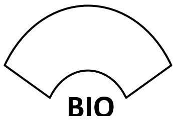
3.4 Post Construction Stormwater Control Fact Sheets (PTP)

Post Construction Stormwater Control Practices	PTP-10 Bioretention Systems



Symbol

BIO

TSS Reduction: 80%

Description

Bioretention systems are structural water quality control devices that capture and temporarily store, treat, and release stormwater runoff. A properly designed area will replicate a small, dense forest floor. Bioretention systems consist of two main components: a pretreatment area and filtration chamber. The pretreatment area removes floatable materials and heavy sediments, and helps reduce flow velocities. The filtration chamber traps and strains pollutants, and allows the microbial removal of pollutants. Target pollutants for bioretention systems include suspended solids, suspended particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and others. Bioretention systems employ organic materials such as peat or compost combined with sand, and plantings and mulch on the surface layer. This allows additional pollutant removal via bacterial decomposition and vegetation uptake of nutrients. The two main structures of bioretention systems (the pretreatment area and filtration area) may include or be enhanced by the following components:

- Grass filter strip
- Sand bed
- Ponding area or pretreatment basin
- Organic layer
- Planting soil layer
- Plant material
- Underdrain/collection system

Applications

Bioretention systems are often used to manage stormwater runoff from urban areas where space is limited, and can be applied to areas where retrofit is needed, and are typically suitable in the following applications:

- Small stabilized drainage areas
- Drainage areas with high impervious cover
- Off-line facilities adjacent to parking lots
- Along road drainage swales
- Within larger landscaped pervious areas
- Landscaped islands in impervious or high-density environments (i.e. parking lots)
- Retrofitting exiting parking lot islands/off-line facilities

Bioretention systems are **not** suitable in the following applications:

- Within drainage areas that have not been stabilized
- Areas with mature trees
- Adjacent to areas with slopes greater than 5:1 (H:V)
- Areas that experience continuous flow from surface water, groundwater, sump pumps, or other sources

Bioretention systems should only be applied to stabilized drainage areas, as heavy sediment loads from construction areas will clog and disable it. Likewise, they should not be used in areas where stormwater has potential for high silt or clay content, and areas with a high water table. As a guide, sites implementing bioretention systems should have over 50% impervious cover in the drainage area.

Bioretention systems should typically be designed for off-line use to capture the first flush of runoff. A diversion structure such as a flow splitter or weir may be necessary to separate and route the first flush to the bioretention system for water quality control, and route the remaining stormwater to a water quantity control device downstream. Other options include an overflow structure than carries flows larger than the water quality treatment requirement. Bioretention systems are most effective when turbulent flow is minimized and the flow is spread uniformly across the surface area.

Bioretention is best employed close to the source of runoff generation and is often located in the upstream portion of the stormwater treatment train, with additional stormwater BMPs following downstream. Strong consideration should be given to multiple smaller bioretention system rather than one large bioretention system.

Bioretention System Variations

FILTRATION/PARTIAL RECHARGE FACILITY

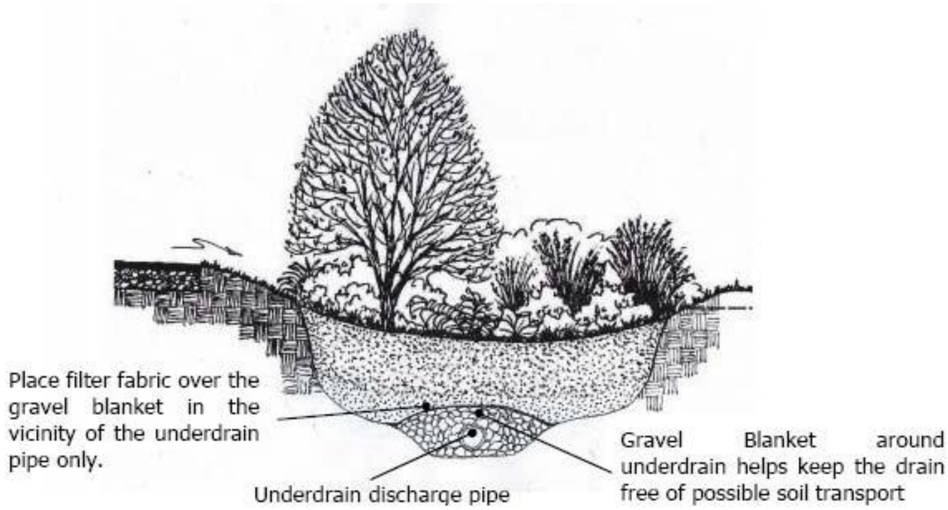


Figure PTP-10- 1 Filtration/Partial Recharge Facility
Source, Minnesota Stormwater Manual

This type of facility is suitable for areas where high filtration and partial recharge of runoff would be beneficial. This facility is designed with an under-drain at the invert of the planting soil mix to ensure that the facility drains at a desired rate. The facility allows for partial recharge, as an impervious liner is not used. The depth is also shallow (2.5') to allow the facility to handle high capacity flows if necessary. Siting of this performance type is suitable for visually prominent or gateway locations in a community. The facility type is suitable for areas and land uses that are expected to generate nutrient and metals loadings (residential, business campus, or parking lots). Attention to mulch type and amount will ensure the adequate treatment of the anticipated loadings. The facility shown above incorporates a filter material between the gravel blanket around the under-drain and the planting soil above. The filter fabric does not need to extend to the side walls. The filter fabric may be installed horizontally above the gravel blanket-extending just 1-2 feet on either side of the under-drain pipe below. Do ***not*** wrap the under-drain with filter fabric. Instead of using a filter fabric, the designer may opt to utilize a pea gravel diaphragm over the under-drain gravel blanket. This type of facility is also recommended for tight impermeable soils where infiltration is limited. Some volume reduction will be seen from evapotranspiration.

Bioretention System Variations

INFILTRATION/FILTRATION/RECHARGE FACILITY

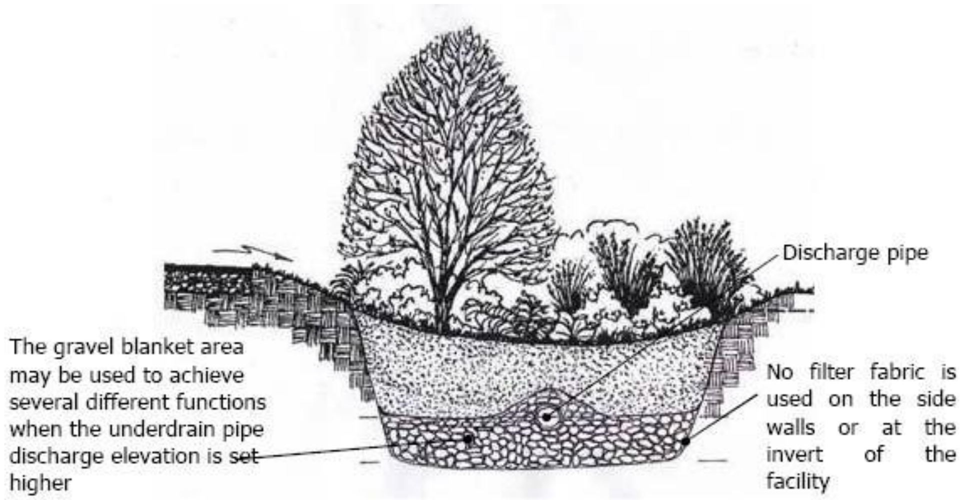


Figure PTP-10- 2 Infiltration/Filtration/Recharge Facility
Source, Minnesota Stormwater Manual

This type of facility is recommended for areas where higher nutrient loadings (particularly nitrates) are anticipated. The facility is designed to incorporate a fluctuating aerobic/anaerobic zone below the raised under-drain discharge pipe. This fluctuation created by saturation and infiltration into the surrounding soils will achieve de-nitrification. With a combination of a fresh mulch covering, nitrates will be mitigated through the enhancement of natural denitrification processes. This type of facility would be suitable for areas where nitrate loadings are typically a problem (residential communities). The raised under-drain has the effect of providing a storage area below the invert of the under-drain discharge pipe. This area provides a recharge zone and quantity control can also be augmented with this storage area. The storage area is equal the void space of the material used.

Bioretention System Variations

FILTRATION ONLY FACILITY

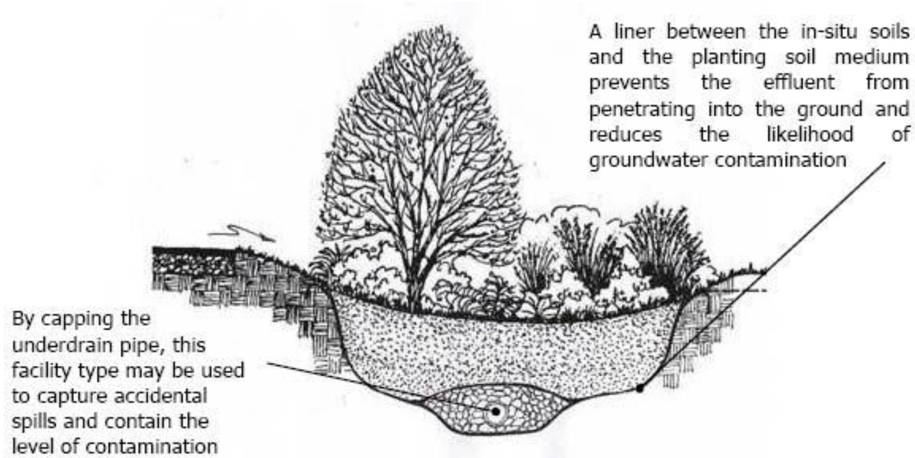


Figure PTP-10- 3 Filtration Only Facility
Source, Minnesota Stormwater Manual

This type of facility is recommended for areas that are known as potential stormwater "hot-spots" (gas stations, transfer sites, and transportation depots). An important feature of this type of facility is the impervious liner designed to reduce or eliminate the possibility of ground water contamination. The facility provides a level of treatment strictly through filtration processes that occur when the runoff moves through the soil material to the underdrain discharge point. In the event of an accidental spill, the under-drain can be blocked and the objectionable materials siphoned through the observation well and safely contained.

Maintenance

Maintenance access should be provided for appropriate equipment, vehicles, and personnel.

Monthly

- Remove trash or debris
- Inspect the bioretention system for clogging
- Pruning and weeding to maintain appearance.
- Mulch replacement when erosion is evident.

Semi-annually

- The planting soils should be tested for pH to establish acidic levels. If the pH is below 5.2, limestone should be applied. If the pH is above 7.0 to 8.0, then iron sulfate plus sulfur can be added to reduce the pH.

Annually

- Remove sediment as necessary
- Repair or replace any damaged structural parts
- Stabilize any eroded areas
- Replace mulch over the entire area.
- Replace gravel diaphragm if warranted every 2 to 3 years.

As Needed

- Inspect inflow points for clogging (off-line systems). Remove any sediment.
- Inspect grass filter strip/grass channel for erosion or gullying. Re-seed or sod as necessary.
- Trees and shrubs should be inspected to evaluate their health and remove any dead or severely diseased vegetation.
- Ponding of water on the surface for more than 48 hours indicates that the filtering capacity is substantially diminished. Replace mulch layer by removing the top few inches that contain sediment. Core aeration or cultivating of unvegetated areas may also be required to ensure adequate filtration. The removed sediment should be disposed of properly, such as in a landfill.
- Silt or sediment should be removed from the bioretention system at the accumulation of approximately 2 inches.
- Properly dispose of any material generated during maintenance activities.

Inspection Checklist

Monthly

- ❑ Contributing area, facility, inlets, and outlets are clear of debris
- ❑ Contributing area is stabilized and mowed, with clippings bagged or removed
- ❑ Treatment area is not clogging – also inspect after moderate/major storm events
- ❑ Activities in the drainage area minimize oil/grease and sediment entering the system
- ❑ Standing water is not present
- ❑ No erosion is present in the bioretention system
- ❑ Pretreatment area shows no evidence or erosion
- ❑ Deposition of sediment should be no more than 2 inches before it is cleaned out

Annually

- ❑ Treatment area contains no more than 2 inches of sediment
- ❑ No evidence of deterioration, spalling, or cracking is present on concrete, if present
- ❑ Inspect grates, where applicable
- ❑ Inlets, outlets, and overflow spillways or diversion structures show no evidence of erosion or deterioration
- ❑ Flow is not bypassing the bioretention system
- ❑ Wetland vegetation is not present in the bioretention area (signifies poor drainage)

Figure PTP-10- 4 Bioretention System
Source, Maryland Department of Natural Resources, www.dnr.state.md.us

Design Criteria

- The size of the drainage area typically dictates the size of the bioretention practice. These areas should be limited to a maximum contributing drainage area of five (5) acres. One-half (0.5) to two (2) acre drainage areas are preferred. Multiple bioretention areas may be required for larger drainage areas. No more than 50 percent of the drainage area can be pervious.
- Sloped areas immediately adjacent to the bioretention system should be no greater than 5:1 (H:V) nor less than 1% to promote positive flow toward the system.
- Bioretention systems should be sized based on the principles of Darcy's Law, as shown in the Design Procedures section. However, the minimum size of a bioretention system is 200 square feet (equivalent to 10-feet wide and 20 feet long).
- The bioretention system surface slope should not exceed 1%, to promote even distribution of flow throughout the system.
- The maximum side slopes for a bioretention system is 3:1 (H:V).
- Planting soils should contain less than 5% clay by volume. Additional specifications for soils are outlined in the Design Components section.
- Where feasible ponding depths should be no greater than 6 inches. The maximum allowable pooling depth is 18 inches.
- The bioretention system should be designed such that it is drained within 48 hours from the peak water level in the system.
- Bioretention systems require pre-treatment and as many pretreatment components as feasible should be incorporated. Pretreatment components are described below.
    - For applications where runoff enters the bioretention system through sheet flow, such as from parking lots, or residential back yards, a grass filter strip with a gravel diaphragm is the preferred method of pretreatment.
    - For applications where concentrated (or channelized) runoff enters the bioretention system, such as through a slotted curb opening, a grassed channel with a gravel diaphragm is the preferred method of pretreatment.
- Underdrains are required in bioretention systems to carry flow to another conveyance element. The underdrains should be equipped with a minimum 8-inch perforated PVC pipe surrounded by a 12-inch thick gravel layer. The underdrain can be installed at the bottom of the storage area or at an elevation above the bottom of the storage area, depending on the treatment goals for the system.
- When designing the underdrain, infiltration of the in situ soils should not be considered. Zero drawdown through the in situ soils should be assumed. The underdrain system must be sized to drain the entire water quality volume (WQ_v) within 48hrs
- The elevation difference from the inflow to the outflow must be 4-6 feet.
- A minimum of 3 feet (5 feet recommended) of separation must be provided between the bottom of the bioretention system and seasonally saturated soils.
- Potential for erosion of stabilized areas and the bioretention system should be evaluated.
- Bioretention systems must have a detailed landscaping plan.

Design Components

- ***Pre-treatment*** – Pre-treatment areas capture and remove coarse sediment particles from runoff prior to discharging into the bioretention area. Incorporation of pretreatment components helps to reduce the maintenance burden of bioretention, and reduces the likelihood that the planting soil layer will clog over time.
  - ***Gravel Diaphragm*** – Located at the beginning of the grass buffer strip to reduce velocity of runoff, filter particles in the stormwater, and spread flow across the grass buffer strip.
  - ***Grass Buffer Strip/Grass Channel*** – Reduces velocity of runoff and filters particles in the stormwater. The length of the grass buffer strip depends on the drainage area, imperviousness, and the buffer strip slope. When bioretention is used to treat runoff from parking lots or roadways that are frequently sanded during snow events, grass buffer strips should be a minimum of 10 feet long and grass channels a minimum of 20 feet long.
  - ***Concrete Forebay or Curb*** – Often bioretention areas are incorporated into parking lots and other highly impervious areas. Curbs and/or concrete forebays can be constructed to slow runoff and allow larger solids to settle before reaching the bioretention area. Curbs can simply have a lip set 1-2 inches above the parking lot elevation and effectively settle large particles. A concrete forebay can also be installed to aid maintenance and cleaning.
  - ***Ponding Area or Pretreatment Basin*** – Runoff is detained to settle particulates suspended in stormwater.

- **Treatment –**
  - ***Surface/Ponding Area*** –The surface area of all infiltration based bioretention systems is a function of the infiltration capacity of the underlying soils. The surface area of all filtration based bioretention practices is a function of the filtration capacity of the soil medium and underdrain. Ponding depths should be kept to a minimum to reduce hydraulic overload of in-situ/planting soils and to maximize the surface area to system depth ratio, where space allows. It is recommended that approximately 5-10% of the tributary impervious area be dedicated to the bioretention system footprint.
  - ***Organic Layer*** – A layer of mulch filters pollutants out of the stormwater and protects soil from eroding. The layer can also sustain a nutrient rich environment with microbes that can break down petroleum-based contaminants. The layer should contain approximately 2 to 3 inches fresh shredded bark mulch, when possible, to maximize nitrogen retention. If aged mulch is used, use the shredded type instead of the "chip" variety to minimize floating action. Too much mulch can restrict oxygen flow to roots.

Design Components

- ***Planting Soil Layer*** – This layer is used to provide nutrients and store water for the area's plantings.
  - The planting soil should be a well blended, homogenous mixture of 50-60% construction sand, 20-30% top soil, and 20-30% organic leaf compost. This blend is necessary to provide a planting soil layer with a high infiltration/filtration capacity.
  - Field experiments show that pollutant removal is accomplished within the top 30" of soil depth with minimal additional removal beyond that depth (Prince George's County, 2002). Therefore, the recommended depth of the prepared soil is 30 inches. However, if large trees are preferred in the design, a soil depth of 48"-52" should be utilized. The soil depth generally depends upon the root depth of the prescribed vegetation and content of underlying soils.
  - Clay material can absorb heavy metals, hydrocarbons and other pollutants. However, clay should be mixed with sand or topsoil such that the planting soil layer has a clay content of less than 5%.
  - Additionally, the design permeability rate through the planting soil bed should be high enough to fully drain the stormwater quality design storm runoff within 48hrs. It is recommended that this permeability rate be determined by field testing.
  - The planting soil should have a pH ranging from 5.5 to 6.5.
- ***Plant Material*** – Consider surrounding environment, climate, maintenance requirements and types of pollutants that the plants must withstand and treat, while maintaining a positive aesthetic enhancement.
- ***Underdrain/Collection System*** – Necessary to collect and send flows to a stormwater conveyance system. This system should contain a minimum 8-inch perforated PVC pipe surrounded by a 12-inch thick gravel layer. The gravel shall be washed and 1-1/2" in size. Increasing the diameter of the underdrain makes freezing less likely, and provides a greater capacity to drain standing water from the system. Pipe perforations should be sized approximately 3/8 inch in diameter spaced at 6-inch intervals on center. At a minimum, 4 holes per row should be used, and pipe grade placement should be at least 0.5%. Pipes should be spaced no more than 10 feet on center. The porous gravel layer prevents standing water in the system by promoting drainage. Gravel is also less susceptible to frost heaving than finer grain media. A pea gravel diaphragm and/or permeable filter fabric should be placed between the gravel layer and the planting soil layer.

Landscaping

- Impervious area construction must be completed and a dense and vigorous vegetative cover should be established over the contributing pervious drainage areas **BEFORE** runoff can be accepted into the bioretention system.
- Consult with a landscaping professional to select vegetation which fits into the landscape, is appropriate for the hardiness zone, and can tolerate conditions found in bioretention areas (short durations of 6 inch ponding water). Vegetation should be selected based on specified zone of hydric tolerance.
- The bioretention area should be vegetated to resemble a terrestrial forest ecosystem, with a mature tree canopy, sub canopy of under story trees, shrub layer, and herbaceous ground cover. Three species each of both trees and shrubs are recommended to be planted. Many bioretention systems feature wild flowers and grasses in addition to trees and shrubs. Other typical landscape plants can be used, such as day lilies, landscape grasses, or other native plantings.
- The tree-to-shrub ratio should be 2:1 to 3:1. On average, the trees should be spaced 8 feet apart. Plants should be placed at regular intervals to replicate a natural forest.
    - Woody vegetation should not be specified at inflow locations.
    - Trees should not be planted directly over top of underdrains and may be best located along the perimeter of the system.
- After the trees and shrubs are established, the ground cover and mulch should be established. Mulch should not be mounded around the base of plants since this encourages damage from pests and diseases.
- Salt resistant vegetation should be used in locations with probable adjacent salt applications, i.e. roadside, parking lot, etc.
- Choose plants based on factors such as resistance to drought and inundation, cost, aesthetics, maintenance, etc. Native plant species should be specified over non-native species.
- Fluctuating water levels following seeding (prior to germination) can cause seed to float and be transported. Seed is also difficult to establish through mulch, a common surface component of bioretention systems. It may take up to two growing seasons to establish the function and desired aesthetic of mature vegetation via seeding. Therefore mature plantings are recommended over seed.
- If a minimum coverage of 50% is not achieved after the first growing season, a reinforcement planting is required.
- Bioretention system locations should be integrated into the site planning process, and aesthetic considerations should be taken into account in the siting and design.

Design Procedure

Step 1 – Make a preliminary judgment as to whether site conditions are appropriate for the use of a bioretention system, and identify the function of bioretention in the overall treatment system.

- Consider basic issues for initial suitability screening, including:
  - Site drainage area
  - Site topography and slopes
  - Soil infiltration capacity
  - Site location/minimum setbacks
  - Presence of active karst features
- Determine how the bioretention system will fit into the overall stormwater treatment system.
  - Decide whether the bioretention system is the only BMP to be employed, or if there are other BMPs addressing some of the treatment requirements.
  - Decide where on the site the bioretention system is most likely to be located.

Step 2 – Confirm design criteria, site constraints, and applicability.

- Determine the design criteria that will be used.
- Determine any constraints the site will place on the bioretention system such as:
  - High pervious area in the drainage area
  - Limited amount of surface area available for treatment
  - High water table
  - Water surface elevation in any downstream treatment practices or conveyance
- Ensure that stormwater runoff from impervious surfaces is being treated to the 80% TSS reduction standard.
  - The equation for determining the weighted TSS reduction for a site with multiple outlet points is below.

$$\%TSS = \frac{\sum_n^1 (TSS_1 A_1 + TSS_2 A_2 + ... + TSS_n A_n)}{\sum_n^1 (A_1 + A_2 + ... + A_n)}$$

Where:

TSS_1 = TSS reduction by BMP providing treatment for A_1
A_1 = area 1, (acres)
TSS_2 = TSS reduction by BMP providing treatment for A_2
A_2 = area 2, (acres)

  - Where one BMP discharges into another, the treatment train TSS reduction can be found by the following equation:

$$TSS_{train} = A + B - \frac{(A \times B)}{100}$$

Design Procedure

Where:

TSS_{train} = total TSS reduction through successive BMPs
A = TSS reduction through first BMP
B = TSS reduction through second BMP

Step 3 – Perform field verification of site suitability.

- Determine the depth to groundwater. A minimum of 3 feet of separation between the bottom of the bioretention system and seasonally saturated soils (or from bedrock) is required (5 feet recommended).
- The field verification should be conducted by a qualified geotechnical professional.
- If the initial evaluation indicates that a bioretention practice would be a good BMP for the site, it is recommenced that soil borings or pits be dug (in the same location as the proposed bioretention practice) to verify soil types and infiltration capacity characteristics and to determine toe depth to ground water and bedrock. The number of soil borings should be selected as needed to determine local soil conditions.

It is recommended that the minimum depth of the soil borings or pits be five feet below the bottom elevation of the proposed bioretention system.

Step 4 – Compute runoff control volumes and peak flows.

- Calculate the Water Quality Volume (WQ_V), peak runoff for the 25 year storm (Q_{P25}), and the peak runoff for the 100 year storm (Q_{P100}). Refer to Section 2 for more information stormwater quantity design.
    - The required water quality treatment volume is 1.1 inches of runoff from the new impervious surfaces created from the project.
    - Determine Water Quality Volume (WQ_V).

      $$WQ_v = [P\ R_v)(A)]/12$$

      Where:

      P = is the average rainfall, (inches)
      R_V = 0.05 + 0.009(I), where I is the percent impervious cover
      A = the area of imperviousness, (acres)

- Calculate the peak flows for Q_{P25} and Q_{P100} to meet detention requirements.

Design Procedure

Note: Steps 5-8 are iterative

Step 5 – Determine bioretention type and size.

- Select type of bioretention basin – after completion of the previous steps the designer should know the depth to the water table, bedrock or other impermeable layers, and the contributing drainage area.
  - Determine Water Quality Volume (WQ_V) for bioretention system.
    - If part of the overall WQ_V is to be treated by other BMPs, subtract that portion from the WQ_V to determine the part of the WQ_V to be treated by the bioretention system.
    - If the bioretention system has an underdrain the volume of voids in the underdrain system should be subtracted from the WQ_v. The volume of voids should be estimated at 35% of the total volume of the underdrain system.
  - Based on the known WQ_V, infiltration rates of the underlying soils and the known existing potential pollutant loading from proposed/existing landuse select the appropriate bioretention type (see Section 2.6).

- Size Bioretention System With An Underdrain
  - The bioretention surface area is computed using the following equation, for those systems that are designed with an underdrain:

$$A_f = (WQ_V \times d_f) / [k \times (h_f + d_f) \times t_f]$$

Where:

A_f = surface area of bioretention system, (ft^2)
WQ_V = water quality volume, (ft^3)
d_f = filter bed depth, (ft)
k = coefficient of permeability of filter media, (ft/day) (0.5 ft/day is the recommended k for planting medium / filter media soil. This value is conservative to account for clogging associated with accumulated sediment.)
h_f = average height of water above filter bed, (ft)
t_f = design filter bed drain time, (days) (48 hours is the required maximum t_f for bioretention)

STEP 6 – Size outlet structure and/or flow diversion structure, if needed.

- It is required that a secondary outlet be incorporated into the design of a bioretention system to safely convey excess stormwater. Stormwater quantity requirements can be found in Section 2.4.7.
- Potential for erosion to stabilized areas and bioretention system should be evaluated and the design should incorporate ways to mitigate erosive flows.

Design Procedure

STEP 7 – Determine pre-treatment volume and design pre-treatment measures.

- Some form of pre-treatment is required prior to the discharge of stormwater into the bioretention system, to remove any sediment and fines that may result in clogging of the soils in the treatment area.
- Grass filter strips should be sized based on the following table.

Table PTP-10- 1 Grass Filter Strip Sizing *(Minnesota Stormwater Manual)*

Parameter	Impervious Parking Lots				Residential Lawns			
Maximum Inflow Approach Length (ft)	35		75		75		150	
Filter Strip Slope	≤2%	>2%	≤2%	>2	≤2%	>2%	≤2%	>2%
Filter Strip Minimum Length	10’	15’	20’	25’	10’	12’	15’	18’

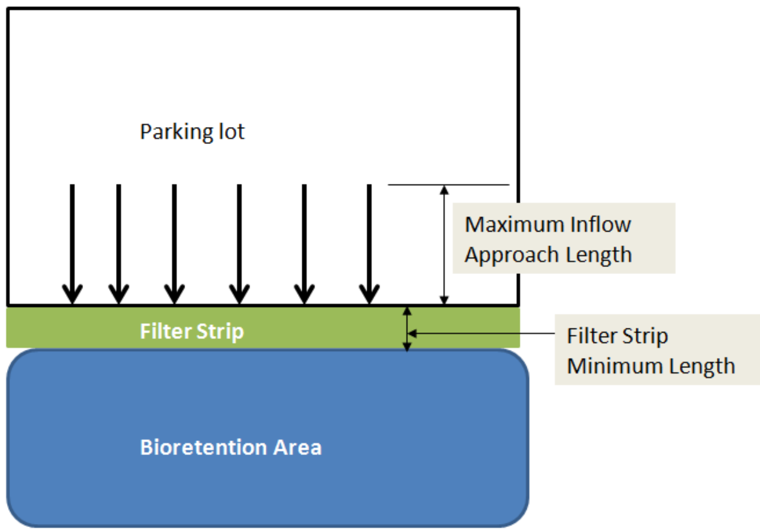


Figure PTP-10- 1. Filter Strip Design Parameters

- Grass channels should be a minimum of 20 feet in length and designed according to the following.
    - Parabolic or trapezoidal cross-section with bottom widths between 2 and 8 feet.
    - Channel side slopes no steeper than 3:1 (H:V)
    - Flow velocities limited to 1 foot per second or less for peak flow associated with the water quality event storm.

Flow depth of 4 inches or less for peak flow associated with the water quality event storm.

STEP 9 – Prepare vegetation and landscaping plan

- Prepare vegetation and landscaping management plan based on the guidance given in the Landscaping Section.

STEP 10 – Prepare operations and maintenance plan

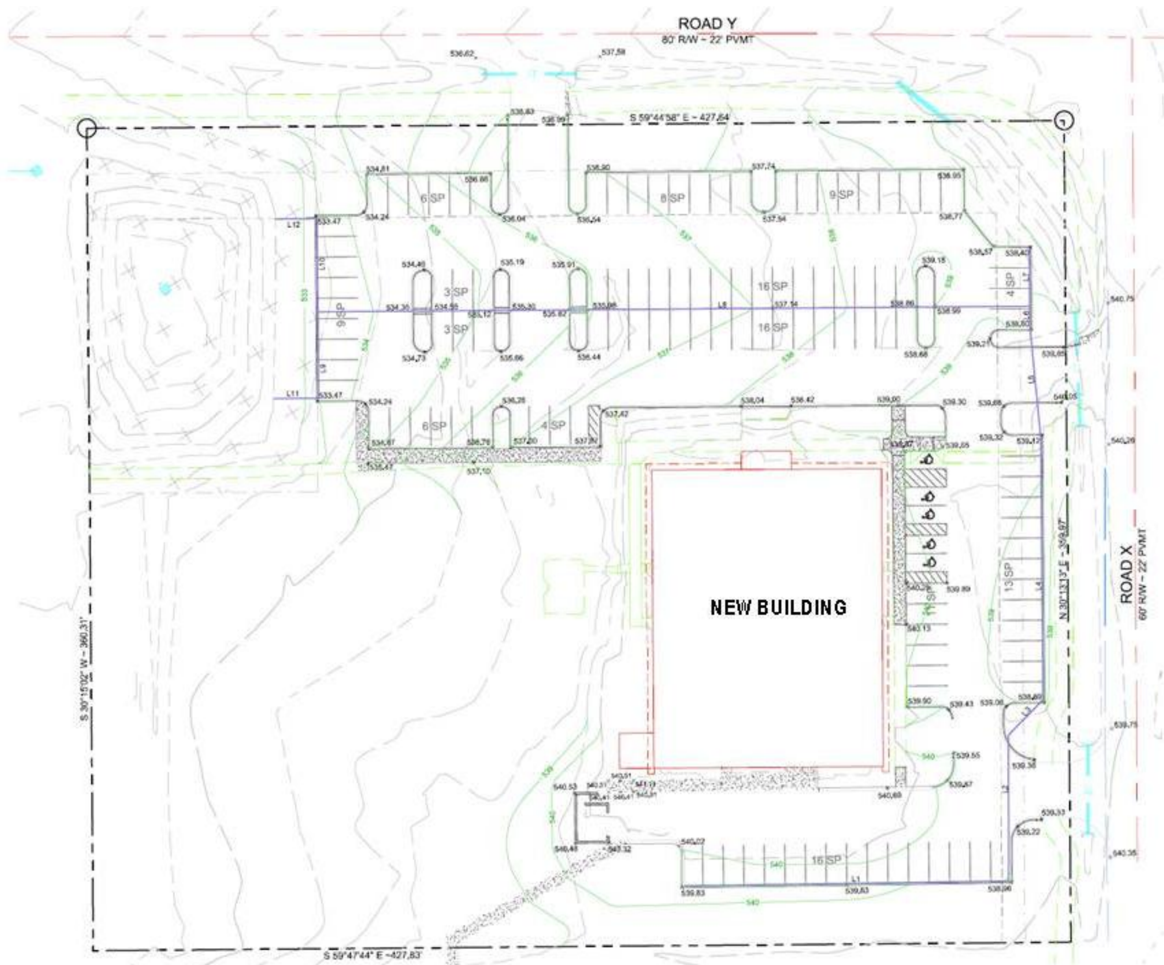
Prepare operations and maintenance plan based on the guidance given in the Maintenance Section.

Design Procedure

STEP 11 – Complete the Design Summary Table.

Design Parameter	Required Size	Actual Size
WQ_v		
Underdrain storage, Su		
Treatment area, Af		
Ponding depth		
Treatment area (LxW)		

Example Design



Proposed development of an undeveloped site into an office building and associated parking.

Base Data Total Drainage Area = 5 ac Site Area = 3.54 ac Soils Type "C" ***Pre-Development*** Impervious Area = 0 ac; or I = 0% Meadow (CN = 71) ***Post-Development*** Impervious Area = 1.72 ac; or I = 1.72/3.54 = 49% Open Space, Fair (CN = 79) Paved parking lots, roofs, driveways, etc. (CN =98)	**Hydrologic Data** Pre Post CN 71 89 **WQ_v Depth** = 1.1 in **Precipitation** 2yr, 24hr 3.54 in 25yr, 24hr 5.88 in 100yr, 24hr 7.43 in

Example Design

This example focuses on the design of a bioretention facility to meet the water quality treatment requirements of the site. In general, the primary function of bioretention is to provide water quality treatment and not large storm attenuation. As such, flows in excess of the water quality volume are typically routed to bypass the facility or non-erosively pass through the facility. Where quantity control is required, the bypassed flows can be routed to conventional detention basins (or some other facility such as underground storage vaults).

Problem: Design a water quality treatment plan for this site. A dry detention pond will be constructed to meet the required detention standards and will provide 60% TSS reduction for the site. The total drainage area to the pond is 5 ac. Include multiple bioretention systems in the landscape islands in the parking area to meet the water quality goal of 80% TSS reduction.

Step 1 – Make a preliminary judgment as to whether site conditions are appropriate for the use of a bioretention system, and identify the function of bioretention in the overall treatment system.

- Consider basic issues for initial suitability screening, including:
  - The site has type “C” soils
  - There are no minimum setbacks
  - There are active karst areas on the site. Bioretention systems will not be located close to the sinkhole.
- Determine how bioretention system will fit into the overall stormwater treatment system.
  - Bioretention systems will be constructed in combination with a dry detention pond for water quality and quantity control on the site. Design of the dry detention pond can be found in Section 4.8.
  - Landscaping islands in the parking lot are likely spaces for bioretention systems.
  - The treated water quality volume will be collected by an underdrain and routed to the dry pond located in the northwest corner of the site for water quantity control. Flows greater than the water quality volume will bypass the bioretention systems and be routed to the dry pond for water quantity control and treatment prior to discharging.

Step 2 – Confirm design criteria, site constraints, and applicability.

- The following minimum criteria will be used in the design.
  - Minimum 200 sq ft of surface area
  - Maximum 6 in ponding depth
  - Maximum 48hr drain time from peak water level
  - Minimum 8 in underdrain enveloped in a 12 in gravel layer
  - Minimum 3 ft separation from bottom to seasonally saturated soils
- Determine any constraints the site will place on the bioretention system:
  - Do not place bioretention near sinkhole

Example Design

- Ensure that stormwater runoff from impervious surfaces is being treated to the 80% TSS reduction standard.
  - Determining the weighted TSS reduction.

    Bioretention Systems have an 80% TSS reduction, and all stormwater runoff from impervious surfaces flow through one of three bioretention facilities. Therefore, a weighted TSS calculation is not necessary.
  - Determine the treatment train TSS reduction.

    After the water quality volume is treated by bioretention, it is then treated in the dry pond before leaving the site. Bioretention Systems have an 80% TSS reduction. Dry ponds have a 60% TSS reduction.

$$TSS_{train} = A + B - \frac{(A \times B)}{100}$$

Where:

A = 80%

B = 60%

$$TSS_{train} = 80 + 60 - \frac{(80 \times 60)}{100}$$

$$TSS_{train} = 92\%$$

Step 3 – Perform field verification of site suitability.

- The bioretention systems will be designed as filtration BMPs, with the full WQv discharging within 48 hrs through the underdrain. Therefore, the only field testing required is to determine the high water elevation under the BMP locations.

Field soil tests show the high water elevation to be 8 feet or more below the parking lot.

Step 4 – Compute runoff control volumes and peak flows.

- Calculate the Water Quality Volume (WQ_V), Peak Flow Volume (V_{P25}), and the Extreme Flood Volume (V_{P100}).

Total Water Quality Volume:

WQv = [*P Rv*)(*A*)]/12

Where:

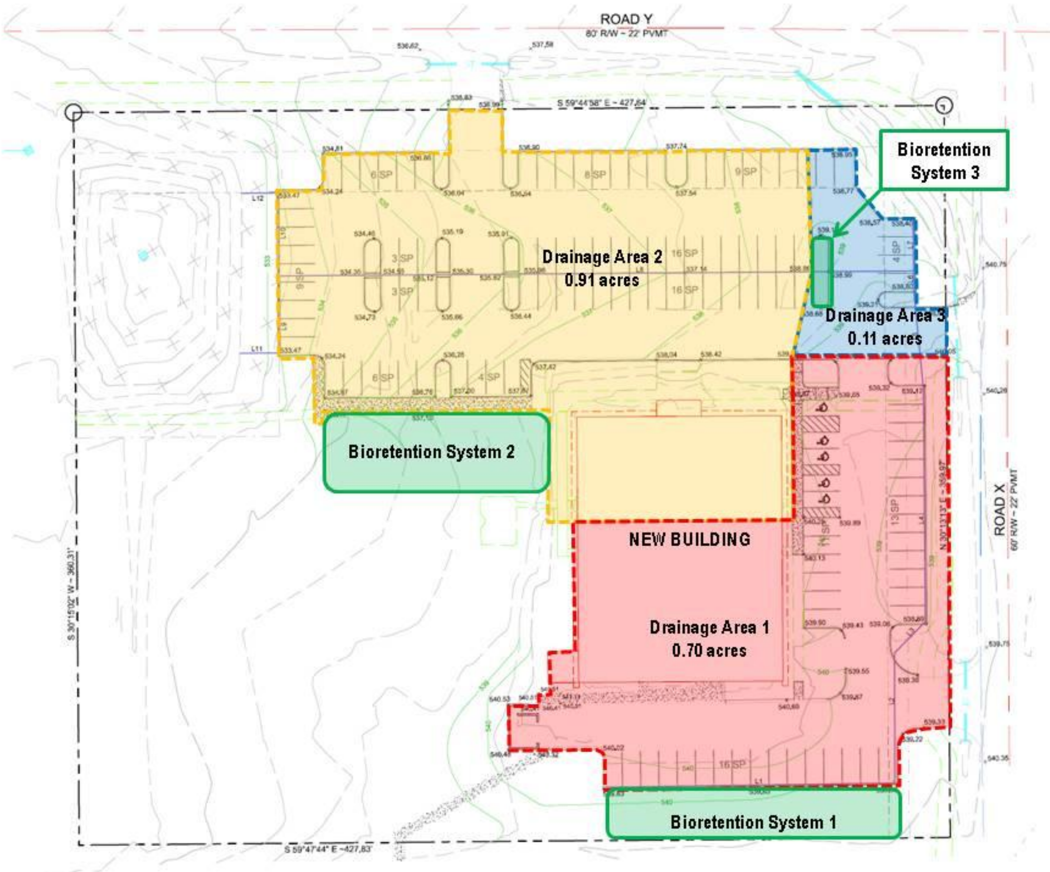
P = 1.1 inches
Rv = 0.05 + 0.009(I)
I = 49
Rv = 0.05 + 0.009(49) = 0.491
A = 1.72 acres

WQv = (1.1in x 0.491 x 1.72ac)/12 = 0.077 acre-ft = 3372 ft^3

Example Design

The pre- and post development volumes for both 25-yr and 100-yr 24-hour return frequency storms should be calculated to determine the required water quantity controls. See Appendix B for more information regarding detention and quantity design.

- Calculate the pre- and post-development peak flows for 25 yr (Q_{p25}) and 100 yr (Q_{p100}) storms for the design of flow diversions, outlet structures, and overflow structures.



Example Design

Note: Steps 5-8 are iterative

Step 5 – Determine bioretention type and size.

- Select type of bioretention basin
  - The bioretention system will treat the entire water quality volume.
  - The bioretention system will include an underdrain/collection system.
- Determine Water Quality Volume (WQ_V) for bioretention system.
  - Bioretention System 1
    - A_1 = 0.70 ac; I = 100; WQ_v = 3655 ft^3
  - Bioretention System 2
    - A_2 = 0.91 ac; I=100; WQ_v = 3452 ft^3
  - Bioretention System 3
    - A_3 = 0.11 ac; I=100; WQ_v = 417 ft^3
- Size Bioretention System With An Underdrain
  - Set ponding depth at 6 inches (h_f)
  - Set depth of the filter bed at 5 ft (d_f)
  - Design to drain in 48 hours (t_f)
  - Assume 35% storage (S_u) of WQ_v in underdrain gravel layer
  - Computed surface area
    - Bioretention System 1

      Assume Underdrain 70 ft long

      S_u = 0.35 x 70 ft x [0.5 x 1 ft x (8 ft +2 ft)] = 122.5 ft^3

      A_f = [(WQ_V - S_u) x d_f] / [k x (h_f + d_f) x t_f]

      = [(3655 ft^3 – 122.5 ft^3)x 5 ft] / [0.5 ft/day x (0.5 ft + 5 ft) x 2 days)

      = 3211 ft^2
    - Bioretention System 2

      Assume Underdrain 75 ft long

      S_u = 0.35 x 75ft x [0.5 x 1 ft x (8ft +2 ft)] = 131.25 ft^3

      A_f = [(WQ_V - S_u) x d_f] / [k x (h_f + d_f) x t_f]

      = [(3452 ft^3 – 131.25 ft^3)x 5 ft] / [0.5 ft/day x (0.5 ft + 5 ft) x 2 days)

      = 3019 ft^2

Example Design

- Bioretention System 3

  Assume Underdrain 25 ft long

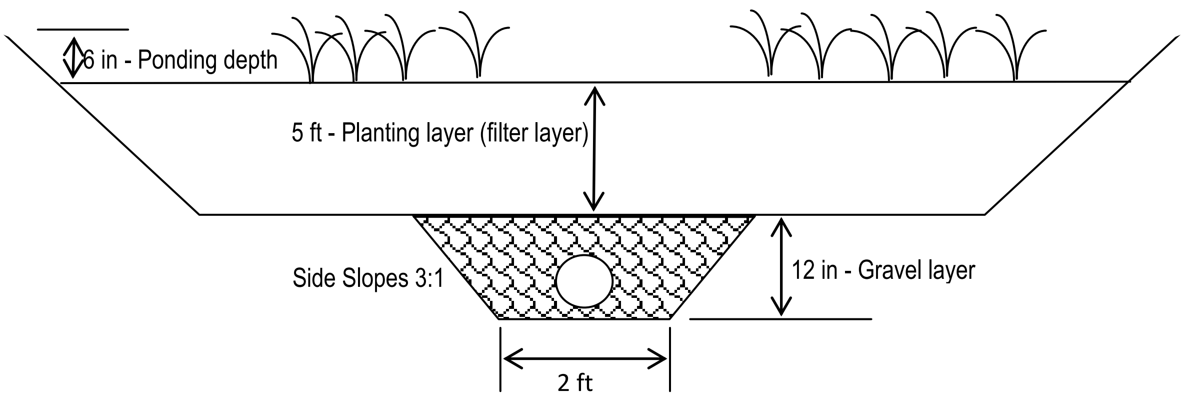
  S_u = 0.35 x 25 ft x [0.5 x 1 ft x (8 ft +2 ft)] = 43.75 ft^3

  A_f = [(WQ_V - S_u) x d_f] / [k x (h_f + d_f) x t_f]

  = [(417 ft^3 – 43.75 ft^3)x 5 ft] / [0.5 ft/day x (0.5 ft + 5 ft) x 2 days)

  = 339 ft^2

Bioretention System Cross Sectional View



- Determine Dimensions of Bioretention System
  - Bioretention System 1

    A_f = 3211 ft^2

    Length = 120 ft; Width = 27 ft
  - Bioretention System 2

    A_f = 3019 ft^2

    Length = 80 ft; Width = 40 ft
  - Bioretention System 3

    A_f = 339 ft^2

    Length = 30 ft; Width = 12 ft

STEP 7 – Size outlet structure and/or flow diversion structure, if needed.

- A secondary outlet should be designed for the bioretention systems to safely convey excess stormwater.
- Potential for erosion to stabilized areas and bioretention system should be evaluated and the design should incorporate ways to mitigate erosive flows.

Example Design

STEP 8 – Determine pre-treatment volume and design pre-treatment measures.

- Some form of pre-treatment is required prior to the discharge of stormwater into the bioretention system, to remove any sediment and fines that may result in clogging of the soils in the filtration area.
- Bioretention System 1 will use curb cuts with lips raised 2 inches above the pavement elevation.
- Bioretention System 2 will use a Grass Filter Strip that is sized based on the Table PTP10-1. The maximum inflow length of 205 feet and the filter strip slope is less than 2%. The grass filter strip should be 25 feet long. There will also be a gravel diaphragm prior to the grass filter strip as an additional pretreatment measure.
- Bioretention System 3 will use curb cuts with lips raised 2 inches above the pavement elevation.

STEP 9 – Prepare vegetation and landscaping plan

- Prepare vegetation and landscaping management plan based on the guidance given in the Landscaping Section.

STEP 10 – Prepare operations and maintenance plan

- Prepare operations and maintenance plan based on the guidance given in the Maintenance Section.

STEP 11 – Complete the Design Summary Table

Bioretention Area 1

Design Parameter	**Required Size**	**Actual Size**
WQ_v	3655 ft^3	
Underdrain storage, Su	122.5 ft^3	
Treatment area, Af	3211 ft^2	3240 ft^2
Ponding depth	6 inches	
Treatment area (LxW)	120' x 27'	

Example Design

Bioretention Area 2

Design Parameter	Required Size	Actual Size
WQ_v	3452 ft^3	
Underdrain storage, Su	131.5 ft^3	
Treatment area, Af	3019 ft^2	3200 ft^2
Ponding depth	6 inches	
Treatment area (LxW)	80’x40’	

Bioretention Area 3

Design Parameter	Required Size	Actual Size
WQ_v	417 ft^3	
Underdrain storage, Su	43.75 ft^3	
Treatment area, Af	339 ft^2	360 ft^2
Ponding depth	6 inches	
Treatment area (LxW)	30’x12’’	