has been issued.
- Filtering practices are prohibited as follows, unless an impermeable liner is provided:
    - Into areas groundwater protection areas where stormwater is from a high-load area
    - Into areas where contaminants occur in groundwater above ambient standards (Env-Or 603.03)
    - Into areas where contaminants occur in soil above site-specific standards (Env-Or 600)
    - Into areas with slopes > 15%, unless calculations show that seepage will not cause slope instability
    - From areas with soil contaminants above site-specific standards (Env-Or 600)
    - From areas with underground or aboveground storage tanks regulated by RSA 146-C or RSA 146-A, where gasoline is dispensed or transferred
- Pretreatment is required (see Section 4-4) if BMP will receive stormwater other than roof runoff (except permeable pavements do not require pretreatment of runoff from their surfaces)
- Underdrain system is required if underlying native soil or fill soil has an infiltration rate < 0.5 inches per hour
- Where infiltration applies, the design infiltration rates must be determined in accordance with the protocols discussed in Chapter 2.
- Provide recommended clearances to seasonal high water table, to maintain adequate drainage, prevent structural damage to the filter, and minimize the potential for interaction with groundwater.

4a. Surface Sand Filter

The surface sand filter is typically designed as an off-line device, so that storms exceeding the water quality volume are diverted from the BMP. Thus, the system usually includes a flow splitter, used to divert the first flush of runoff into a pretreatment device, such as a sedimentation chamber (wet or dry) where coarse sediments settle out of the water. Pretreated runoff then enters the sand filter, saturating the filter bed and filling temporary storage volume provided above the bed. As the water filters down through the sand bed, pollutants are strained from the water or adsorbed to the filter media. The top surface of the sand filter is exposed to the elements, but is kept free of vegetation.

If the filter is designed for infiltration, the treated water is allowed to percolate into the underlying native soil. Alternatively, the filter can be designed with a perforated underdrain system to collect treated water at the bottom of the sand filter and direct it to a suitable outlet. If necessary, the underdrained sand filter can be designed with a liner to isolate it from adjacent soil material and prevent discharge of treated water to the groundwater table.

Design Considerations

- Sand and other media filters may be advantageous for specialized applications where specific target pollutants must be addressed.
- Sand and other media filters may be advantageous for sites with limited space.
- Pretreatment is essential to the long-term function of surface sand filtration systems.
- Where ultimate discharge from the filter is by infiltration into the subsoil, the preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
    - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to permanent filtration/infiltration BMPs.
    - Do not traffic exposed soil surface with construction equipment. If feasible, perform excavations with equipment positioned outside the limits of the infiltration components of the system.
- Do not place filtration systems into service until the contributing areas have been fully stabilized.

Maintenance Requirements

- Systems should be inspected at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Pretreatment measures should be inspected at least twice annually, and cleaned of accumulated sediment as warranted by inspection, but no less than once annually.
- Trash and debris should be removed at each inspection.
- Manufactured filter media should be replaced periodically per manufacturer's specifications
- At least once annually, system should be inspected for drawdown time. If a filtration system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore filtration function, including but not limited to removal of accumulated sediments or reconstruction of the filter.

Design References

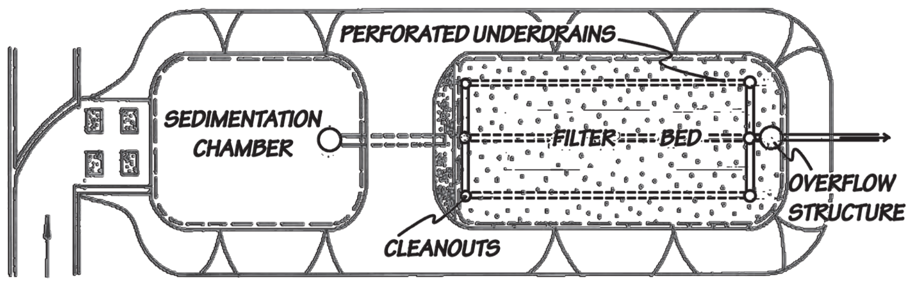
- Claytor & Schueler (1996)
- UNH Stormwater Center
- EPA (1999c)

Table 4-3. Filter Mixtures

Component Material	Percent of Mixture by Volume	Gradation of Material	
		Sieve No.	Percent by Weight Passing Standard Sieve
Filter Media Option A			
ASTM C-33 concrete sand	50 to 55		
Loamy sand topsoil, with fines as indicated	20 to 30	200	15 to 25
Moderately fine shredded bark or wood fiber mulch, with fines as indicated	20 to 30	200	< 5
Filter Media Option B			
Moderately fine shredded bark or wood fiber mulch, with fines as indicated	20 to 30	200	< 5
Loamy coarse sand	70 to 80	10	85 to 100
		20	70 to 100
		60	15 to 40
		200	8 to 15

Example Design

Plan View



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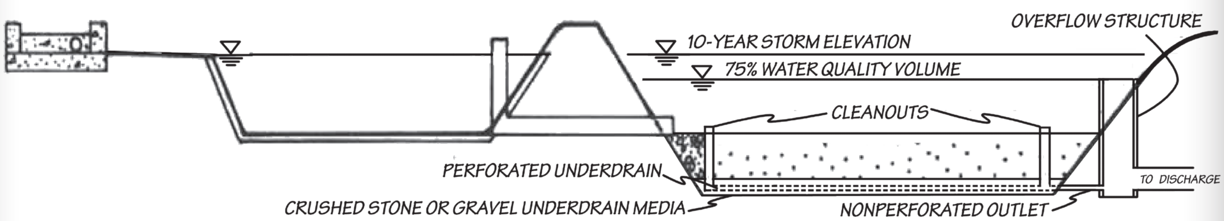
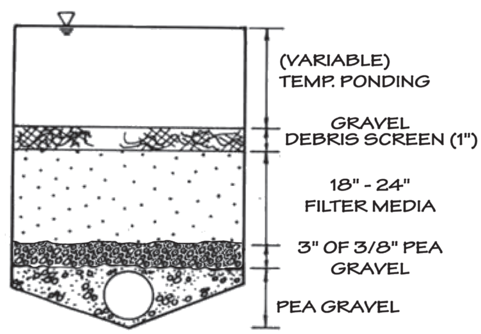


Section



Adapted from Claytor & Schueler (1996)

Design Criteria

Design Parameter	Criteria
Filter Volume	≥ 75% WQV (including storage area above filter, filter media voids, and pre-treatment area)
Watershed	< 10 acres of contributing drainage area
Depth of Filter Media	18 to 24 inches
Filter Media	See Table 4-3 Filter should not be covered with grass
Filter Appurtenances	Must have access grate
Drain Time	< 72 hours for complete drainage
Underdrain (where required)	≥ 6-inch diameter perforated PVC or HDPE set in 3/4 to 2-inch diameter stone or gravel free of fines and organic material
Depth to Bedrock and Seasonal High Water Table Elevation	If not providing an impermeable liner: ≥ 1 foot below the bottom of the filter course material. If within groundwater or water supply intake protection area the practice should also have: • 1 foot of separation from the bottom of the *practice* to the SHWT or • 1 foot of separation from the bottom of the filter course material *and* twice the depth of the filter course material recommended.
Overflow Discharge Capacity	10-year, 24-hour storm

4B. Underground Sand Filter

The underground sand filter operates in a similar fashion to the surface sand filter, except that the system is enclosed in a below-grade structure. The structure may consist of a multi-chambered vault that accommodates pretreatment, as well as the filtration component of the system. The structure is made accessible through manholes or grate openings.

A typical structure incorporating pretreatment will consist of a three-chambered vault, with the first chamber comprising a sedimentation chamber, the second chamber consisting of the filter, and the final chamber serving as the outlet control for the system. The first chamber provides pretreatment by settling coarse sediments and by trapping floating materials such as trash and oil. The pretreated water then enters the sand filter. A permeable layer of gravel may be installed on top of the filter to help prevent clogging of the filter media. A perforated underdrain at the bottom of the filter directs treated water towards an outlet. Similar to the surface sand filter, the subsurface filter should be designed as an off-line device, with capacity to treat the Water Quality Volume, with larger storm events diverted from the device.

Typical subsurface filter systems are fully enclosed in structures. However, some systems may be designed with an open bottom in contact with native soils, allowing for infiltration to occur. In these systems, the "hybrid" BMP needs to be designed to meet the requirements of Subsurface Infiltration Systems, in addition to the requirements for the filter system.

Design Considerations

- Sand and other media filters may be advantageous for specialized applications where specific target pollutants must be addressed.
- Sand and other media filters may be advantageous for sites with limited space.
- Pretreatment is essential to the long-term function of surface sand filtration systems.
- Do not place filtration systems into service until the contributing areas have been fully stabilized.
- Where ultimate discharge from the filter is by infiltration into the subsoil, the preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
    - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to permanent filtration/infiltration BMPs.
    - Do not traffic exposed soil surface with construction equipment. If feasible, perform excavations with equipment positioned outside the limits of the infiltration components of the system.

Maintenance Requirements

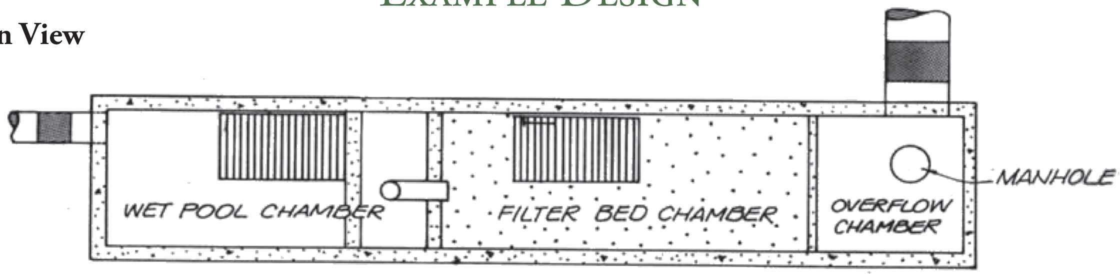
- Systems should be inspected at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Pretreatment measures should be inspected at least twice annually, and cleaned of accumulated sediment as warranted by inspection, but no less than once annually.
- Trash and debris should be removed at each inspection.
- Manufactured filter media should be replaced periodically per manufacturer's specifications.
- At least once annually, system should be inspected for drawdown time. If a filtration system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore filtration function, including but not limited to removal of accumulated sediments or reconstruction of the filter.

Design References

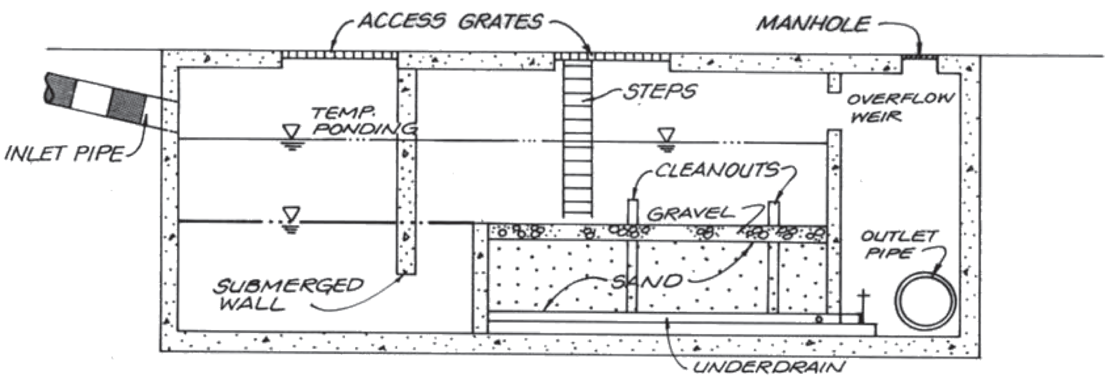
- Claytor & Schueler (1996)
- EPA (1999c)

Example Design

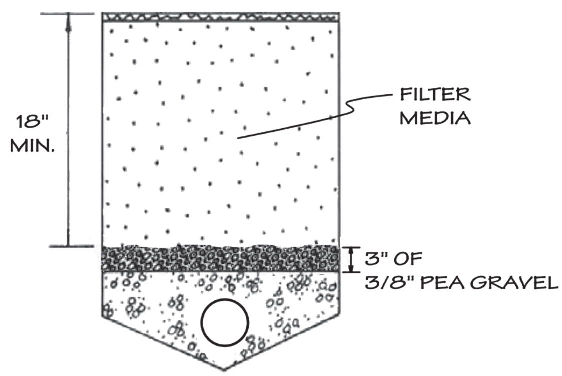
Plan View



Profile



Section



Adapted from Claytor & Schueler (1996)

Design Criteria

Design Parameter	Criteria
Filter Volume	≥ 75% WQV (including storage area above filter, filter media voids, and pre-treatment area)
Watershed	< 10 acres of contributing drainage area
Depth of Filter Media	≥ 24 inches
Filter Media	See Table 4-3
Filter Appurtenances	Must have access grate
Drain Time	< 72 hours for complete drainage
Underdrain (where required)	≥ 6-inch diameter perforated PVC or HDPE set in 1- to 2-inch diameter stone or gravel free of fines and organic material
Depth to Bedrock and Seasonal High Water Table Elevation	If not providing an impermeable liner: ≥ 1 foot below the bottom of the filter course material. If within groundwater or water supply intake protection area the practice should also have: • 1 foot of separation from the bottom of the *practice* to the SHWT or • 1 foot of separation from the bottom of the filter course material *and* twice the depth of the filter course material recommended.
Overflow Discharge Capacity	10-year, 24-hour storm

4c. Bioretention System

A bioretention system (sometimes referred to as a "rain garden") is a type of filtration BMP designed to collect and filter moderate amounts of stormwater runoff using conditioned planting soil beds, gravel beds and vegetation within shallow depressions. The bioretention system may be designed with an underdrain, to collect treated water and convey it to discharge, or it may be designed to infiltrate the treated water directly to the subsoil. Bioretention cells are capable of reducing sediment, nutrients, oil and grease, and trace metals. Bioretention systems should be sited in close proximity to the origin of the stormwater runoff to be treated.

The major difference between bioretention systems and other filtration systems is the use of vegetation. A typical surface sand filter is designed to be maintained with no vegetation, whereas a bioretention cell is planted with a variety of shrubs and perennials whose roots assist with pollutant uptake. The use of vegetation allows these systems to blend in with other landscaping features.

Design Considerations

- Bioretention areas should be located close to the source of runoff.
- Bioretention areas are particularly adaptable to integration with site landscaping, and offer an aesthetically attractive opportunity to provide highly effective stormwater treatment.
- Bioretention areas can also be used to meet recharge objectives, where allowed by land use and receiving water characteristics.
- Do not place bioretention systems into service until the BMP has been planted and its contributing areas have been fully stabilized.
- Where ultimate discharge from the bioretention area is by infiltration into the subsoil, the preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
    - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to the bioretention area during any stage of construction.
    - Do not traffic exposed soil surface with construction equipment. If feasible, perform excavations with equipment positioned outside the limits of the infiltration components of the system.

Maintenance Requirements

- Systems should be inspected at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Pretreatment measures should be inspected at least twice annually, and cleaned of accumulated sediment as warranted by inspection, but no less than once annually.
- Trash and debris should be removed at each inspection.
- At least once annually, system should be inspected for drawdown time. If bioretention system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore filtration function or infiltration function (as applicable), including but not limited to removal of accumulated sediments or reconstruction of the filter media.
- Vegetation should be inspected at least annually, and maintained in healthy condition, including pruning, removal and replacement of dead or diseased vegetation, and removal of invasive species.

Design References

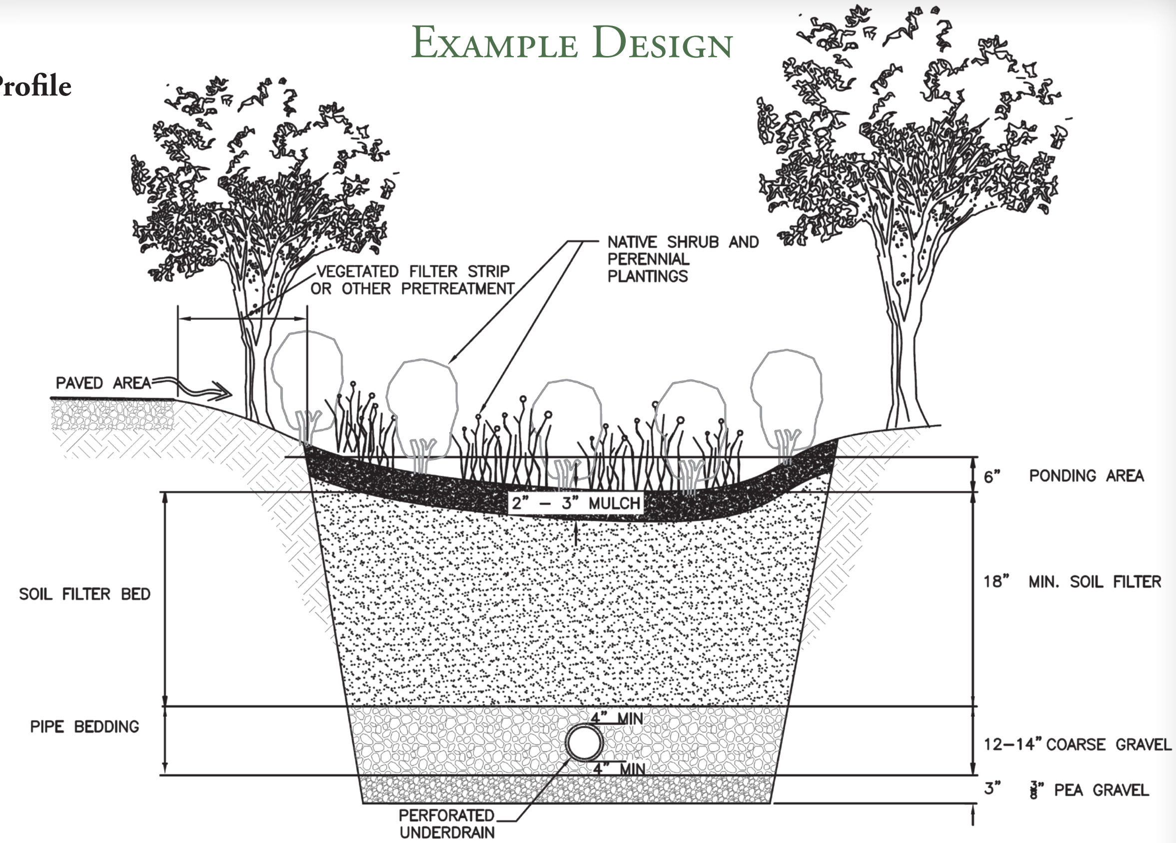
- UNH Stormwater Center
- EPA (1999a)

Table 4-4. Bioretention Filter Media

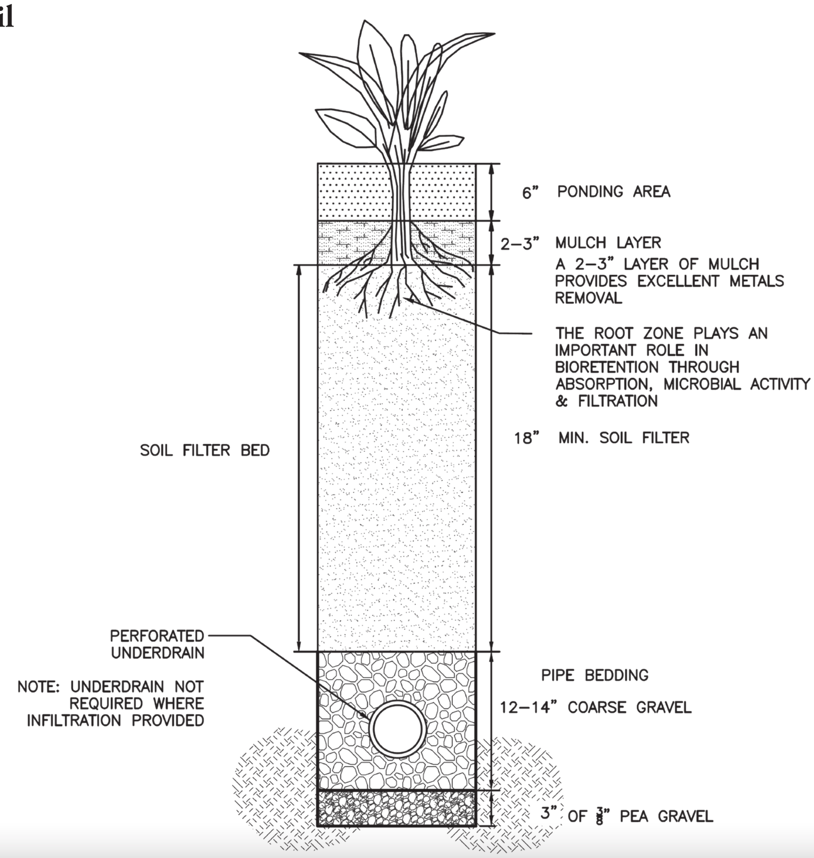
Component Material	Percent of Mixture by Volume	Gradation of Material	
		Sieve No.	Percent by Weight Passing Standard Sieve
Filter Media Option A			
ASTM C-33 concrete sand	50 to 55		
Loamy sand topsoil, with fines as indicated	20 to 30	200	15 to 25
Moderately fine shredded bark or wood fiber mulch, with fines as indicated	20 to 30	200	< 5
Filter Media Option B			
Moderately fine shredded bark or wood fiber mulch, with fines as indicated	20 to 30	200	< 5
Loamy coarse sand	70 to 80	10	85 to 100
		20	70 to 100
		60	15 to 40
		200	8 to 15

Example Design

Profile



Column Detail



Design Criteria

Design Parameter	Criteria
Bioretention Volume	≥ WQV (including storage area above filter and filter media voids)
Watershed	< 5 acres of contributing drainage area
Depth of Filter Media	18 – 24 inches
Filter Media	See Table 4-4
Drain Time	< 72 hours for complete drainage
Underdrain (where required)	≥ 6-inch diameter perforated PVC or HDPE set in 1- to 2-inch diameter stone or gravel free of fines and organic material
Depth to Bedrock and Seasonal High Water Table Elevation	If not providing an impermeable liner: ≥ 1 foot below the bottom of the filter course material. If within groundwater or water supply intake protection area the practice should also have: • 1 foot of separation from the bottom of the *practice* to the SHWT or • 1 foot of separation from the bottom of the filter course material *and* twice the depth of the filter course material recommended.
Overflow Discharge Capacity	10-year, 24-hour storm
Maximum Side Slopes	2:1
Surface Covering	2 to 3 inches well-aged shredded bark mulch (uniform in color, free of foreign and plant material)
Planting Design	Only native, non-invasive species Random and natural plant layout No woody vegetation near inflow locations Only facultative wetland species directly over the filter media Provide trees or large shrubs along perimeter Establish a tree canopy with an understory of shrubs and herbaceous plants Vegetation should be drought tolerant

4d. Tree Box Filter

The Tree Box Filter is essentially a small bioretention system, combining the function of a curb-side drainage inlet with the water quality treatment functions of a vegetated soil media. It consists of an open bottom or closed bottom concrete box or barrel filled with a porous soil media. An underdrain system, consisting of a perforated pipe bedded in crushed gravel, is provided beneath the soil media. A tree is planted in the soil media. Stormwater is directed from surrounding impervious surfaces through the top of the soil media.

If the device has an open bottom, the stormwater percolates through the media into the underlying ground. If the filtered stormwater exceeds the infiltration capacity of the underlying natural soil, the excess will be intercepted by the underdrain, where it may be directed to a storm drain, other device, or surface water discharge.

Where a closed bottom box filter is used, such as where necessary to protect groundwater resources, the filter is isolated from the underlying soil. In this case, all of the stormwater that passes through the soil media filter will be intercepted by the underdrain and conveyed to a suitable outlet.

Design Considerations

- Tree box filters should be carefully integrated into the design of parking areas and streets, to provide a sufficient number of units in suitable locations for capturing the required Water Quality Volume. Generally, these systems are sized and spaced similarly to catch basin inlets.
- Tree box filters are particularly adaptable to integration with site landscaping, and offer an aesthetically attractive opportunity to provide highly effective stormwater treatment.
- Do not use tree box filters to treat runoff from high-load areas (see the discussion of high load areas in Section 3-1 of this manual).
- Tree box filters can be used to meet recharge objectives, where underlying soils are suitable and where allowed by land use and receiving water characteristics.
- Do not place tree box filters into service until the BMP has been planted and its contributing areas have been fully stabilized.
- Where ultimate discharge from the tree box filter is by infiltration into the subsoil, the preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
    - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to the tree box filter during any stage of construction.
    - Do not traffic or compact exposed soil surface within the area of the filter with construction equipment. Perform excavation for the construction of this BMP with equipment positioned outside the limits of the system.

Maintenance Requirements

- Systems should be inspected at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Trash and debris should be removed at each inspection.
- If inspection indicates that the system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the tree box filter to determine measures required to restore filtration function or infiltration function (as applicable), including but not limited to removal of accumulated sediments or reconstruction of the filter media.
- The tree should be inspected at least annually, and maintained in healthy condition, including pruning. A dead or diseased tree, or a tree in stressed condition because of the constricted root space in the filter, should be removed and replaced. Filter media should be replaced when the tree is replaced.

Design References

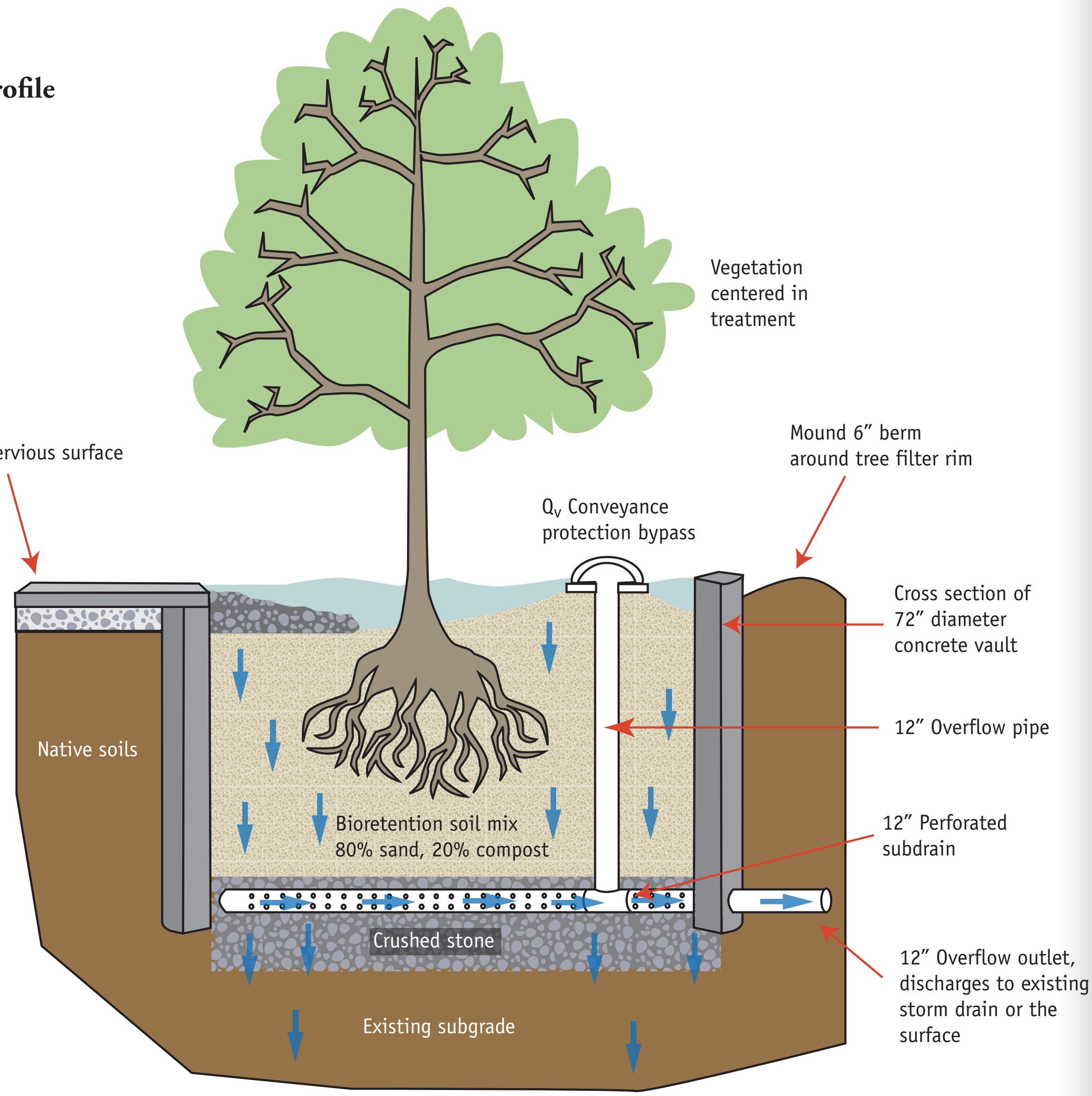
- UNH Stormwater Center (2007a)

Table 4-5. Tree Box Filter Media

Component Material	Percent of Mixture by Volume	Required Material Characteristics
Sand	80	ASTM C-33 concrete sand
Organic material, ***composted*** bark mulch recommended	20	< 5 % passing #200 Sieve
General requirements applicable to the mixture	1. Soil mix should be uniform, free of stones, stumps, roots, or similar materials larger than 2 inches. 2. Soil pH should be between 5.5 and 6.5	

Example Design

Profile



Source: UNH Stormwater Center (2007a)

Design Criteria

Design Parameter	Criteria
Pretreatment	Pretreatment not required. However, tree box filters should not be used for high-load areas.
Tree Box Filter Volume	≥ WQV (including storage area above filter and filter media voids)
Depth of Filter Media	36 inches, minimum
Filter Media	See Table 4-5
Drain Time	< 72 hours for complete drainage
Underdrain (where required)	≥ 6-inch diameter perforated PVC or HDPE set in 1- to 2-inch diameter stone or gravel free of fines and organic material
Depth to Bedrock and Seasonal High Water Table Elevation	If not providing an impermeable liner (or vault with integral bottom): ≥ 1 foot below the bottom of the filter course material. If within groundwater or water supply intake protection area the practice should also have: • 1 foot of separation from the bottom of the practice to the SHWT or • 1' of separation from the bottom of the filter course material and twice the depth of the filter course material recommended.
Overflow Discharge Capacity	10-year, 24-hour storm
Planting Design	Vegetation selected for these systems should consist of native, drought-tolerant and salt-tolerant species. Plants with aggressive root growth may clog the sub-drain, and therefore may not be suitable for this type of system.

4E. Permeable Pavement

Permeable pavement consists of a porous surface, base, and sub-base materials which allow penetration of runoff through the surface into underlying soils. The surface materials for permeable pavement can consist of paving blocks or grids, pervious asphalt, or pervious concrete. These materials are installed on a base which serves as a filter course between the pavement surface and the underlying sub-base material. The sub-base material typically comprises a layer of crushed stone that not only supports the overlying pavement structure, but also serves as a reservoir to store runoff that penetrates the pavement surface until it can percolate into the ground.

Although traffic loading capacities vary, permeable pavement alternatives are generally appropriate for low traffic areas (e.g. sidewalks, parking lots, overflow parking, residential roads). Pavement type and thickness are selected based on anticipated load (light, moderate, heavy) and maintenance requirements. Careful maintenance is essential for long term use and effectiveness.

Frequently, permeable pavements filter only the runoff generated on the pavement surface itself. However, runoff from other areas can be directed to permeable pavement if properly designed. Runoff generated from adjacent areas of the site may require pretreatment prior to discharge to the pavement surface, to prevent clogging of the pavement structure and (where the pavement is used to infiltrate as well as filter the runoff) the underlying soils.

Porous asphalt is very similar to conventional asphalt except that it is mixed without particles smaller than coarse sand (less than 600 µm or No. 30 sieve). Without these smaller size particles, water is able to pass through the surface and into a crushed stone storage area. The lack of fine particles in the asphalt, however, limits the loading capacity of the asphalt relative to conventional asphalt. Because of this limitation, pervious asphalt should not be used in high-traffic areas. An advantage to the use of porous asphalt is the reduced need for stormwater conveyance systems and other additional BMPs.

Pervious concrete uses carefully controlled amounts of water and cementitious materials to create a thick coating around aggregate particles, but retaining significant void space in the placement of the mixture. A pervious concrete mixture contains little or no sand, creating this void content. The installed surface will typically have between 15% and 25% voids in the hardened concrete, capable of passing water at extremely high flow rates through the surface. The low mortar content and high porosity reduce the strength of this surface compared to conventional concrete mixtures, which limits the use of the surface to low load-bearing areas, as is the case for porous asphalt. The pervious concrete surface is placed over an aggregate filter and storage layer, similar in characteristics to porous asphalt.

Design Considerations

- Permeable pavements are generally applicable to low-traffic access ways, residential drives, overflow or low-use parking areas, pedestrian access ways, alleys, bikepaths, and patios. Because of the reduced strength of pavement associated with permeable pavement surfaces such as porous asphalt and concrete, these surfaces are not typically appropriate for high traffic or heavy vehicle loads.

- Particular care must be taken during construction to assure preparation of subgrade, placement of aggregates, and installation of pavements meets design specifications.

- On sloping pervious pavement surfaces, impermeable trench berms should be considered within the filter and reservoir courses to minimizing flow laterally within the pavement courses. The berm should be sized to a depth necessary to retain the stormwater for sufficient time to infiltrate.
- Where infiltration is provided by the design, the preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
    - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) into areas designated for permeable pavement.
    - Do not allow stormwater from other areas of the site to flow onto the completed permeable pavement until those areas have been fully stabilized.

Maintenance Requirements

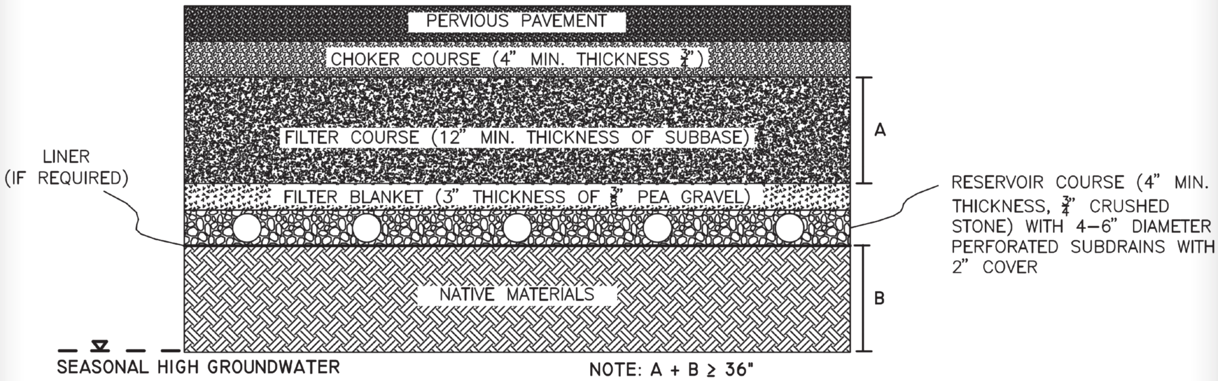
- Provision of signs is recommended, to indicate locations of permeable pavements and the applicability of special maintenance measures.
- No winter sanding of permeable pavements is permitted.
- Minimize application of salt for ice control.
- Never reseal or repave with impermeable materials.
- Inspect annually for pavement deterioration or spalling.
- Monitor periodically to ensure that the pavement surface drains effectively after storms
- For porous asphalt and concrete, clean periodically (2-4 times per year) using a vacuum sweeper. Power washing may be required prior to vacuum sweeping, to dislodge trapped particles.
- For interlocking paving stones, periodically add joint material to replace lost material
- For seeded grid systems, periodic reseeding of grass pavers to fill in bare spots
- Major clogging may necessitate replacement of pavement surface, and possibly filter course and sub-base course.

Design References

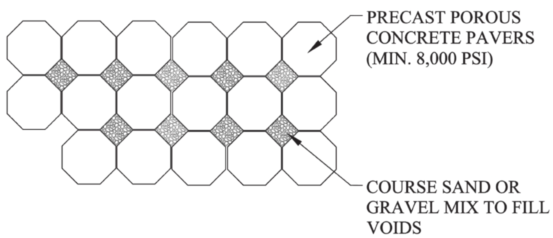
- See Design Criteria references for type of surfacing.

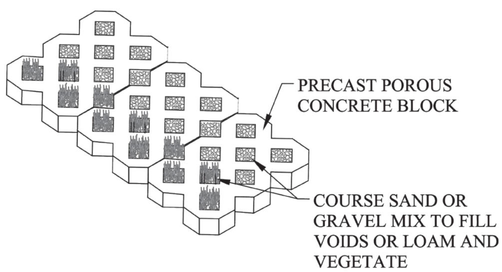
Example Design

Permeable Pavement Profile



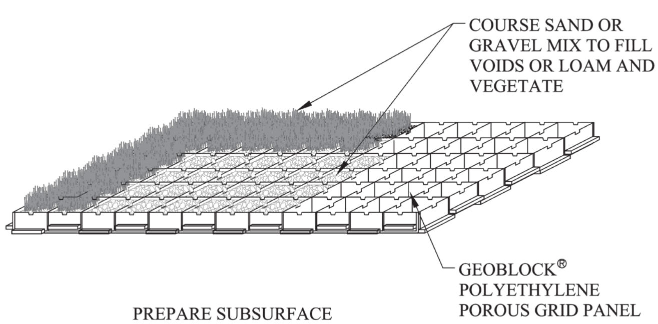
Permeable Concrete Pavers





PREPARE SUBSURFACE RESERVOIR TO MATCH BELOW

Geoblock Porous Pavement



PREPARE SUBSURFACE RESERVOIR TO MATCH BELOW

Design Criteria

Design Parameter	Criteria
Porous asphalt design	UNHSC (2007b)
Porous concrete design	American Concrete Institute (2006)
Porous concrete installation	Conractor certified by the National Ready Mix Concrete Association (NRMCA) through the NRMCA Pervious Concrete Contractor Certification program
Pervious interlocking paver design	Interlocking Concrete Pavement Institute (2002)
Filter Course Material	NHDOT (2006) sand, Item 304.1
Filter Course Thickness	> 12 inches for any section which receives only direct rainfall to its surface; or > 12 inches * Total contributing area area of the surface
Total Section Thickness	65% of the frost depth. Typically the frost depth in New Hampshire is about 48 inches. Therefore, total section thickness (top of pervious pavement to the native ground) should be at least 32”.
Aggregate Storage Volume (Reservoir Course, Filter Blanket, Filter Course, Choker Course)	≥ Larger of WQV or Recharge Volume, as applicable for purpose of BMP
Underdrain (where required)	≥ 6-inch diameter perforated PVC or HDPE set in 1- to 2-inch diameter stone or gravel free of fines and organic material
Depth to Bedrock and Seasonal High Water Table Elevation	If not providing an impermeable liner: ≥ 1 foot below the bottom of the filter course material. If within groundwater or water supply intake protection area the practice should also have: • 1 foot of separation from the bottom of the *practice* to the SHWT, or • 1’ of separation from the bottom of the filter course material *and* twice the depth of the filter course material recommended.
Overflow Discharge Capacity	10-year, 24-hour storm
Overflow outlet	Provide overflow from aggregate storage layer
Observation Well(s)	Necessary to monitor conditions in reservoir course

5. TREATMENT SWALES

General Description

Treatment swales are designed to promote sedimentation by providing a minimum hydraulic residence time within the channel under design flow conditions (Water Quality Flow). This BMP may also provide some infiltration, vegetative filtration, and vegetative uptake. Conventional grass channels and ditches are primarily designed for conveyance. Treatment swales, in contrast, are designed for hydraulic residence time and shallow depths under water quality flow conditions. As a result, treatment swales provide higher pollutant removal efficiencies. Pollutants are removed through sedimentation, adsorption, biological uptake, and microbial breakdown.

Treatment swales also differ from practices such as underdrained swales (for example, "dry swales" and "bioretention swales"), which are essentially filtration practices, and "wet swales," which are similar in function to pocket ponds.

General Requirements Applicable to Treatment Swales

- Swales are prohibited in areas of RSA 482-A jurisdiction unless a wetlands permit has been issued
- Swales are prohibited in groundwater protection areas receiving stormwater from a high-load area unless an impermeable liner is provided
- Swale shape should be trapezoidal or parabolic
- Swale must have ≥ 85% vegetated growth prior to receiving runoff
- Bottom of swale must be above seasonal high water table

Design Considerations

- Flow-Through Swales must be designed so that the flow travels the full length to receive adequate treatment. For this reason, flow must be directed to the inlet end of the swale, rather than the swale collecting water continuously along its length.
- All channels should be designed for capacity and stability. A channel is designed for capacity when it can carry the maximum specified design flow within the design depth of the channel (allowing for recommended freeboard). A channel is designed for stability when the channel lining (vegetation, riprap, or other material) will not be eroded under maximum design flow velocities. Analyses of these conditions must account for both the type of lining and its condition (for example, capacity analysis for a grassed channel must consider the

resistance of the maximum height of grass, while the stability analysis must consider the grass under its shortest, mowed condition).

- Vegetation should be selected based on site soils conditions, planned mowing requirements (height, frequency), and design flow velocities.
- The roughness coefficient, n, varies with the type of vegetative cover and flow depth. At very shallow depths, where the vegetation height is equal to or greater than the flow depth, the n value should be approximately 0.15. This value is appropriate for flow depths up to 4 inches typically. For higher flow rates and flow depths, the n value decreases to a minimum of 0.03 for grass channels at a depth of approximately 12 inches. The n value must be adjusted for varying flow depths between 4" and 12" (see chart below).

Maintenance Requirements

- Inspect annually for erosion, sediment accumulation, vegetation loss, and presence of invasive species.
- Perform periodic mowing; frequency depends on location and type of grass. Do not cut shorter than Water Quality Flow depth (maximum 4-inches)
- Remove debris and accumulated sediment, based on inspection.
- Repair eroded areas, remove invasive species and dead vegetation, and reseed with applicable grass mix as warranted by inspection.

Design References

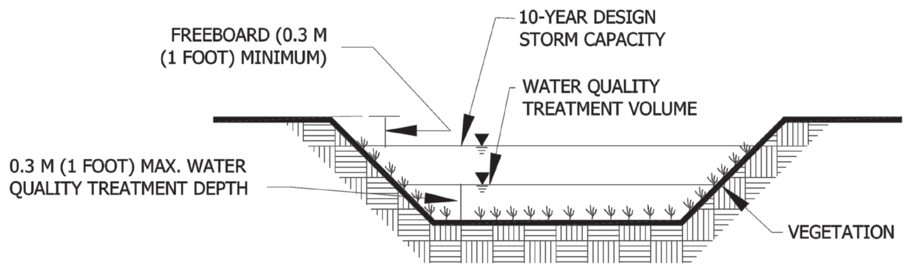
- Minton (2005)

Design Criteria

Design Parameter	Criteria
Minimum Length	≥ 100 feet (not including portions in a roadside ditch)
Bottom Width	4 to 8 feet (widths up to 16 feet are allowable with dividing berm/structure such that neither channel width exceeds 8 feet)
Longitudinal Slope	0.5% to 2% without check dams 2% to 5% with check dams
Maximum Side Slopes	3:1
Flow Depth	4 inches maximum at the WQF
Hydraulic Residence Time	> 10 minutes during the WQF
Design Discharge Capacity	10-year, 24-hour storm without overtopping

Example Design

Section



Adapted from MassHighway (2004)

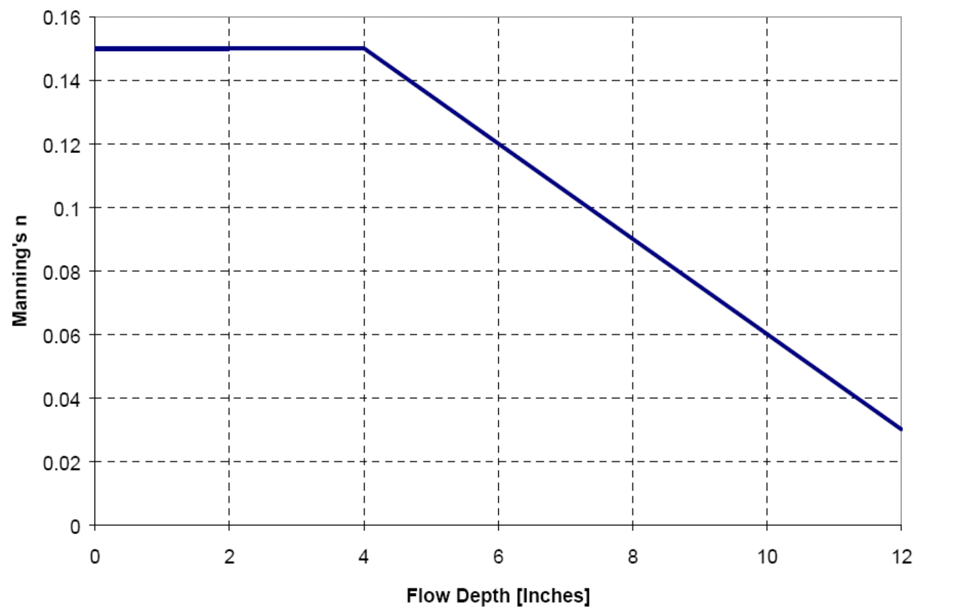


Figure 4-3. Manning's n Value with Varying Flow Depth (Source: Claytor and Schueler, 1986)

6. VEGETATED BUFFERS

General Description

Vegetated buffers are areas of natural or established vegetation allowed to grow with minimal to no maintenance. Natural, undisturbed buffers are particularly desirable along shorelines of waterbodies and wetlands, as well as along connecting habitat corridors. Buffers reduce the velocity of runoff, promote groundwater recharge, filter out sediments and provide shade to reduce the thermal impacts of runoff to receiving waters. Buffers also provide habitat for wildlife.

Vegetated buffers include, but are not limited to:

- Residential or small pervious area buffers
- Developed area buffers
- Roadway Buffers

General Requirements Applicable to Vegetated Buffers

- Ditch turn-out buffers
- Buffers shall not be located in areas of RSA 482-A jurisdiction unless a wetlands permit has been issued
- Buffers should be directly adjacent to the area being treated and receive runoff as sheet flow
- Buffers should not be interrupted by any intermittent or perennial stream channel or other drainage way
- Sizing of buffer will be a function of:
    - Vegetative cover type: forest, meadow, or combination forest/meadow (determine required sizing using a weighted average based on percent of buffer with each cover type)
    - Hydrologic soil group: (determine required buffer size using a weighted average based on percent of buffer in each soil type)
- Buffers must be identified on plans and protected by deed restrictions, covenants, or both, to ensure that buffer remains in an unaltered state

6a. Residential or Small Pervious Area Buffer

This type of vegetated buffer is for individual residential lots or for developments with limited areas of impervious surface, where runoff enters the buffer as sheet flow without the aid of a level spreader. This type of buffer can be sited adjacent to single family or duplex residential structures, or impervious surfaces where flow length over the surfaces is limited. This design is not appropriate for treating large impervious areas where there is the likelihood for runoff flows to concentrate and create channels through the buffer instead of discharging as dispersed sheet flow.

Design Considerations

- Care is required to prepare site so that flow enters the buffer as sheet flow.

Maintenance Requirements

- Inspect buffer at least annually for signs of erosion, sediment buildup, or vegetation loss.
- If a meadow buffer, provide periodic mowing as needed to maintain a healthy stand of herbaceous vegetation.
- If a forested buffer, then the buffer should be maintained in an undisturbed condition, unless erosion occurs.
- If erosion of the buffer (forested or meadow) occurs, eroded areas should be repaired and replanted with vegetation similar to the remaining buffer. Corrective action should include eliminating the source of the erosion problem, and may require retrofit with a level spreader.
- Remove debris and accumulated sediment, based on inspection.

Design References

- Maine DEP (2006)

Design Criteria

Design Parameter	Criteria
Allowable Contributing Area	• Single family or duplex residential lot • Developed area < 10% impervious cover, flow path over developed area ≤ 150 feet • Impervious area ≤ 1 acre where flow path across impervious area ≤ 100 feet
Maximum Slope	15 %, slope must be uniform
Length of Buffer Flow Path	Size flow length of buffers per Tables 4-6 and 4-7.
Width of Buffer	Buffer should extend the width of the contributing impervious surface

Example Design

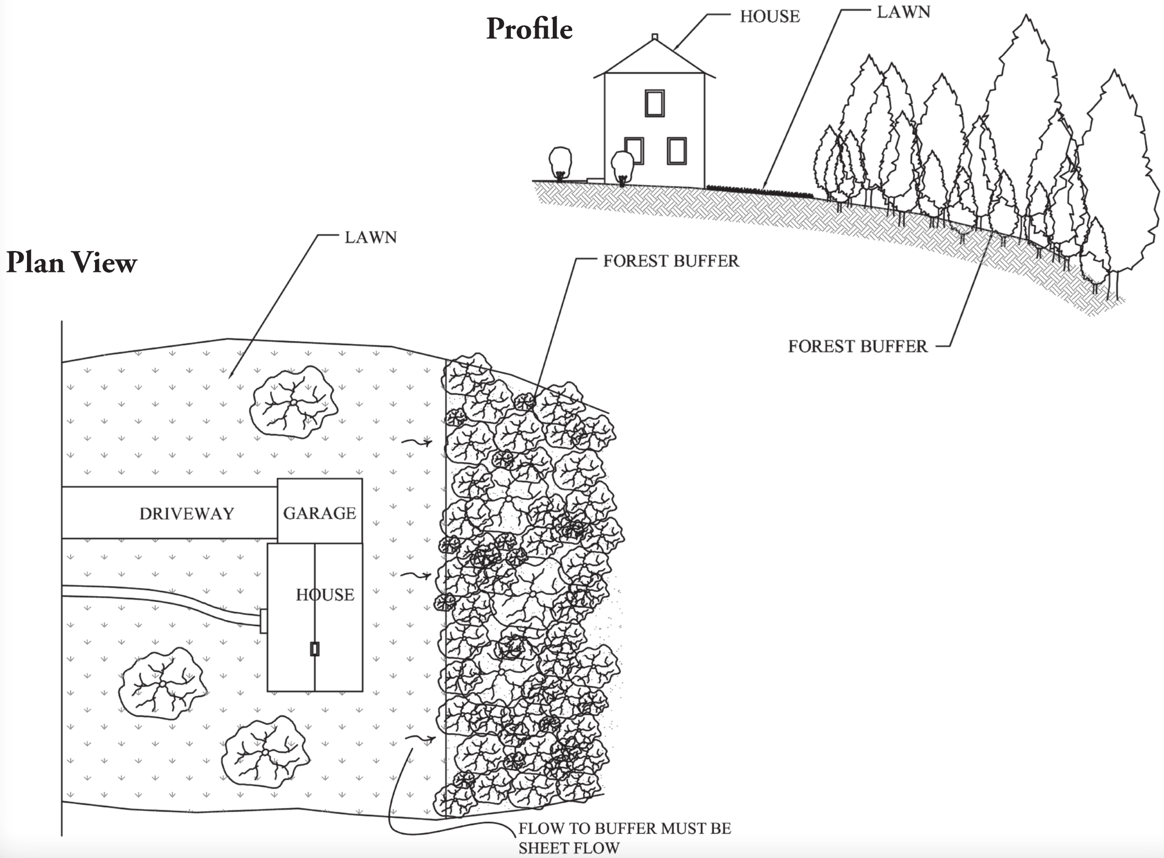


Table 4-6. Required Buffer Flow Path Length per Soil and Vegetative Cover Types with 0% to 8% Buffer Slope		
Hydrologic Soil Group of Soil in Buffer	Length of Flow Path for Forested Buffer (feet)	Length of Flow Path for Meadow Buffer (feet)
A	45	75
B	60	85
C	75	100
D	150	Not Applicable

Table 4-7. Required Buffer Flow Path Length per Soil and Vegetative Cover Types with Greater Than 8% to 15% Buffer Slope		
Hydrologic Soil Group of Soil in Buffer	Length of Flow Path for Forested Buffer (feet)	Length of Flow Path for Meadow Buffer (feet)
A	55	90
B	70	100
C	90	120
D	180	Not Applicable

Note: If a detention structure is used upstream of the level spreader, Tables 4-6 and 4-7 may be used with the assumption that 1.0 acre of impervious area is equivalent to a peak flow of 1.0 cfs during the 2-year, 24-hour storm.

6B. Developed Area Buffer

Developed Area Buffers serve areas that exceed the thresholds for “residential or small pervious area buffers.” They may also be used for small areas where the runoff is discharged as concentrated flow, rather than sheet flow. Developed area buffers require the use of stone-berm level spreaders to discharge runoff into the buffers as sheet flow.

Runoff is directed to the channel upstream of the stone berm, which is located along the contour of the slope at the upper margin of the buffer area. This stone berm spreads the runoff so that it uniformly seeps through the berm and evenly distributes across the top of the buffer as sheet flow.

Design Considerations

- Proper grading is essential to establish the level spreader along the contour, so that the outlet of the device is level and distributes discharge as sheet flow over the width of the buffer.
- Soil stabilization measures should be implemented to prevent erosion and local rill and gulley formation until permanent vegetation is established.

Maintenance Requirements

- Inspect level spreader and buffer at least annually for signs of erosion, sediment buildup, or vegetation loss.
- If a meadow buffer, provide periodic mowing as needed to maintain a healthy stand of herbaceous vegetation.
- If a forested buffer, then the buffer should be maintained in an undisturbed condition, unless erosion occurs.
- If erosion of the buffer (forested or meadow) occurs, eroded areas should be repaired and replanted with vegetation similar to the remaining buffer. Corrective action should include eliminating the source of the erosion problem, and may require retrofit with a level spreader.
- Remove debris and accumulated sediment, based on inspection.

Design References

- Maine DEP (2006)

Design Criteria

Design Parameter	Criteria
Allowable contributing area	Maximum area will be governed by the available width of buffer.
Maximum Slope	15 %, slope must be uniform
Length of Buffer Flow Path	Size flow length of buffers per Tables 4-8 and 4-9.
Minimum Level Spreader Length	20 feet
Stone Berm Level Spreader	Must meet the requirements for level spreaders described in Section 4.6.

Table 4-8. Required Level Spreader Berm Length Per Acre of Impervious Area and Lawn Area Draining to the Buffer for a Given Buffer Length with 0% to 8% Buffer Slope

Hydrologic Soil Group of Soil in Buffer	Available Buffer Length (feet)	Level Spreader Berm Length to a Forested Buffer (feet)		Level Spreader Berm Length to a Meadow Buffer (feet)	
		Impervious Area	Lawn Area	Impervious Area	Lawn Area
A	75	75	25	125	35
	100	65	20	75	25
	150	50	15	60	20
B	75	100	30	150	45
	100	80	25	100	30
	150	65	20	75	25
C	75	125	35	150	45
	100	100	30	125	35
	150	75	25	100	30
D	150	150	45	200	60

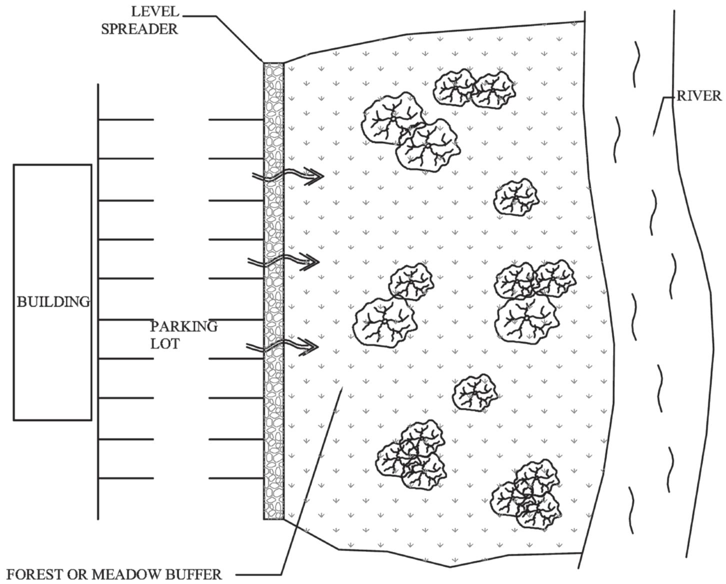
Table 4-9. Required Level Spreader Berm Length Per Acre of Impervious Area and Lawn Area Draining to the Buffer for a Given Buffer Length with Greater than 8% to 15% Buffer Slope

Hydrologic Soil Group of Soil in Buffer	Available Buffer Length (feet)	Level Spreader Berm Length to a Forested Buffer (feet)		Level Spreader Berm Length to a Meadow Buffer (feet)	
		Impervious Area	Lawn Area	Impervious Area	Lawn Area
A	75	90	30	150	40
	100	80	25	90	30
	150	60	20	70	25
B	75	120	35	180	55
	100	95	30	120	35
	150	80	25	90	30
C	75	150	40	180	55
	100	120	35	150	40
	150	90	30	120	35
D	150	180	55	240	70

Note: If a detention structure is used upstream of the level spreader, Tables 4-8 and 4-9 may be used with the assumption that 1.0 acre of impervious area is equivalent to a peak flow of 1.0 cfs during the 2-year, 24-hour storm.

Example Design

Plan View



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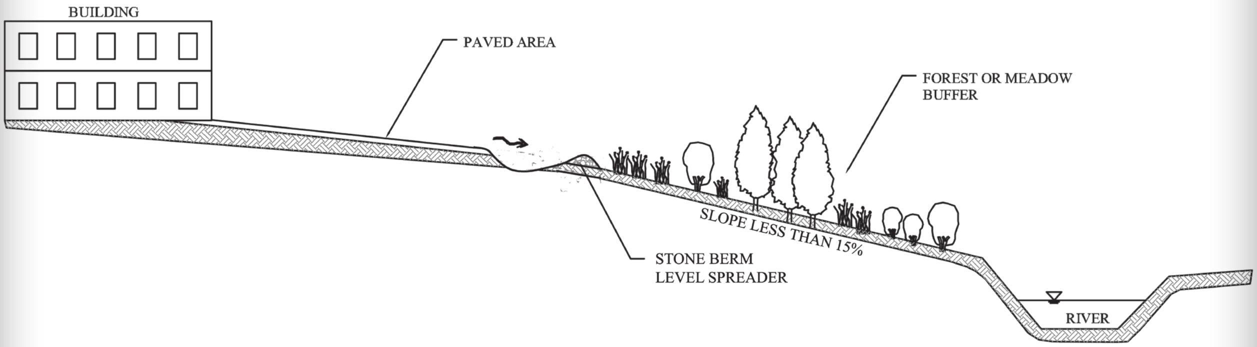


6c. Roadway Buffer

A buffer adjacent to the down-hill side of a road should be sited directly adjacent to the roadway. In addition, the road must be parallel to the contour of the slope. Runoff must sheet immediately into the buffer, and must not include runoff from areas other than the adjacent road surface and shoulder. The buffer may consist of man-made buffer, natural buffer, or a combination.

Design Considerations

- Care is required to prepare site so that flow passes through the buffer as sheet flow. The buffer slope should be planar or convex in shape; concave (or "dish-shaped") slopes tend to concentrate runoff, increasing the potential for erosion and short-circuiting of runoff through the buffer.
- Roadside buffers are not suited to steep terrain.

Maintenance Requirements

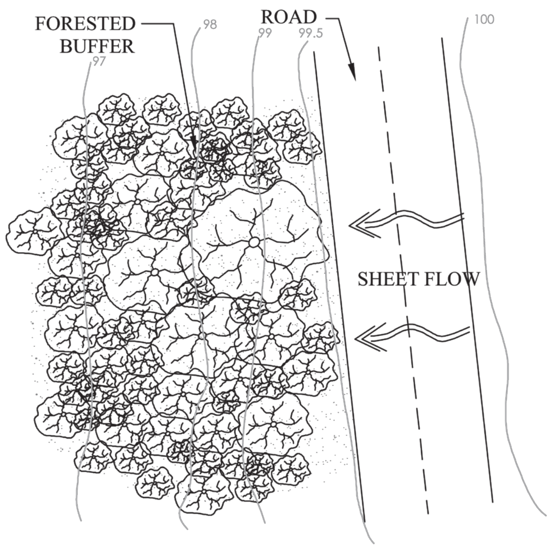
- Inspect buffer at least annually for signs of erosion, sediment buildup, or vegetation loss.
- If a meadow buffer, provide periodic mowing as needed to maintain a healthy stand of herbaceous vegetation.
- If a forested buffer, then the buffer should be maintained in an undisturbed condition, unless erosion occurs.
- If erosion of the buffer (forested or meadow) occurs, eroded areas should be repaired and replanted with vegetation similar to the remaining buffer. Corrective action should include eliminating the source of the erosion problem, and may require retrofit with a level spreader.
- Remove debris and accumulated sediment, based on inspection.

Design References

- Maine DEP (2006)

Example Design

Plan View



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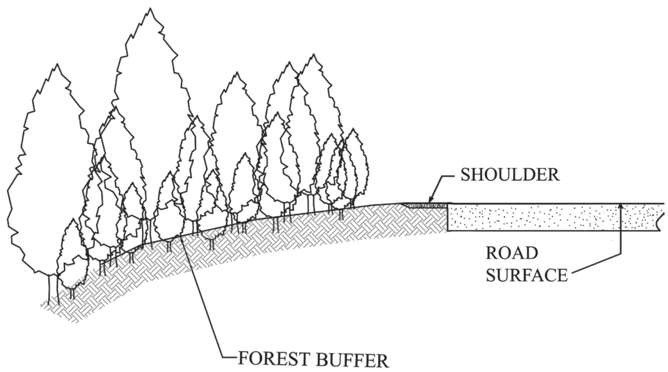


Design Criteria

Design Parameter	Criteria
Contributing Road Surface	• Road surface and shoulder must sheet flow directly into the buffer • No areas other than the road surface and shoulder should be directed to the buffer • Road should parallel the contour of the buffer slope
Buffer Slope Requirements	Man made buffer slope must be uniform and ≤ 15 %; except: A maximum of 20 feet of vegetated roadway embankment slope of 3:1 or flatter may count toward the total required buffer length Natural buffer slope must be uniform and ≤ 20%
Length of Buffer Flow Path	≥ 50 feet flow path for one travel lane ≥ 80 feet flow path for two travel lanes
Other	Buffer should be vegetated

6d. Ditch Turn-out Buffer

A ditch turn-out buffer diverts runoff collected in a roadside ditch into a buffer. A combination of check dams and bermed level lip spreaders convert the concentrated ditch flows into sheet flow. The sheet flow distributes across the top of the buffer.

Design Considerations

- Proper grading is essential to establish the level spreader along the contour, so that the outlet of the device is level and distributes discharge as sheet flow over the width of the buffer.
- Soil stabilization measures should be implemented to prevent erosion and local rill and gulley formation until permanent vegetation is established.

Maintenance Requirements

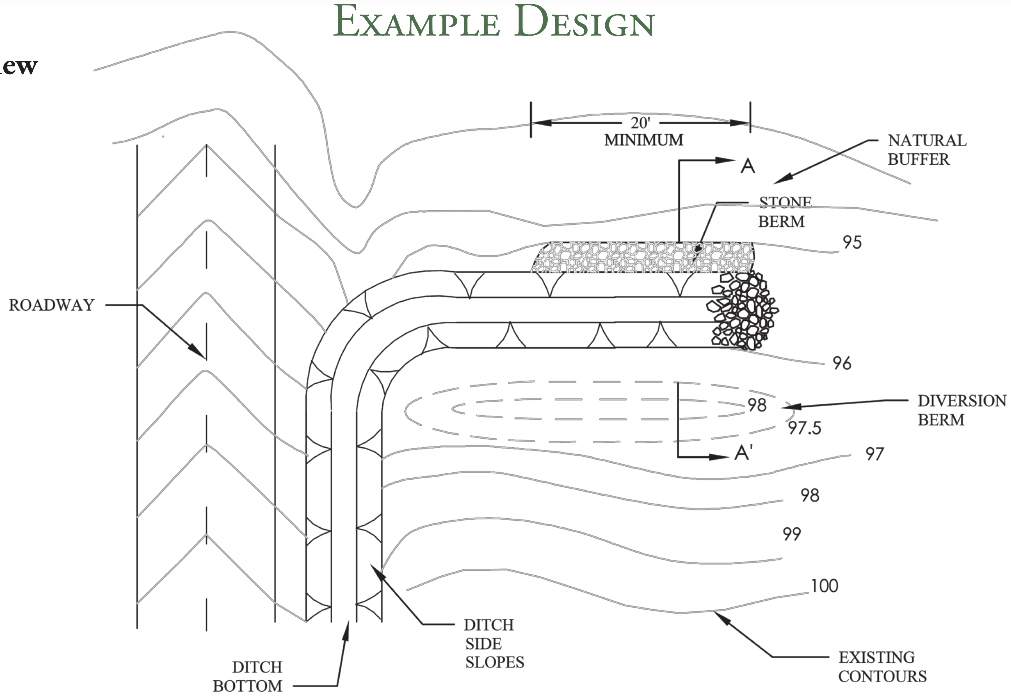
- Inspect level spreader and buffer at least annually for signs of erosion, sediment buildup, or vegetation loss.
- If a meadow buffer, provide periodic mowing as needed to maintain a healthy stand of herbaceous vegetation.
- If a forested buffer, then the buffer should be maintained in an undisturbed condition, unless erosion occurs.
- If erosion of the buffer (forested or meadow) occurs, eroded areas should be repaired and replanted with vegetation similar to the remaining buffer. Corrective action should include eliminating the source of the erosion problem, and may require retrofit with a level spreader.
- Remove debris and accumulated sediment, based on inspection.

Design References

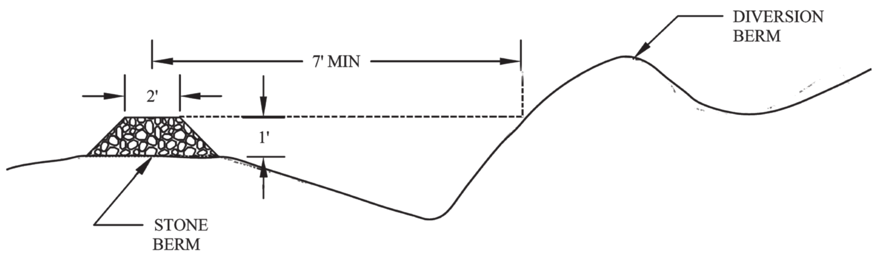
- Maine DEP (2006)

Example Design

Plan View



Section



Design Criteria

Design Parameter	Criteria
Allowable Contributing Area	• No areas other than road surface, shoulder, and road ditch • ≤ 500 feet of 1 travel lane + ditch • ≤ 250 feet of 2 travel lanes + ditch • ≤ 6,000 sq. ft. of pavement, if > 2 lanes + ditch are directed to the buffer
Maximum Slope	15 %, slope must be uniform
Length and Width of Buffer	Size flow length of buffers per Tables 4-10 and 4-11.
Minimum Level Spreader Length	20 feet
Stone Berm Level Spreader	Must meet the requirements for level spreaders described in Section 4.6.

Table 4-10. Required Buffer Flow Path Length per Length of Road or Ditch with 0% to 8% Buffer Slope			
Hydrologic Soil Group of Soil in Buffer	**Maximum Length of a One Lane road or Ditch Draining to a Buffer (feet)**	**Length of Flow Path for Forested Buffer (feet)**	**Length of Flow Path for Meadow Buffer (feet)**
A or B	200	50	70
	300	50	85
	400	60	100
C	200	60	100
	300	75	120
	400	100	Not Applicable
D	200	100	150

Table 4-11. Required Buffer Flow Path Length per Length of Road or Ditch with Greater than 8% to 15% Buffer Slope			
Hydrologic Soil Group of Soil in Buffer	**Maximum Length of a One Lane road or Ditch Draining to a Buffer (feet)**	**Length of Flow Path for Forested Buffer (feet)**	**Length of Flow Path for Meadow Buffer (feet)**
A or B	200	60	85
	300	60	100
	400	70	120
C	200	70	120
	300	90	145
	400	120	Not Applicable
D	200	120	180