Structural BMP Criteria

BMP #: Vegetated Filter Strip

The EPA defines a Vegetated Filter Strip as a "permanent, maintained strip of planted or indigenous vegetation located between nonpoint sources of pollution and receiving water bodies for the purpose of removing or mitigating the effects of nonpoint source pollutants such as nutrients, pesticides, sediments, and suspended solids."

Key Design Elements

- Sheet Flow across Vegetated Filter Strip
- Filter Strip length is a function of the slope, vegetated cover, and soil type.
- Minimum recommended length of Filter Strip is 25 ft, however shorter lengths provide some water quality benefits as well.
- Maximum Filter Strip slope is based on soil type and vegetated cover.
- Filter strip slope should never exceed 8%. Slopes less than 5% are generally preferred.
- Level spreading devices are recommended to provide uniform sheet flow conditions at the interface of the Filter Strip and the adjacent land cover.
- Maximum contributing drainage area slope is generally less than 5%, unless energy dissipation is provided.
- Filter strip width should always equal the width of the contributing drainage area.
- Construction of filter strip shall entail as little disturbance to existing vegetation at the site as possible.
- See Appendix XX for list of acceptable filter strip vegetation.

Potential Applications

Residential Subdivision:	**YES**
Commercial:	**YES***
Ultra Urban:	**LIMITED***
Industrial:	**LIMITED***
Retrofit:	**YES**
Highway/Road:	**YES**

** Depending on size and site constraints*

Stormwater Functions

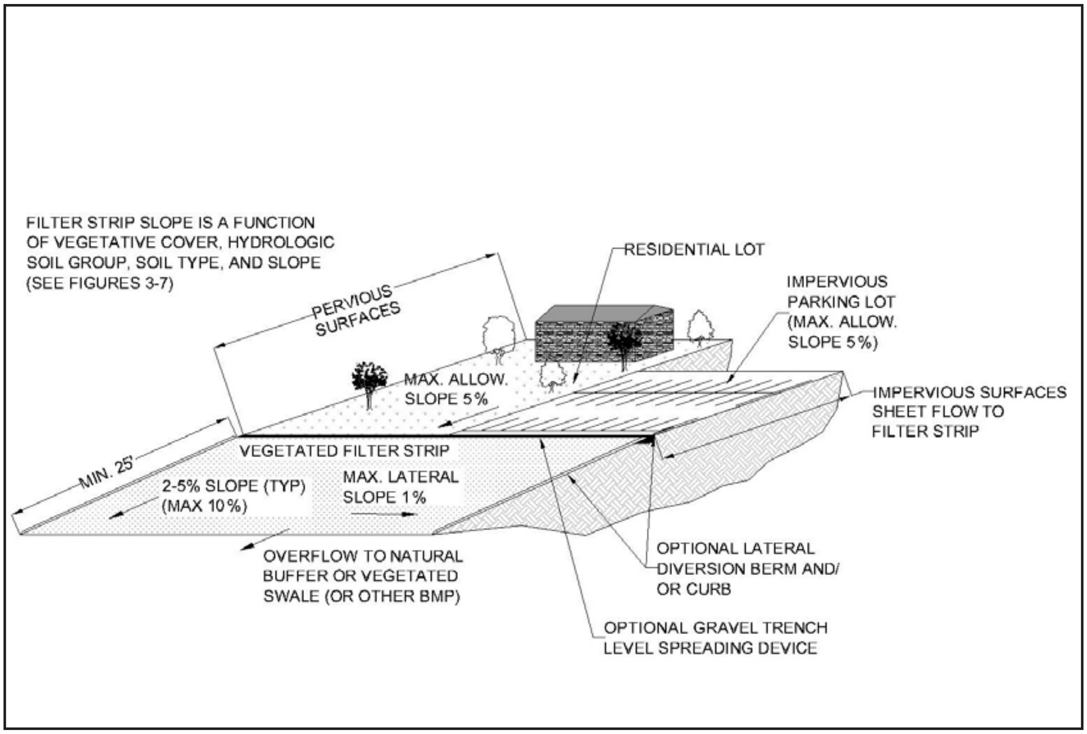
Volume Reduction:	**Low-Med**
Recharge:	**Low-Med**
Peak Rate Control:	**Low**
Water Quality:	**Medium**

Pollutant Removal

Total Suspended Solids:	**x**
Nutrients:	**x**
Metals:	**x**
Pathogens:	**x**

Other Considerations

- Regular Maintenance required for continued performance



Vegetated Filter Strip Application

Description

Filter strips are gently sloping, densely vegetated areas that filter, slow, and infiltrate sheet flowing stormwater. Filter strips are best utilized to treat runoff from roads and highways, roof down-spouts, small parking lots, and pervious surfaces. In highly impervious areas, they are generally not recommended as “stand alone” features, but as pretreatment systems for other BMPs, such as Infiltration Trenches or Bioretention Areas. Filter Strips are primarily designed to reduced TSS levels, however pollutant levels of hydrocarbons, heavy metals, and nutrients may also be re-duced. Pollutant removal mechanisms include sedimentation, filtration, absorption, infiltration, biological uptake, and microbial activity. Depending on hydrologic soil group, vegetative cover type, slope, and length, a filter strip can allow for a modest reduction in runoff volume through infiltration.

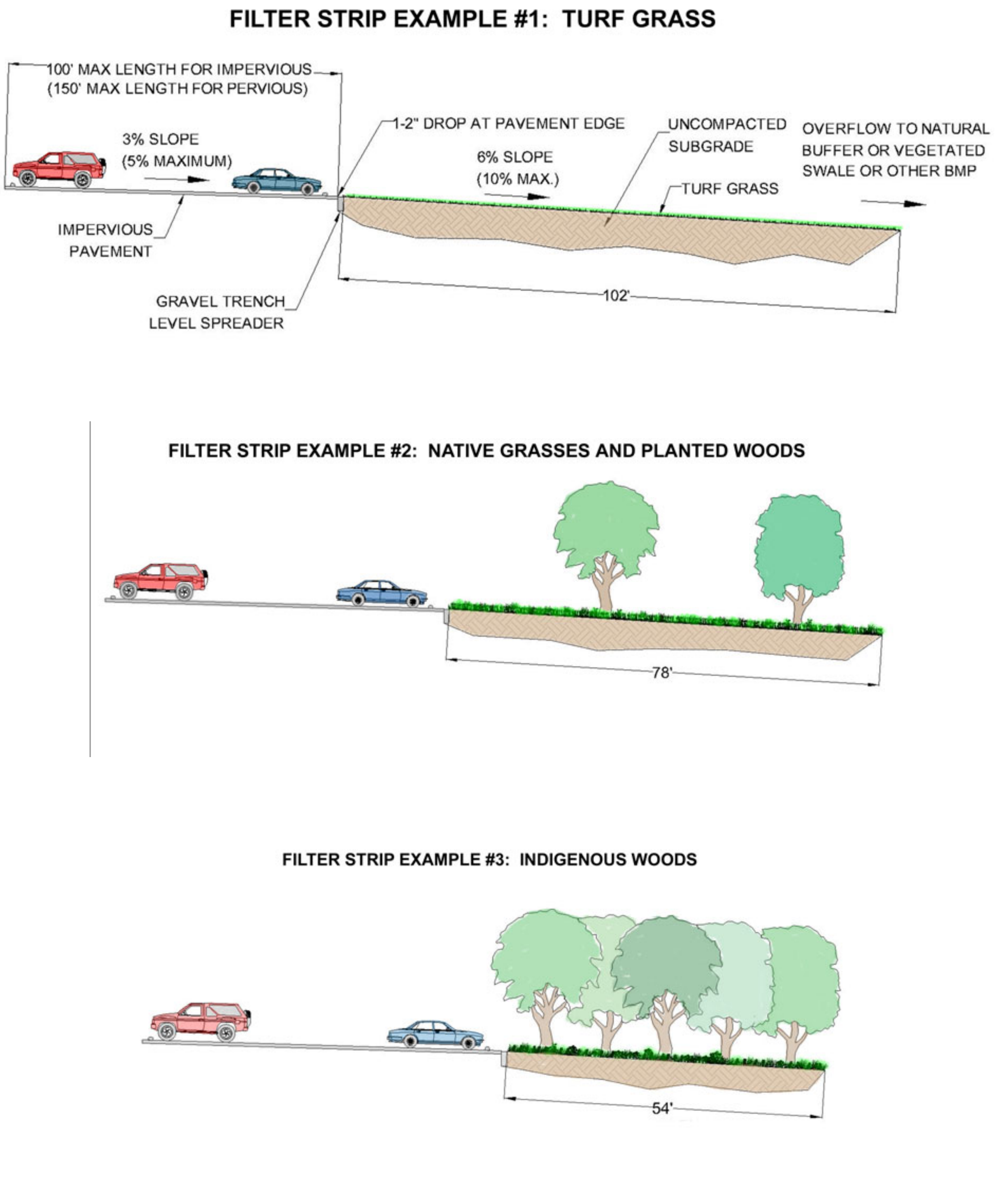
The vegetation for Filter Strips may be comprised of:

- Turf Grasses
- Meadow grasses, shrubs, and native vegetation, including trees
- Indigenous areas of woods and vegetation.

Filter strips may be comprised of a variety of trees, shrubs, and native vegetation to add aesthetic value as well as water quality benefits. The use of turf grasses will increase the required length of the filter strip, as compared to other vegetation options. The use of indigenous vegetated areas that have surface features that disperse runoff is encouraged, as the use of these areas will also reduce overall site disturbance and soil compaction. Runoff must be distributed so that erosive conditions cannot develop.

The vegetation in Filter Strips must be dense and healthy. Indigenous wooded areas should have a healthy layer of leaf mulch or duff. Indigenous areas that have surface features that concentrate flow are not acceptable.

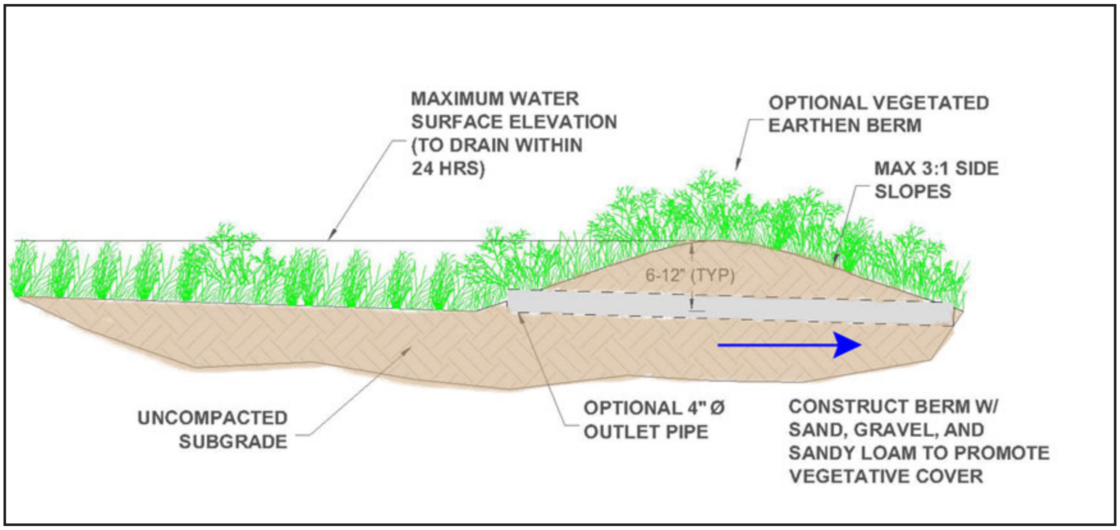
The following example shows three filter strips that vary only by cover type. Each strip is on type 'C' soils and has a slope of 6%. Using the recommended sizing approach, the filter strip covered with turf grass required a length of 102 ft, while the strip with indigenous woods required only 54ft. The strip covered with native grasses and some trees required 78ft.



Filter Strip Design Example (Hydrologic soil group 'C' and 6% slope)

Variations

Filter strip effectiveness may be enhanced through the addition of a pervious berm at the toe of the slope. A pervious berm allows for greater runoff velocity and volume reduction and thus better pollutant removal ability, by providing a temporary (very shallow) temporarily ponded area. The berm should have a height of not more than six to twelve inches and be constructed of sand, gravel, and sandy loam to encourage vegetative cover. An outlet pipe(s) or overflow weir should be provided and sized to ensure that the area drains within 24 hours, or to convey larger storm events. The berm must be erosion resistant under the full range of storm events. Likewise, the ponded area should be planted with vegetation that is resistant to frequent inundation.



Optional Earthen Berm at Toe of Filter Strip

Check dams may be implemented on filter strips with slopes exceeding 5%. Check dams shall be constructed of durable, non-toxic materials such as rock, brick, wood, not more than six inches in height, and placed at appropriate intervals to encourage ponding and prevent erosion.

Applications

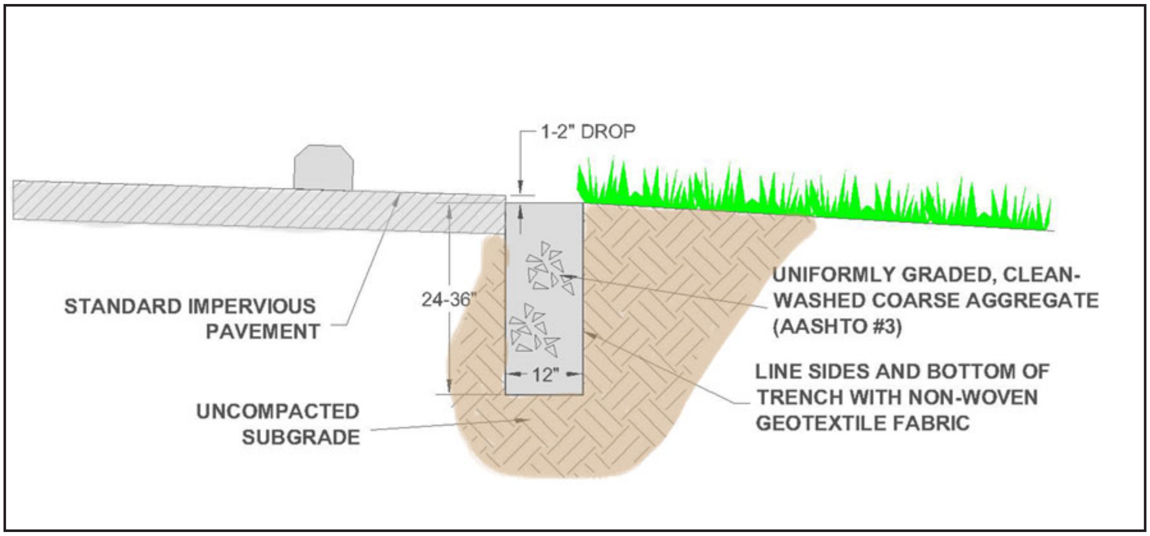
- Residential development lawn and housing areas
- Roads and highways
- Parking lots
- Pretreatment for other structural BMPs (Infiltration Trench, Bioretention, etc.)
- Commercial and light industrial facilities
- As part of a Riparian Buffer (located in Zone 3)

Design Considerations

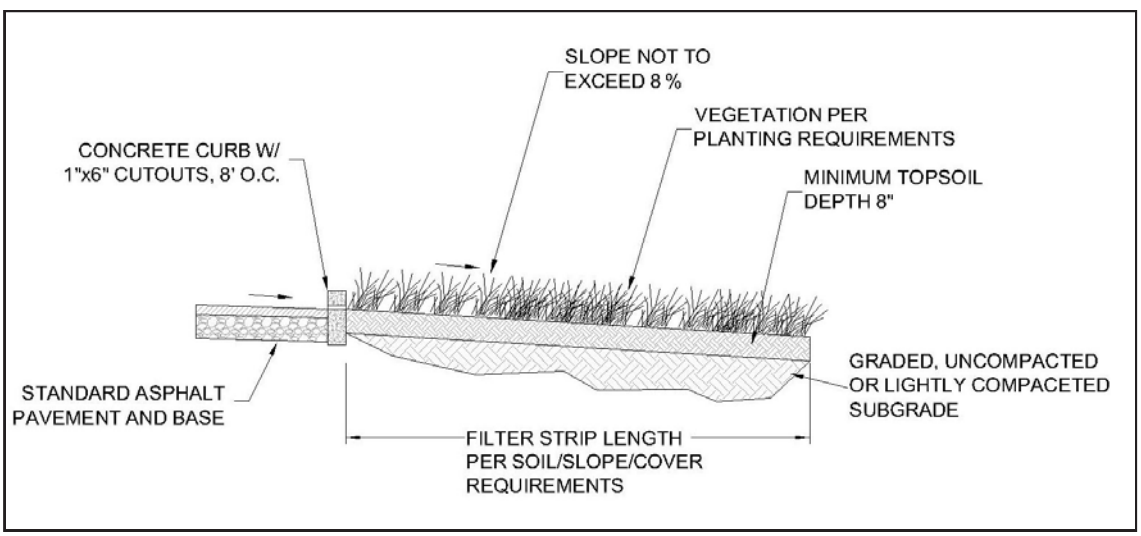
1. The design of vegetated filter strips is determined by site conditions (contributing drainage area, length, slope, etc.) site soil group, proposed cover type, and filter strip slope. The filter length can be determined from the appropriate graph (Figures #3-7).
2. Level spreading devices or other measures are required to provide uniform sheet flow conditions at the interface of the filter strip and the adjacent land cover. Concentrated flows are explicitly discouraged from entering filter strips, as they can lead to erosion and thus failure of the system. Examples of level spreader applications include:

a. A gravel-filled trench, installed along the entire upgradient edge of the strip. The gravel in the trenches may range from pea gravel (ASTM D 448 size no. 6, 1/8” to 3/8”) for most cases to shoulder ballast for roadways. Trenches are typically 12” wide, 24-36” deep, and lined with a non-woven geotextile. When placed directly adjacent to an impervious surface, a drop (between the pavement edge and the trench) of 1-2” is recommended, in order to inhibit the formation of the initial deposition barrier.
b. A concrete sill (or lip)
c. Curb stops
d. Slotted or depressed curbs
e. An earthen berm with optional perforated pipe.

3. Where possible, more “natural” spreader designs and materials, such as earthen berms, are generally recommended, though they can be more susceptible to failure due to irregularities in berm elevation and density of vegetation. When it is desired to treat runoff from roofs or curbed impervious areas, a more structural approach, such as a gravel trench, is required. In this case, runoff shall be directly conveyed, via pipe from downspout or inlet, into the subsurface gravel and uniformly distributed by a perforated pipe along the trench bottom.



Filter Strip with Gravel Trench Level Spreader



Filter Strip with Curb Cutout

4. The upstream edge of a filter strip should be level and directly abut the contributing drainage area.
5. The seasonal high water table must be at least 2 to 4 ft lower than the bottom of the filter strip.
6. In areas where the soil infiltration rate has been compromised (e.g. by excessive compaction), the filter strip shall be tilled prior to establishment of vegetation. However, tilling will only have an effect on the top 12-18in of the soil layer. Therefore, other measures, such as planting trees and shrubs, may be needed to provide deeper aeration. Deep root penetration will promote greater absorptive capacity of the soil.
7. The ratio of contributing drainage area to filter strip area shall never exceed 6:1.
8. The filter strip area shall be densely vegetated with a mix of salt- and drought- tolerant and erosion-resistant plant species. Filter strip vegetation, whether planted or indigenous, may range from turf and native grasses to herbaceous and woody vegetation. The optimal vegetation strategy consists of plants with dense growth patterns, a fibrous root system for stability, good regrowth ability (following dormancy and cutting), and adaptability to local soil and climatic conditions. Native vegetation is always preferred. (See Appendix XX for filter strip vegetation recommendations.)
9. Natural areas, such as forests and meadows, should never be unduly disturbed by the creation of a filter strip. If these areas are not already functional as natural filters, they may be enhanced by restorative methods or construction of a level spreader.
10. Maximum lateral slope of filter strip is 1%.
11. To prohibit runoff from laterally bypassing a strip, berms and/or curbs can be installed along the sides of the strip, parallel to the direction of flow.
12. Pedestrian and/or vehicular traffic on filter strips should be strictly discouraged. Since the function of filter strips can be easily overlooked or forgotten over time, a highly visible, physical “barrier” is suggested. This can be accomplished, at the discretion of the owner, by simple post and chain, signage, or even the level-spreading device itself.
13. Vegetated filter strips may be designed to discharge to a variety of features, including natural buffer areas, vegetated swales, infiltration basins, or other structural BMPs.
14. In cold climates, the following recommendations should be considered:
    a. Filter strips often make convenient areas for snow storage. Thus, filter strip vegetation should be salt-tolerant and the maintenance schedule should involve removal of sand build-up at the toe of the slope.
    b. The bottom of the gravel trench (if used as the level spreader) shall be placed below the frost line to prohibit water from freezing in the trench. The perforated pipe in the trench shall be at least 8in in diameter to further discourage freezing.
    c. Other water quality options may be explored to provide backup to filter strips during the winter, when their pollutant removal ability is reduced.

Required Length as a Function of Slope, Soil, Cover

Detailed Stormwater Functions

Volume Reduction Calculations:
To determine the volume reduction over the length of a filter strip the following equation is recommended: (draft format)

Filter Strip Volume Reduction = Filter Strip Area x Infiltration Rate x Storm Duration

When a berm is positioned at the toe of the slope, the total volume reduction shall be defined as the amount calculated above plus the following:

Berm Storage Volume = (Cross-sectional Area Behind Berm x Length of Berm) + (Surface Area Behind Berm x Infiltration Rate x 12 hours)

The inundated area behind the berm shall be designed to drain within 24 hours. An outlet pipe or overflow weir may be needed to provide adequate drain down. In that case, the infiltration volume behind the berm should be adjusted based on the invert of the overflow mechanism.

Peak Rate Mitigation Calculations:
See Section z/z in Section 8 for Peak Rate Mitigation methodology which addresses link between volume reduction and peak rate control.

Water Quality Improvement:
See Section a/a in Section 8 for Water Quality Improvement methodology which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Begin filter strip construction only when the upgradient site has been sufficiently stabilized and temporary erosion and sediment control measures are in place. (Erosion and sediment control methods shall adhere to the Pennsylvania Department of Environmental Protection's Erosion and Sediment Pollution Control Program Manual, March 2000 or latest edition.) The strip shall be installed at a time of the year when successful establishment without irrigation is most likely. However, temporary irrigation may be needed in periods of little rain or drought.
2. For planted (not indigenous Filter Strips) clear and grub site as needed. Care shall be taken to disturb as little existing vegetation as possible, whether in the designated filter strip area or in adjacent areas, and to avoid soil compaction. Grading a level slope may require removal of existing vegetation.
3. Rough grade the filter strip area, including the berm at the toe of the slope, if proposed. Only the lightest, least disruptive equipment may be used, to avoid excessive compaction and/or land disturbance.
4. Construct level spreader device at the upgradient edge of the strip. For gravel trenches, do not compact subgrade. (Follow construction sequence for Infiltration Trench.)
5. Fine grade the filter strip area. Accurate grading is crucial for filter strips. Even the smallest irregularities may compromise sheet flow conditions.
6. Seed or sod, as desired. Plant more substantial vegetation, such as trees and shrubs, if proposed. If sod is proposed, place tiles tightly enough to avoid gaps and stagger the ends to prevent channelization along the strip. Use a roller on sod to prevent air pockets between the sod and soil from forming.
7. Concurrent with #6, stabilize seeded filter strips with appropriate permanent soil stabilization methods, such as erosion control matting or blankets. Erosion control for seeded filter strips shall be required for at least the first 75 days following the first storm event of the season. (Erosion and sediment control methods shall adhere to the Pennsylvania Department of Environmental Protection's Erosion and Sediment Pollution Control Program Manual, March 2000 or latest edition.)
8. Once the filter strip is sufficiently stabilized, remove temporary erosion and sediment controls. It is very important that filter strip vegetation be fully established before receiving upland stormwater flow. One full growing season is the recommended minimum time for establishment.
9. Follow maintenance guidelines, as discussed below.

Note: When and if a filter strip is used for temporary sediment control, it must be regraded and reseeded immediately after construction and stabilization has occurred.

Maintenance Issues

As with other vegetated BMPs, filter strips must be properly maintained to ensure their effectiveness. In particular, it is critical that sheet flow conditions and infiltration are sustained throughout the life of the filter strip. Field observations of strips in more urban settings show that their effectiveness can deteriorate due to lack of maintenance, inadequate design/location, and poor vegetative cover. Compared with other vegetated BMPs, filter strips require only minimal maintenance efforts, many of which may overlap with standard landscaping demands.

Vegetated filter strip components that receive or trap sediment and debris shall be inspected for clogging, density of vegetation, damage by foot or vehicular traffic, excessive accumulations, and channelization. Inspections shall be made on a quarterly basis for the first two years following installation, and then on a biannual basis thereafter. Inspections shall also be made after every storm event greater than 1in. during the establishment period Guidance information, usually in written manual form, for operating and maintaining filter strips shall be provided to all facility owners and tenants. Facility owners are encouraged to keep an inspection log, where they can record all inspection dates, observations, and maintenance activities.

Sediment and debris shall be routinely removed (but never less than bi-annually), or upon observation, when buildup exceeds 2in in depth in either the strip itself or the level spreader. If erosion is observed, measures shall be taken to improve the level spreader or other dispersion method to address the source of erosion. Rills and gullies observed along the strip may be filled with topsoil, stabilized with erosion control matting, and either seeded or sodded, as desired. For channels less than 12in wide, filling with crushed gravel, which allows grass to creep in over time, is acceptable. For wider channels, i.e. greater than 12in, regrading and reseeding may be necessary. (Small bare areas may only require overseeding.) Regrading may also be required when pools of standing water are observed along the slope. (In no case shall standing water be tolerated for longer than 48-72 hours.) If check dams are proposed, they shall be inspected for cracks, rot, structural damage, obstructions, or any other factors that cause altered flow patterns or channelization. Inlets or sediment sumps that drain to filter strips shall be cleaned periodically or as needed.

Sediment shall be removed when the filter strip is thoroughly dry. Trash and debris removed from the site shall be deposited only at suitable disposal/recycling sites and must comply with applicable local, state, and federal waste regulations. In the case where a filter strip is used for sediment control, it shall be regraded and reseeded immediately after construction has concluded.

Maintaining a vigorous vegetative cover on a filter strip is critical for maximizing pollutant removal efficiency and erosion prevention. Grass cover shall be mowed, with low ground pressure equipment, as needed to maintain a height of 4-6in. Mowing shall be done only when the soil is dry, in order to prevent tracking damage to vegetation, soil compaction, and flow concentrations. Generally speaking, grasses should be allowed to grow as high as possible, but mowed frequently enough to avoid troublesome insects or noxious weeds. Fall mowing should be controlled to a grass height of 6in, to provide adequate wildlife winter habitat. When and where cutting is desired for aesthetic reasons, a high blade setting shall be used.

If vegetative cover is not fully established within the designated time, it shall be replaced with an alternative species. (It is standard practice to contractually require the contractor to replace dead vegetation.) Unwanted or invasive growth shall be removed on an annual basis. Biweekly inspections are recommended for at least the first growing season, or until the vegetation is permanently established. Once the vegetation is established, inspections of health, diversity, and density shall be performed at least twice per year, during both the growing and non-growing season. Vegetative cover should be sustained at 85% and reestablished if damage greater than 50% is observed. Whenever possible, deficiencies in vegetation are to be mollified without the use of fertilizers or pesticides. These treatment options, as well as any other methods used to achieve optimum vegetative health, may only be used under special circumstances and if they do not compromise the functionality of the filter strip.

Two other maintenance recommendations involve soil aeration and drain down time. If a filter strip exhibits signs of poor drainage and/or vegetative cover, periodic soil aeration may be required. In addition, depending on soil characteristics, the strip may require periodic liming. The design and maintenance plan of filter strips, especially those with flow obstructions such as berms and check dams, must specify the approximate time it should normally take for the system to “drain down” the maximum design storm runoff volume. Post-rainfall inspections shall include evaluations of the filter’s actual drain down time compared to the specified time. If significant differences (either increase or decrease) are observed, or if the 72 hour maximum time is exceeded, strip characteristics such as soils, vegetation, and groundwater levels must be reevaluated. Measures shall be taken to establish, or reestablish as the case may be, the specified drain down time of the system.

Cost Issues

The real cost of filter strips is the land they require. When unused land is readily available at a site, filter strips may prove a sensible and cost-effective approach. However, where land costs are at a premium (i.e. not readily available), this practice may prove cost-prohibitive in the end. The cost of establishing a filter strip itself is relatively minor. Of course, the cost is even less when an existing grass or meadow area is identified as a possible filter strip area before development begins.

The cost of filter strips includes grading, sodding (when applicable), installation of vegetation (trees, shrubs, etc.), the construction of a level spreader, and the construction of a pervious berm, if proposed. Depending on whether seed or sod is applied, not to mention enhanced vegetation use or design variations (such as check dams), construction costs may range anywhere from $0 (assuming the area was to be grassed regardless of use as treatment) to $50,000 per acre. The annual cost of maintaining filter strips (mowing, weeding, inspection, litter removal, etc.) generally runs from $100 to $1400 per acre and in fact, may overlap with standard landscape maintenance costs. Maintenance costs are highly variable, as they are a function of frequency and local labor rates.

Specifications:

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Seed** – See Appendix XX
2. **Sod** – See Appendix XX
3. **Topsoil** – See Appendix XX
4. **Vegetation** – See Appendix XX
5. **Erosion and Sediment** Control components shall conform to the Pennsylvania Department of Environmental Protection's Erosion and Sediment Pollution Control Program Manual, March 2000 or latest edition.

For a gravel trench level spreader:

6. **Pipe** shall be continuously perforated, smooth interior, high-density polyethylene (HDPE) with a minimum inside diameter of 8-inches. The pipe shall meet AASHTO M252, Type S or AASHTO M294, Type S. Acceptable manufactures include Hancor, Advanced Drainage Systems, and Lane.
7. **Stone** for infiltration trenches shall be 2-inch to 1-inch uniformly graded coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 3 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids ³ 35% as measured by ASTM-C29.
Pea gravel (clean bank-run gravel) may also be used. Pea gravel shall meet ASTM D 448 and be sized as per No.6 or 1/8" to 3/8".

8. **Non-Woven Geotextile** shall consist of needled non-woven polypropylene fibers and meet the following properties:

a. Grab Tensile Strength (ASTM-D4632) ³ 120 lbs
b. Mullen Burst Strength (ASTM-D3786) ³ 225 psi
c. Flow Rate (ASTM-D4491) ³ 95 gal/min/ft2
d. UV Resistance after 500 hrs (ASTM-D4355) ³ 70%
e. Heat-set or heat-calendared fabrics are not permitted

Acceptable types include Mirafi 140N, Amoco 4547, and Geotex 451.

For check dams:
9. If wood is desired, natural wood is preferred – black locust, red mulberry, cedars, catalpa, white oak, chestnut oak, black walnut
For pervious berms:
10. The berm shall have a height of 6-12in and be constructed of sand, gravel, and sandy loam to encourage grass cover. (Sand: ASTM C-33 fine aggregate concrete sand 0.02”-0.04”, Gravel: AASHTO M-43 ½” to 1”)

References and Additional Sources:

Structural BMP Criteria

BMP #: Infiltration Trench

An Infiltration Trench is a "leaky" pipe in a stone-filled trench with a level bottom. An Infiltration Trench may be used as part of a larger storm sewer system, such as a relatively flat section of storm sewer. Or it may serve as a stormwater system for a small area, such as a portion of a roof or a single catch basin. In all cases, an Infiltration Trench must be designed with a positive overflow.

Key Design Elements

- Continuously perforated pipe set at a minimum slope in a stone filled, level-bottomed trench
- Limited in width (3 to 8 feet) and depth of stone (6 feet max. recommended)
- Trench is wrapped in non-woven geotextile (top, sides, and bottom)
- Placed on uncompacted soils
- Minimum cover over pipe is 12-inches
- A minimum of 6" of topsoil is placed over trench and vegetated
- Positive Overflow always provided

Potential Applications

Residential Subdivision:	**YES**
Commercial:	**YES***
Ultra Urban:	**YES***
Industrial:	**YES***
Retrofit:	**YES**
Highway/Road:	**YES***

** With consideration of hotspots*

Stormwater Functions

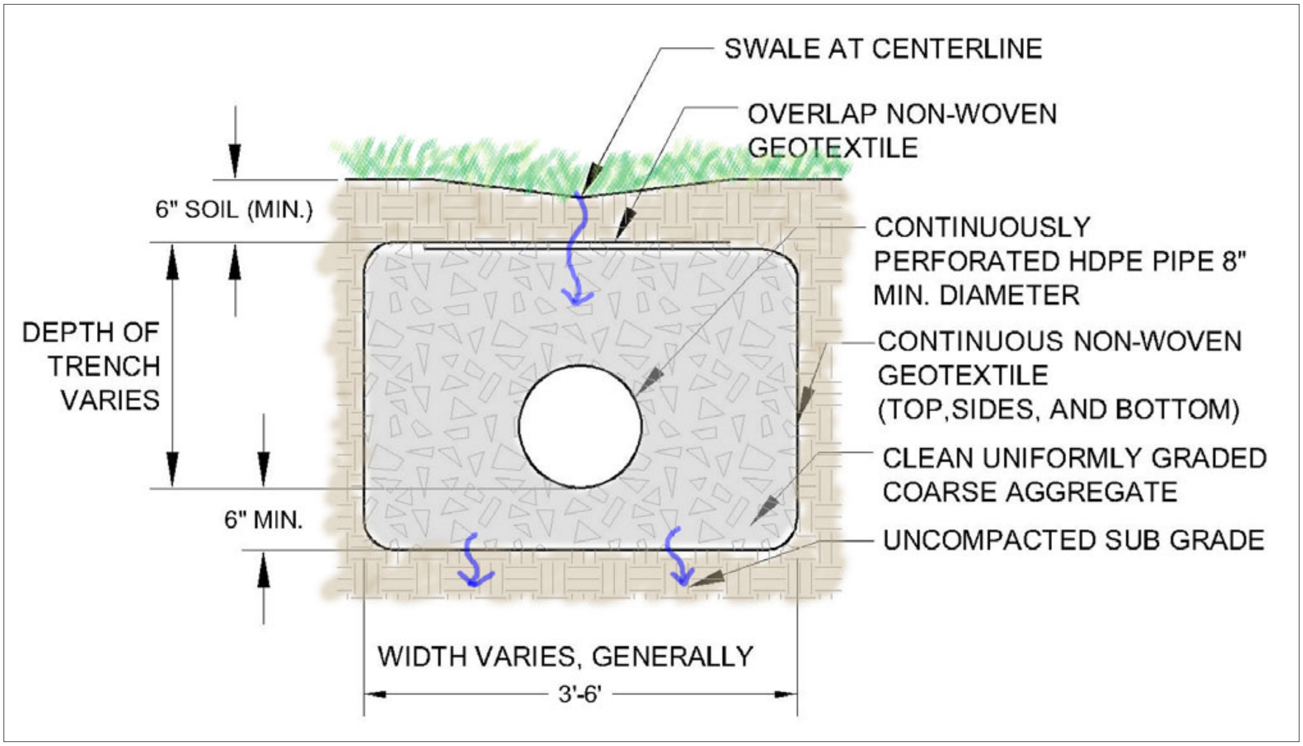
Volume Reduction:	**Medium**
Recharge:	**High**
Peak Rate Control:	**Medium**
Water Quality:	**High**

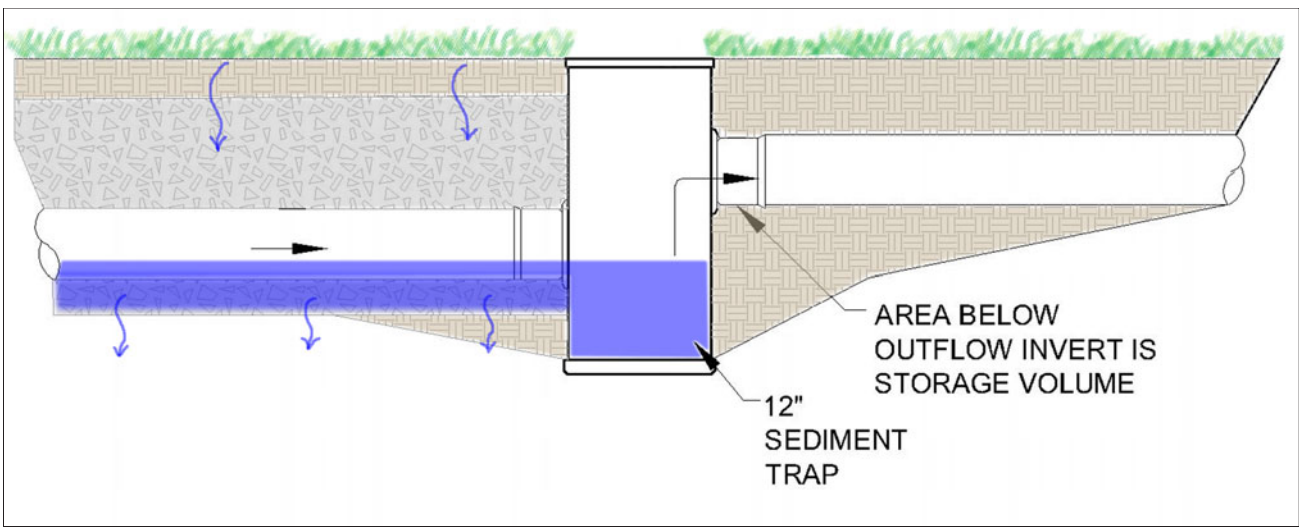
Other Considerations

- Soil Investigation Required
- Guidelines for Infiltration Systems Apply

Pollutant Removal

Total Suspended Solids:	**x**
Nutrients:	**x**
Metals:	**x**
Pathogens:	**x**





Description

An Infiltration Trench is a linear stormwater BMP consisting of a continuously perforated pipe at a minimum slope in a stone-filled trench. Usually an Infiltration Trench is part of a **conveyance system** and is designed so that large storm events are conveyed through the pipe with some runoff volume reduction. During small storm events, volume reduction may be significant and there may be little discharge. All Infiltration Trenches are designed with a **positive overflow**.

An Infiltration Trench differs from an Infiltration Bed in that it may be constructed without heavy equipment entering the trench. It is also intended to convey some portion of runoff in many storm events.

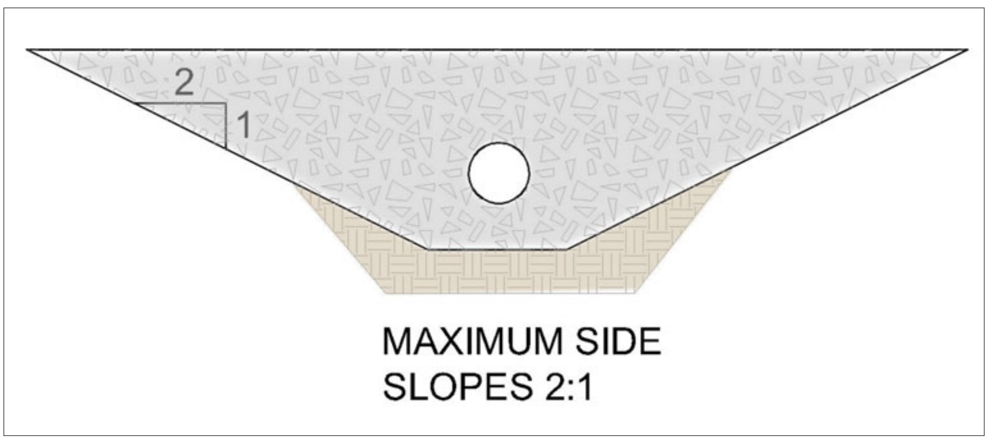
All Infiltration Trenches must be designed in accordance with the Guidelines for Infiltration Systems. Although the width and depth can vary, it is recommended that Infiltration Trenches be limited in depth to not more than six (6) feet of stone. This is due to both construction issues and Loading Rate issues (as described in the Guidelines for Infiltration Systems). Appropriate depth should be considered by the designer.

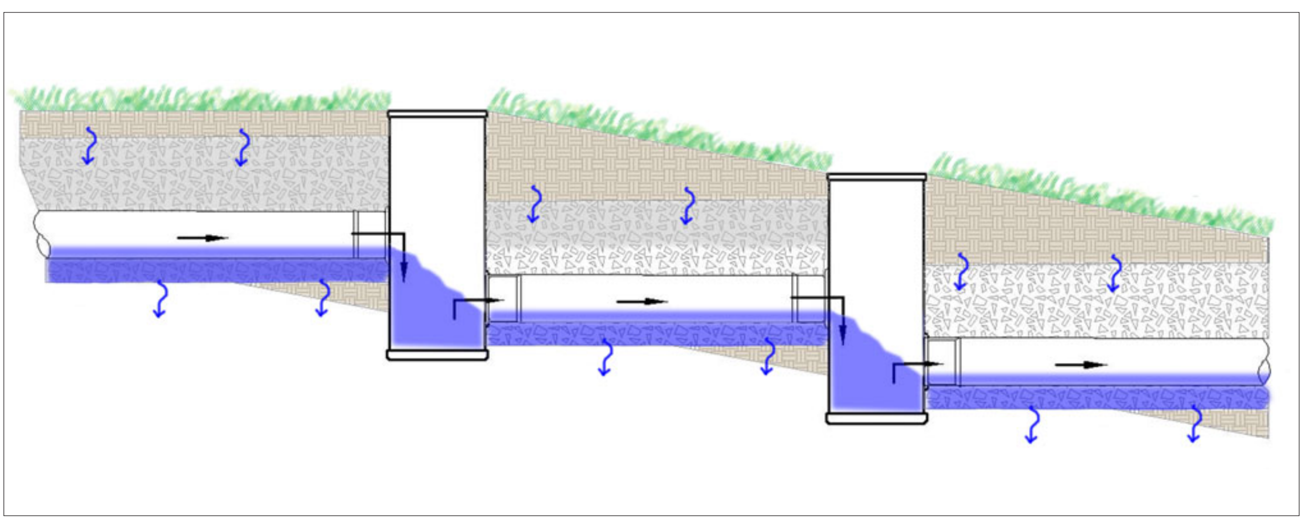
Variations

Infiltration Trenches generally have a vegetated (grassed) or gravel surface. Infiltration Trenches also may be located beneath or within roadways or impervious paved areas with proper design. The sub-surface drainage direction should be to the downhill side (away from sub-base of pavement), or located lower than the impervious subbase layer. Proper measures must be taken to prevent water infiltrating into the subbase of impervious pavement.

Infiltration Trenches may also be located down a mild slope by “stepping” the sections between control structures as shown in Figure x. A level or nearly level bottom is recommended for even distribution.

The side walls may be designed with a 2:1 slope as necessary for site or soil conditions.





Applications

- **Direct connection of Roof Leaders**

Roof Leaders may be directly connected to Infiltration Trenches. Roof Runoff generally has lower sediment levels and often is ideally suited for discharge through and Infiltration Trench. A cleanout with sediment sump must be provided between the building and Infiltration Trench.

- **Direct Connection of Inlets**

Catch Basins, inlets, and area drains may be connected to Infiltration Trenches, however, sediment/debris removal must be addressed. Structures should include a sediment trap area below the invert of the pipe for solids and debris. In areas of high traffic or areas where excessive sediment, litter, and other similar materials may be generated, a water quality insert is required.

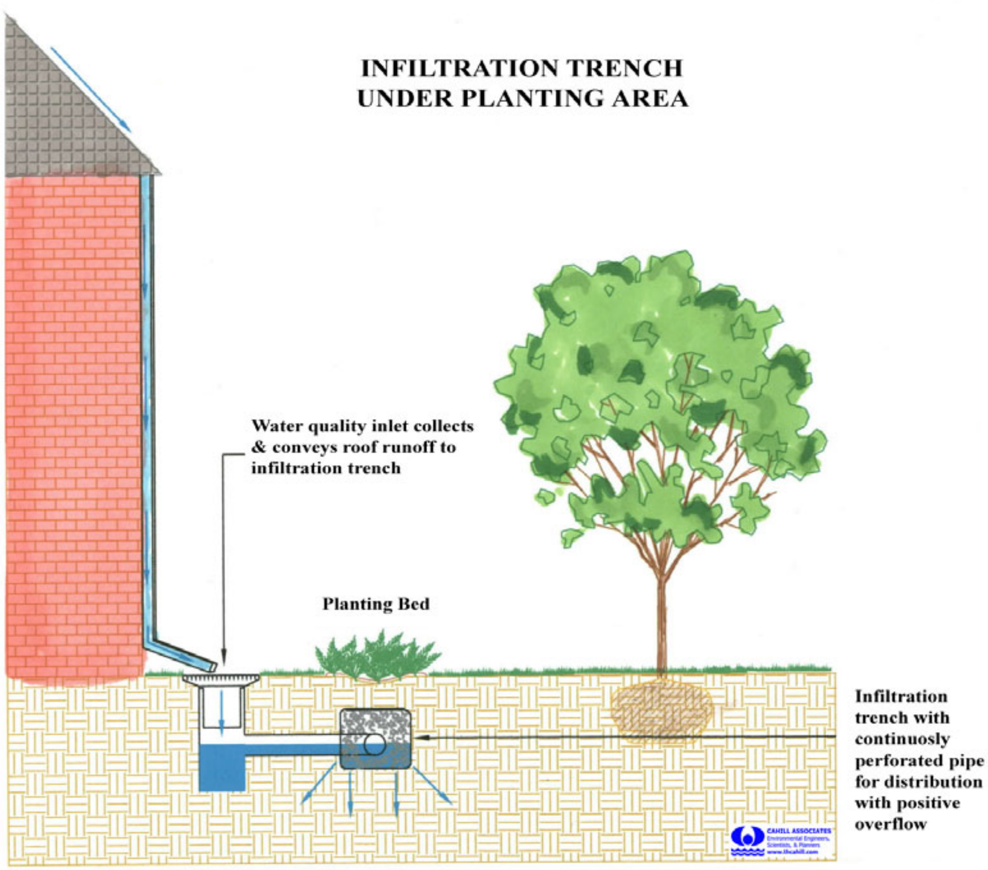


Figure __. Roof leaders connect to infiltration trench under planting area.

- **In Combination with Vegetative Filters**

An Infiltration Trench may be preceded by or used in combination with a Vegetative Filter, Grassed Swale, or other vegetative element used to reduce sediment levels from areas such as high traffic roadways. Design must ensure proper functioning of vegetative system.

- **Other Applications**

Other applications of Infiltration Trenches may be determined by the Design Professional as appropriate.

Design Considerations

1. Soil Investigation and Percolation Testing is required (see Section x/x)
2. Guidelines for Infiltration Systems must be met (i.e., depth to water table, setbacks, Loading Rates, etc. See Section x/x)
3. Water Quality Inlet or Catch Basin with Sump (see Sections x/x) required for all surface inlets, designed to avoid standing water for periods greater than 48 hours.
4. A continuously perforated pipe must extend the length of the trench and have a positive flow connection designed to allow high flows to be conveyed through the Infiltration Trench.
5. The slope of the Infiltration Trench bottom should be level or with a slope no greater than 1%. The Trench may be constructed as a series of "steps" if necessary. A level bottom assures even water distribution and infiltration.
6. Cleanouts or inlets must be installed at both ends of the Infiltration Trench and at appropriate intervals to allow access to the perforated pipe.
7. The discharge or overflow from the Infiltration Trench must be properly designed for anticipated flows.

Detailed Stormwater Functions

Infiltration Area:

The Infiltration Area is the bottom area of the Trench, defined as:

Length of Trench x Width of Trench = Infiltration Area (Bottom Area)

This is the area to be considered when evaluating the Loading Rate to the Infiltration Trench.

Volume:

The storage volume of the Infiltration Trench is defined as the area beneath the discharge invert. This is equal to:

Length x Width x Depth below invert x Void Ratio in Stone

The void ratio in stone is 40% for AASTO No 3. If the conveyance pipe is within the Storage Volume area, the volume of the pipe may also be included. All Infiltration Trenches should be designed to infiltrate or empty within 48 hours.

Peak Rate Mitigation Calculations:
See Section z/z in Section 8 for Peak Rate Mitigation methodology which addresses link between volume reduction and peak rate control..

Water Quality Improvement:
See Section a/a in Section 8 for Water Quality Improvement methodology which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Protect Infiltration Trench area from compaction prior to installation.
2. If possible, install Infiltration Trench during later phases of site construction to prevent sedimentation and/or damage from construction activity. After installation, protect sediment laden water from entering inlets and pipes.
3. Install and maintain proper Erosion and Sediment Control Measures during construction.
4. Excavate Infiltration Trench bottom to a uniform, level uncompacted subgrade free from rocks and debris. Do NOT compact subgrade.
5. Place non-woven geotextile along bottom and sides of trench. Non-woven geotextile rolls should overlap by a minimum of 24 inches within the trench. Fold back and secure excess geotextile during stone placement.
6. Install upstream and downstream Control Structures, cleanouts, etc.
7. Place uniformly graded, clean-washed aggregate in 6-inch lifts, lightly compacting between lifts.
8. Install Continuously Perforated Pipe as indicated on plans. Backfill with uniformly graded, clean-washed aggregate in 6-inch lifts, lightly compacting between lifts.
9. Fold and secure non-woven geotextile over Infiltration Trench, with minimum overlap of 12-inches.
10. Place 6-inch lift of approved Topsoil over Infiltration Trench, as indicated on plans.
11. Seed and stabilize topsoil.
12. Do not remove Inlet Protection or other Erosion and Sediment Control measures until site is fully stabilized.
13. Any sediment which enters inlets during construction is to be removed within 24 hours.

Installation of Infiltration Trench

(From left to right) Installation of Inlets and Control Sturcture; Non-woven Geotextile is folded over Infiltration Trench; Stabilized Site

Trench is excavated along existing roadway. Waterproofing is installed along subbase of existing roadway. Infiltration Trench is on downhill side of roadway. Infiltration Trench is Installed. Infiltration Trench is paved with standard pavement material.

Maintenance and Inspection Issues

- Catch Basins and Inlets should be inspected and cleaned on an annual basis.
- The vegetation along the surface of the Infiltration Trench should be maintained in good condition, and any bare spots immediately revegetated.
- Vehicles should not be parked or driven on a vegetated Infiltration Trench, and care should be taken to avoid excessive compaction by mowers.

Cost Issues

The construction cost of infiltration trenches can vary greatly depending on the configuration, location, site-specific conditions, etc. Typical construction costs in 2003 dollars range from $4 - $9 per cubic foot of storage provided (SWRPC, 1991; Brown and Schueler, 1997). Annual maintenance costs have been reported to be approximately 5 to 10 percent of the capital costs (Schueler, 1987).

Specifications:

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

<u>1. Stone</u> for infiltration trenches shall be 2-inch to 1-inch uniformly graded coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 3 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids ³ 35% as measured by ASTM-C29.

<u>2. Non-Woven Geotextile</u> shall consist of needled non-woven polypropylene fibers and meet the following properties:

a. Grab Tensile Strength (ASTM-D4632) ³ 120 lbs
b. Mullen Burst Strength (ASTM-D3786) ³ 225 psi
c. Flow Rate (ASTM-D4491) ³ 95 gal/min/ft^2
d. UV Resistance after 500 hrs (ASTM-D4355) ³ 70%
e. Heat-set or heat-calendared fabrics are not permitted

Acceptable types include Mirafi 140N, Amoco 4547, and Geotex 451.

<u>3. Topsoil</u>

<u>4. Pipe</u> shall be continuously perforated, smooth interior, with a minimum inside diameter of 8-inches. High-density polyethylene (HDPE) pipe shall meet AASHTO M252, Type S or AASHTO M294, Type S.

<u>5. Catch Basins/Inlet Boxes</u>

References and Additional Sources

BMP #: Constructed Wetlands

U.S. Fish and Wildlife Service, 2001

Constructed Wetlands are shallow marsh systems planted with emergent vegetation that are designed to treat stormwater runoff.

Key Design Elements

- Adequate drainage area (usually 5 to 10 acres minimum)
- Maintenance of permanent water surface
- Multiple vegetative growth zones through varying depths
- Robust and diverse vegetation
- Relatively impermeable soils or engineered liner
- Sediment collection and removal
- Adjustable permanent pool and dewatering mechanism

Potential Applications

Residential Subdivision:	**YES**
Commercial:	**YES**
Ultra Urban:	**LIMITED**
Industrial:	**YES**
Retrofit:	**YES**
Highway/Road:	**YES**

Stormwater Functions

Volume Reduction:	**Low**
Recharge:	**Low**
Peak Rate Control:	**High**
Water Quality:	**High**

Pollutant Removal

Total Suspended Solids:	**x**
Nutrients:	**x**
Metals:	**x**
Pathogens:	**x**

Figure 1. Demonstration Constructed Wetlands in Arizona (http://ag.arizona.edu/AZWATER/arroyo/094wet.html)

Description

Constructed Wetlands are shallow marsh systems planted with emergent vegetation that are designed to treat stormwater runoff. While they are one of the best BMPs for pollutant removal, Constructed Wetlands (CWs) can also mitigate peak rates and even reduce runoff volume to a certain degree. They also can provide considerable aesthetic and wildlife benefits. CWs use a relatively large amount of space and require an adequate source of inflow to maintain the permanent water surface.

Variations

Constructed Wetlands can be designed as either an online or offline facilities. They can also be used effectively in series with other flow/sediment reducing BMPs that reduce the sediment load and equalize incoming flows to the CW. Constructed Wetlands are a good option for retrofitting existing detention basins. CWs are often organized into four groups:

- Shallow Wetlands are large surface area CWs that primarily accomplish water quality improvement through displacement of the permanent pool.
- Extended Detention Shallow Wetlands are similar to Shallow Wetlands but use extended detention as another mechanism for water quality and peak rate control.
- Pocket Wetlands are smaller CWs that serve drainage areas between approximately 5 and 10 acres and are constructed near the water table.
- Pond/Wetland systems are a combination of a wet pond and a constructed wetland.

Although this BMP focuses on surface flow Constructed Wetlands as described above, subsurface flow CWs can also be used to treat stormwater runoff. While typically used for wastewater treatment, subsurface flow CWs for stormwater may offer some advantages over surface flow wetlands, such as improved reduction of total suspended solids and oxygen demand. They also can reduce the risk of vectors (especially mosquitoes) and safety risks associated with open water. However, nitrogen removal may be deficient (Campbell and Ogden, 1999). Perhaps the biggest disadvantage is the relatively low treatment capacities of subsurface flow CWs – they are generally only able to treat small flows. For more information, please consult the “References and Additional Resources” list.

Applications

- **Alternating bands of deeper water and shallow marsh.**

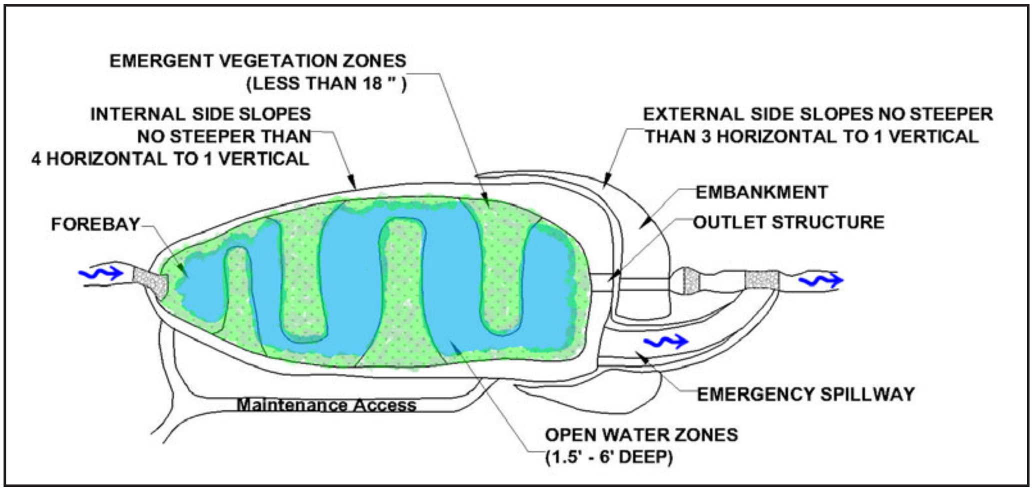


Figure 2. "Banded Bathymetric" Constructed Wetland (Auckland pp 6-10).

- **Wet Pond/Wetland System**

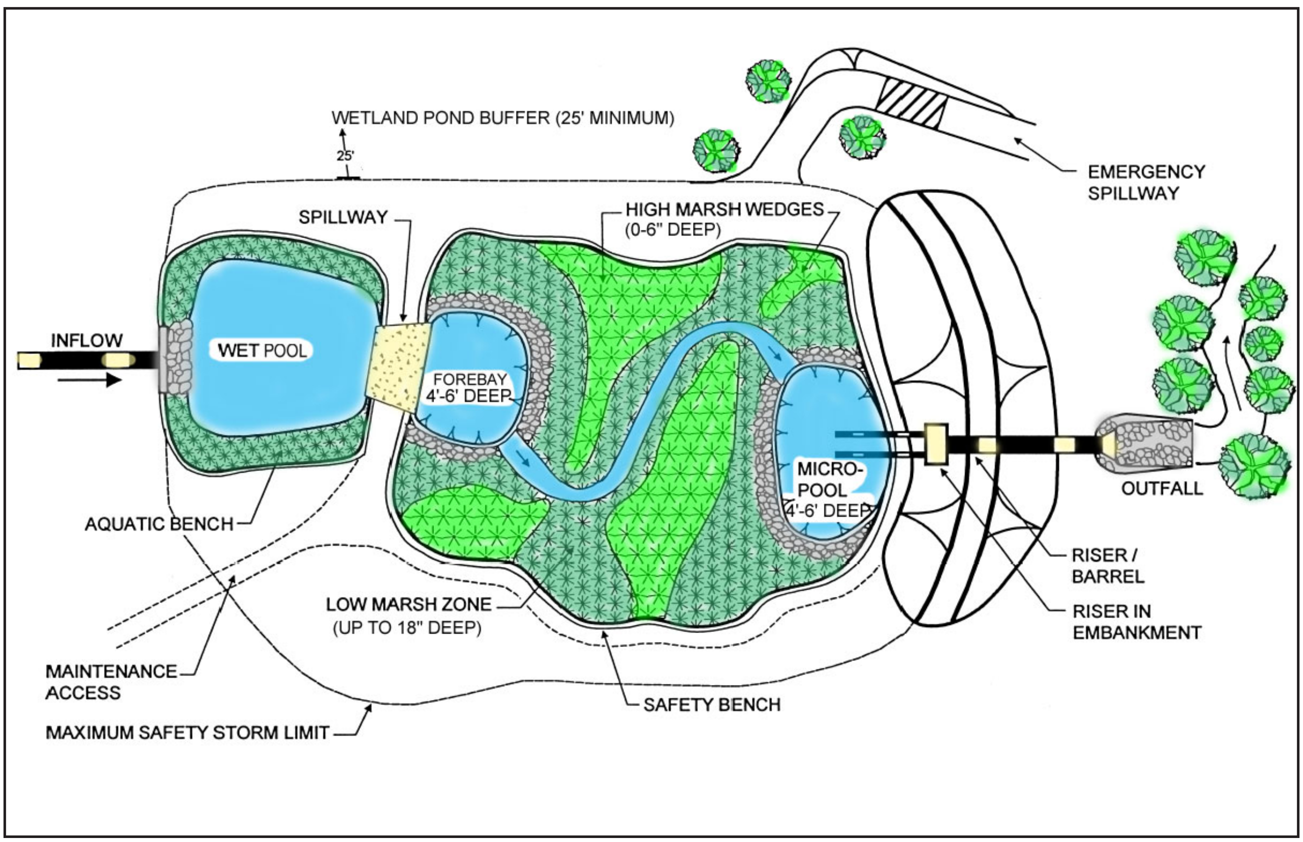
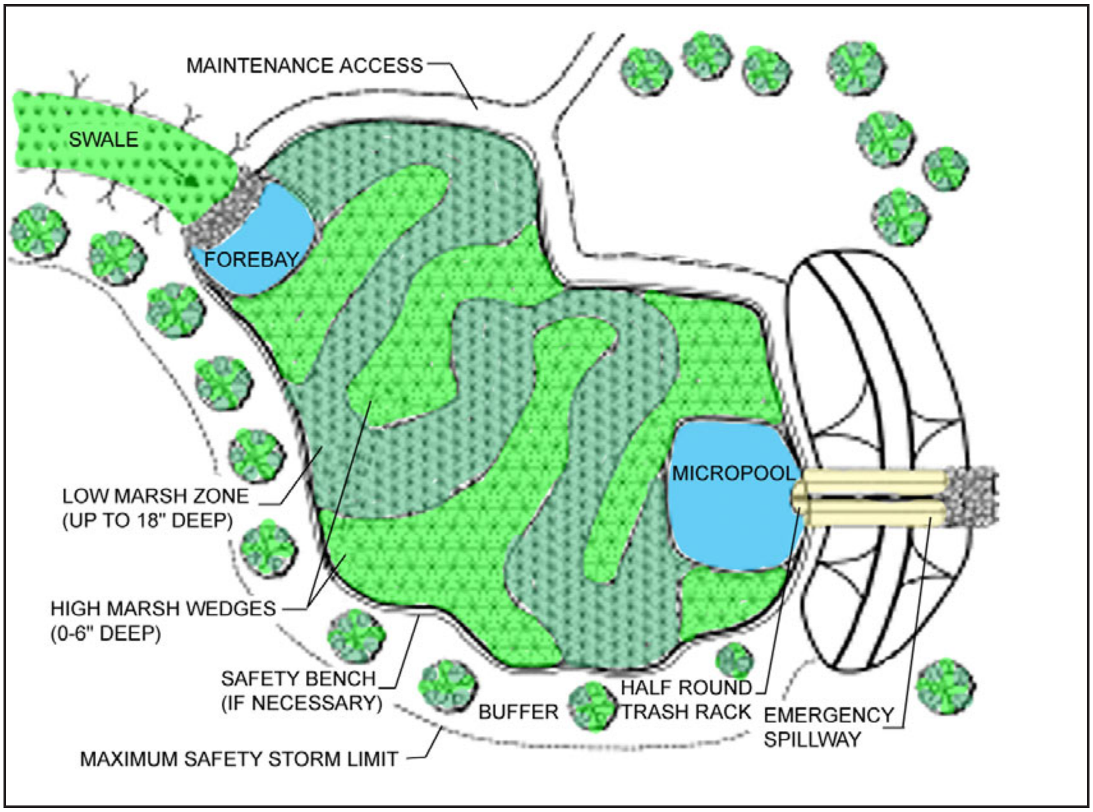


Figure 3. Pond/Wetland System (Maryland pp 3.19).

- **Pocket Wetland**



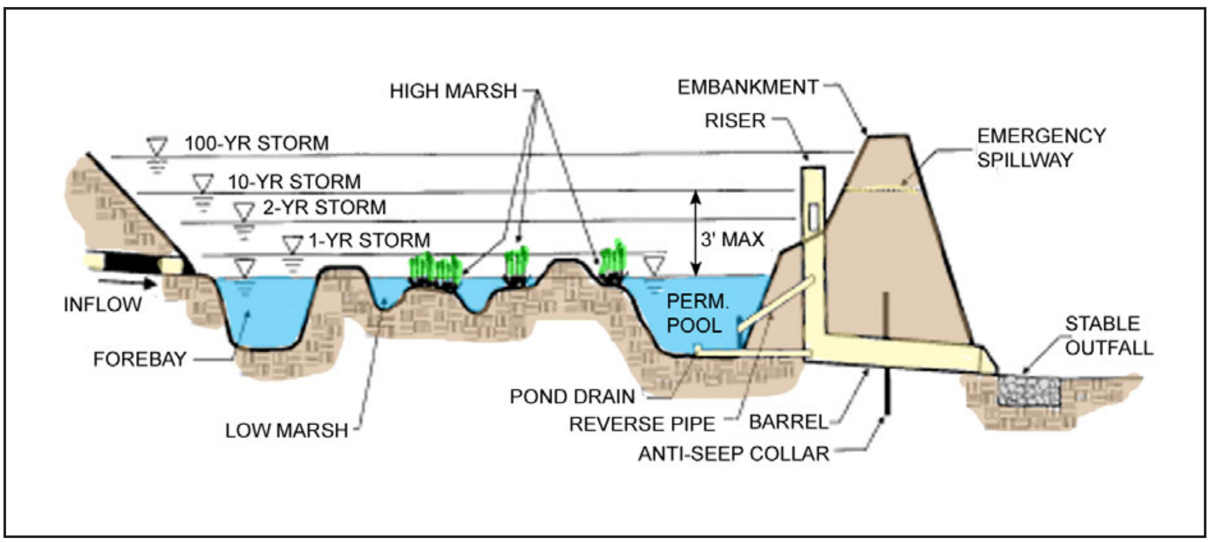


Figure 4. Pocket Wetland (Georgia Vol. 2, Section 20-3-2-2).

- **Offline Constructed Wetland**
- **Retrofit for existing detention basins**

Figure 5. Constructed Wetland Created from an Existing Detention Basin (Tredyffrin Twp., PA)

Design Considerations

1. HYDROLOGY. Constructed Wetlands must be able to receive and retain enough flow from rain, runoff, and groundwater to ensure long-term viability. Hydrologic calculations (or a water balance) should be performed to verify this. Shallow marsh areas can become dry at the surface but not for greater than one month, even in the most severe drought. A permanent water surface in the deeper areas of the CW should be maintained during all but the driest periods. A relatively stable normal water surface elevation will reduce the stress on wetland vegetation. A CW must have a drainage area of at least 10 acres (5 acres for “pocket” wetlands) or some means of sustaining constant inflow. Even with a large drainage area, a constant source of inflow can improve the biological health and effectiveness of a Constructed Wetland. Pennsylvania’s precipitation is generally well distributed throughout the year and is therefore suited for CWs.

Example of stabilized inflow channel during construction.

2. UNDERLYING SOILS. Underlying soils must be identified and tested. Generally hydrologic soil groups “C” and “D” are suitable without modification, “A” and “B” soils may require a clay or synthetic liner. Soil permeability must be tested in the proposed Constructed Wetland location to ensure that excessive infiltration will not cause the CW to dry out. If necessary, CWs should have a highly- compacted subsoil or an impermeable liner to minimize infiltration.
3. PLANTING SOIL. Organic soils should be used for Constructed Wetlands. Organic soils can serve as a sink for pollutants and generally have high water holding capacities. They will also facilitate plant growth and propagation and may hinder invasion of undesirable species.
4. SIZE AND VOLUME. The area required for a CW is generally 3 to 5 percent of its drainage area. CWs should be sized to treat the water quality volume and, if necessary, to mitigate the peak rates for larger events.
5. VEGETATION. Vegetation is an integral part of a Wetland system. Vegetation may help to reduce flow velocities, promote settling, provide growth surfaces for beneficial microbes, uptake pollutants, prevent resuspension, provide filtering, limit erosion, prevent short-circuiting, and maintain healthy bottom sediments (Braskerud, 2001). Constructed Wetlands should have several different zones of vegetation as described in Table 5-X. The emergent vegetation zone (areas not more than 18” deep) should comprise about 60 to 65 percent of the normal water surface area, although recommendations in recent literature range from less than 50 to over 80 percent.

Table 5-X

Vegetation Zone	**Description**
Open Water	Areas between 18 inches and 6 feet deep
Emergent Vegetation	Areas up to 18 inches deep, contains the majority of aquatic vegetation
Low Marsh	Portion of Emergent Vegetation Zone between 6 and 18 inches deep
High Marsh	Portion of Emergent Vegetation Zone up to 6 inches deep
Ephemeral Storage	Area that is periodically inundated during runoff events
Buffer	Area outside of maximum water surface area

Example of recently planted constructed wetland.

Robust, non-invasive, perennial plants that establish quickly are ideal for CWs. The designer should select species that are tolerant of a range of depths, inundation periods, etc. Monoculture planting must be avoided due to the risk from pests and disease. See Appendix X for recommended plant lists.

6. CONFIGURATION.

a. General. Constructed Wetlands should be designed with a length to width ratio of at least 2:1 wherever possible. If the length to width ratio is lower, the flow pathway through the CW should be maximized. CWs should not be constructed within 10 feet of the property line or within 50 feet of a private well or septic system. CWs should be designed so that the 10-year water surface elevation does not exceed the normal water surface elevation by more than 3 feet. Slopes in and around Constructed Wetlands should be 4:1 to 5:1 (horizontal:vertical) whenever possible.

b. Forebay/Inflows. Constructed Wetlands should have a forebay at all major inflow points to capture coarse sediment, prevent excessive sediment accumulation in the remainder of the CW, and minimize erosion by inflow. The forebays should contain 10 to 15 percent of the total permanent pool volume and should be 4 to 6 feet deep (at least as deep as other open water areas). They should be physically separated from the rest of the wetland by a berm, gabion wall, etc. Flows exiting the forebay must be non-erosive to the newly constructed CW. Vegetation within forebays can increase sedimentation and reduce resuspension/erosion. The forebay bottom can be hardened to facilitate sediment removal. Forebays should be installed with permanent vertical markers that indicate sediment depth. Inflow channels should be fully stabilized. Inflow pipes can discharge to the surface or be partially submerged. CWs must be protected from the erosive force of the inflow.

c. Vegetation and Open Water Zones. About half of the emergent vegetation zone should be high marsh (up to 6” deep) and half should be low marsh (6” to 18” deep). Varying depths throughout the CW can improve plant diversity and health. The open water zone (approx. 35 to 40% of the total surface area) should be between 18 inches and 6 feet deep. Allowing a limited 5-foot deep area can prevent short-circuiting by encouraging mixing, enhance aeration of water, prevent resuspension, minimize thermal impacts, and limit mosquito growth. Alternating areas of emergent vegetation zone (up to 18 inches deep) and open water zone – as shown in Figures 2 and 4 – can also minimize short-circuiting and hinder mosquito propagation.

d. Outlet. Outlet control devices should be in open water areas 4 to 6 feet deep comprising about 5 percent of the total surface area to prevent clogging and allow the CW to be drained for maintenance. Outlet devices are generally multi-stage structures with pipes, orifices, or weirs for flow control. Orifices should be at least 2.5 inches in diameter and should be protected from clogging. Outlet devices should be installed in the embankment for accessibility. It is recommended that outlet devices enable the normal water surface to be varied. This allows the water level to be adjusted (if necessary) seasonally, as the CW accumulates sediment over time, if desired grades are not achieved, or for mosquito control. The outlet pipe should generally be fitted with an anti-seep collar. Online facilities should have an emergency spillway that can safely pass the 100-year storm with 1 foot of freeboard. All outflows should be conveyed downstream in a safe and stable manner.

e. Safety Benches. All areas that are deeper than 4 feet should have two safety benches, each 4 to 6 feet wide. One should be situated about 1 to 1.5 feet above the normal water elevation and the other 2 to 2.5 feet below the water surface.

7. CONSTRUCTED WETLAND BUFFER. To enhance habitat value, visual aesthetics, and wetland health, a 25-foot buffer should be added from the maximum water surface elevation. The buffer should be planted with trees, shrubs, and native ground covers. Existing trees within the buffer should be preserved. If soils in the buffer will become compacted during construction, soil

restoration should take place to aid buffer vegetation.
8. MAINTENANCE ACCESS. Permanent access must be provided to the forebay, outlet, and embankment areas. It should be at least 9 feet wide, have a maximum slope of 15%, and be stabilized for vehicles.
9. PLAN ELEMENTS. The plans detailing the Constructed Wetlands should clearly show the CW configuration, elevations and grades, depth/vegetation zones, and the location, quantity, and propagation methods of wetland/buffer vegetation. Plans should also include site preparation techniques, construction sequence, as well as maintenance schedules and requirements.
10. REGULATION. Constructed Wetlands that have drainage areas over 100 acres, embankments greater than 15 feet high, or a capacity greater than 50 acre-feet may be regulated as a dam by PADEP (see Title 25, Chapter 105 of the Pennsylvania Code). Once established, CWs may be regulated as Wetlands.

Detailed Stormwater Functions

Volume Reduction Calculations:
Although not typically considered a volume-reducing BMP, Constructed Wetlands can achieve some volume reduction through infiltration and evapotranspiration, especially during small storms. Hydrologic calculations that should be performed to verify that the CW will have a viable amount of inflow can also predict the water surface elevation under varying conditions. The volume stored between the predicted water level and the lowest outlet elevation will be removed from the storm that occurs under those conditions.

Peak Rate Mitigation Calculations:
Peak rate is primarily controlled in Constructed Wetlands through the transient storage above the normal water surface. See Section z/z in Section 8 for Peak Rate Mitigation methodology.

Water Quality Improvement:
Constructed Wetlands improve runoff quality through settling, filtration, uptake, chemical and biological decomposition, volatilization, and adsorption. CWs are effective at removing many common stormwater pollutants including suspended solids, heavy metals, total phosphorus, total nitrogen, toxic organics, and petroleum products. The pollutant removal effectiveness varies by season and may be affected by the age of the CW. It has been suggested that CWs do not remove nutrients in the long term unless vegetation is harvested because captured nutrients are released back into the water by decaying plant material. Even if this is true, nutrients are generally released gradually and during the non-growing season when downstream susceptibility is generally low (Hammer, 1990). See Section a/a in Section 8 for Water Quality Improvement methodology which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Separate wetland area from contributing drainage area:
   a. All channels/pipes conveying flows to the CW must be routed away from the CW area until it is completed and stabilized.
   b. The area immediately adjacent to the CW must be stabilized in accordance with the PADEP's Erosion and Sediment Pollution Control Program Manual (2000 or latest edition) prior to construction of the CW.

2. Clearing and Grubbing:
   a. Clear the area to be excavated of all vegetation.
   b. Remove all tree roots, rocks, and boulders.
   c. Fill all stump holes, crevices and similar areas with impermeable materials.

3. Excavate bottom of CW to desired elevation (Rough Grading).

4. Install surrounding embankments and inlet and outlet control structures.

5. Grade and compact subsoil.

6. Apply and grade planting soil.
   a. Matching design grades is crucial because aquatic plants can be very sensitive to depth.

7. Apply geo-textiles and other erosion-control measures.

8. Seed, plant and mulch according to Planting Plan

9. Install any anti-grazing measures, if necessary.

10. Follow required maintenance and monitoring guidelines.

Installation of Clay Liner

Maintenance Issues

Constructed Wetlands must have a maintenance plan and privately owned facilities should have an easement, deed restriction, or other legal measure to prevent neglect or removal. During the first growing season, vegetation should be inspected every 2 to 3 weeks. During the first 2 years, CWs should be inspected at least 4 times per year and after major storms (greater than 2 inches in 24 hours). Inspections should access the vegetation, erosion, flow channelization, bank stability, inlet/outlet conditions, and sediment/debris accumulation. Problems should be corrected as soon as possible. Wetland and buffer vegetation may require support – watering, weeding, mulching, replanting, etc. – during the first 3 years. Undesirable species should be removed and desirable replacements planted if necessary.

Once established, properly designed and installed Constructed Wetlands should require little maintenance. They should be inspected at least biannually and after major storms as well as rapid ice breakup. Vegetation should maintain at least an 85 percent cover of the emergent vegetation zone. Annual harvesting of vegetation may increase the nutrient removal of CWs; it should generally be done in the summer so that there is adequate re-growth before winter. Care should be taken to minimize disturbance, especially of bottom sediments, during harvesting. The potential disturbance from harvesting may outweigh its benefits unless the CW receives a particularly high nutrient load or discharges to a nutrient sensitive waterbody. Sediment should be removed from the forebay before it occupies 50 percent of the forebay, typically every 3 to 7 years.

Cost Issues

The construction cost of Constructed Wetlands can vary greatly depending on the configuration, location, site-specific conditions, etc. Typical construction costs in 2004 dollars range from approximately $30,000 to $65,000 per acre (USEPA Wetlands Fact Sheet, 1999). Costs are generally most dependent on the amount of earthwork and the planting. Annual maintenance costs have been reported to be approximately 2 to 5 percent of the capital costs although there is very little data available to support this.

Specifications:

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Excavation**
   a. The area to be used for the CW should be excavated to the required depth below the desired bottom elevation to accommodate any required impermeable liner, organic matter, and/or planting soil.
   b. The compaction of the subgrade and/or the installation of any impermeable liners will follow immediately.
2. **Subsoil Preparation**
   a. Subsoil shall be free from hard clods, stiff clay, hardpan, ashes, slag, construction debris, petroleum hydrocarbons, or other undesirable material. Subsoil must not be delivered in a frozen or muddy state.
   b. Scarify the subsoil to a depth of 8 to 10 inches with a disk, rototiller, or similar equipment.
   c. Roll the subsoil under optimum moisture conditions to a dense seal layer with four to six passes of a sheepsfoot roller or equivalent. The compacted seal layer shall be at least 8 inches thick.
3. **Impermeable Liner**
   a. If necessary, install impermeable liner in accordance with manufacturer's guidelines.
   b. Place a minimum 12 inches of subsoil on top of impermeable liner in addition to planting soil.
4. **Planting Soil (Topsoil)**
   a. See Appendix X for general Planting Soil requirements.
   b. Use a minimum of 12 inches of topsoil in marsh areas of the Wetland. If natural topsoil from the site is to be used it must have at least 8 percent organic carbon content (by weight) in the A-horizon for sandy soils and 12% for other soil types.
   c. If planting soil is being imported it should be made up of equivalent proportions of organic and mineral materials.

   d. Lime should not be added to planting soil unless absolutely necessary as it may encourage the propagation of invasive species.
   e. The final elevations and hydrology of the wetland zones should be evaluated prior to planting to determine if grading or planting changes are required.
5. **Vegetation**
   a. Plant Lists for CWs can be found in Appendix X. No substitutions of specified plants will be accepted without prior approval of the designer. Planting locations shall be based on the Planting Plan and directed in the field by a qualified wetland ecologist.
   b. All wetland plant stock shall exhibit live buds or shoots. All plant stock shall be turgid, firm, and resilient. Internodes of rhizomes may be flexible and not necessarily rigid. Soft or mushy stock shall be rejected. The stock shall be free of deleterious insect infestation, disease and defects such as knots, sun-scald, injuries, abrasions, or disfigurement that could adversely affect the survival or performance of the plants.
   c. All stock shall be free from invasive or nuisance plants or seeds such as those listed in Appendix X.
   d. During all phases of the work, including transport and onsite handling, the plant materials shall be carefully handled and packed to prevent injuries and desiccation. During transit and on-site handling, the plant material shall be kept from freezing and shall be kept covered, moist, cool, out of the weather, and out of the wind and sun. Plants shall be watered to maintain moist soil and/or plant conditions until accepted.
   e. Plants not meeting these specifications or damaged during handling, loading, and unloading will be rejected.
   f. Detailed planting specifications can be found in Appendix X.

6. **Outlet Control Structure**
   a. Outlet control structures shall be constructed of non-corrodible material.
   b. Outlets shall be resistant to clogging by debris, sediment, floatables, plant material, or ice.
   c. Materials shall comply with applicable specifications (PennDOT or AASHTO, latest edition)

References and Additional Sources

Structural BMP Criteria

BMP #: Filters

Filters are structures or excavated areas containing a layer of sand, compost, organic material, peat, or other filter media that reduce pollutant levels in stormwater runoff by filtering sediments, metals, hydrocarbons, and other pollutants.

Key Design Elements

- Sized to treat Water Quality Volume
- Drain down – should empty within 48-72 hrs
- Minimum permeability of filtration medium required
- Minimum depth of filtering medium = 18"
- Perforated pipes (4" min) in stone
- May be designed to collect and convey filtered runoff down-gradient
- May be designed to infiltrate
- Pretreatment for debris and sediment may be needed
- Must be sized for drainage area
- Regular inspection and maintenance required

Other Considerations

- Certain applications may warrant spill containment
- Guidelines for Infiltration Systems apply if designed with Infiltration
- Soil Investigation Required if designed with Infiltration

Potential Applications

Residential Subdivision:	**LIMITED**
Commercial:	**YES**
Ultra Urban:	**YES**
Industrial:	**YES**
Retrofit:	**YES**
Highway/Road:	**YES**

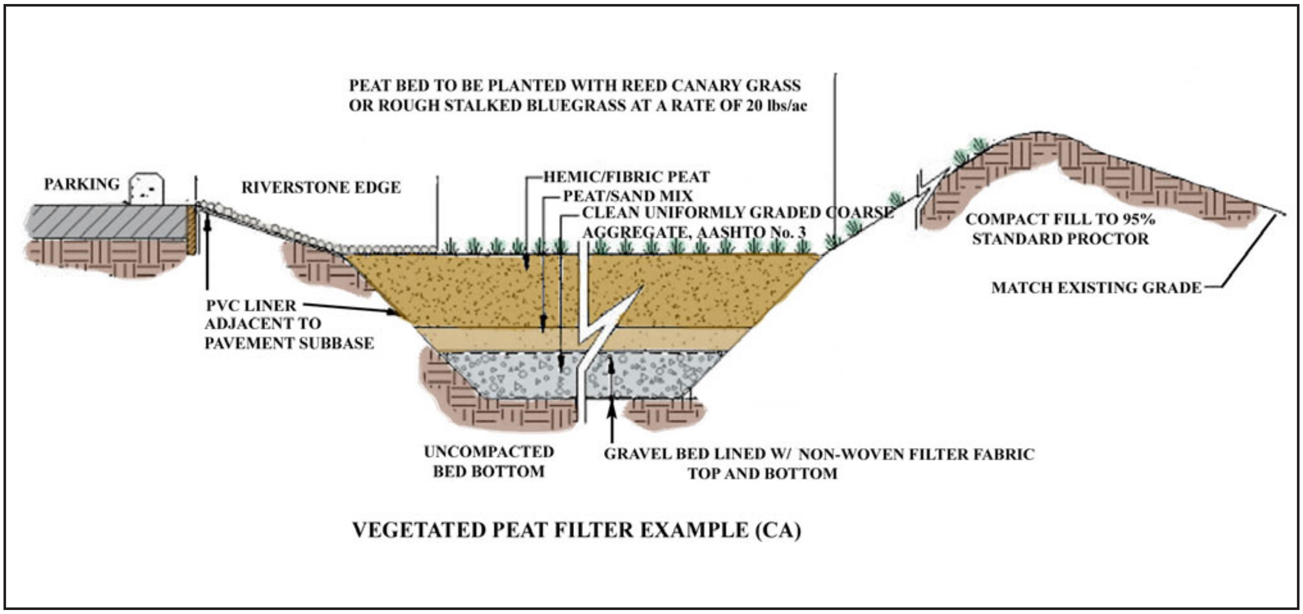
Stormwater Functions

Volume Reduction:	**Low-Med***
Recharge:	**Low-Med***
Peak Rate Control:	**Low**
Water Quality:	**High**

**If Infiltration Used*

Pollutant Removal

Total Suspended Solids:	**x**
Nutrients:	**x**
Metals:	**x**
Pathogens:	**x**



Description

A stormwater filter is a structure or excavation filled with material and designed to filter stormwater runoff to improve water quality. The filter media may be comprised of materials such as sand, peat, compost, granular activated carbon (GAC), perlite, or other material. In some applications the stormwater runoff flows through an open air, "pre-treatment" chamber to allow the large particles and debris to settle out (sedimentation). Surface vegetation is another good option for pretreatment. The runoff then passes through the filter media where smaller pollutants are filtered out, and is collected in an under-drain and returned to the conveyance system, receiving waters or infiltrated into the soil mantle.

Variations

There are a wide variety of Filter Applications, including surface and sub-surface, vegetated, perimeter, infiltration, and others. There are also a variety of filter products that may be purchased. Examples of these variations include:

Surface Non-vegetated Filter

A Surface Non-vegetated Filter is constructed by excavation or by use of a structural container. The surface may be covered in sand, peat, gravel, river stone, or similar material.

Figure 1. Surface Sand and Peat Filters (U of MN, NERC)

Vegetated

A layer of vegetation is planted on top of the filtering medium. Plants may be placed directly in filtering material such as peat. For filters composed of filtering media such as sand (where topsoil is required for vegetation) a layer of non-woven, permeable geotextile should separate the topsoil and vegetation from the filter media.

Figure 2. Vegetated Peat Filter, Carlisle, PA

Infiltration

Filters may be designed to allow some portion of the treated water to infiltrate. Infiltration Design Criteria apply for all Filters designed with infiltration. In all cases, a positive overflow system is recommended.

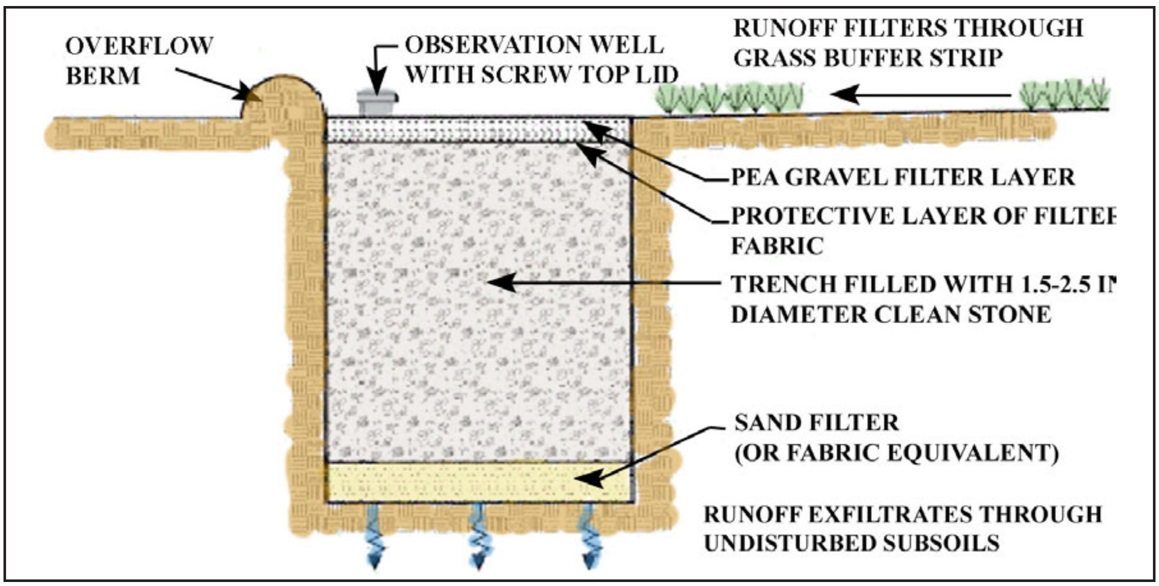


Figure 3. Combination Filter and infiltration (CA – Lehigh example)

Contained

In contained Filters, infiltration is not incorporated into the design. Contained Filters may consist of a physical structure, such as a precast concrete box. For excavated filters, an impermeable liner is added to the bottom of the excavation to convey the filtered runoff downstream.

Figure 4. Contained Filter, (Portland, OR BMP manual)

Linear "Perimeter" Filters

Perimeter Filters may consist of enclosed chambers (such as trench drains) that run along the perimeter of an impervious surface. Perimeter Filters may also be constructed by excavation and vegetated. All perimeter filters must be designed with the necessary filter medium and sized in accordance with the drainage area.

Figure 5. Perimeter filter (GA manual)

Small Subsurface

A Small Subsurface filter is an inlet designed to treat runoff at the collection source by filtration. Small Subsurface filters are useful for Hotspot Pretreatment and similar in function to Water Quality Inserts. Small Subsurface filters must be carefully designed and maintained so that runoff is directed through the filter media.

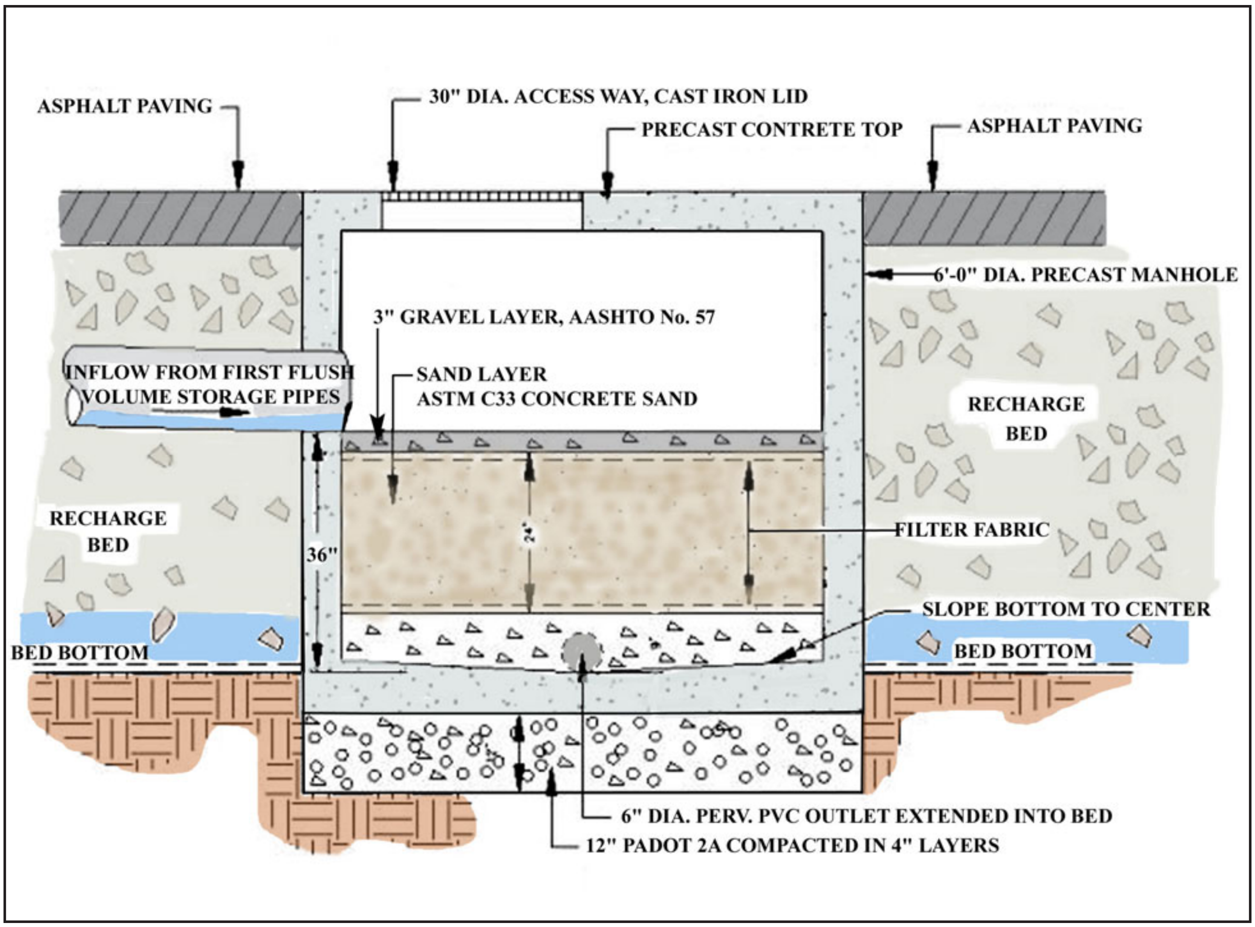


Figure 6. Small Subsurface filter (CA)

Large Subsurface

Large Subsurface Filters receive relatively large amounts of flow directed into an underground box that has separate chambers, one to settle large particles, and one to filter small particles. The water discharges through an outlet pipe and into the stormwater system.

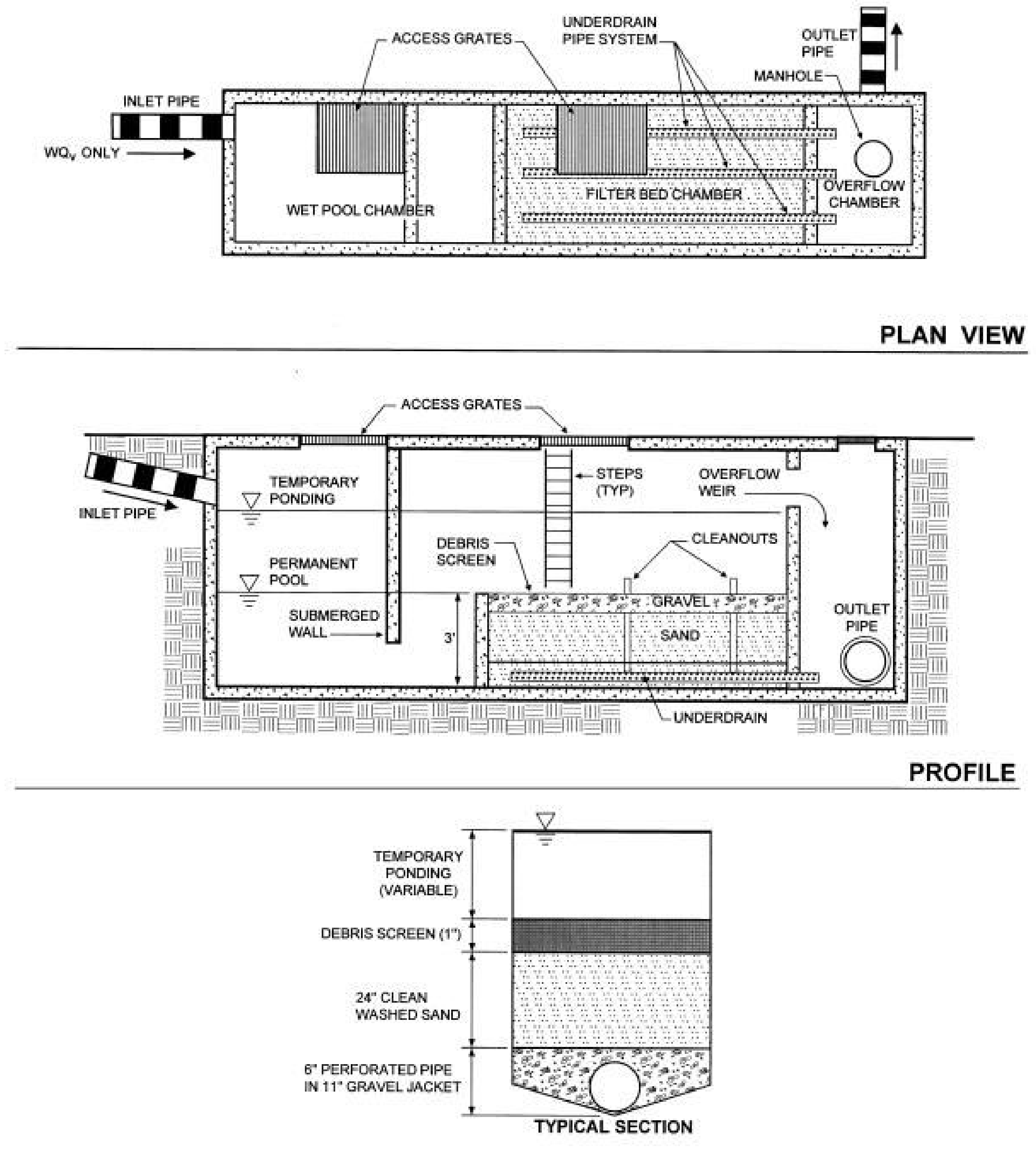


Figure 7. Large Underground Filter (NY BMP manual)

Manufactured Filtration Systems

There are a considerable number of manufactured filtration systems available, some of which also incorporate oil/water separators, vortex systems, etc. Appendix X includes information on manufactured systems available at the time of publication of this manual. The Designer should obtain product specific information directly from the manufacturer.

Applications

Filters are applicable in urbanized areas of high pollutant loads and are especially applicable where there is limited area for construction of other BMPs. Filters may be used as a pretreatment BMP before other BMPs such as Wet Ponds or Infiltration systems. Filters may be used in Hot Spot areas for water quality treatment, and spill containment capabilities may be incorporated into a filter. Examples of typical areas that benefit from the use of a Filter BMP include:

- Parking lots
- Roadways and Highways
- Light Industrial sites
- Marina areas
- Transportation facilities
- Fast food and shopping areas
- Waste Transfer Stations
- Urban Streetscapes

Design Considerations

1. Filters are designed to treat small frequent storms or the WQv. All filters must be designed so that **larger storms may safely overflow or bypass the filter**. Flow splitters, multi-stage chambers, and other devices may be used. A flow splitter may be necessary to allow only a portion of the runoff to enter the filter. This would create an "off-line" filter, where the volume and velocity of runoff entering the filter is controlled. If the filter is "on-line", excess flow should be designed to bypass filter and continue to another quality BMP.

2. **Entering velocity must be controlled**. A level spreader may be used to spread flow evenly across the filter surface during all storms without eroding the filter material. Parking lots may be designed to sheet flow to filters. Small rip-rap or riverstone edges may be used to reduce velocity and distribute flow.

3. **Pretreatment** may be necessary in areas with especially high levels of debris, large sediment, etc. Pretreatment may include oil/grit separators, vegetated filter strips, or grass swales. These measures will settle out the large particles and reduce velocity of the runoff before it enters the filter. If a sedimentation chamber is needed, the following formulas can be used to size it:

$A = 0.066 \cdot WQv$ for areas with <75% impervious
$A = 0.081 \cdot WQv$ for areas with >75% impervious

These formulas are reduced from $A = -(Q./w) \cdot Ln(1-E)$
A = surface area of sedimentation chamber
E = efficiency (90%)

w = particle settling velocity (0.0004 ft/sec for imperviousness<75%, 0.0033 ft/sec for imperviousness > 75%)
Qo = inflow to sedimentation chamber
WQv = water quality volume in 24 hours

4. The **Filter Media** may be a variety of materials and in most cases should have a minimum depth of 18 inches and a maximum depth of 30 inches, although variations on these guidelines are acceptable if justified by the designer. Coarser materials allow for more hydraulic conductivity, but finer media filter particles of a smaller size. Sand has been found to be a good balance between these two criteria (Urbonas), but different types of media remove different pollutants. While sand is a reliable material to remove TSS, (Debusk and Langston, 1997) peat removes slightly more TP, Cu, Cd, and Ni than sand. The Filter Media should have a minimum hydraulic conductivity (k) as follows:

- Sand 3.5 ft/day
- Peat 2.5 ft/day
- Leaf compost 8.7 ft/day

5. A **Gravel Layer** at least 6" deep is recommended beneath the Filter Media.

6. **Under drain piping** should be 4"minimum (diameter) perforated pipes, with a lateral spacing of no more than 10'. A collector pipe can be used, (running perpendicular to laterals) with a slope of 1%. All underground pipes should have clean-outs accessible from the surface.

7. A **Drawdown Time** of not more than 72 hours is recommended for Filters.

8. The **Size** of a Filter is determined by the Water Quality Volume to be treated:

A = WQv x d / (k x t(h+d))

A	=	Surface area of Filter (square feet)
WQv	=	Water quality volume (cubic feet)
d	=	Depth of Filter Media (min 1.5 ft; max 2.5 ft)
t	=	Drawdown time (days)
h	=	Head (average in feet)
k	=	Hydraulic conductivity (ft/day)

9. When a Filter has accumulated sediment in its pore space, its hydraulic conductivity is reduced, and so it its ability to removal pollutants. **Maintenance and Inspection** are essential for continued performance of a Filter. Based upon inspection, some or all portions of the filter media may require replacement.

10. Filters must be designed with **sufficient maintenance access** (clean-outs, room for surface cleaning, etc.). Filters that are visible and simple in design are more likely to be maintained correctly.

Detailed Stormwater Functions

Volume Reduction Calculations:
If a Filter is designed to include infiltration, the Volume Reduction is a function of the Area of the

Filter and infiltration rate. There is minimal volume reduction for Filters that are not designed to infiltrate.

Peak Rate Mitigation Calculations:
The time of travel for water through a surface filter can be calculated (equal to the resonance time) to increase the time of concentration for the overall drainage area if the system is “on-line” (all the water passes through the filter BMP).

Water Quality Improvement:
The type of filter material used, the depth of material, the influent conditions of the runoff, and the maintenance completed will determine the effectiveness of a filter. The TSS removal rate will be achieved if designed and maintained properly.

Construction Sequence

1. Permanent Filters should not be installed until the site is stabilized. Excessive sediment generated during construction can clog the Filter and prevent or reduce the anticipated post-construction water quality benefits. Stabilize all contributing areas before runoff enters filters.
2. Structures such as inlet boxes, reinforced concrete boxes, etc. should be installed in accordance with the manufacturers’ or design engineers guidance.
3. Excavated filters that infiltrate or structural filters that infiltrate should be excavated in such a manner as to avoid compaction of the sub-base. Structures may be set on a layer of clean, lightly compacted gravel (such as AASTO #57).
4. Infiltration Filters should be underlain by a layer of permeable non-woven-geotextile.
5. Place underlying gravel/stone in minimum 6 inch lifts and lightly compact. Place underdrain pipes in gravel during placement.
6. Wrap and secure non-woven geaotextile to prevent gravel/stone from clogging with sediments.
7. Lay filtering material. Do not compact.
8. Saturate filter media and allow media to drain to properly settle and distribute.
9. For vegetated filters, a layer of non-woven geotextile between non-organic filter media and planting media is recommended.
10. There should be sufficient space (head) between the top of the filtering bed and the overflow of the Filter to allow for the maximum head designed to be stored before filtration.

Figure 8. Laying pipes in a filter. (U of MN, NERC)

Maintenance and Inspection

Filters require a consistent inspection and maintenance program in order to maintain the integrity of the filtering system and pollutant removal mechanisms. Studies have shown that filters are very effective upon installation, but quickly decrease in efficiency as sediment accumulates in the filter. (Urbonas, Urban Drainage and Flood Control District, CO) Odor is also a concern for filters that are not maintained. Inspection of the filter is recommended **four times a year**.

During inspection the following conditions should be considered:

- **Standing water** – any water left in a surface filter after the design drain down time indicates the filter is not optimally functioning.
- **Film or discoloration** of any surface filter material – this indicates organics or debris have clogged the filter surface.

Figure 9. Example of sand bed "film" on top (CA manual)

Filter Maintenance:

- Remove trash and debris as necessary
- Scrape silt with rakes
- Till and aerate filter area
- Replace filtering medium if scraping/removal has reduced depth of filtering media

In areas where the potential exists for the discharge and accumulation of toxic pollutants (such as metals), filter media removed from filters must be handled and disposed of in accordance with all state and federal regulations.

Winter concerns:

Pennsylvania's low temperature dips below freezing about four months out of every year, and surface filtration may not take place as well in the winter. Peat and compost may hold water, freeze, and become impervious on the surface. Design options that allow directly for sub-surface discharge into the filter media during cold weather may overcome this condition.

Cost Issues

Filter costs vary according to the filtering medial (sand, peat, compost), land clearing, excavation, grading, inlet and outlet structures, perforated pipes, encasing structure (if used), and maintenance cost. Underground structures may contribute significantly to the cost of a Filter.

Specifications:

1. **Stone/Gravel** shall be uniformly graded coarse aggregate, 1 inch to ¾ inch with a wash loss of no more than 0.5%, AASHTO size number 57 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids ³ 35% as measured by ASTM-C29.

2. **Peat** shall have ash content <15%, pH range 3.3-5.2, loose bulk density range 0.12-0.14 g/cc.

3. **Sand** – shall be ASTM-C-33 (or AASHTO M-6) size (0.02" – 0.04"), concrete sand, clean, medium to fine sand, no organic material.

4. **Leaf Compost**

5. **Non-Woven Geotextile** shall consist of needled non-woven polypropylene fibers and meet the following properties:

a. Grab Tensile Strength (ASTM-D4632) ³ 120 lbs
b. Mullen Burst Strength (ASTM-D3786) ³ 225 psi
c. Flow Rate (ASTM-D4491) ³ 95 gal/min/ft^2
d. UV Resistance after 500 hrs (ASTM-D4355) ³ 70%
e. Heat-set or heat-calendared fabrics are not permitted

6. **Topsoil**

7. **Pipe** shall be continuously perforated, smooth interior, with a minimum inside diameter of 8-inches. High-density polyethylene (HDPE) pipe shall meet AASHTO M252, Type S or AASHTO M294, Type S.

8. **Catch Basins/Inlet Boxes**

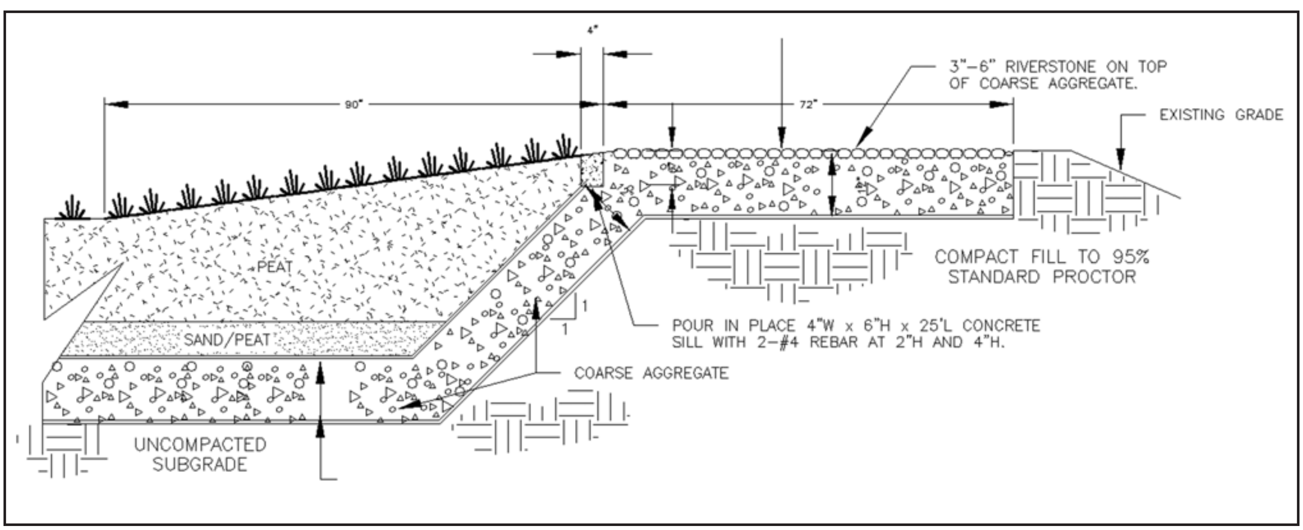


Figure 10. Peat Surface Filter

References and Additional Sources