2I-4 Vegetated Filter Strips

Source: UDFCD, 1999

BENEFITS Low <30% Medium=30-65% High=65-100%			
	Low	Med	High
Suspended Solids			■
Nitrogen	■	■	
Phosphorous	■		
Metals			■
Bacteriological	*	*	*
Hydrocarbons	*	*	*

* Insufficient data

Description: Vegetated filter strips (VFS) are zones of vegetation through which sediment and pollutant-laden flow are directed before being discharged to a concentrated flow channel. They may closely resemble many natural ecological communities such as grassy meadows or riparian forests. Dense vegetative cover facilitates sediment attenuation and pollutant removal. VFS provide little treatment for concentrated flows. Grading and level spreaders are often used to create a uniformly sloping area to distribute the runoff evenly across the filter strip.

Typical uses:

- Manage runoff from residential sites, parking areas, and along perimeter of paved roadways.
- Located in a drainage easement at the rear of side of residential parcels.
- Road shoulder rights-of-way; used adjacent to paved roadways in place of curb and gutter, or used as a conveyance channel on the back-side of curb-cut openings.

Advantages/benefits:

- Mitigates runoff from impervious surfaces.
- Remove sediment and pollutants to improve water quality.
- Reduce runoff rate and volume in highly impervious areas; reduce runoff velocity.
- Provide for groundwater recharge if design and site soils provide sufficient infiltration.
- Good retrofit opportunities for residential or institutional areas of low to moderate density.
- Linear configuration works well with highway or residential street applications.

Disadvantages/limitations:

- Sediment and pollutant removal sensitive to proper design of slope and maintaining sufficient vegetation density.
- Limited to small areas (<5 acres); cannot be used on steep slopes (>6%).
- Possible re-suspension of sediment.

Maintenance requirements:

- Needs routine landscape maintenance; maintain grass height of approximately 2-4 inches.
- Inspect annually for erosion problems; seed or sod bare areas.

A. Description

Vegetated filter strips (VFS) are uniformly-graded and densely-vegetated sections of land engineered and designed to treat runoff and remove pollutants through vegetative filtering and infiltration. The primary purpose of a VFS is either to enhance the quality of stormwater runoff on small sites in a treatment system approach, or as a pre-treatment device for another BMP. The dense vegetative cover facilitates conventional pollutant removal through detention, filtration by vegetation, sediment deposition, and infiltration and adsorption in the soil (Yu and Kaighn, 1992). VFS can also be used as a pre-treatment BMP in conjunction with a primary BMP. This reduces the sediment and particulate pollutant load reaching the primary BMP, which in turn reduces the BMP maintenance costs and enhances its pollutant removal capabilities. Filter strips are located adjacent to impervious areas and can be used in residential and commercial areas and along highways and roads. Because their effectiveness depends on having an evenly-distributed sheet flow over their surface, the size of the contributing area and the associated volume of runoff have to be limited. Flow can be directly accepted from a parking lot, roadway, or building roof, provided the flow is distributed uniformly over the strip. They are ideal components of the outer zone of a stream buffer, or as pre-treatment for another structural stormwater control. Filter strips can serve as a buffer between incompatible land uses, landscaped to be aesthetically pleasing, and provide groundwater recharge in areas with pervious soils.

VFS are generally grouped into three categories:

- **Constructed filter strips.** Constructed filter strips are filter strips that are constructed and maintained to allow for overland sheet flow through the vegetation, primarily grass-like plants with density approaching that of tall lawn grass.
- **Natural vegetative strips.** Natural vegetative strips are any natural vegetative area through which sediment-laden flow is directed, including riparian vegetation around drainage channels. Flow is typically not broad overland sheet flow, but occurs in small concentrated flow channels or flow zones. Vegetation can range from grass-like plants to brush or trees with ground litter.
- **Riparian vegetative buffer strips.** Riparian vegetative buffer strips are strips of vegetation that grow along stream and concentrated flow channels. The vegetation may be constructed or natural. To be effective, the VFS will normally be located on the contour perpendicular to the general direction of flow.

Filter strips are often used as a stormwater site design credit when used in conjunction with other structural practices. Filter strips rely on the use of vegetation to slow runoff velocities and filter out sediment and other pollutants from urban stormwater. There can also be a significant reduction in runoff volume for smaller flows that infiltrate pervious soils while contained within the filter strip. To be effective, sheet flow must be maintained across the entire filter strip. Once runoff flow concentrates, it effectively short-circuits the filter strip and reduces the water quality performance. Therefore, a flow spreader must normally be included in the filter strip design.

There are two different filter strip designs:

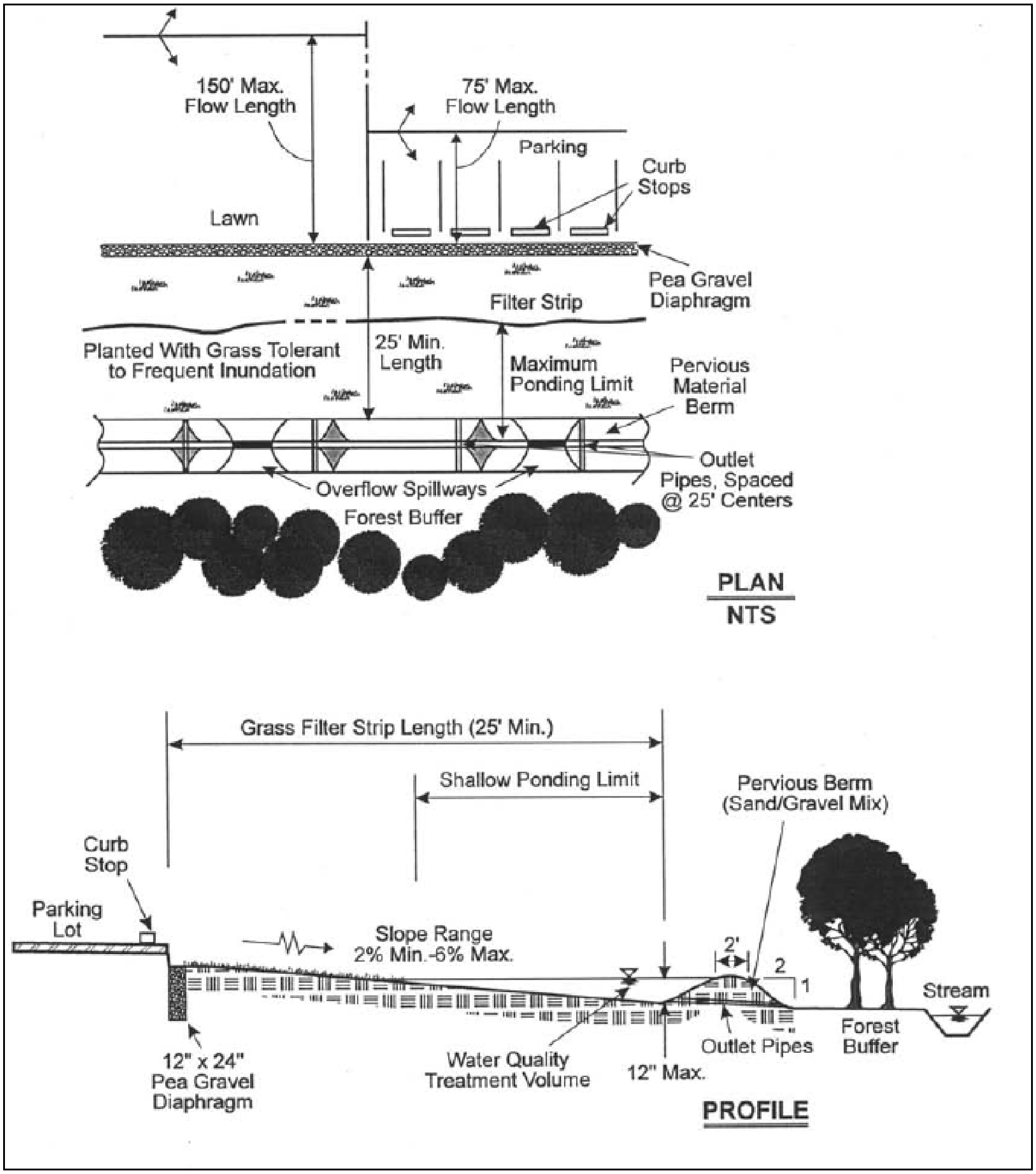
1. A filter strip design that includes a permeable berm at the bottom (Figure 1). The presence of the berm increases the contact time with the runoff, thus reducing the overall width of the filter strip required to treat stormwater runoff.

2. A simple filter strip (See Figure 2).

Filter strips are typically an on-line practice, so they must be designed to withstand the full range of storm events without eroding. The design approach for filter strips involves site design techniques to maintain prescribed maximum sheet flow distances, as well as checking to ensure adequate temporary storage for the WQv for a 24-hour period. Filter strips are also designed using volume-based sizing criteria.

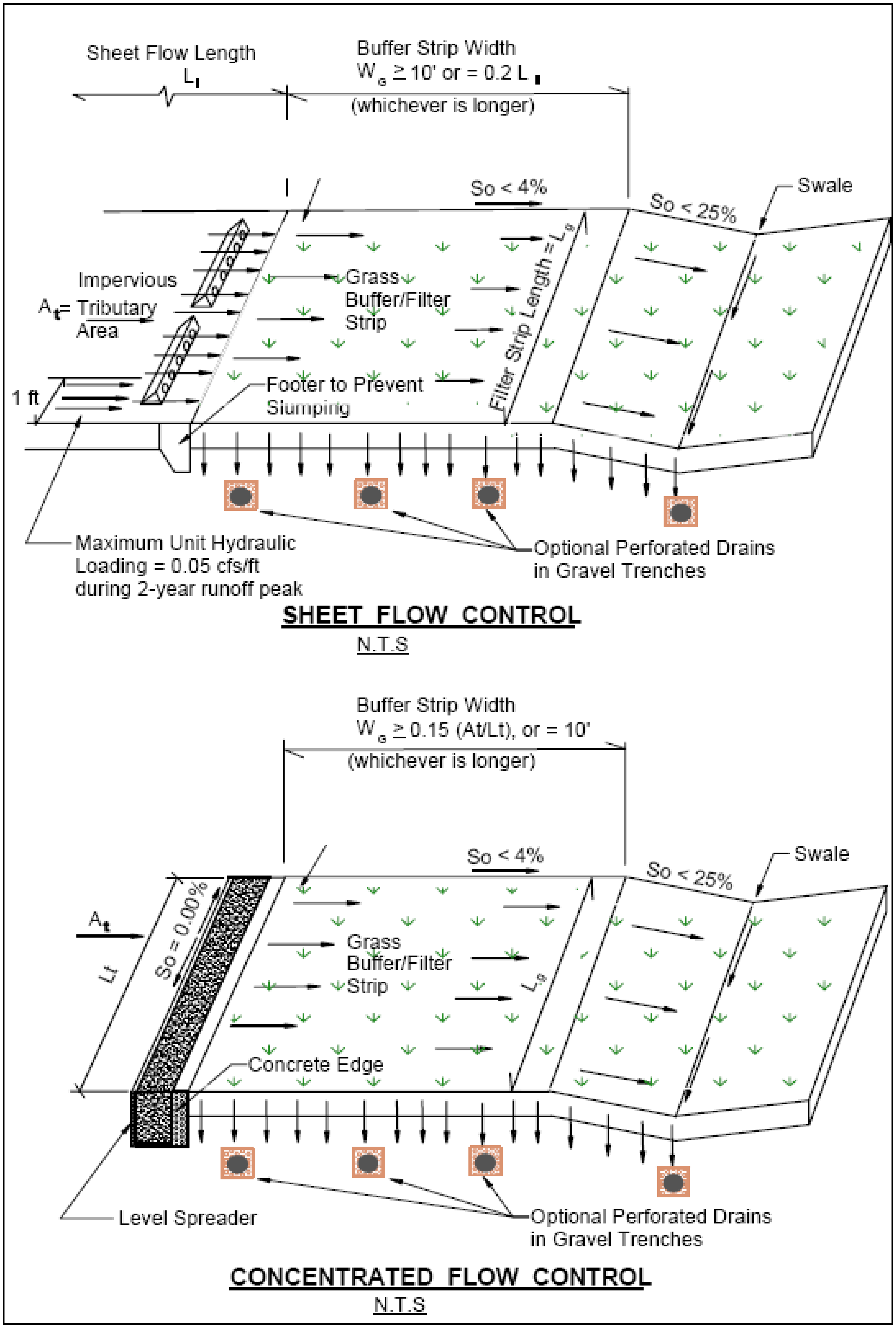
Therefore, the use of filter strips to treat stormwater runoff is primarily a function of limiting the flow path to the filter. One of the main abuses of the past has been draining too much area through the filter strip. In most cases the sheet flow distance limitations will be the controlling factor. Figures 1 and 2 illustrate the primary design components of the two filter strip design variants.

Figure 1: Vegetated filter strip (with berm)



Source: Claytor and Schueler, CRC, 1996

Figure 2: Grass buffer filter strip (without berm)



Source: UDFCD, 1999

B. Pollutant removal capabilities

Filter strips provide only marginal pollutant removal and require that follow-up structural BMPs be provided. Pollutant removal from filter strips is highly variable and depends primarily on density of vegetation and contact time for filtration and infiltration. These in turn depend on soil and vegetation type, slope, and presence of sheet flow. The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling, and professional judgment.

- Total suspended solids – 50%
- Total phosphorus – 20%
- Total nitrogen – 20%
- Fecal coliform – insufficient data
- Heavy metals – 40%

C. Design criteria

1. **General criteria.**

    a. Filter strips should be used to treat small drainage areas. Flow must enter the filter strip as sheet flow spread out over the width (long dimension normal to flow) of the strip, generally no deeper than 1-2 inches. As a rule, flow concentrates within a maximum of 75 feet for impervious surfaces, and 150 feet for pervious surfaces (Claytor and Schueler, 1996). For longer flow paths, special provisions must be made to ensure design flows spread evenly across the filter strip.

    b. Filter strips should be integrated within site designs.

    c. Filter strips should be constructed outside the natural stream buffer area whenever possible to maintain a more natural buffer along the streambank.

    d. Filter strips should be designed for slopes between 2-6%. Greater slopes than this would encourage the formation of concentrated flow. Flatter slopes would encourage standing water.

    e. Filter strips should not be used on soils that cannot sustain a dense grass cover with high retardance. Designers should choose a grass that can withstand relatively high-velocity flows at the entrances, and both wet and dry periods. See SUDAS Specifications Manual Section 9010 for a list of appropriate grasses for use in Iowa.

    f. The filter strip should be at least 15 feet long to provide filtration and contact time for water quality treatment. Twenty-five feet is preferred (where available), though length will normally be dictated by design method.

    g. Both the top and toe of the slope should be as flat as possible to encourage sheet flow and prevent erosion.

    h. An effective flow spreader is to use a pea gravel diaphragm (a small trench running along the top of the filter strip) at the top of the slope (ASTM D 448 size no. 6, 1/8-3/8-inch). The pea gravel diaphragm serves two purposes. First, it acts as a pre-treatment device, settling out sediment particles before they reach the practice. Second it acts as a level spreader, maintaining sheet flow as runoff flows over the filter strip. Other types of flow spreaders include a concrete sill, curb stops, or curb and gutter with saw-teeth cut into it.

i. Ensure that flows in excess of design flow move across or around the strip without damaging it. Often a bypass channel or overflow spillway with protected channel section is designed to handle higher flows.

j. Pedestrian traffic across the filter strip should be limited by providing a designated walkway.

k. Maximum discharge loading per foot of filter strip width (perpendicular to flow path) is found using Manning's equation:

$$q = \frac{0.00236}{n} Y^{5/3} S^{1/2} \qquad \textbf{Equation 1}$$

where:
q = discharge per foot of width of filter strip (ft^3/sec-ft)
Y = allowable depth of flow (inches)
S = slope of filter strip (%)
n = Manning's roughness coefficient

Use 0.15 for medium grass, 0.25 for dense grass, and 0.35 for very dense grass. (See Table 1).

l. The minimum width of a filter strip is:

$$W_{f\text{-}MIN} = Q/q \qquad \textbf{Equation 2}$$

where: $W_{f\text{-}MIN}$ = minimum filter strip width perpendicular to flow (feet)

2. **Filter strip without berm.**

a. Size filter strip (parallel to flow path) for a contact time of 5 minutes minimum.

b. Equation for filter length is based on the SCS TR55 travel time equation (SCS, 1986):

$$\frac{L_f = (T_t)^{1.25} (P_{2\text{-}24})^{0.625} (S)^{0.5}}{3.34n} \qquad \textbf{Equation 3}$$

where:
L_f = length of filter strip parallel to flow path (ft)
T_t = travel time through filter strip (minutes)
$P_{2\text{-}24}$ = 2-yr, 24-hr rainfall depth (inches)
S = slope of filter strip (%)
n = Manning's roughness coefficient

Use 0.15 for medium grass, 0.25 for dense grass, and 0.35 for very dense grass. (See Table 1).

3. **Filter strip with berm.**

   a. Size outlet pipes to ensure that the water detained by the berm drains within 24 hours.

   b. Specify grasses resistant to frequent inundation within the shallow ponding limit.

   c. Berm material should be of sand, gravel and sandy loam to encourage grass cover (Sand: ASTM C-33 fine aggregate concrete sand 0.02-inch to 0.04-inch; Gravel: 1/2-inch to 1-inch: use IA DOT #3-coarse PCC aggregate or IA DOT #29-porous backfill).

   d. Size filter strip to contain the WQv within the wedge of water backed up behind the berm.

   e. Maximum berm height is 12 inches.

4. **Filter strips for pre-treatment.**

   a. A number of other structural controls, including bioretention areas and infiltration trenches, may utilize a filter strip as a pre-treatment measure. The required length of the filter strip depends on the drainage area, imperviousness, and the filter strip slope. Table 1 provides sizing guidance for bioretention filter strips for pre-treatment.

Table 1: Pre-treatment filter strip sizing guidance

Parameter	Impervious Areas				Pervious Areas (i.e. Lawns)			
Maximum inflow approach length (feet)	35		75		75		100	
Filter strip slope (maximum = 6%)	<2%	>2%	<2%	>2%	<2%	>2%	<2%	>2%
Filter strip minimum length (feet)	10	15	20	25	10	12	15	18

Source: Claytor and Schueler, 1996

D. Inspection and maintenance requirements

Filter strips require similar maintenance to other vegetative practices. Maintenance is very important for filter strips, particularly in terms of ensuring that flow does not short-circuit the practice.

Table 2: Typical maintenance activities for vegetated filter strips

Activity	Schedule
Mow grass to maintain a 2-4 inch height.	Regularly (as required seasonally)
Inspect pea gravel diaphragm for clogging and remove accumulated sediment.	Annual inspection (semi-annual first year)
Inspect vegetation for rill and gully erosion. Seed or sod bare areas.	
Inspect to ensure that grass has established. If not, replace with alternate species.	

Source: Claytor and Schueler, CRC, 1996

E. Design example

Filter strip.

1. **Basic site data.** Small commercial parcel located in Ankeny, IA

   a. Parcel size: 240 feet deep x 200 feet wide

   b. Drainage area (A) = 1.1 acres

   c. Soils – HSG-B

   d. Roof and paved parking: 28,800-ft^2 (0.66 acres)

   e. Impervious percentage (I) = 60%

   f. Slope = 3.6%, Manning's n = 0.25

   g. Design for allowable flow depth of 1 inch

Figure 3: Data for Polk County example

Rainfall Data for Polk County Example
(24-hr duration)

Return period	Rainfall, P (inches)
0.3-yr (WQ event)	1.25
1-yr	2.38
2-yr	3.2
5-yr	4.1
10-yr	4.7
25-yr	5.5
100-yr	6.7

2. **Calculate maximum discharge loading per foot of filter strip width.** Use Equation 1:

   $q = (0.00236/0.25) \times (1.0)^{5/3} \times (3.6)^{0.5} = 0.018\ ft^3/sec\text{-}ft$

3. **Compute WQv and WQv peak flow (Q_{wq}).**

   a. Compute water quality volume in inches:
      1) P = 1.25 inches
      2) Rv = 0.05 + 0.009(60) = 0.59
      3) WQv = P x Rv = 1.25 inches x 0.59 = 0.74 inches

   b. Compute modified CN for 1.25-inch rainfall (P=1.25). (See Section 2C-7).

      $CN = 1000/[10+5P+10Q-10(Q^2+1.25QP)^{0.5}$
      $= 1000/[10+(5)(1.25)+(10)(0.74) -10((0.74)^2+(1.25)(0.74)(1.25))^{0.5}]$
      $= 94.36$ (Use CN = 94)

   c. For CN = 94 and an estimated time of concentration (tc) of 8 minutes (0.13 hours) compute the Q_{wq} for the 1.25-inch storm. Results from WINTR55 are:

$Qwq = 1.21\ ft^3/sec$

d. For standard CN based on actual impervious and pervious area on B soils: CN=83. Compute Q_{p-2} and Q_{p-10} for developed condition. Results from WINTR55 are:

Q_{p-2} = 2.73 cfs $\qquad$ Q_{p-10} = 4.9 cfs

4. **Compute minimum filter width.** Use Equation 2:

$W_{f\text{-}MIN} = Q/q = 1.21\ ft^3/sec\ /\ 0.018 ft^3/sec\text{-}ft = 67\ feet$

Since the width of the parcel is 200 feet, the actual width of the filter strip can depend on site grading and the flow path configuration to the filter strip in sheet flow through a pea gravel level spreader.

5. **Filter without a berm.**

a. 2-yr, 24-hr storm for Polk County = 3.2 inches

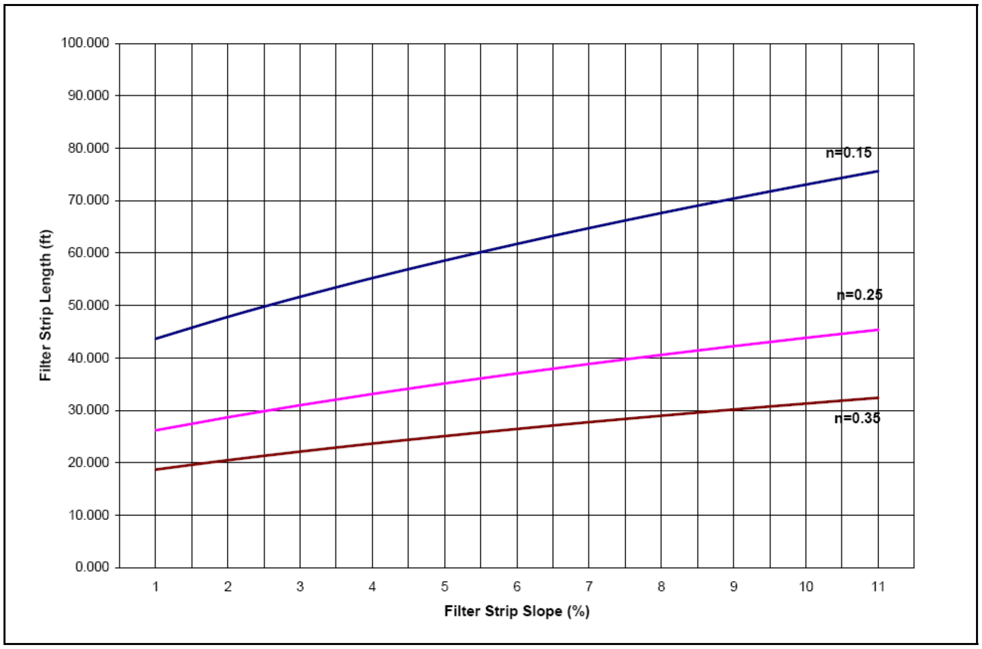
b. Use 5-minute travel contact time

c. Use Equation 3:

$L_f = (5)^{1.25} \times (3.2)^{0.625} \times (3.6)^{0.5} / (3.34 * 0.25) = 35\ feet$

Note: Reducing the filter strip slope to 2% and planting a denser grass (raising the Manning n to 0.35) would reduce the filter strip length to 22 feet. Sensitivity to slope and Manning's n changes are illustrated for this example in Figure 4.

Figure 4: Example problem sensitivity of filter strip length to slope and Manning's n



6. **Filter with berm.**

   a. Pervious berm height is 8 inches

   b. Compute WQv in cubic feet: (Use WQv result in Step 3.a)

      WQv = 0.74 inches x 1.1 acres x 1/12 ft/inch x 43,460 ft^2/acre = 2,955 ft^3

   c. For a berm height of 8 inches, the volume of the wedge of water captured by the filter strip is:

      Volume = W_f x L_f x ½ x 0.67 ft = $0.335W_fL_f$ = 2,955 ft^3

   d. For a maximum width of the filter of 200 feet, the length of the filter would then be 44 feet.

   e. For a 1-foot berm height, the length of the filter would be 30 feet.