Guidance for Design of Biofiltration Facilities for Stream Water Quality Control

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WATERSHED MANAGEMENT

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SECTION G-2.160 BIOFILTRATION DESIGN GUIDANCE

G-2.160 A. General

Biofiltration is appropriate in certain situations for water quality enhancement. It is effective during the summer months when plants are actively growing. Biofiltration facilities treat storm water by utilizing fine, close-growing, water resistant grasses as filters for runoff from frequent storms. On sites where the biofilter will intercept groundwater or where there is little or no slope to allow for good drainage, emergent herbaceous wetland vegetation is an acceptable planting alternative (Seattle WPCD, 1992).

Two types of biofiltration facilities are addressed in this section: vegetative swales and vegetative filter strips. A vegetative swale is a channel lined with vegetation which treats runoff as it flows through the vegetation at a shallow depth and relatively slow velocity. A vegetative filter strip is an area covered by vegetation over which runoff sheet flows at a very shallow depth and in a dispersed manner.

Design criteria that will maximize the effectiveness of biofiltration swales and strips are still in the developmental stage because their use for treating storm water has only been applied and investigated for a relatively short time (Puget Sound, 1992).

1. Background

    a. Swales

       Vegetative swales can provide sufficient runoff control to replace curb and gutter in single-family residential subdivisions and on highway medians. Their ability to control large storms is limited because they are designed for a 2-year storm event; therefore, in most cases swales must be used in combination with other Best Management Practices (BMPs) downstream. Swales are usually less expensive to construct than curb and gutter but may require more land. Swale performance diminishes sharply in highly urbanized settings. This reduction may be due to the use of swales for storm water conveyance at flow rates higher than the biofiltration design flow. It should be kept in mind that swales can complement (but seldom substitute for) other BMPs. Swales can last indefinitely if properly designed, periodically mowed, and if sediment is removed as needed (Schueler, 1992).

    b. Filter Strips

       A filter strip is well suited to treating runoff from impervious areas such as parking lots where, for example, frequent gaps in the extruded asphalt curbing provide dispersed inflow points to the filter strip (King County, 1992). In order to distribute runoff uniformly for sheet flow, drainage areas of not more than 5 acres are recommended.

2. Mechanisms of Pollutant Removal

The principal mechanism of treatment in biofiltration is the slowing of particles to which pollutants are attached, allowing them to settle out. Biofiltration removes solids by gravity sedimentation and by filtration through the vegetation (Horner, 1993). This treatment is enhanced by the "taking-up" of the dissolved fraction of pollutants by the vegetation (King County, 1992). Metals are removed by adsorption and ion exchange on the soil surface and in the upper soil horizon. Organics are removed by bacterial decomposition on the vegetation and soils and adsorption in the soils. Nutrient removal is accomplished by plant uptake (Horner, 1993).

3. Pollutant Removal Performance

Ten conventional residential and highway swale systems monitored by six researchers had mixed results. Half of the swales demonstrated a moderate to high pollutant removal capability and the other half showed no removal or negative removal capability. They achieved mixed performance in removing particulate pollutants such as suspended solids and trace metals and were generally unable to remove significant amounts of soluble nutrients. Biofilters that increase detention, infiltration and wetland uptake within the swale have the potential to substantially improve swale removal rates. The vast majority of swales studied are operating as designed with relatively minor maintenance (grass mowing) (Schueler, 1992).

Horner (1993) reports that a recent swale biofiltration performance study in western Washington focused on two residence times (9.3 and 4.6 minutes). The 9.3 minute residence time provided pollutant reduction rates as shown below:

83% Total Suspended Solids (TSS)
67% Lead (relatively insoluble metals)
75% Oil and grease
46% Copper (relatively soluble metals)

There were poor or even negative dissolved nutrient captures, and fecal coliform removal was very inconsistent. Pollutant reductions for the 4.6 minute residence time were generally less, but only by a statistically significant amount in the cases of zinc and iron (Horner, 1993).

Two studies of filter strips in urban areas have indicated that filter strips do not trap pollutants efficiently in urban settings due to high runoff velocity. If the velocity can be controlled (e.g. through flow spreading devices), filter strip performance may increase. Research to date on vegetated filter strips has largely focused on filter strips in agricultural settings. Most of these studies indicate that, when functioning properly, filter strips can remove particulate pollutants with some reliability, but are less dependable for nutrient removal (Schueler, 1992).

G-2.160 B. Applicability

1. Performance in Cold Climates and Use in Anchorage

   No studies have been conducted in the Anchorage area or similar sub-arctic regions. Due to the lack of research and knowledge of effectiveness in a climate such as Anchorage's, innovation is being encouraged. Flexibility is allowed to permit site-by-site assessment and to allow for discretionary design, installation, operating, and maintenance requirements, as long as they do not conflict with the general intent of the requirements stated below (Seattle WPCD, 1992).

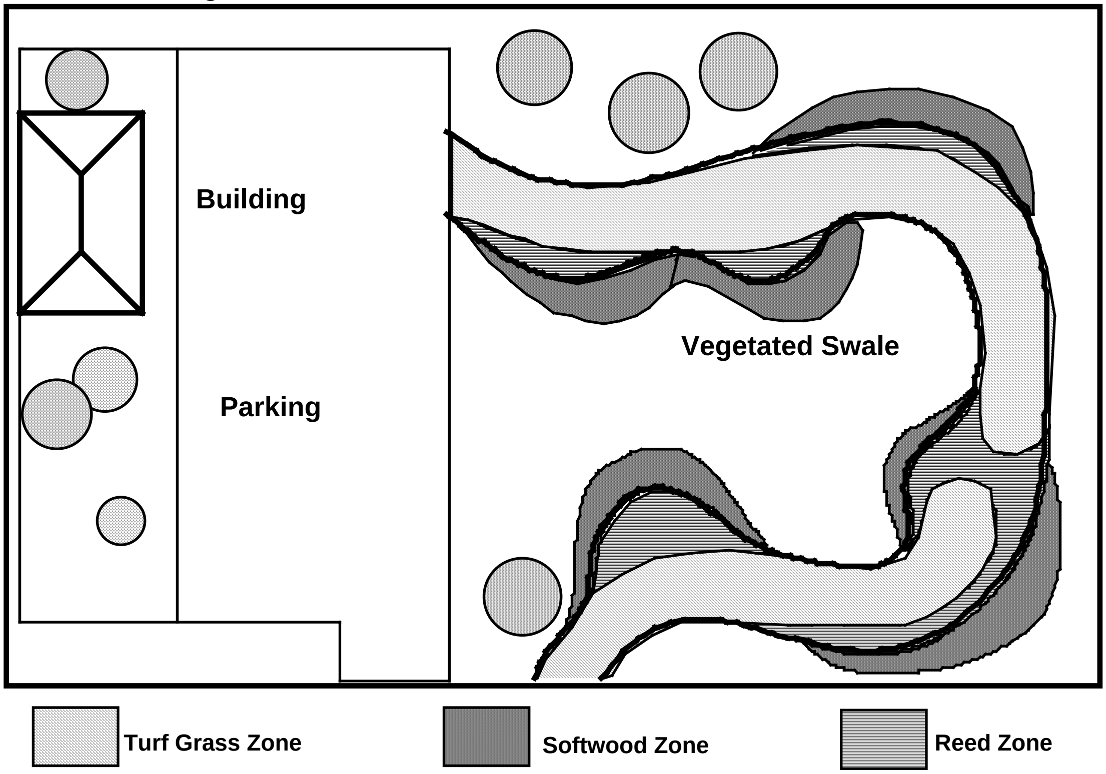
   a. In Anchorage, biofiltration is not applicable during spring breakup and even as long as 4 to 6 weeks after breakup, depending on weather and vegetation growth. Therefore, biofiltration is not useful for snow meltwater runoff at all. Other BMPs will have to be utilized for spring meltwater. Biofiltration's usefulness is limited to summer rainfall and runoff from irrigation, primarily during the months of June through September. However, the superior performance of biofilters in reducing the quantity of pollutants that remain untreated by sedimentation alone overrides the limits caused by the short season of operation (Marshall, 1991).

   b. The performance of swales in removing pollutants may be reduced in regions with long, cold winters and snowmelt conditions, particularly where salts and other de-icing chemicals are applied or where snow plowing scrapes the shoulder (Schueler, 1992). Snow storage along roadsides may also reduce effectiveness by damaging vegetation. Sediment buildup along road shoulders from sanding in the winter may prevent proper drainage into the biofiltration facility.

2. Integration with Landscape Design

   Vegetated swales can be integrated into landscape designs to provide adequate site drainage, aesthetic amenities and created habitats for certain wildlife. By using a curvilinear configuration, edges of vegetated swales can be shaped in a naturalistic way to offer texture, rhythm and interest to any landscape design (Figure G2-1). Vegetated swales should be aligned with the most advantageous solar aspect to provide maximum exposure to sunlight and winter warmth. Pockets along the swale can be planted with native rushes, sedges and willow to soften the visual impact of the swale, aid in residence time and improve pollutant removal. Vegetated swales with integrated wetland plant species should also be considered as relatively low-maintenance design solutions for large sites where moisture is consistent throughout the growing season and the project calls for a unique approach to design, mitigation and environmental sensitivity.

Figure G2-1
Naturalized Vegetative Swale



3. Placement in Conjunction with Other BMPs

Biofiltration should be regarded as one possible element of an integrated storm water management plan for any given site or class of sites. Selection and implementation of alternatives should be based on stated water quality objectives. Meeting the objectives may require the use of two or more techniques that have complementary features in a treatment train; the analysis of options should consider such applications. If a retention/detention pond is required for runoff quantity control at the site, the biofilter should normally follow it in order to receive regulated flow introduction and presettling benefits. Where sufficient land does not exist for both a runoff quantity control pond and a biofilter, nesting a circular biofilter around the circumference of a pond should be considered to allow for both treatment of low flows and the required quantity control. If there is a significant potential for discharge of sediment or oil and grease into the biofilter, the necessary controls should be placed upstream to minimize the entrance of these materials (Seattle WPCD, 1992). Swales can also be coupled with plunge pools, infiltration trenches or pocket wetlands (Schueler, 1992).

G-2.160 C. General Criteria and Guidelines

1. Sources of Plant Materials

   Many of the plants recommended for use in vegetated swales are not commonly found in large quantities by regional suppliers. In many cases, core plugs 3 to 4 inches in diameter can be collected from donor sites as long as permitting and local code requirements are met. Rhizomes, legumes and stolons may be available for certain plants and should be planted 3 to 4 inches below the topsoil surface. Plants should be kept moist and flows should be diverted until plants have germinated and are 3 to 4 inches above the soil surface.

   Grasses used for turf and reed zones are readily available and can be applied by hydromulching. Erosion protection fabrics or geotextiles should be employed within the initial stages of the revegetation to aid in soil retention and even germination of plant seedlings.

   Plant Sources

   Alaska Plant Materials Center
   HC Box 7440
   Palmer, Alaska 99645
   (907) 745-4469

   Seeds of Alaska
   Box 3127
   Kenai, Alaska 99611
   (907) 262-3755

   Tryck Nursery
   PO Box 11-104
   Anchorage, Alaska 99511
   (907) 345-2507

   Plant Source Journal
   606 110th Avenue NE Suite 301
   Bellevue, Washington 98004
   (206) 454-7733

   Directory of Alaska Plant Sources
   Alaska Department of Natural Resources
   Plant Materials Center
   HCO2 BOX 7440
   Palmer, Alaska 99645
   (907) 745-4469

2. Manning Equation

Flow in a biofilter occurs by gravity, under no pressure or confinement, and is classified as open channel flow. The basic equation for open channel flow was first proposed by Manning in 1889:

$$V = (1.49/n)\ R^{0.67}\ s^{0.5}$$

or

$$Q = (1.49/n)\ AR^{0.67}\ s^{0.5}$$

where:

where:	V	=	Velocity (ft/s)
	n	=	Manning's roughness coefficient
	A	=	Cross-sectional area (ft^2)
	R	=	Hydraulic radius (ft) = A/wetted perimeter For filter strips, R _ y (design flow depth) (Seattle WPCD, 1992).
	s	=	Longitudinal Slope as a ratio of vertical rise over horizontal run(ft/ft)
	Q	=	Flow rate (ft^3/s, cfs)

Experiments were conducted during a 1991-92 biofiltration performance study in western Washington to determine the Manning's n roughness coefficient for a typical swale using a common grass mix. It was found that Manning's n = 0.20 was appropriate for typical grass swales mowed somewhat regularly. The number would be somewhat higher (about 0.24) for untended, densely growing swales and grass stands (Horner, 1993).

3. Swale Design

The swale design must meet four tests: maximum flow depth and minimum retention time for the design flow, and adequate channel capacity and channel stability during a reasonably expected high flow event.

- Maximum flow depth determines the channel dimensions, based on the channel geometry and Manning's equation.
- Retention time is checked using the design velocity and swale length. 100 feet is the minimum recommended swale length in order to assure adequate treatment.
- Channel capacity is checked using Manning's equation with the higher flow rate and a lower Manning's n. (The lower n value would reflect channel conditions under high flow.)
- Channel stability is based on the maximum velocity the channel should experience to prevent channel erosion, given that a certain degree of retardance will be provided by the density and height of the vegetative cover. Several studies have been made that relate the maximum permissible swale velocity to three factors: grass types, slope, and soil erosion resistance (Horner, 1993). Maximum permissible velocities found in these studies ranged from 6 fps for erosion-resistant soils with bluegrass turf on shallow slopes to 2.5 fps for easily eroded soils with less dense grasses on slopes exceeding 5 per cent. A maximum permissible swale velocity for of 4 fps for stability

is recommended in the design criteria, based on the results of these studies and the anticipated conditions for vegetated swale applications.

G-2.160 D. Operating Criteria and Guidelines

Keeping the biofilter free of lawn debris and pet wastes is important if the biofilter is to be effective. This may require public education for residents living nearby (Seattle WPCD, 1992). It not only keeps the biofilter attractive, but also reduces the tendency to channelization (Seattle WPCD, 1992)

Urban filter strips that are not regularly maintained may quickly become nonfunctional. Field studies indicate that filter strips tend to have short life spans because of lack of maintenance, improper location and poor vegetative cover (Schueler, 1992). Clean curb cuts when soil and vegetation buildup interferes with flow introduction (Seattle WPCD, 1992).

1. Mowing and Vegetation Harvesting

   Mowing should occur on a regularly scheduled basis during the warm months when turf grasses are growing. Seed mixes for “manicured lawn” or “lawn” applications will need mowing weekly to twice monthly while seed mixes for “naturalized” areas will need mowing once or twice throughout the growing season. Vegetated swales must be mown and cleared of any dead plant material regularly to avoid smothering of other plants and depositing nutrients back into the swale and storm water. Mowing or harvesting encourages young, vigorous growth which is the most effective growth for use in biofiltration swales and strips. The height of the turf depends on the degree of retardance needed for proper residence time. An average height between 2 to 6 inches will serve well for most vegetated swales. Grasses taller than 6" in height lay flat when water flows over them, which prevents sedimentation (Puget Sound, 1992).

   If grass-like plants and woody shrubs are integrated into the swale their foliage should be harvested annually to encourage young, vigorous growth. Harvesting should occur in early spring to clear decaying material allowing oxygen exchange for young growth and plant roots. A line-trimmer or "weed-eater" with steel blade attachment should be used to cut plants back to a height of 8" above the soil level. All debris should be removed from the swale once all plants have been trimmed.

2. Removal of Sediment

   Sediment should be removed whenever it covers vegetation or begins to reduce the biofilter's capacity. Have the grass cut short so that the bed can be made as level as possible (Seattle WPCD, 1992). It is strongly recommended that a device such as a Ditch Master, not a backhoe or dragline, be used to remove sediment (Puget Sound, 1992). If removing sediments by hand, use a flat-bottomed shovel (Seattle WPCD, 1992). Sediments should also be removed from inlet structures, to maintain function and capacity.

3. Plant Maintenance

   a. Reseeding

      Periodic weeding and replanting, particularly in the first few years of life, will allow the vegetative cover to stabilize and become permanent (Schueler, 1992). Reseed damaged or maintained areas immediately or sod with grass plugs from an adjacent upslope area. If possible, redirect flow until the new grass is firmly established. Otherwise, cover the seeded areas with a high quality erosion control fabric (Seattle WPCD, 1992). This periodic repair of eroded areas and regrading around the biofilter may be necessary to assure that flows do not concentrate through or around the biofilter.

   b. Irrigation

      Consideration should be made for access to irrigation water to assure plant success in dry periods.

4. Inspection

   Inspect biofilters periodically, especially after heavy runoff (monthly and after each storm with greater than 0.5 inch of rainfall). Remove sediments and repair vegetation as necessary (Seattle WPCD, 1992). The primary maintenance problem is the gradual build-up of soil and grass adjacent to roads which prevents entry of runoff in swales (Schueler, 1992).

G-2.160 E. Design Methodology Example (Biofiltration Swale)

1. Preliminary Design Procedure

a.	Estimate runoff flow rate	Assume:	Q = 0.5 cfs
b.	Establish longitudinal slope	Set at 2%:	s = 0.02
c.	Select vegetation cover	Grass Mix	
d.	Height of vegetation	5 inches	
	Design depth of flow	3 inches (0.25 ft)	y = 0.25 ft
e.	Select a value of Manning's n	For typical grass swales, mowed regularly:	n = 0.20
f.	Select swale shape	Trapezoid, with side slope, Z	Z = 3:1

g.	Calculate the width	$b = \dfrac{Qn}{1.49\, y^{1.67} s^{0.5}} - Zy$ For Q = 0.5, n = 0.20, y = 0.25, s = 0.02, and Z = 3:	b = 4.1 ft
h.	Compute the cross sectional area	$A = by + Zy^2$ For b = 4, Z = 3, and y = 0.25:	A = 1.19 sf
i.	Compute the flow velocity	V = Q/A For Q = 0.5 and A = 1.19:	V = 0.42 fps
j.	Compute the swale length	L = Vt For V=0.42 and t = 9 min (540 seconds)	L = 227 ft

Assume that in this case, there is only enough space for the swale to be 180 feet long. Try reducing the design length by increasing the width of the bottom of the swale. This can be accomplished by reducing the flow velocity and solving for b:

k.	L = Vt	For L = 180 ft and t = 9 minutes:	V = 0.33 fps
	A = Q/V	For Q = 0.5 and V = 0.33	A = 1.52 sf
	From Figure 2-30, the equation for A is: $A = by + Zy^2$	Solving this equation for b results in: $b = \dfrac{A - Zy^2}{y}$ For A = 1.52, Z = 3, and y = 0.25:	b = 5.33 ft

2. Check Design for Channel Stability

a.	Highest expected flow rate and least vegetation cover expected	Assume: Select: Grass Height = 3 inches Coverage = Fair	Q = 1.6 cfs
b.	Degree of retardance	from Figure 2-32	Low (D)
c.	Maximum permissible velocity for erosion prevention	Assume for easily eroded soils planted with grasses:	V_{max} = 4 fps
d.	Select a value of Manning's n	For poor vegetation coverage and low height:	n = 0.04
e.	First approximation for the product of velocity and hydraulic radius (VR)	For n = 0.04 and "D" Degree of Retardance, from Figure 2-33:	VR_{approx} = 3 ft^2/s

f.	Compute the hydraulic radius for the maximum permissible velocity	$R = VR_{approx}/V_{max}$ For VR_{approx} = 3 and V_{max} = 4:	R = 0.75 ft
g.	Solve for the actual product of velocity and hydraulic radius	$VR = (1.49/n)\ R^{1.67}s^{0.5}$ For n = 0.04, R = 0.75, and s = 0.02:	$VR = 3.26\ ft^2/s$
	Compare to approximation	VR _ VR_{approx} by >5%	
	Increase n	n = 0.041 and "D", from Figure 2-33:	VR_{approx} = $2.6\ ft^2/s$
	Recompute the hydraulic radius for v_{max}	$R = VR_{approx}/V_{max}$ For VR_{approx} = 2.6 and V_{max} = 4:	R = 0.65 ft
	Solve again for the actual product of velocity and hydraulic radius	$VR = (1.49/n)\ R^{1.67}s^{0.5}$ For n = 0.041, R = 0.65, and s = 0.02:	$VR = 2.7\ ft^2/s$
		VR _ VR_{approx} by <5%, therefore use newly calculated VR:	$VR = 2.5\ ft^2/s$
h.	Compute the actual velocity for the final design conditions	V = VR/R For VR = 2.5 <CR> and R = 0.65:	V = 3.85 fps
	Compare v and v_{max}	3.85 < 4 V < V_{max}, therefore OK	
i.	Compute the required cross sectional area for stability and compare to the design cross sectional area	$A_{stability} = Q/V$ For Q = 1.6 and V = 3.85:	$A_{stability} = 0.42\ ft^2$
	If $A_{stability} > A_{design}$, select new trial sizes for width and flow depth	0.42 < 1.52 $A_{stability} < A_{design}$, therefore design is stable enough to prevent erosion	
j.	Calculate the depth of flow at the stability check flow rate condition and compare to the design depth of flow	$y = \frac{-b \pm (b^2 + 4ZA)^{0.5}}{2Z}$ For b = 5.33, Z = 3, and A = 0.42:	y = 0.08 ft
	Select the larger y and add one foot freeboard for total depth of swale	y = 0.25	Depth of Swale = 1.25 ft
	Calculate the top width	T = b + 2yZ For b = 5.33, y = 1.25, and Z = 3:	T = 12.83 ft

k.	Check for flow capacity based on the stability check design storm and maximum vegetation height and cover	$A = by + Zy^2$ $R = by + Zy^2$ $b + 2y (z^2 + 1)^{0.5}$ For b = 5.33, Z = 3, and y = 1.25:	$A = 11.35\ ft^2$ R = 0.86 ft
		$Q = (1.49/n)\ AR^{0.67}\ s^{0.5}$ For n = 0.2, A = 11.35, R = 0.86, and s = 0.02:	Q = 10.8 cfs
	Compare the flow capacity to the largest expected event	10.8 > 1.6, flow capacity is greater than largest expected flow volume, therefore OK	

Review the general criteria and guidelines in section 2.160 C. and specify appropriate features for the vegetatitve swale.

G-2.160 F. References

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Schueler, Thomas R., Peter A. Kumble, and Maureen A. Heraty. 1992. A Current Assessment of Urban Best Management Practices, Techniques for Reducing Non-Point Source Pollution in the Coastal Zone. Prepared for USEPA, Office of Wetlands, Oceans, and Watersheds. March.

Water Quality Facility Design. 1992. In King County, Washington, Surface Water Design Manual. King County Department of Public Works. November.

SECTION 2.160 BIOFILTRATION DESIGN CRITERIA

2.160 A. Objective

General and specific criteria are presented in this section for the evaluation, siting, design, construction, and maintenance of vegetative swales and vegetative filter strips for water quality enhancement. A vegetative swale is a channel lined with vegetation which treats runoff as it flows through the vegetation at a shallow depth and relatively slow velocity. A vegetative filter strip is an area covered by vegetation over which runoff sheet flows at a very shallow depth and in a dispersed manner. Schematics of these two structures are shown in Figure 2-26.

2.160 B. Site Selection Criteria

1. Use of natural topographic low areas for biofiltration is encouraged.

2. Roadside ditches are significant potential biofiltration sites, but winter damage from snow plowing scrapes, deicing chemicals, sand application or snow storage may damage vegetation and reduce effectiveness. Road design and ditch maintenance should be considered.

3. The percolation rate of underlying soils may require additional design elements.

4. Biofilters can be integrated into landscape designs by use of wetland plants, wild flowers, bushes and trees on upper areas of swales.

5. Filter strips can be used for drainage areas up to 5 acres because of their sheet flow design and the difficulty in spreading flows from larger areas uniformly.

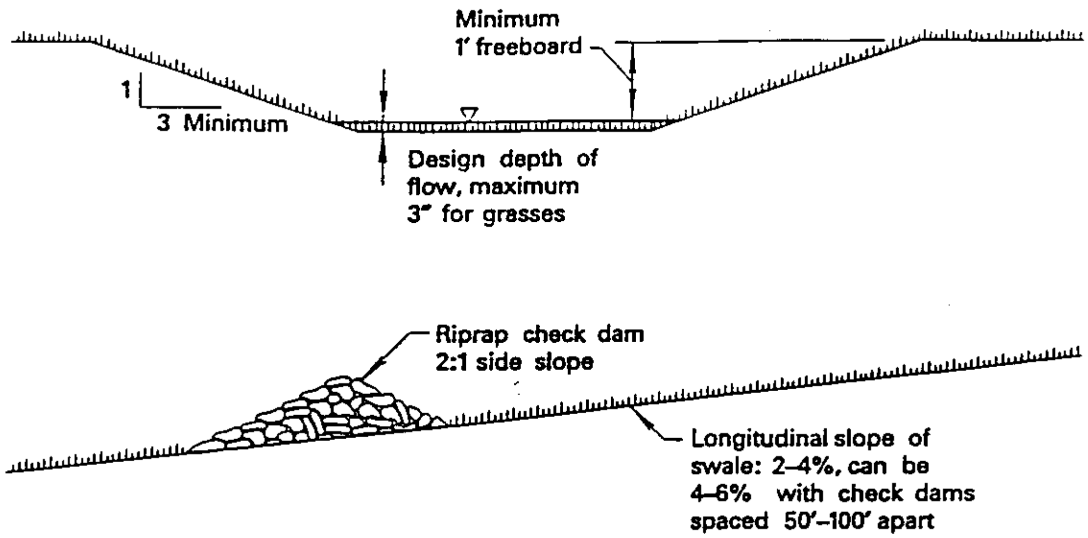
2.160 C. Design Considerations

The success of biofiltration depends on proper construction and maintenance. The design, planning, operation and maintenance details that follow have been adapted from the best available information, but it must be considered as interim and subject to modification as experience is gained with applications in Anchorage.

1. Design Criteria for Swales and Filter Strips

   Design variables for swales and filter strips are summarized in Figure 2-27. Flow is open channel, as described by Manning's equation. Grade biofilters carefully to attain uniform longitudinal and lateral slopes and to eliminate high and low spots. If the grading equipment blade is wider than the swale bottom width, obtain a smaller blade or employ hand finishing in order to ensure uniformity.

VEGETATIVE SWALE



VEGETATIVE FILTER STRIP

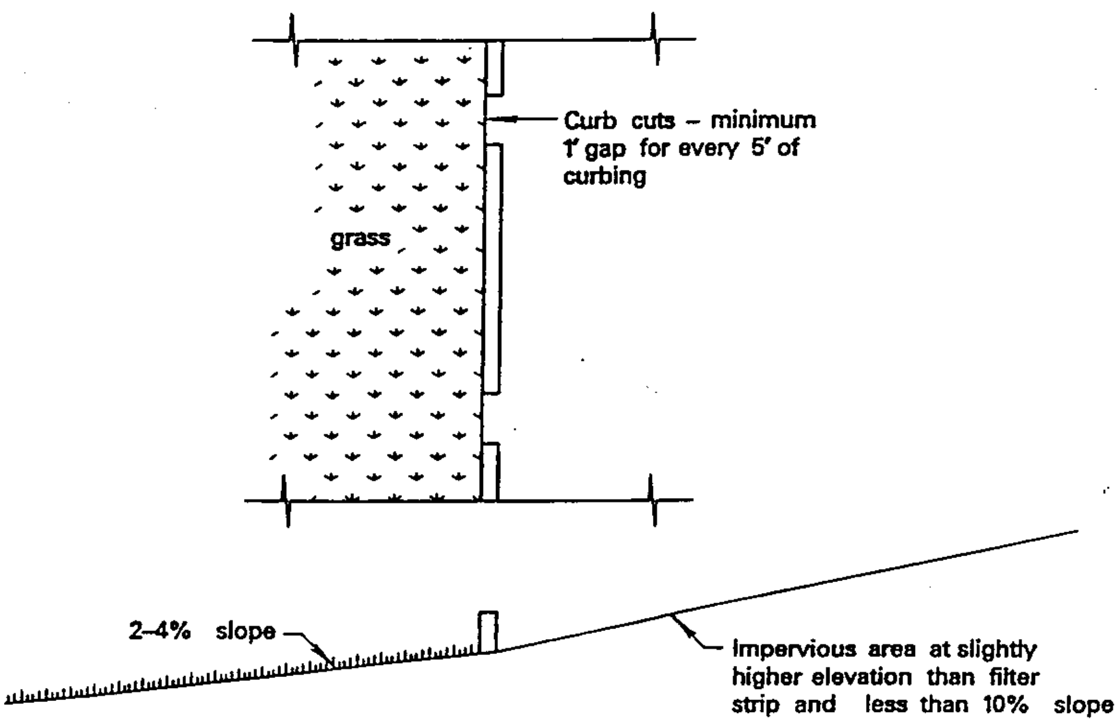


FIGURE 2–26

Figure 2-27
Biofiltration Design Criteria

Criteria	Swale	Filter Strip
Width	2 foot minimum	No greater than the width for which uniform flow distribution is possible
Length[a]	> 100 feet	No limit
Depth of Design Flow	Grass: maximum 3 inches (< 1/3 height of unmowed grass, < 1/2 height mowed grass) > 2 inches below normal height of wetland plants	_ 0.5 inch
Velocity[b]	0.9 ft/s maximum	0.9 ft/s maximum
Longitudinal Slope[c]	2 to 4 percent	2 to 4 percent
Side Slope	No steeper than 3 horizontal to 1 vertical	Not applicable
Design Flow Rate	Peak flow rate from the 2-year, 6-hour rainfall event	No greater than uniform flow will allow
Manning's n	0.20 for mowed grass 0.24 for untended grass	0.20 for mowed grass 0.24 for untended grass
Hydraulic Residence Time	9 minutes optimal 5 minutes minimum	9 minutes optimal 5 minutes minimum

(a) A wide-radius curved path may be used to gain length where land is not adequate for a linear swale, but sharp bends must be avoided. In order to provide adequate treatment, 100 feet is recommended as a minimum length.

(b) During a study in western Washington, the grass began bending from a vertical position when the flow velocity increased above 0.9 ft/s.

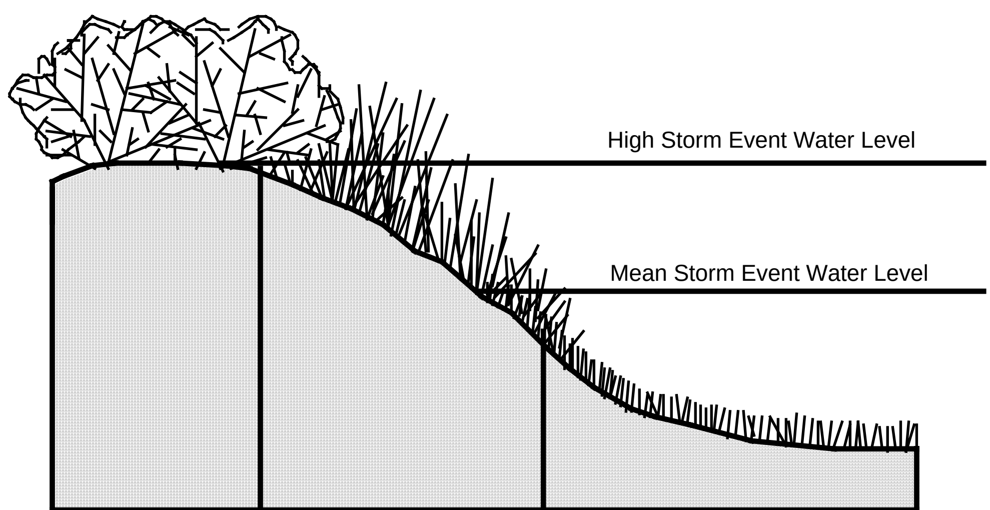
(c) If slope is 1 to 2 percent, install an underdrain with perforated pipe or, if moisture is adequate, establish wetland species. With an underdrain, use topsoil with a relatively large proportion of sand. Place a six inch minimum diameter perforated pipe in a trench filled with 5/8-inch minus round rocks and lined with Mirafi 140 NS or equivalent filter fabric. The pipe should be at least 12 inches below the biofilter bed. If slope is between 4 and 6 percent, add check dams at 50 to 100 foot intervals. If the slope is greater than 6 percent, traverse the grade to reduce the slope of any segment to below 4 percent, or to below 6 percent with check dams.

2. Vegetation

Select plants based on their structural, aesthetic and biochemical characteristics in order to provide pleasing visual characteristics, optimum structure and contamination removal potential. Consideration of potential contaminants should include, but is not limited to: suspended solids, excess nutrients, non-soluble heavy metals, oil, grease, deicing salts and winter sanding particles. Maximize available light and warmth to encourage vigorous plant growth for the longest time possible. A southern exposure with little shade is preferred.

Three zones for plants have been established to help in the appropriate selection of plants for creating vegetated swales with more than one plant type: the Softwood Zone, the Reed Zone and the Turf Grass Zone. Figure 2-28 depicts the planting zones and gives the technical parameters for proper plant selection. It should be noted that the Turf Grass Zone is shown as the lowest zone in the graphic, but if the vegetated swale will remain saturated or is within close proximity to ground water, plants for the Reed Zone will serve most efficiently in the basin of the swale. Plants native to the Anchorage area have been cross referenced for their applicability within these zones and are found in Figure 2-29. This list should serve as a basic source although research on the Anchorage area plants suitable for vegetated swales is limited at this time.

Figure 2-28
Planting Zones



Softwood Zone	Reed Zone	* Turf Grass Zone
1.5 Feet Above Mean Storm Event Water Level	6 Inches To 1.5 Feet Above Mean Storm Event Water Level	6 Inches Above to 6 Inches Below Mean Storm Event Water Level

***** The Turf Grass Zone is lowest in the graphic but, if the swale remains saturated or is close to groundwater, Reed Zone plants should be used as basin cover materials.

Figure 2-29
Vegetation Suitable for Biofiltration in Anchorage

Shrubs and Woody Plants (Softwood and Reed Zones)

Common Name	Scientific Name	Nat. Indicator
Red Osier Dogwood	*Cornus stolonifera*	FAC
Pacific Willow	*Salix caslandra*	FACW
Scouler Willow	*Salix scoulerana*	FAC

Grass-Likes (Reed and Turf Grass Zones)

Common Name	Scientific Name	Nat. Indicator
Water Sedge	*Carex aquatilis*	OBL
Least Spikerush	*Eleocharis acicularis*	OBL
Creeping Spikerush	*Eleocharis palustris*	OBL
Square-Stemmed Spike Rush	*Eleocharis quadangulata*	NI
Fowl Manna Grass	*Glyceria striata*	OBL
Soft Rush	*Juncus effusus*	OBL
Three Stamen Rush	*Juncus ensifolius*	FACW
Slender Rush	*Juncus tenuis*	FACW
Hard-Stemmed Bullrush	*Scirpus acutus*	FAC
Olney's Bulrush	*Scirpus americanus*	OBL
Small Fruit Bulrush	*Scirpus microcarpus*	OBL
Softstem Bulrush	*Scirpus validus*	OBL

Grasses (Turf Grass and Reed Zones)

Common Name	Scientific Name	Nat. Indicator
Wheatgrass	*Agrophyron macrourum*	FAC
Redtop	*Agrostis alba*	OBL
Egan Sloughgrass	*Beckmannia syzigahne*	FAC
Bluejoint Reedgrass	*Calamagrostic canadensis*	FAC
Red fescue	*Festuca Rubra*	FAC
Reed meadowgrass	*Glyceria maxima*	OBL
Three stamen Rush	*Juncus ensifolius*	FACW
Slender Rush	*Juncus tenuis*	FACW
Reed Canary Grass	*Phalaris arundinacea*	OBL
Small Fruit Bulrush	*Scirpus microcarpus*	OBL

Figure 2-29 (Cont.)
Vegetation Suitable for Biofiltration in Anchorage

Forbs (All Zones)

Common Name	Scientific Name	Nat. Indicator
Watershield	*Brasenia schreberi*	OBL
Common Hornwort	*Ceratophyllum dermersum*	OBL
Lesser Duckweed	*Lemna minor*	OBL
Eurasian Water Milfoil	*Myriophyllum spicatum*	OBL
Pigmy Water Lilly	*Nymphaea tetragona*	OBL
Yellow Cow Lilly	*Nymphaea tuteam*	OBL
Water Parsley	*Oenanthe sarmentosa*	OBL
Leafy Pondweed	*Potamegeton foliosus*	OBL
Grassy Pondweed	*Potamegeton gramineus*	OBL
Floating Leaf Pondweed	*Potamegeton natans*	OBL
Sago Pondweed	*Potamegeton pectinatus*	OBL
Small Pondweed	*Potamegeton pusillus*	OBL
Flat-Stemmed Pondweed	*Potamegeton zosteriformis*	OBL
Floating Leaf Pondleaf	*Potamogeton gramineus*	OBL
Floating- Leaf Pondweed	*Potamogeton natans*	OBL
Widgeon-Grass	*Ruppia maritima*	OBL
Small Burreed	*Scirpus minimum*	OBL
Seaside Arrow Grass	*Triglochin maritimum*	OBL
Broad-Leaf Cattail	*Typha latifolia*	OBL
Horned Pondweed	*Zannichellia palustris*	OBL
Eel Grass	*Zostera marina*	OBL

NOTE:

Natural Indicator Categories

1. Obligate Wetland (OBL): Occur almost always under natural conditions in wetlands.
2. Facultative Wetland (FACW): Usually occur in wetlands, but occasionally found in non-wetlands.
3. Facultative (FAC): Equally likely to occur in wetlands or non-wetlands.
4. Facultative Upland (FACU): Usually occur in non-wetlands, but occasionally found in wetlands.
5. No indicator (NI): Not an indicator species.

When specifying appropriate seed mixes for areas to be managed as turf, both the amount of maintenance an area will receive (i.e. mowing), as well as the desired aesthetic appeal should be considered. These variables are directly related. The following list describes both the maintenance and aesthetic attributes of respective seed mixes. (The grasses listed in Figure 2-30 include introduced and indigenous species; they are not all included in Figure 2-29.) Turf areas should be watered one-half inch per day during the first fourteen days after seeding.

Figure 2-30
Seed Mixture Attributes

Type	Aesthetic Description	Maintenance Requirements	Seed Mixes
Schedule A:	Manicured Lawn	High Maintenance	5% Annual Rye Grass, 30% “Nugget” Kentucky Bluegrass, 25% “Merion” Kentucky Bluegrass, 40% Boreal Fescue
Schedule C:	Naturalized Grasses	Low Maintenance	15% Red Fescue (Boreal Arctared), 30% Meadow Foxtail, 30% Timothy (Engmo), 25% Hard Fescue (Tournament, Scaldis)
Schedule D:	Manicured Lawn	Moderate Maintenance	30% Red Fescue, 10% Clover, 20% “Merion” Kentucky Bluegrass 30% “Nugget” Kentucky Bluegrass 10% Hard Fescue (Tournament, Scaldis)

NOTE: Application rate for all types is 5 lbs/1000 sf.
(Reference Municipality of Anchorage Standard Specifications, Section 75.05 Article 5.2, 1994 edition)

3. Substrate

   a. If there is a possibility of ground water contamination, a 12” liner of Bentonite clay will be necessary. The requirement for a clay layer can be waived under certain conditions:

- A horizontally continuous, 12” or thicker layer of underlying soils in one of the following frost categories: F3c, F4c, and F4d (per MOA Design Criteria Manual Figure 1-29) is present between the surface and the ground water table.
- The area is down gradient of any ground water recharge or withdrawal area.
- Ground water quality is not likely to be impaired for use.
- Other demonstrated mitigating circumstances are present at the site.

b. A 12" layer of topsoil is recommended for all vegetated swales, consisting of:

Organic (excluding animal waste)	5 to 15% by weight
Silt	40 to 50% by weight passing #200 sieve
Sand	40 to 50% by weight
Gravel	less than 2%

4. Flow Bypass

a. If the biofilter is preceded by a runoff quantity control device, a high-flow bypass will not be needed. Consider a bypass if the biofilter discharges directly to a sensitive receiving water without quantity control, in order to maintain the vegetation in an appropriate condition to treat subsequent smaller storms. If a bypass is used, it should consist of an inlet flow regulating device and a pipe or channel. Above the peak runoff for the 2-year, 6-hour duration design storm event for the proposed developed conditions, runoff should bypass the swale in a separate conveyance to the point of discharge.

b. A mechanism should also be provided at the bypass point to allow the swale to be manually taken "off-line" for maintenance and repair.

5. Inlet

Install a flow-spreading device to uniformly distribute flow in the swale inlet or across the width of the filter strip. Shallow weirs, stilling basins, riprap, and perforated pipes provide for energy dissipation at the inlet. For riprap, 6-to 9-inch rocks should be fitted tightly together across the bed and for a distance of 5- to 10-feet downstream. If vandalism is likely, embed the rocks in concrete. Provide access for sediment clean-out of inlet structures. Inlet structures should be cleaned annually following break-up, or more frequently if necessary.

Curb cuts in a parking lot and/or a shallow stone trench installed across the top of a filter strip can serve as a level spreader. If flow is to be introduced via curb cuts, place pavement slightly above the biofilter elevation. Curb cuts should be at least 12 inches wide to prevent clogging. Curbing for impervious areas tributary to filter strips shall be designed with a one-foot gap for every 5 feet of curbing. The transverse slope of impervious areas tributary to filter strips shall be level, and the impervious area cross slope shall not exceed 10 percent (Figure 2-26). Make provisions to avoid flow bypassing the filter strip.

6. Check Dam

   If the longitudinal slope is between 4 and 6 percent, add check dams every 50 to 100 feet along the length of the swale, starting 20 feet downstream from the inflow point. The check dam may be constructed of:

   a. Riprap with 2:1 side slopes (Figure 2-26).

   b. A railroad tie with weep holes and riprap on the downstream side to prevent scour.

   c. Plants suitable for reed and softwood zone plantings. Plantings two to three feet in width can adequately slow velocity of water while naturalizing the appearance of the vegetated swale.

7. Access Easements

   Access easements to biofilters on private land are necessary for inspection, monitoring, and maintenance. Provision for water quality monitoring facilities should be made part of the design. An access easement for maintenance is required along all constructed channels located on private property. Restrictions on velocity of flow and retention time may require certain site conditions that may restrict the use of biofiltration. Required easement widths vary with channel top width as shown below:

Figure 2-31
Access Easement Widths

Top Width of Swale (W)	Easement Width
W _ 10’	W + 10’ on one side
10’ < W _ 30’	W + 15’ on one side
30’ < W	W + 15’ on both sides

2.160 D. Design Methodology

1. Initial Design

   a. Determine design flow. Estimate the runoff flow rate for the 2-year, 6-hour rainfall event, using the ILLUDAS system as described in Section 2.050 C. of the Design Criteria Manual.

   b. Establish the slope following the guidelines in Figure 2-27.

   c. Select a vegetation cover suitable to the site from Figure 2-29.

d. Establish the height of vegetation and determine the design depth of flow. If grass will be mowed regularly, the depth of flow should be less than one-half of the grass height. If grass is not mowed, the depth of flow should be less than one-third of the grass height. Maximizing height advances biofiltration and allows greater flow depth, which reduces the width necessary to obtain adequate capacity.

e. Select a value of Manning's n from Figure 2-27.

f. Select a cross section shape. Normally, swales are designed as trapezoidal structures (Figure 2-32). A parabolic shape best resists erosion, but is hard to construct. However, over time a trapezoidal swale may develop a parabolic shape. For the trapezoidal shape, the side slope (Z) must be greater than or equal to 3.

g. Determine the channel width. The Manning equation is:

$$Q = (1.49/n)\ AR^{0.67}\ s^{0.5}$$

where:			
	Q	=	Design flow rate (ft^3/s, cfs)
	n	=	Manning's roughness coefficient
	A	=	Cross-sectional area (ft^2) (see Figure 2-32)
	R	=	Hydraulic radius (ft) = A/wetted perimeter (see Figure 2-32)
	s	=	Longitudinal slope as a ratio of vertical rise over horizontal run (ft/ft)

A value for the width based on rewriting the Manning Equation can be obtained but the equations are difficult to solve manually. The following assumptions can simplify the process. Since T is much greater than y and Z^2 is much greater than 1, certain terms are negligible, so the following approximations for hydraulic radius may be used:

Trapezoidal: R _ y
Parabolic: R _ 0.67 y
Filter Strip: R _ y

Using these approximations and solving for the width results in the following equations:

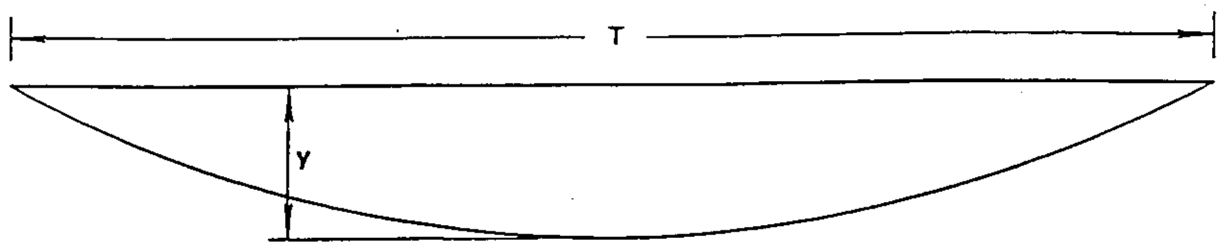
Trapezoidal: $$b \_ \frac{Qn}{1.49\ y^{1.67}\ s^{0.5}} - Z y$$

Parabolic: $$T \_ \frac{Qn}{0.76\ y^{1.67}\ s^{0.5}}$$

Filter Strip: $$T \_ \frac{Qn}{1.49\ y^{1.67}\ s^{0.5}}$$

CHANNEL GEOMETRY

Parabolic Shape

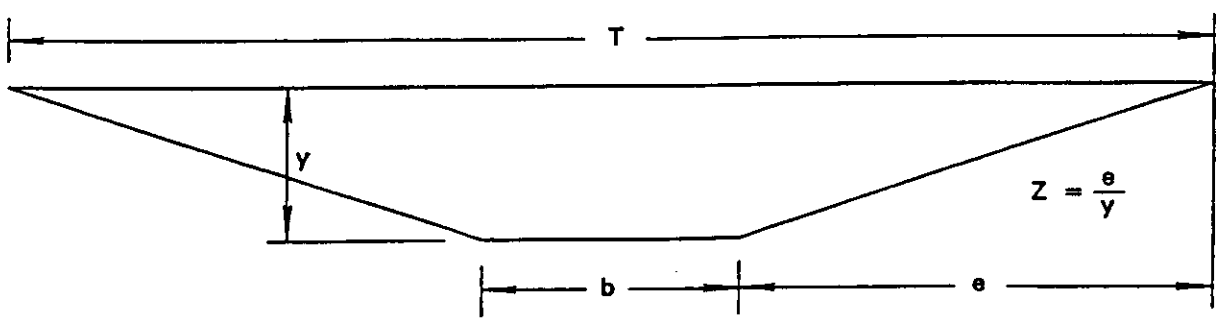


Cross-Sectional Area (A) $= \frac{2}{3} Ty$

Top Width (T) $= \frac{1.5A}{y}$

Hydraulic Radius (R) $= \frac{T^2 y}{1.5T^2 + 4y^2}$

Trapezoidal Shape



Cross-Sectional Area (A) $= by + Zy^2$

Top Width (T) $= b + 2yz$

Hydraulic Radius (R) $= \frac{by + Zy^2}{b + 2y\sqrt{Z^2 + 1}}$

FIGURE 2–32

If b for a swale is less than two feet, which is the minimum allowable width (Figure 2-27), set b equal to two feet and continue.

h. Compute the cross sectional area (Figure 2-32).

i. Compute the flow velocity:

$$V = \frac{Q}{A}$$

If V > 0.9 fps, modify swale design and recalculate.

j. Compute the swale length based on required detention time:

$$L = Vt$$

where: t = 9 minutes

k. If the result is a length greater than the space permits, check to see if Q can be reduced, or if the width or flow depth can be increased. If, after these possibilities have been exhausted, the calculated length is still too long, it can be reduced, but to no less than 5 minutes.

If L< 100 feet, increase it to 100 feet (Figure 2-27).

2. Check Design for Channel Stability and Capacity

a. Select the highest expected flow and least vegetation cover and height. Unless runoff from events larger than the 2-year, 6-hour storm will bypass the biofilter, perform the stability check for the 100-year, 24-hour storm.

b. Estimate the degree of flow retardance from Figure 2-33 based on normal grass height and density of vegetative cover. When uncertain, be conservative by selecting a relatively low degree (higher letter).

Figure 2-33
Guide for Selecting Degree of Flow Retardance

Normal Grass Height (inches)	Very Dense Vegetative Cover		Fairly Dense Vegetative Cover	
	Degree of Retardance		Degree of Retardance	
>25	Very High	A	High	B
11-25	High	B	Moderate	C
6-10	Moderate	C	Low	D
2-6	Low	D	Low	D
<2	Very Low	E	Very Low	E

c. Establish the maximum permissible velocity for erosion prevention (V_{max}) at 4 fps.

d. Select a trial Manning's n. The minimum value for poor vegetation cover and low height is 0.033 (which is possible if the grass is knocked down from high flow). A good initial choice under these conditions is 0.04.

e. Obtain a first approximation for the product of velocity and hydraulic radius (VR_{approx}), using the graph in Figure 2-34.

f. Compute the hydraulic radius for the maximum permissible velocity:

$$R = \frac{VR}{V_{max}}$$

g. Solve for the actual product of velocity and hydraulic radius and compare to the first approximation:

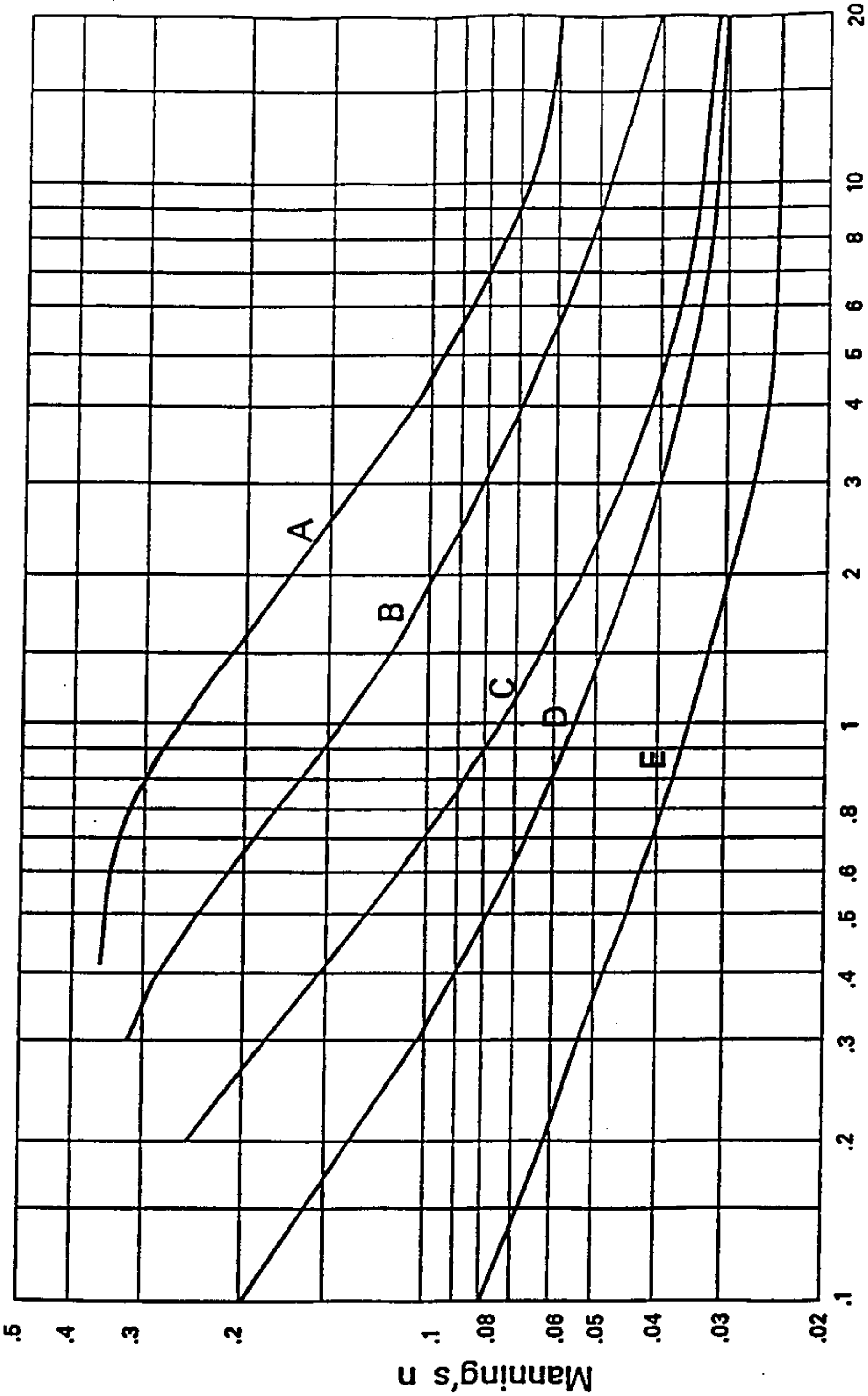
$$VR = 1.49/n\ R^{1.67}\ s^{0.5}$$

If they do not agree within 5 percent, select a new trial Manning's n and recalculate. However, if n < 0.033 is needed for agreement, set n = 0.033, repeat this calculation for the product of velocity and hydraulic radius (VR), and proceed with step h.

h. Compute the actual velocity for the final design conditions:

$$V = VR_{approx/}R$$

Check that $V < V_{max}$ from step c.



Note: VR is the product of velocity and hydraulic radius
Source: Horner, 1993

The Relationship of Manning's n with VR for Various Degrees of Flow Retardance (A–E)

FIGURE 2–34

i. Compute the required cross sectional area for stability:

$$A_{stability} = Q/V$$

Compare to the design cross sectional area. If $A_{stability} > A_{design}$, select new trial sizes for the width and depth of flow.

j. Calculate the depth of flow at the stability check flow rate condition and compare to the design depth of flow. Use the larger of the two and add one foot freeboard to obtain the total depth of the swale. Calculate the top width (T).

k. Check for flow capacity based on the stability check design storm and maximum vegetation height and cover. This check will ensure that capacity is adequate if the largest expected event coincides with the greatest retardance.

3. Review the general criteria and guidelines in section 2.160 C. and specify appropriate features.

2.160 E. Maintenance Requirements

Maintenance is the responsibility of the land owner. The land owner shall maintain vigorous healthy vegetation and preserve the function of the vegetated channel. The land owner will enter into a maintenance agreement with the municipality which details the extent, timing, and scope of maintenance for the biofiltration structure(s).

1. The agreement, at a minimum, will include the following provisions:

   a. Description of the work items to be performed, including but not limited to:
      - routine and post-storm event inspections
      - appropriate watering, pruning, mowing, vegetation harvesting
      - insecticide spraying, fertilizing
      - reseeding, plant replacement
      - sediment removal
      - trash removal
      - other necessary tasks

   b. Schedule for the completion or frequency of each work item
   c. Party performing the work
   d. Party paying for the work
   e. A method of record-keeping detailing when work items were performed

2. No agreement requiring municipal maintenance will be accepted without approval and acceptance by the DPW maintenance division.