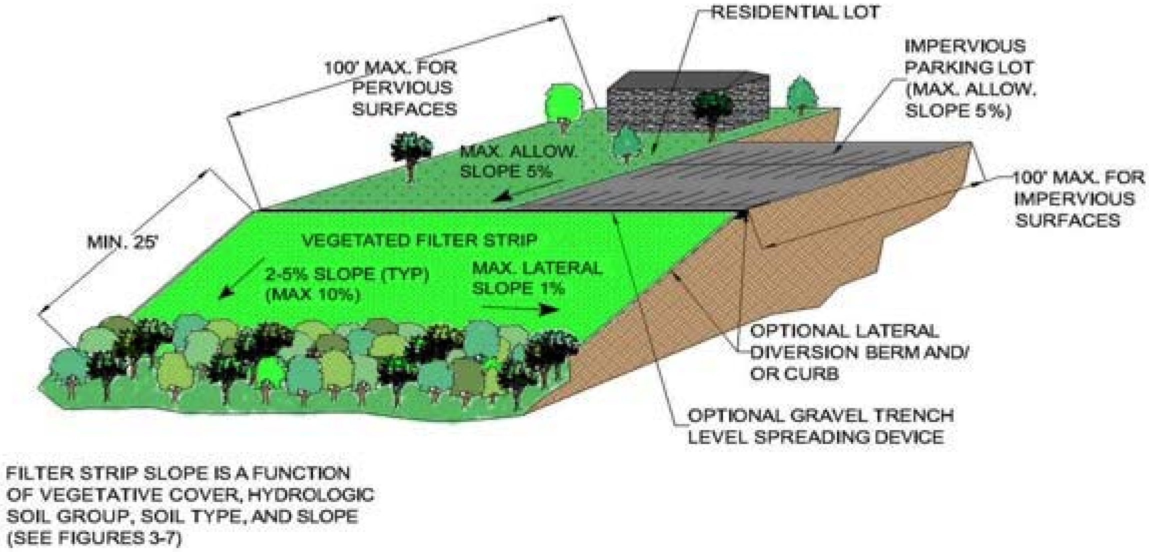
BMP 6.4.9: Vegetated Filter Strip

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	Potential Applications
▪ Sheet Flow across Vegetated Filter Strip ▪ Filter Strip length is a function of the slope, vegetative 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. ▪ Minimum filter strip width should equal the width of the contributing drainage area. ▪ Construction of filter strip should entail as little disturbance to existing vegetation at the site as possible. ▪ See Appendix B for list of acceptable filter strip vegetation.	Residential: Yes Commercial: Yes Ultra Urban: Limited Industrial: Limited Retrofit: Yes Highway/Road: Yes **Stormwater Functions** Volume Reduction: Low/Med. Recharge: Low/Med. Peak Rate Control: Low Water Quality: High **Water Quality Functions** TSS: 30% TP: 20% NO3: 10%

Other Considerations

- Regular maintenance required for continued performance



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 downspouts, 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 reduced. 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:

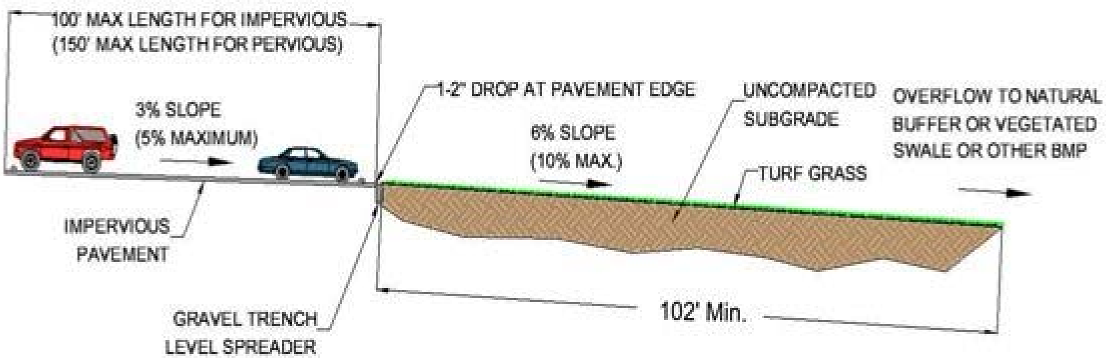
- Turf Grasses
- Meadow grasses, shrubs, and native vegetation, including trees
- Indigenous areas of woods and vegetation.

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.

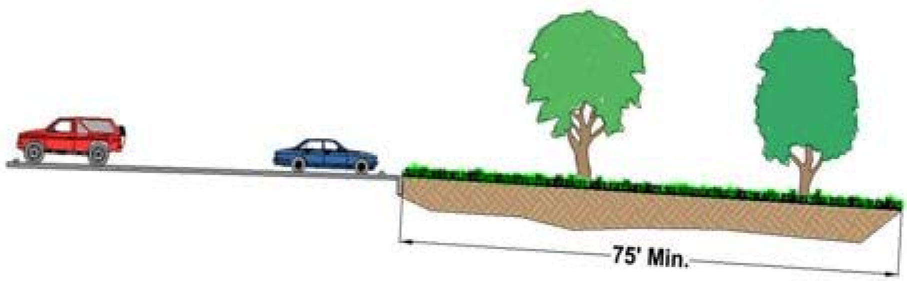
The vegetation in Filter Strips must be dense and healthy. Indigenous wooded areas should have a healthy layer of leaf mulch or duff. Indigenous areas that have surface features that concentrate flow are not acceptable.

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 100 ft, while the strip with indigenous woods required only 50 ft. The strip covered with native grasses and some trees required 75 ft. Where the required length is not available, a filter strip can still be used but it will be less effective.

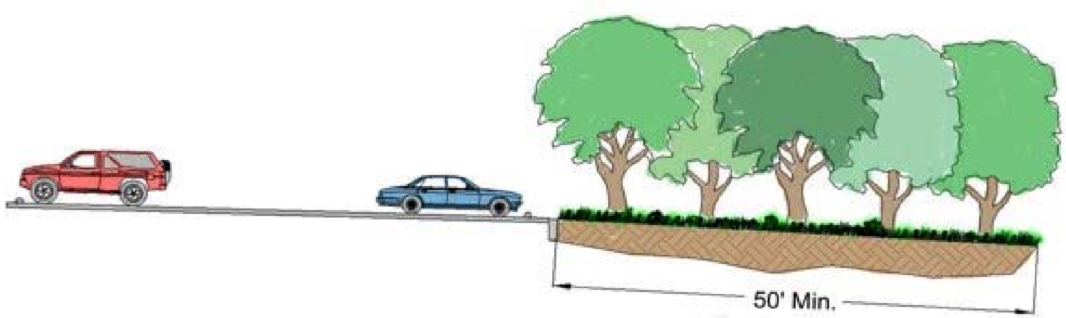
Filter Strip Example #1: Turf Grass



Filter Strip Example #2: Native Grasses and Planted Woods Grass



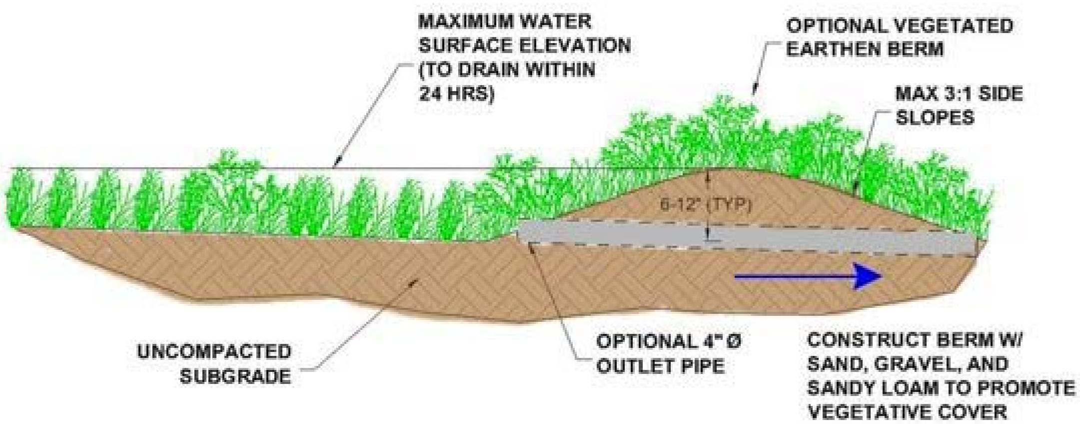
Filter Strip Example #3: Indigenous Woods



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 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.

Check dams may be implemented on filter strips with slopes exceeding 5%. Check dams shall be constructed of durable, nontoxic materials such as rock, brick, wood, not more than six inches in height, and placed at appropriate intervals to encourage ponding and prevent erosion. Care must be taken to prevent erosion around the ends of the check dams.



Applications

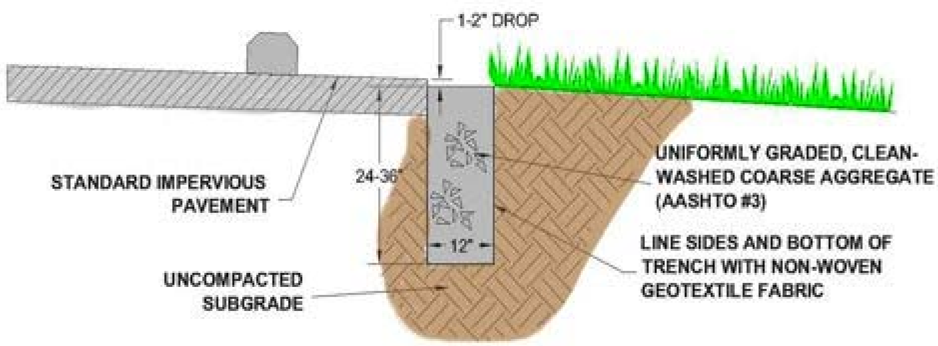
- Residential development lawn and housing areas
- Roads and highways
- Parking lots
- Pretreatment for other structural BMPs (Infiltration Trench, Bioretention, etc.)
- Commercial and light industrial facilities
- As part of a Riparian Buffer (located in Zone 3)

Design Considerations

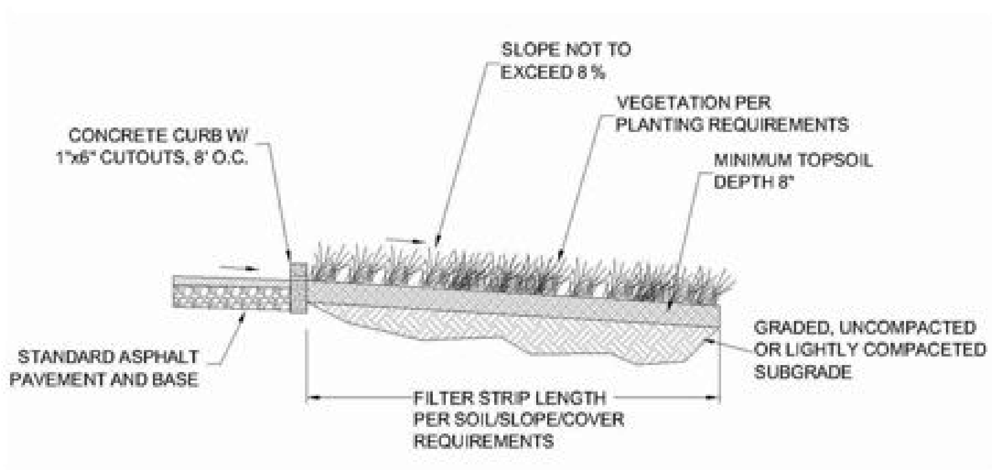
1. The design of vegetated filter strips is determined by site conditions (contributing drainage area, length, slope, etc.) site soil group, proposed cover type, and filter strip slope. The filter length can be determined from the appropriate graph shown below the text.

2. Level spreading devices or other measures may be 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 nonwoven 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. Curb stops



    c. Concrete sill (or lip)

    d. Slotted or depressed curbs

    e. An earthen berm with optional perforated pipe.

3. Although in some locations more "natural" spreader designs and materials, such as earthen berms, are desirable, 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.

4. The upstream edge of a filter strip should be level and directly abut the contributing drainage area.

5. The seasonal high water table should be at least 2 to 4 ft lower than any point along 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 12-18 inches 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 should not exceed 6:1.

8. The filter strip area should 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 B for vegetation recommendations.)

9. Natural areas, such as forests and meadows, should not 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.

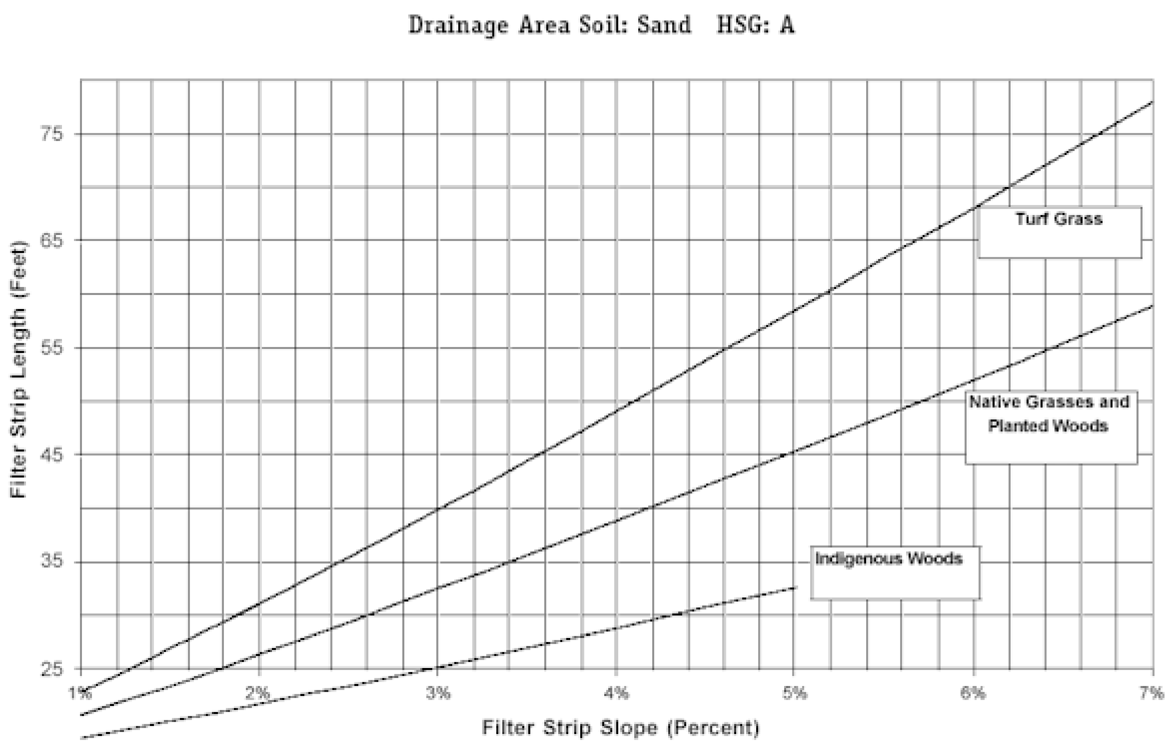
13. Vegetated filter strips may be designed to discharge to a variety of features, including natural buffer areas, vegetated swales, infiltration basins, or other structural BMPs.

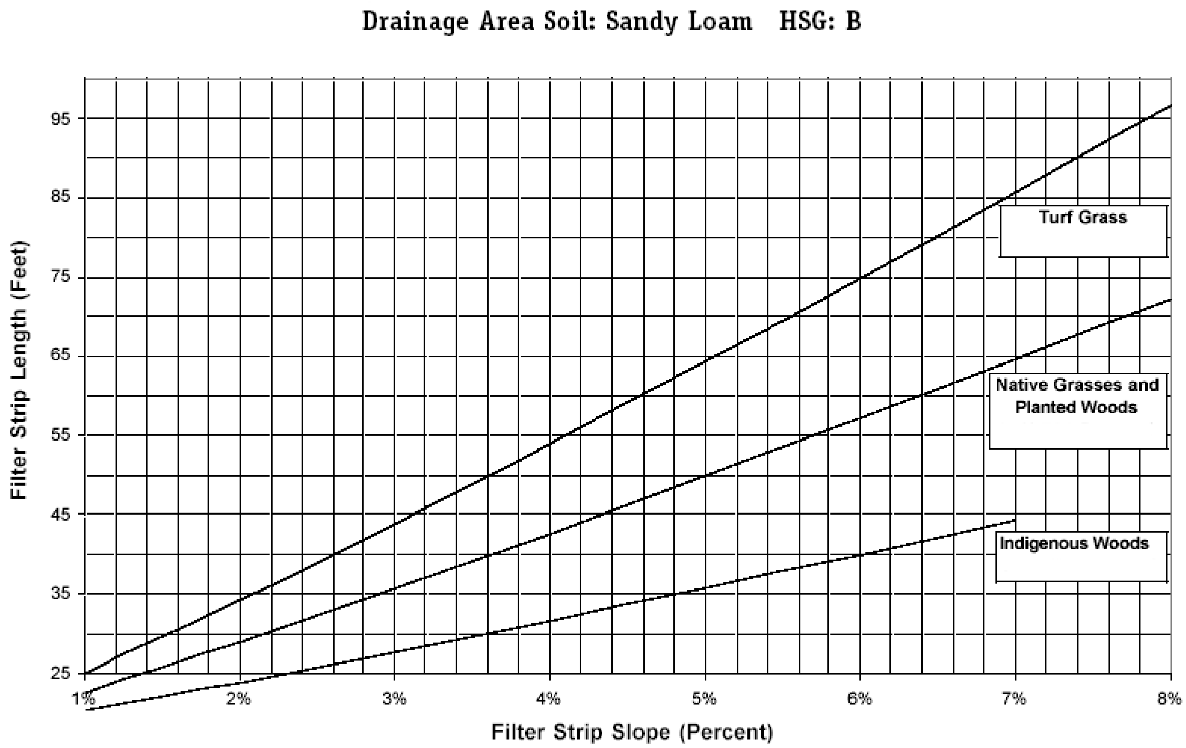
14. In cold climates, the following recommendations should be considered:
    a. Filter strips often make convenient areas for snow storage. Thus, filter strip vegetation should be salt-tolerant and the maintenance schedule should involve removal of sand buildup at the toe of the slope.

b. The bottom of the gravel trench (if used as the level spreader) should be placed below the frost line to prohibit water from freezing in the trench. The perforated pipe in the trench should be at least 8 inches 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

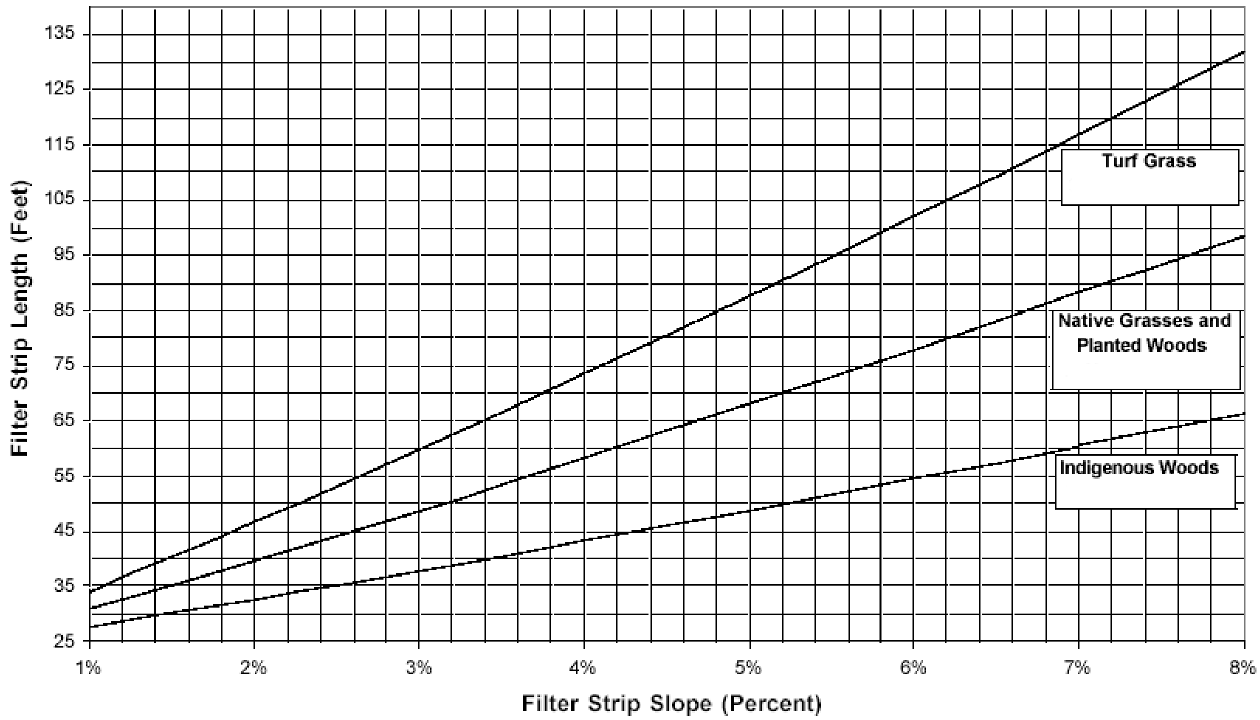
Filter Strip Soil Type	Soil Group	Turf Grass, Native Grasses and Meadows	Planted and Indigenous Woods
Sand	A	7	5
Sandy Loam	B	8	7
Loam, Silt Loam	B	8	8
Sandy Clay Loam	C	8	8
Clay Loam, Silty Clay, Clay	D	8	8



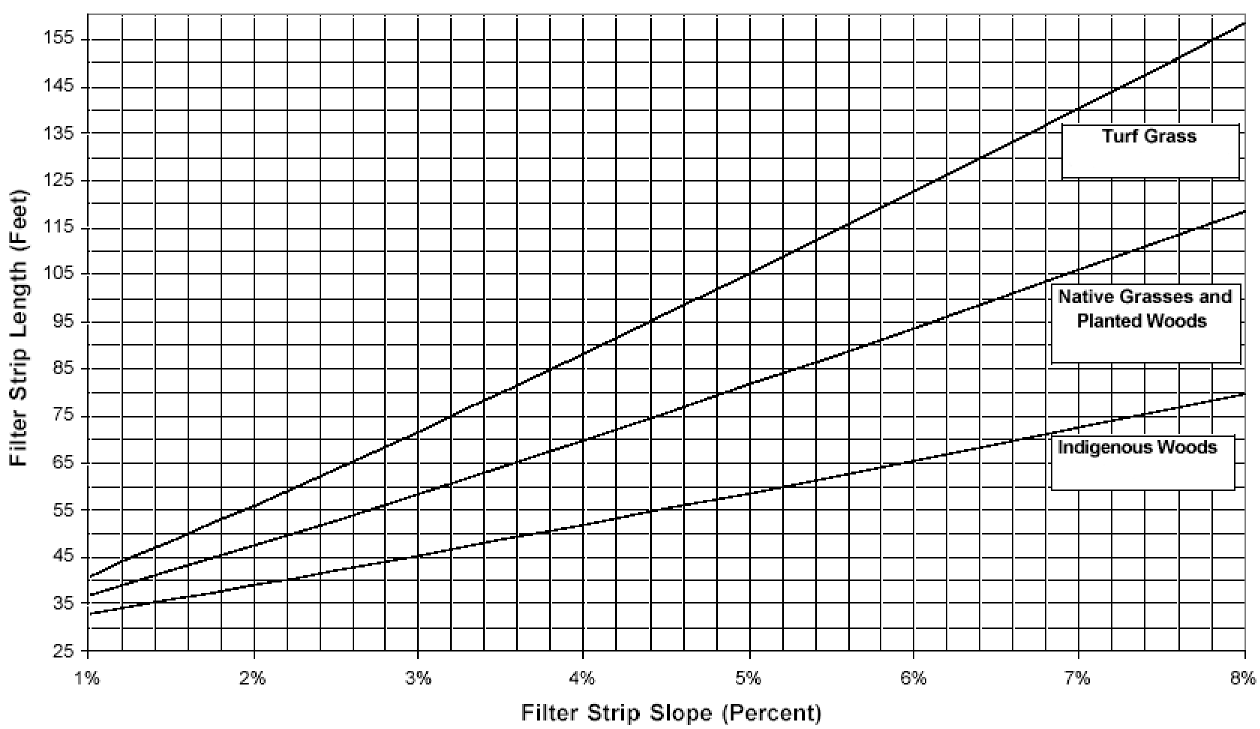

Drainage Area Soil: Sandy Loam HSG: B
Filter Strip Length (Feet)
95
85
75
65
55
45
35
25
1%
2%
3%
4%
5%
6%
7%
8%
Filter Strip Slope (Percent)
Turf Grass
Native Grasses and Planted Woods
Indigenous Woods


Drainage Area Soil: Loam, Silt Loam HSG: B
Filter Strip Length (Feet)
115
105
95
85
75
65
55
45
35
25
1%
2%
3%
4%
5%
6%
7%
8%
Filter Strip Slope (Percent)
Turf Grass
Native Grasses and Planted Woods
Indigenous Woods

Drainage Area Soil: Sandy Clay Loam HSG: C



Drainage Area Soil: Clay Loam, Silty Clay, Clay HSG: D



Detailed Stormwater Functions

Volume Reduction Calculations

To determine the volume reduction over the length of a filter strip the following equation is recommended:

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 should 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 in Section 8 for Peak Rate Mitigation methodology which addresses link between volume reduction and peak rate control.

Water Quality Improvement

See 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 should 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 should 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. Use the lightest, least disruptive equipment 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 should be maintained for at least the first 75 days following the first storm event of the season.

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. Some seed mixtures may require a longer time period to become established.

9. Follow maintenance guidelines, as discussed below.

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

Maintenance Issues

As with other vegetated BMPs, filter strips should 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 should be inspected for clogging, density of vegetation, damage by foot or vehicular traffic, excessive accumulations, and channelization. Inspections should be made on a quarterly basis for the first two years following installation, and then on a biannual basis thereafter. Inspections should also be made after every storm event greater than 1 in during the establishment period. Guidance information, usually in written manual form, for operating and maintaining filter strips should 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 should be routinely removed (but never less than biannually), or upon observation, when buildup exceeds 2 inches in depth in either the strip itself or the level spreader. If erosion is observed, measures should 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 12 inches wide, filling with crushed gravel, which allows grass to creep in over time, is acceptable. For wider channels, i.e. greater than 12 inches, 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 should standing water be tolerated for longer than 48-72 hours.) If check dams are proposed, they should 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 should be cleaned periodically or as needed.

Sediment should be removed when the filter strip is thoroughly dry. Trash and debris removed from the site should 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 should 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 should be mowed, with low ground pressure equipment, as needed to maintain a height of 4-6 inches. Mowing should 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 6 inches, to provide adequate wildlife winter habitat. When and where cutting is desired for aesthetic reasons, a high blade setting should be used.

If vegetative cover is not fully established within the designated time, it should be replaced with an alternative species. It is standard practice to contractually require the contractor to replace dead vegetation. Unwanted or invasive growth should 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 should 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, should 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 needed. In addition, depending on soil characteristics, the strip may need periodic liming. The design and maintenance plan of filter strips, especially those with flow obstructions should specify the approximate time it would take for the system to “drain down” the maximum design storm runoff volume. Post-rainfall inspections should 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 should be reevaluated. Measures should 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, 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. **Vegetation** – See Appendix B

2. **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:

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

4. **Stone** for infiltration trenches should 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 should have voids ≥ 35% as measured by ASTM-C29.

   Pea gravel (clean bank-run gravel) may also be used. Pea gravel should meet ASTM D 448 and be sized as per No.6 or 1/8" to 3/8".

5. **Non-Woven Geotextile** should consist of needled non-woven polypropylene fibers and meet the following properties:
   a. Grab Tensile Strength (ASTM-D4632) ≥ 120 lbs
   b. Mullen Burst Strength (ASTM-D3786) ≥ 225 psi
   c. Flow Rate (ASTM-D4491) ≥ 95 gal/min/ft2
   d. UV Resistance after 500 hrs (ASTM-D4355) ≥ 70%
   e. Heat-set or heat-calendared fabrics are not permitted
   Acceptable types include Mirafi 140N, Amoco 4547, and Geotex 451.

6. **Check dams** constructed of natural wood should be 6 in to 12 in inches diameter and notched as necessary. The following species are acceptable: Black Locust, Red Mulberry, Cedars, Catalpa, White Oak, Chestnut Oak, Black Walnut. The following species are not acceptable since they can rot over time: Ash, Beech, Birch, Elm, Hackberry, Hemlock, Hickories, Maples, Red and Black Oak, Pines, Poplar, Spruce, Sweetgum, and Willow. An earthen check dam should be constructed of sand, gravel, and sandy loam to encourage grass cover. (Sand: ASTM C-33 fine aggregate concrete sand 0.02 in to 0.04 in, Gravel: AASHTO M-43 0.5 in to 1.0 in). A stone check dam should be constructed of R-4 rip rap, or equivalent.

7. **Pervious Berms** The berm should have a height of 6-12 in 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”)

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