SOIL CONSERVATION SERVICE

FILTER STRIP

Definition

A strip or area of vegetation for removing sediment, organic matter, and other pollutants from runoff.

Scope

This standard establishes the minimum acceptable requirements for the design, construction, and maintenance of vegetated filter areas. It applies to areas where surface runoff transports suspended soil and/or organic particles which will pollute surface or ground water.

Vegetated filter strips for waste management systems can be overland flow or channelized flow. The overland flow filter strip is generally not less than 20 feet wide. It has a very shallow flow depth (approximately one-half inch) which will allow infiltration and as much contact with the vegetation and ground surface as possible. A channelized flow filter strip is a natural or constructed channel which is generally less than 20 feet wide. The channel flow depth will usually be one-half foot or less.

This standard does not apply to filter strips used for industrial or human wastes.

Purpose

To remove sediment and other pollutants from runoff by filtration, infiltration, absorption, adsorption, decomposition, and volatilization, thereby reducing pollution and protecting the environment.

Conditions Where Practice Applies

This practice applies:

1. On cropland at the lower edge of fields or on fields adjacent to streams, ponds, and lakes.

2. In areas requiring filter strips as part of a waste management system to treat polluted runoff or waste water when the following conditions are met:

    a. The feedlot or barnyard area is one acre or less.

    b. Bedrock and/or ground water are more than two feet below the ground surface.

c. The animal waste system is not subject to the National Pollutant Discharge Elimination System permit program (no-discharge for "point sources" of pollution).

3. In wooded areas where filter strips are needed as part of a harvesting system to reduce delivery of sediment into waterways.

Planning Considerations

Evaluate the kind of soil; its texture, permeability, available water capacity, friability, and underlying material and slope. Also evaluate vegetative species, time of year for proper establishment of vegetation, necessity of irrigation, visual aspects, fire hazards, and other special needs.

Concentrated flow must be minimized and needed repairs made immediately to reestablish sheet flow over overland flow filter strips.

Erosion control facilities to outlet filter-strip effluent into streams or channels shall be considered.

If filter strips are to be used in treating waste water or polluted runoff from concentrated livestock areas, the following must be considered:

1. Facilities (basin or channel) to remove settleable solids before directing the flow through the filter strip.

2. Good drainage to insure satisfactory performance.

3. A flat filter strip cross section (perpendicular to flow direction) to insure uniform distribution of flow.

4. Provisions for preventing continuous or daily discharge of liquid waste unless the area is adequate for infiltrating all daily applied effluent. Enough rest period to maintain an aerobic soil profile is required.

5. An adequate filter area and length of flow to provide the desired pollutant reduction. A serpentine or switchback channel can be used to provide greater length of flow.

6. Provisions for excluding roof water and unpolluted surface runoff.

7. Filter slopes four percent or less are suggested for overland flow filter strips. Special design is needed for slopes greater than four percent.

8. Provisions for cutting and removing vegetation to maintain the effectiveness of the filter area.

9. The need for a level-lip weir, gated pipe or sprinklers to uniformly distribute the flow across the upstream end of the filter area.

Filter Strip Design Criteria for Runoff from Concentrated Livestock Areas

Runoff

Runoff will be based on the 10-year, 24-hour rainfall. The following values of rainfall and runoff may be used:

Rainfall = 4.0 inches

Runoff Curve No.	Runoff (inches)
85	2.5
90	2.9
95	3.4
98	3.8

The suggested runoff curve numbers are 90 for unpaved lots and 95 for paved lots.

Peak Discharge

The peak discharge from the lot area can be determined from Table 5-3, Tabular Discharges for Type II Storm Distribution (csm/in), Technical Release No. 55, Urban Hydrology for Small Watersheds, or by using other approved hydrology methods. Peak discharges in table 1 may be used for the respective lot sizes and runoff curve numbers.

Flood routing procedures described in the Engineering Field Manual, pages 11-55b and 11-55c may be used when applicable. Sediment and/or manure storage must be considered in all settling basins.

Settling Basin

A settling basin shall be constructed upstream from the filter area when the herd size is greater than 50 animal units. A settling basin is also recommended for herds smaller than 50 animal units. Any of the following types of settling basin may be used:

(A) The settling basin may be a concrete or wood wall constructed at the downstream edge of the lot (storage on the lot). Water outlets from the storage shall be sized according to the filter strip design (i.e. width, slope).

(B) When storage on the lot is not acceptable, a rectangular concrete settling basin may be constructed. The length to width ratio of the rectangular basin will be 3:1 to 5:1. The depth of the rectangular basin will usually be 3-6 feet. A factor of 30% should be added to the volume of water storage to allow for sediment and/or manure storage.

The minimum detention time should be fifteen minutes. The detention time for rectangular basins will be determined by the equation:

$$\text{Detention time (min)} = \frac{\text{Volume (V) of water storage (ft3)}}{\text{*Discharge (cfs)}} = \frac{\text{V (ft)3}}{\frac{\text{ft3}}{\text{Sec}} \times \frac{\text{60 Sec}}{\text{Min}}}$$

*Discharge = the settling basin outlet discharge or the peak discharge from table 1.

(C) A channel which is 200 feet long with a design velocity of 0.5 feet per second or less (Manning's n = 0.025) can be considered a settling basin. A flow depth of 0.5 feet or less is recommended. The channel should have one side slope 8:1 or flatter for cleaning purposes.

Overland Flow Filter Strip

The cross section of the overland flow filter strip shall be flat. The flow must be evenly distributed for the full width of the filter. A weir-type inlet (up-stream) could be used for gravity flow. For slopes greater than two percent and flow lengths greater than 150 feet, a collection system and a system or device to redistribute the flow is recommended.

The minimum width shall be 20 feet. Guide borders (small earth ridges not less than 3" or more than 6" high parallel to the direction of flow) are recommended when the width exceeds 100 feet. The width (greater than 20') shall be determined by using the design discharge to the filter strip.

The minimum filter strip length shall be determined by using the designed contact time. Contact time equals the length of the filter divided by the average flow velocity. The minimum length shall be calculated by using a contact time of 630 seconds for a 1" flow depth or 1000 seconds for a 0.5" flow depth.

The flow velocity shall be calculated by using Manning's equation. The design flow depth shall be not less than 0.5" nor more than 1". Manning's "n" value shall be 0.3. Table 2 can be used for minimum filter strip lengths for 0.5 - 4.0 percent filter strip slopes.

Tables 3 and 4 can also be used for the overland flow filter strip design if applicable.

When runoff from a manure storage or stack or when lot runoff is allowed to directly enter the filter strip (no settling basin), the filter strip length will be increased to 150 percent of the minimum filter length.

Channelized Flow Filter Strip

Foreign water runoff from adjacent acres shall be diverted from the filter area where possible.

The cross section of constructed channels shall be trapezoidal. The minimum design capacity of the channel shall be the maximum discharge of the settling basin (if applicable) or the peak discharge from the lot area. The maximum design flow depth shall be 0.5 feet with a Manning's "n" of 0.25.

The minimum length of the channel shall be determined by using contact time. The minimum contact time shall be 3300 seconds at the design depth and flow. Figures #1 through #8 can be used to determine the flow depth and velocity for various channel widths and volumes of flow.

Criteria For Filter Strips At the Lower Edge of Field or Wooded Areas (harvesting)

The grass filter strip shall be at least 30 feet wide along major intermittent or perennial streams, ponds, and lakes. The seedbed preparation and grass-legume mixtures shall be as shown in "Critical Area Planting" (342) or "Pasture Planting" (512) in the Wisconsin Technical Guide.

Establishing Vegetation - Animal Waste Filter

Seedbed preparation and grass mixtures shall be as stated in "Critical Area Planting" (342) in the Wisconsin Technical Guide. Equipment shall not be operated on the filter strip when the soil is wet. Compacting the soil will tend to reduce the infiltration rate and tracks or depressions will tend to channelize water flow.

Operation and Maintenance - Animal Waste Filter

The lot shall be cleaned or scraped frequently to reduce the amount of sediment leaving the lot area. The manure shall be stacked or stored at a location so that runoff from the storage area does not enter the filter area unless provided for in the design.

The settling basin shall be cleaned as soon as possible after any storm event that causes a significant amount of sediment deposition. Storing accumulated sediment deposits and cleaning the basin during a runoff event can cause large concentrations of pollutants to enter the upstream portion of the filter strip. These large concentrations can damage the vegetation and possibly increase the downstream pollution potential.

The filter system should not be operated daily due to possible anaerobic conditions developing in the soil. Two or more filters may be needed in some cases.

Development of rills and small channels within filter areas must be minimized. Special precautions must be taken to insure an even distribution of flow across the filter width. Annual or more frequent maintenance may be necessary.

Vegetation when cut must be removed from the filter strip. When the vegetation is left on the filter area, the effluent leaving the filter will frequently have a higher pollution potential.

Plans and Specifications

Plans and specifications for filter strips shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

Design Documentation Requirements

Location map, lot area, storage volumes and capacities (manure and/or solids, and water), discharge from lot or settling basin, filter strip length, width and slope, seeding requirements.

Construction (As Built) and/or Certification Documentation Requirements

Weir or orifice measurements, profile and cross section of completed construction, slope, length, statement regarding adequacy of vegetation.

FILTER STRIP SPECIFICATIONS

Engineering Specifications

All trees, stumps, brush, rocks, and similar materials that can interfere with installing the filter strip shall be removed. The materials shall be disposed of in a manner that is consistent with standards for maintaining and improving the quality of the environment and with proper functioning of the filter strip.

The land will be graded to the designed elevations. Fills of more than six inches shall be built up by spreading the soil in layers. Grading operations shall not be performed under soil moisture conditions that will result in excessive damage to soil structure.

After cuts and fills have been completed, the surface shall be smoothed to remove minor irregularities. All grading work shall be finished in accordance with the design and to tolerances specified.

Vegetative Specifications Guide

Specify methods of seedbed preparation; adapted plants; planting dates and rates of seeding or sprigging; need for mulching, use of a stablizing crop, or mechanical means of stabilizing; and fertilizer and soil amendment requirements. Specify requirements for maintenance.

Table 1.

Peak Discharge (cfs) for Various Lot Sizes and Runoff Curve Numbers (RCN)**

Lot Area (ft2)	RCN			
	85	90	95	98
5,000	0.44	0.52	0.60	0.68
10,000	0.89	1.03	1.21	1.35
15,000	1.33	1.55	1.81	2.03
20,000	1.78	2.06	2.42	2.70
30,000	2.67	3.09	3.63	4.05
40,000	3.56	4.12	4.83	5.55

** Peak discharges based on 4.0-inch rainfall (approximately 10-year, 24-hour storm) and 991 csm/in (Table 5-3, TR-55).

Table 2.

MINIMUM LENGTHS FOR VARIOUS OVERLAND FLOW FILTER STRIP SLOPES

Filter Slope (%)	Filter Length (ft)*
0.5	42
1.0	60
1.5	73
2.0	84
2.5	94
3.0	103
3.5	111
4.0	119

* Length = $59.5 \sqrt{\text{slope } (\%)}$

TABLE 3 - OVERLAND FLOW FILTER STRIP DESIGN FOR VARIOUS LOT SIZES & FILTERS

UNPAVED LOT CN=90

Lot Area (ft^2)	Min. Total Storage (ft^3)	Manure Storage Allowed (ft^3)	Minimum Filter	
			Width (ft)	Slope (%)
5,000	1260	465	20	0.5
	1110		40	0.5
	1040		60	0.5
	900		80	1.0
10,000	2970	925	20	0.5
	2520		40	0.5
	2220		60	1.0
	2110		80	1.0
	1940		100	1.5
	1740		120	2.0
15,000	4470	1390	20	1.0
	3920		40	1.0
	3560		60	1.0
	3260		80	1.5
	3120		100	1.5
	2960		120	2.0
	2780		140	2.5
20,000	5440	1850	40	1.0
	4850		60	1.5
	4550		80	1.5
	4420		100	1.5
	4160		120	2.0
	4030		140	2.0
	3860		160	2.5
30,000	8220	2775	40	2.0
	7530		60	2.0
	7280		80	2.0
	6980		100	2.0
	6660		120	2.0
	6410		140	2.5
	6230		160	2.5
	6090		180	2.5
40,000	10870	3700	60	2.0
	10100		80	2.0
	9660		100	2.0
	9260		120	2.5
	9000		140	2.5
	8820		160	2.5
	8620		180	2.5
	8200		200	3.0
	8120		220	3.0

PAVED LOT CN=95

Min. Total Storage (ft^3)	Manure Storage Allowed (ft^3)	Minimum Filter	
		Width (ft)	Slope (%)
1940	925	20	0.5
1725		40	0.5
1550		60	1.0
1400		80	1.5
4550	1850	20	0.5
3700		40	1.0
3450		60	1.0
3200		80	1.5
3030		100	2.0
2850		120	2.5
6330	2775	20	1.0
5570		40	1.5
5320		60	1.5
5060		80	1.5
4820		100	2.0
4640		120	2.5
4550		140	2.5
7890	3700	40	1.5
7360		60	1.5
6920		80	2.0
6730		100	2.0
6550		120	2.0
6310		140	2.5
6190		160	2.5

TABLE 4 - DISCHARGES (Qo) FOR VARIOUS FILTER WIDTHS AND SLOPES

FILTER WIDTH (FT)	FILTER STRIP SLOPE (PERCENT)							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
20	0.036 - 0.112	0.050 - 0.158	0.060 - 0.192	0.070 - 0.222	0.078 - 0.248	0.086 - 0.272	0.092 - 0.294	0.100 - 0.314
40	0.072 - 0.224	0.100 - 0.316	0.120 - 0.384	0.140 - 0.444	0.156 - 0.496	0.172 - 0.544	0.184 - 0.588	0.200 - 0.628
60	0.108 - 0.336	0.150 - 0.474	0.180 - 0.576	0.210 - 0.666	0.234 - 0.744	0.258 - 0.816	0.276 - 0.882	0.300 - 0.942
80	0.144 - 0.448	0.200 - 0.632	0.240 - 0.768	0.280 - 0.888	0.312 - 0.992	0.344 - 1.088	0.368 - 1.176	0.400 - 1.256
100	0.180 - 0.560	0.250 - 0.790	0.300 - 0.960	0.350 - 1.110	0.390 - 1.240	0.430 - 1.360	0.460 - 1.470	0.500 - 1.570
120	0.216 - 0.672	0.300 - 0.948	0.360 - 1.152	0.420 - 1.320	0.468 - 1.488	0.516 - 1.632	0.552 - 1.764	0.600 - 1.884
140	0.252 - 0.784	0.350 - 1.106	0.420 - 1.344	0.490 - 1.554	0.546 - 1.736	0.602 - 1.904	0.644 - 2.058	0.700 - 2.198
160	0.288 - 0.896	0.400 - 1.264	0.480 - 1.536	0.560 - 1.776	0.624 - 1.984	0.688 - 2.176	0.736 - 2.352	0.800 - 2.512
180	0.324 - 1.008	0.450 - 1.422	0.540 - 1.728	0.630 - 1.998	0.702 - 2.232	0.774 - 2.448	0.828 - 2.646	0.900 - 2.826
200	0.360 - 1.120	0.500 - 1.580	0.600 - 1.920	0.700 - 2.220	0.780 - 2.480	0.860 - 2.720	0.920 - 2.940	1.000 - 3.140
220					0.858 - 2.728	0.946 - 2.992	1.012 - 3.234	1.100 - 3.454
240						1.032 - 3.264	1.104 - 3.528	1.200 - 3.768

Footnote - Values were determined by the flood routing method described in the Engineering Field Manual, p. 11-55b, Table A.

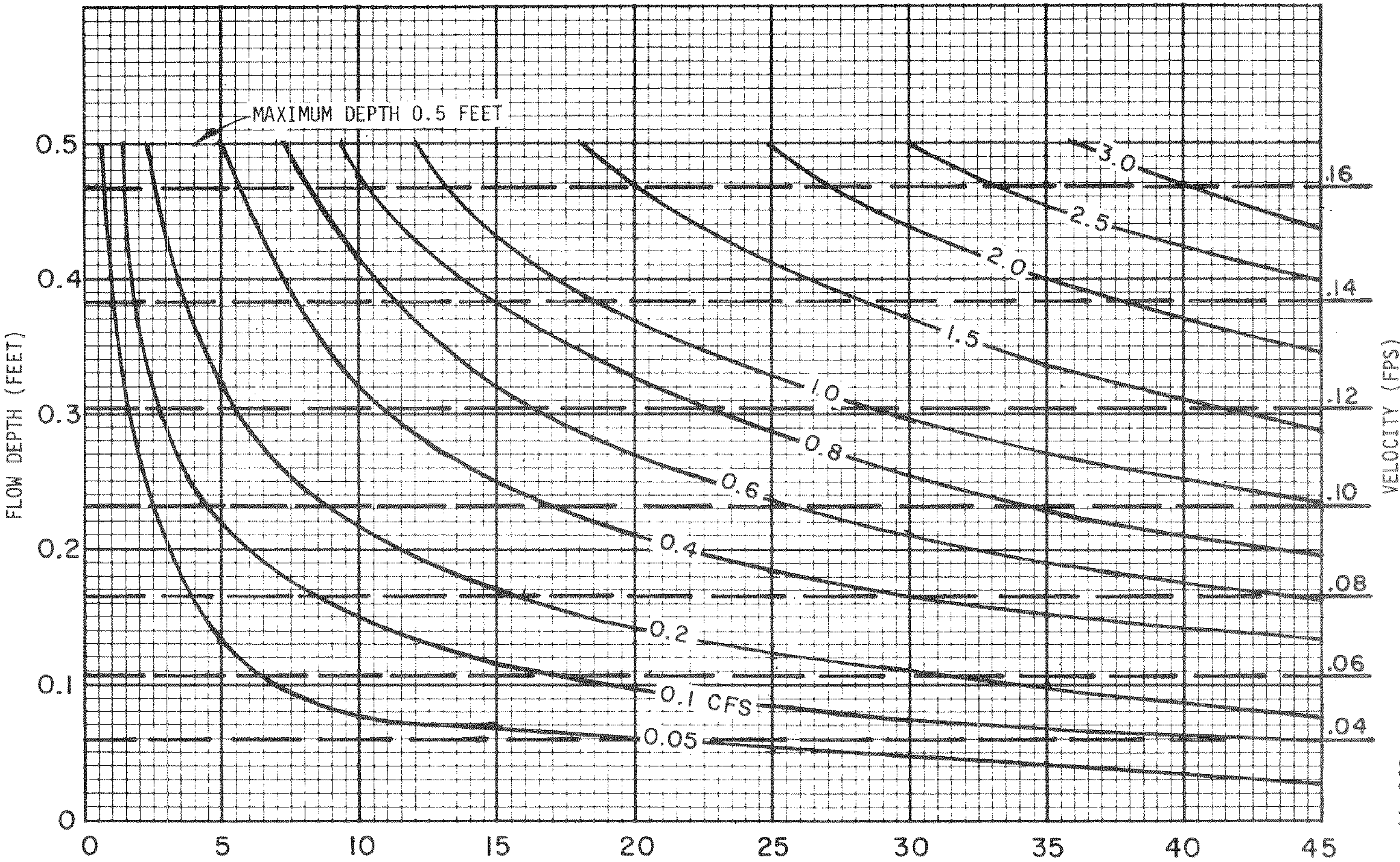

FIGURE 1

FILTER STRIP FOR CHANNELIZED FLOW - 0.2 % SLOPE
(MANNING'S "n" = 0.25)

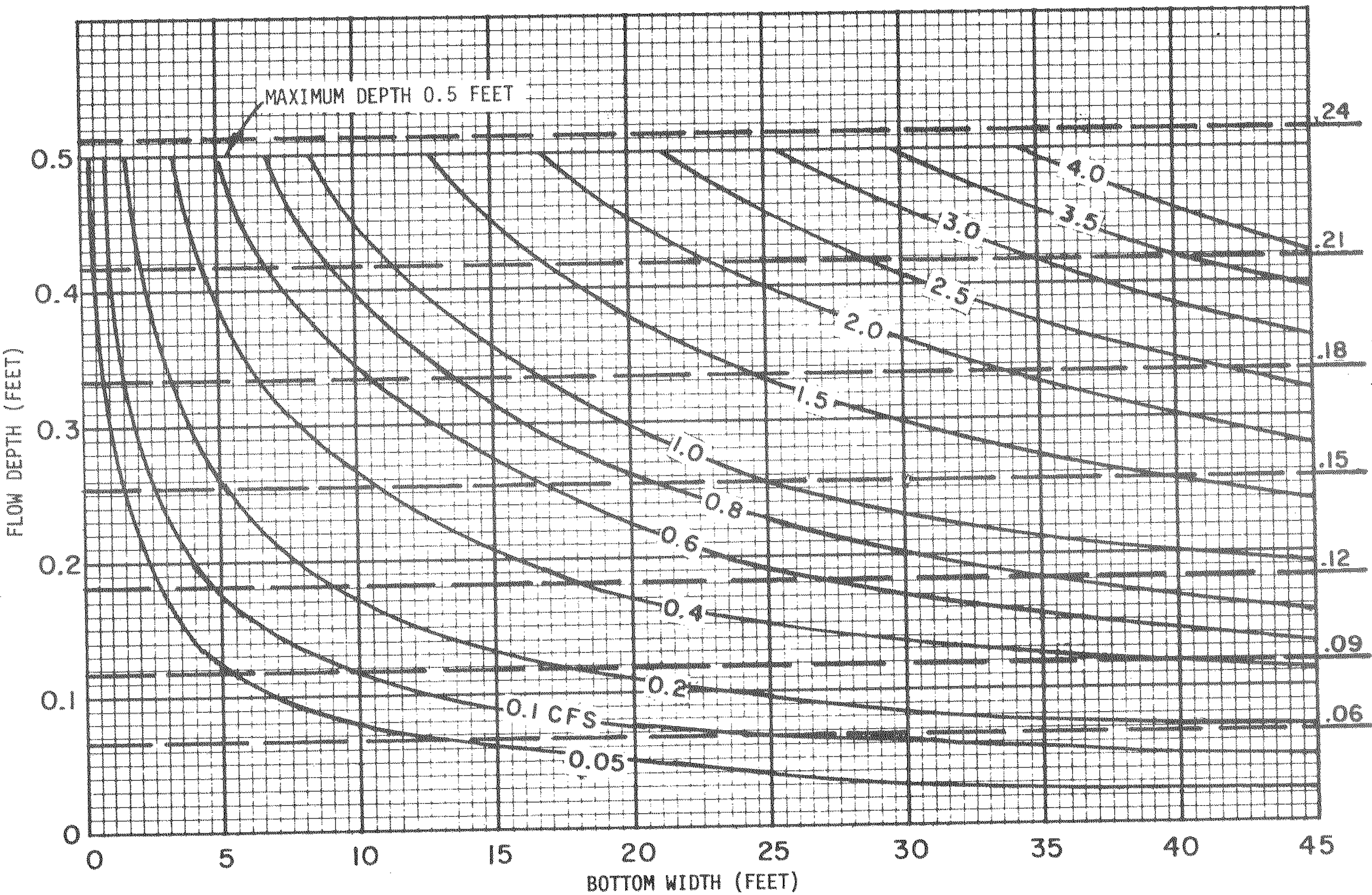

FIGURE 2 FILTER STRIP FOR CHANNELIZED FLOW - 0.4 % SLOPE

(MANNING'S "n" = 0.25)

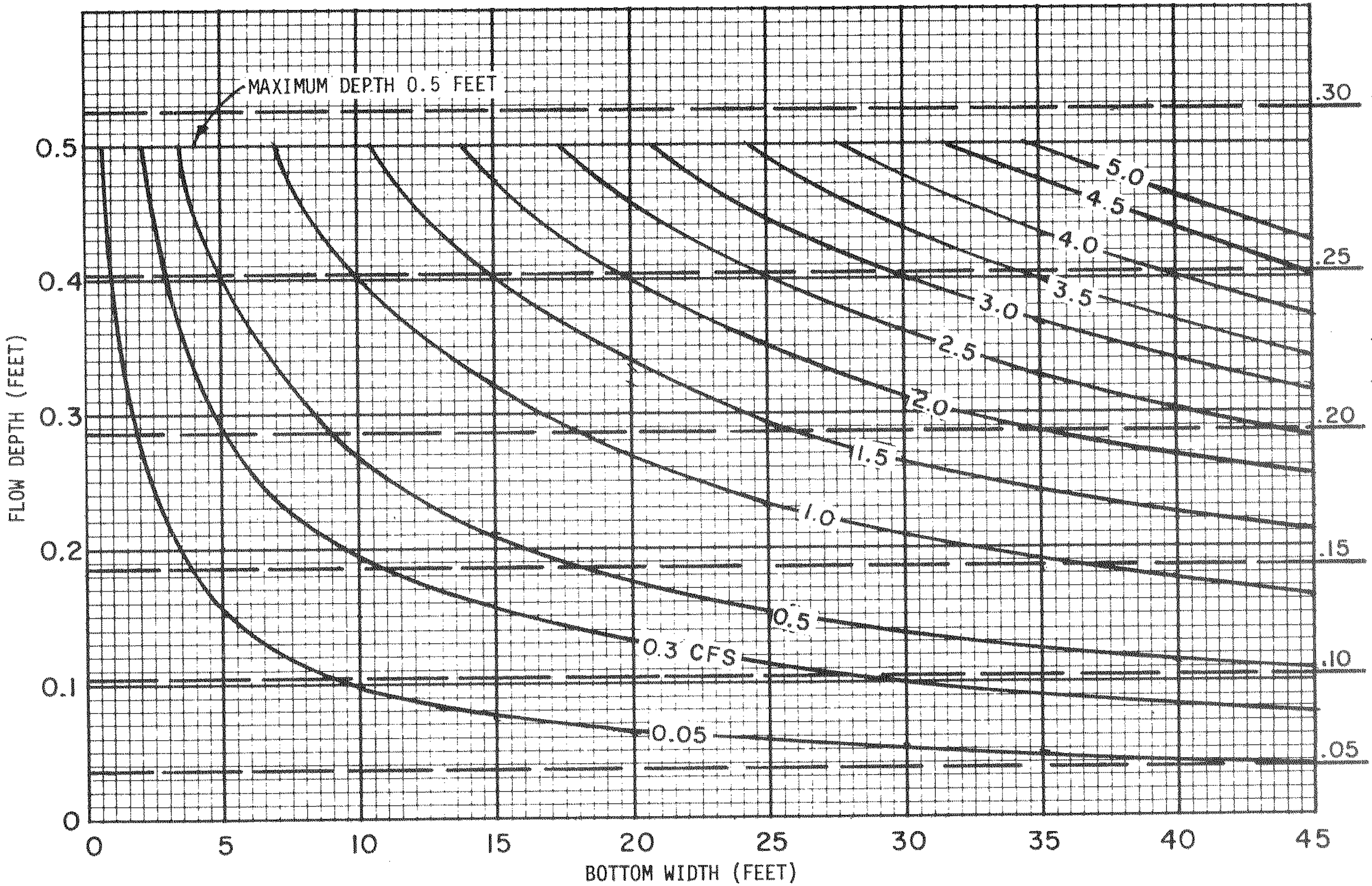

FIGURE 3 FILTER STRIP FOR CHANNELIZED FLOW - 0.6 % SLOPE (MANNING'S "n" = 0.25)

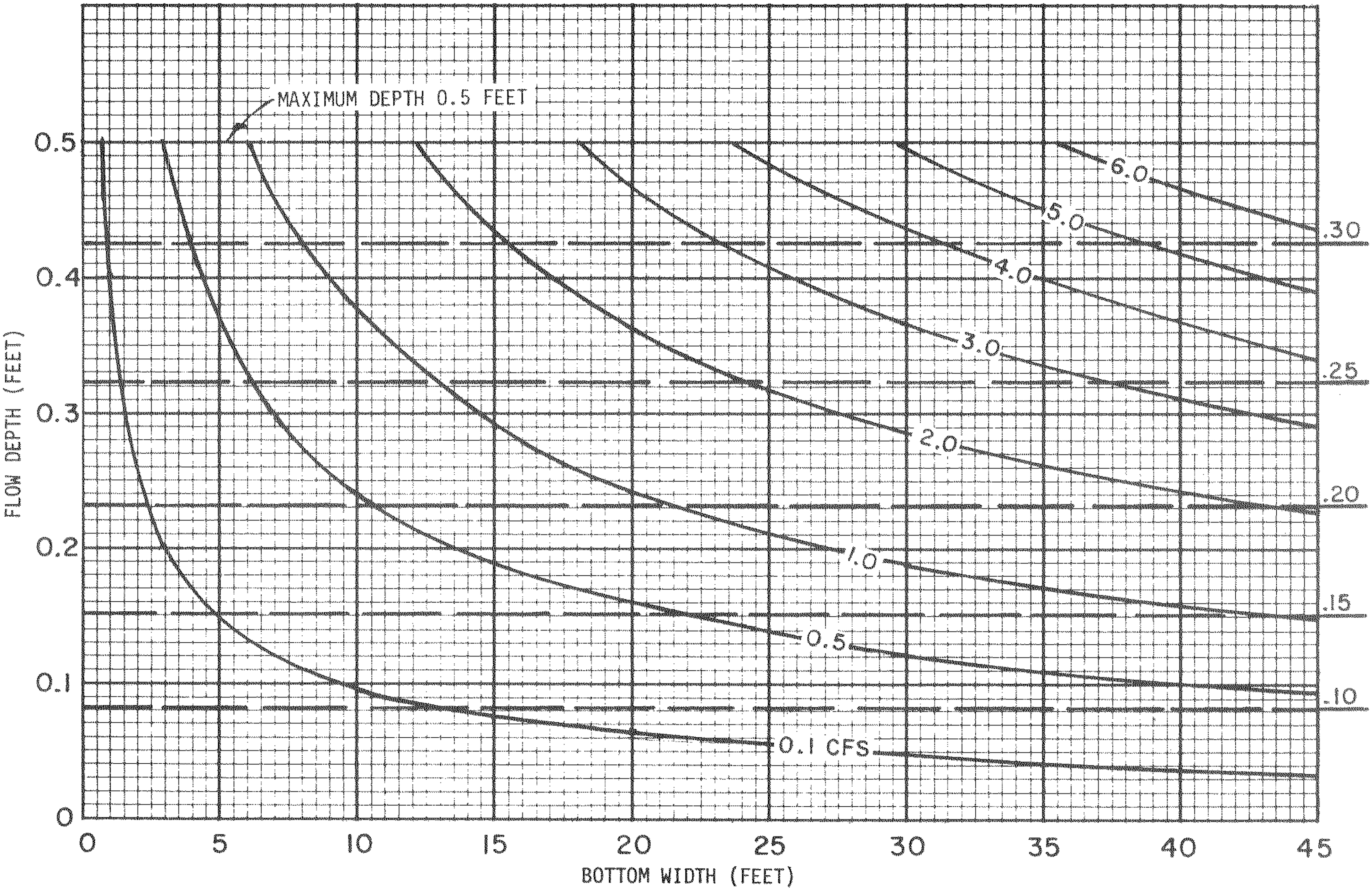

FIGURE 4 FILTER STRIP FOR CHANNELIZED FLOW - 0.8 % SLOPE
(MANNING'S "n" = 0.25)

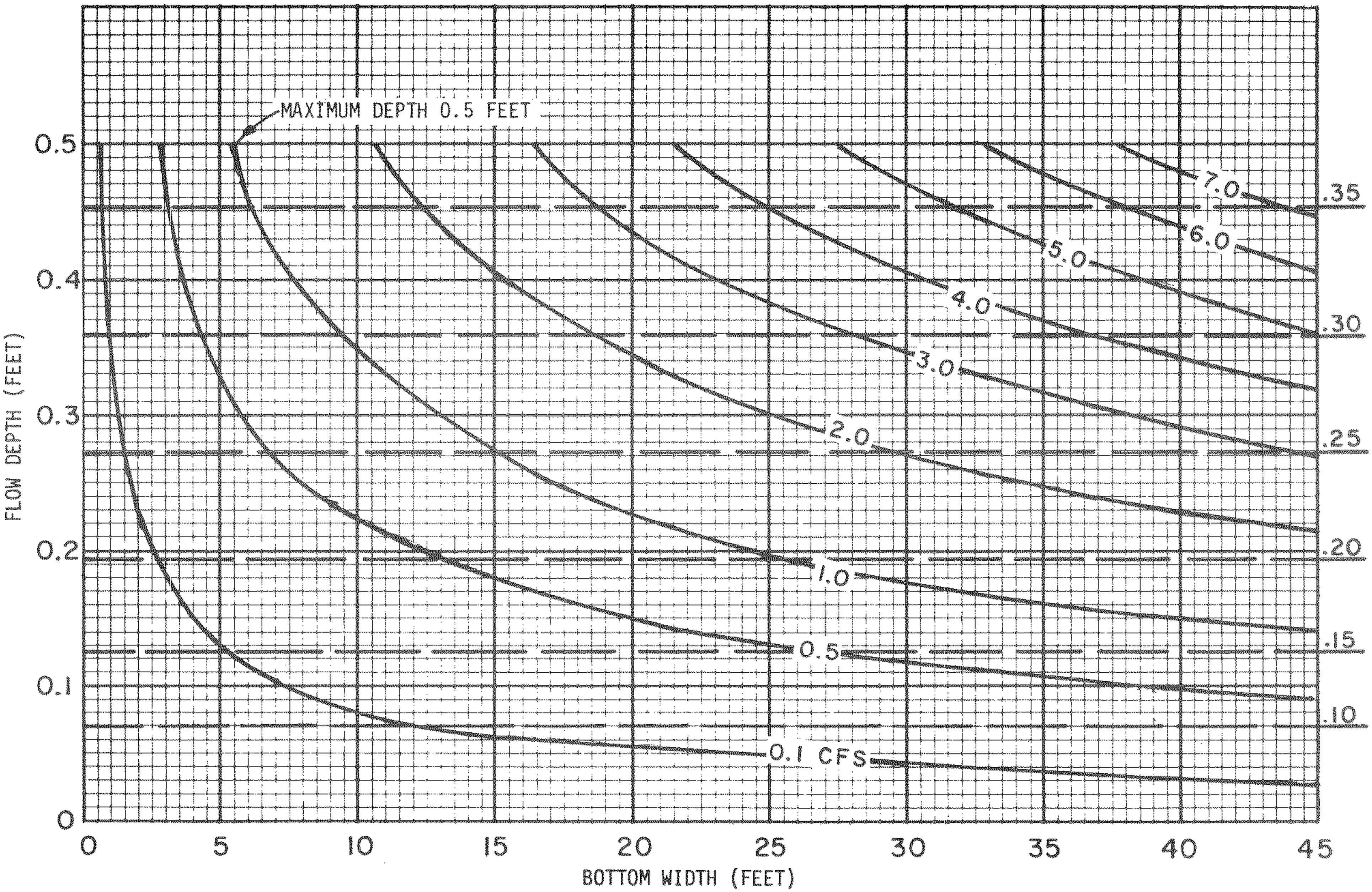

FIGURE 5 FILTER STRIP FOR CHANNELIZED FLOW - 1.0 % SLOPE
(MANNING'S "n" = 0.25)

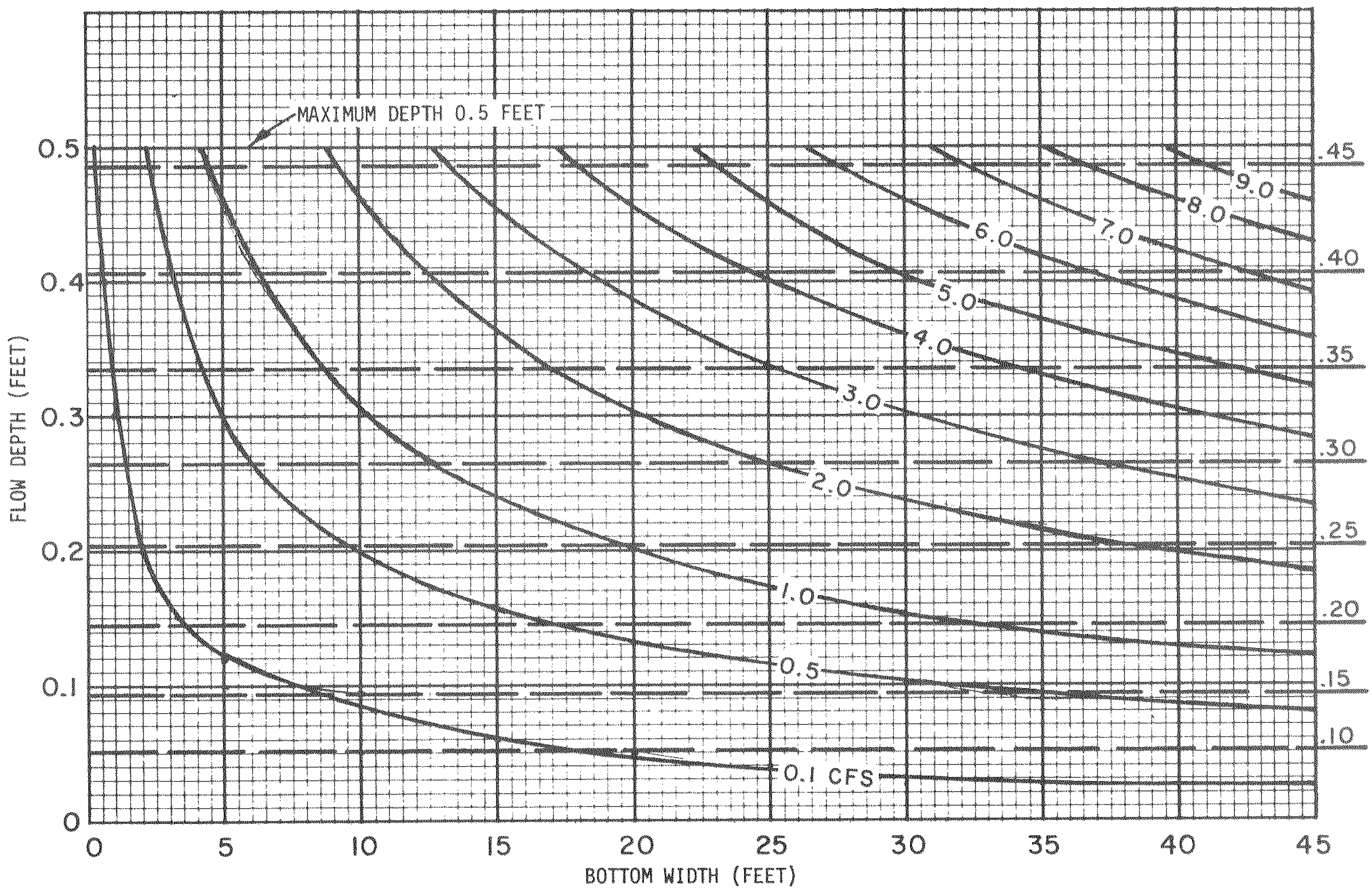

FIGURE 6 FILTER STRIP FOR CHANNELIZED FLOW - 1.5 % SLOPE

(MANNING'S "n" = 0.25)

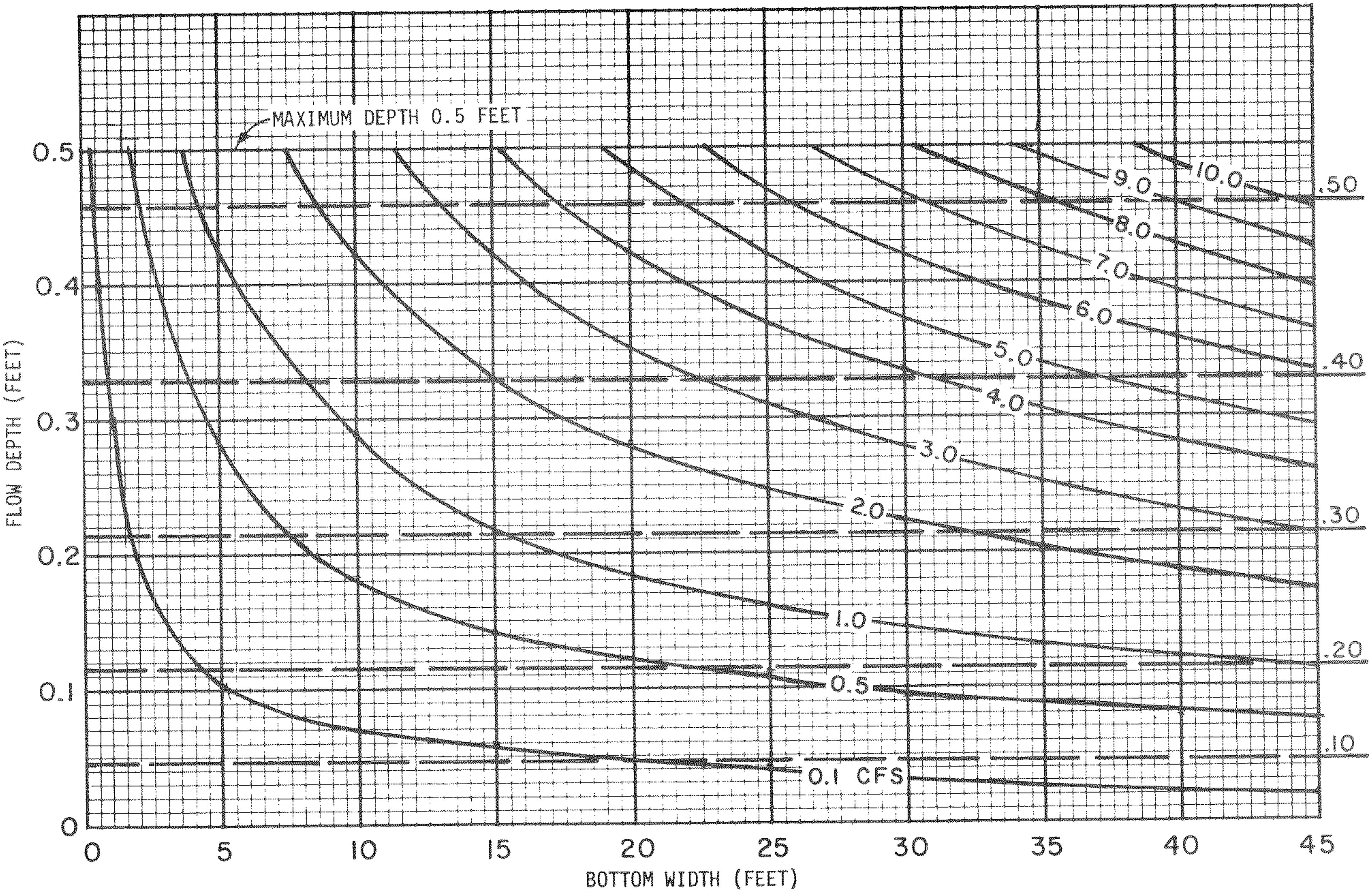

FIGURE 7 FILTER STRIP FOR CHANNELIZED FLOW - 2.0 % SLOPE (MANNING'S "n" = 0.25)

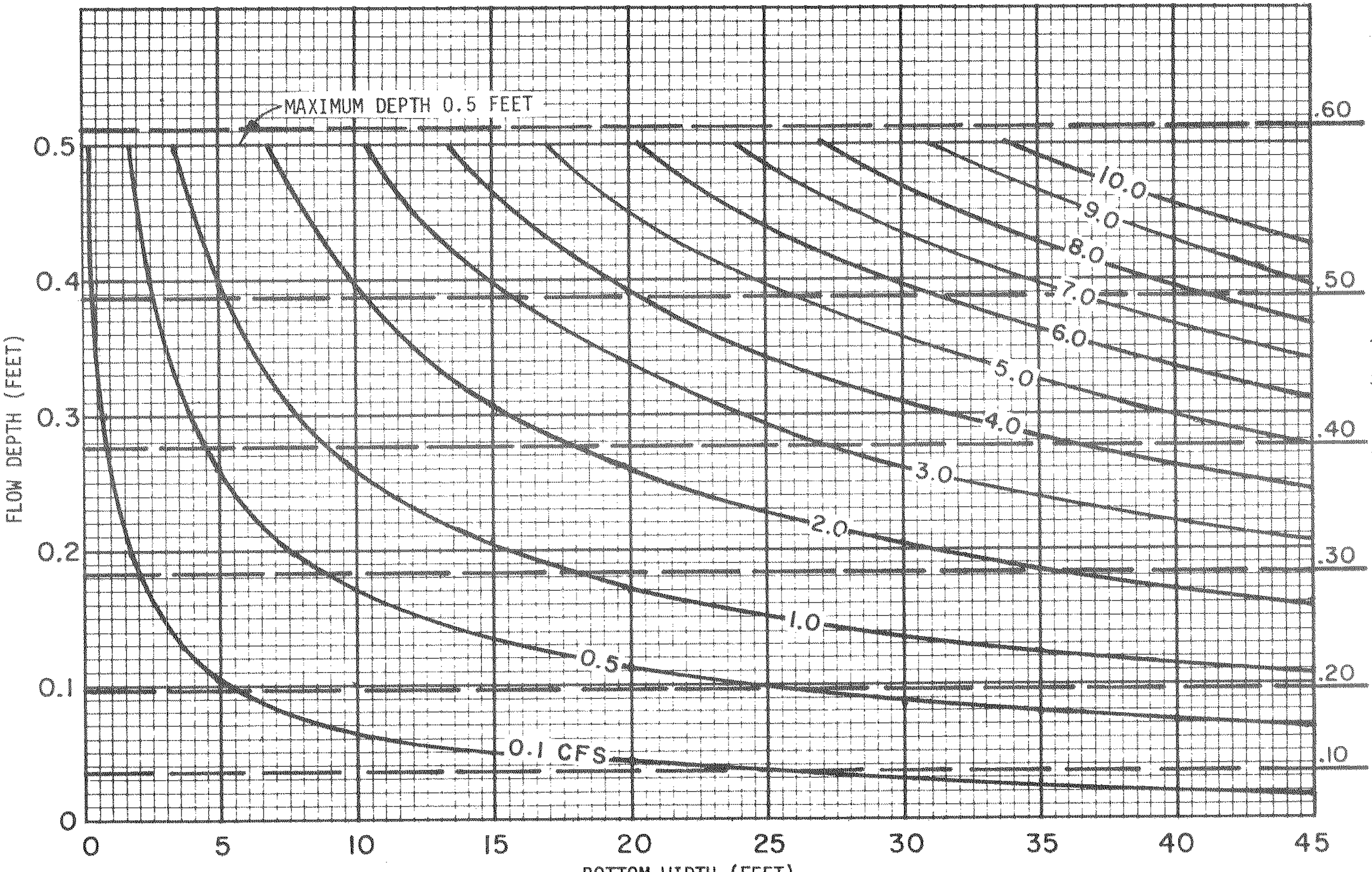

FIGURE 8 FILTER STRIP FOR CHANNELIZED FLOW - 2.5 % SLOPE

(MANNING'S "n" = 0.25)

EXPLANATION OF AND EXAMPLES USING TABLES 3 AND 4

Table 3 -This table provides the minimum filter strip dimensions for a known lot size and storage volumes. The lot area and solid storage numbers shown are maximums. The total storage, filter width, and filter slope are minimums.

Table 4 -This table provides a range of discharges for 1/2" flow depth (first number) and for 1" flow depth (second number) for various filter widths and slopes. Do not use smaller values of Qo than the smallest value shown for the minimum filter width and slope shown in table 3. Discharge values smaller than the smaller Qo do not provide the necessary routing for the design storm. Do not exceed the larger Qo for a selected filter width and slope.

Example #1 - Design orifice for minimum overland flow filter from table 3.

Known: 49 head 1400# dairy cows
4,950 ft^2 lot area paved
800 ft^3 manure storage needed between scapings
2,000 ft^3 total storage available

Design procedure:

1. From table 3 - Area < 5,000 ft^2; manure storage needed < 925 ft^3; total storage available > 1,940 ft^3. Find minimum filter width and slope: width = 20', slope = 0.5%.

2. From table 4 - Qo's for w=20', s=0.5%
   Qo min. = 0.036 cfs
   Qo max. = 0.112 cfs

3. Select orifice to discharge in the range of Qo's.

4. Select length of filter from table 2 for slope used. (42' for 0.5%).

Example #2 - Design system for existing or planned overland flow filter strip slope.

Known: Same as example #1 except total available storage = 1,700 ft^3

Design procedure:

1. From table 3 - Area < 5,000 ft^2; manure storage needed < 925 ft^3; total storage available = 1,700 ft^3 > 1,550 ft^3 and 1,700 < 1,725 ft^3. Use the "1,550 line". Find the minimum filter width and slope: width = 60', slope = 1.0%.

2. From table 4 - Qo's for w=60', s=1.0%
   Qo min. = 0.150 cfs
   Qo max. = 0.474 cfs

   Note the Qo minimum is 0.150 cfs, this outflow must be equaled or exceeded for all filter slopes because this is the minimum outflow for these flood routing conditions. For a smaller Qo, more total storage or less manure storage would be needed and the flood routing would need to be recalculated.

3. Assume the planned or existing slope and find the corresponding Qo and filter width.

Example designs that are permissible:

Filter slope (%)	Filter* length (ft)	Filter width (ft)	Qo min (cfs)	Qo max** (cfs)	Orifice design range (cfs)
0.5	42	100	0.180	0.560	***0.150 - 0.560
1.5	73	60	0.180	0.576	0.150 - 0.576
2.0	84	60	0.210	0.666	0.150 - 0.666
2.5	94	40	0.156	0.496	0.150 - 0.496
3.0	103	40	0.172	0.544	0.150 - 0.544

(All other filter slopes and widths with a minimum Qo that exceeds 0.150 cfs are acceptable.)

* Filter length from table 2.

** The maximum orifice (outlet) design changes with the filter width and slope selected. The minimum Qo from the original minimum filter must be equaled or exceeded.

***0.150 cfs is the minimum Qo needed to satisfy the flood routing.

4. Design orifice to discharge within the range of Qo's for the selected filter slope and width.

Example #3 - Design overland flow filter width and slope for a predetermined orifice (outlet) discharge.

Known: Same as example #1 plus a known orifice discharge of 0.5 cfs.

Design procedure:

1. From table 3 - minimum filter yields w=20, s=0.5%

2. From table 4 - minimum Qo for w=20, s=0.5%. 0.5 cfs >>> 0.036cfs.

3. From table 4, select a filter width and slope that has a Qo maximum of 0.5 cfs or greater.

   For example: w=100', s=0.5%; w=80', s=1.0%; w=60', s=1.5%; w=60', s=2.0%; w=60', s=2.5%; w=40', s=3.0%.

4. From table 2, select the appropriate filter length for the corresponding slope.

Example #4 - Conditions not covered by tables 3 & 4

Known: 60 head 1400# dairy cows
4,950 ft^2 lot area, paved
800 ft^3 manure storage needed between scrapings
1,100 ft^3 total storage available

Design procedure:

1. From table 3 - Area < 5,000 ft^2; manure storage needed < 925 ft^3; total storage = 1,100 ft^3 which is less than shown in the table for 5,000 ft^2 paved area.

2. Flood route by using the Engineering Field Manual, p. 11-55b.

   a. Volume of water storage (V_s) available = 1,100 - 800 ft^3 = 300 ft^3.

   $$V_s \text{ (watershed-in.)} = 300 \text{ ft}^3 \times \frac{\text{ac-ft}}{43{,}560 \text{ ft}^3} \times \frac{12 \text{ in}}{\text{ft}} \times \frac{43{,}560 \text{ ft}^2}{\text{ac}}$$

   $$\times \frac{\text{w.sh}}{4{,}950 \text{ ft}^2} = \frac{300 \text{ ft}^3 \text{ water storage}}{4{,}950 \text{ ft}^2 \text{ lot area}} \times (12) = 0.73 \text{ watershed in.}$$

   b. $$\frac{\text{Volume of storage}}{\text{Volume of runoff}} = \frac{0.73}{3.4 \text{ in*}} = 0.21$$

   *based on 4.0" rainfall, RCN = 95

   c. From table A, page 11-55b, EFM Qo/Qi = 0.67

   d. Qo = 0.67 (Qi) = 0.67 (0.6**cfs) = 0.402 cfs

   **from Table 1 (5,000 ft^2, RCN 95)

3. From table 4 - find a filter slope and width that has a minimum Qo of > 0.4 cfs

   For example: w=160', s=1.0%; w=140', s=1.5%; w=120', s=2.0%; w=120', s=2.5%; w=100', s=3.0%; w=100', s=3.5%; and w=80', s=4.0%.

4. Select orifice to discharge design Q for filter. It must be 0.4 cfs or greater for the calculated storage values.

5. Select length for filter slope from table 2.

   Alternate Step 2 - select a filter width and slope that provides the necessary contact time for the peak Qo (0.6 cfs from table 2).

Example #5 - Design of channelized flow filter strip

Known: 90 head 1400# dairy cows
8,000 ft^2 lot area, paved
1,500 ft^3 manure storage needed between scrapings
3,200 ft^3 total storage available
0.8% channel slope

Design procedure:

1. From table 3 - Area < 10,000 ft^2; manure storage needed < 1,850 ft^3; total storage = 3,200 ft^3. Find the minimum filter width and slope: width = 80'; slope = 1.5%

2. From table 4, find the minimum Qo for w=80', s=1.5%. The minimum design Qo = 0.24 cfs is needed to satisfy the routing.

3. For a discharge of 0.24 cfs, find from figure 4: bottom width (selected for equipment, etc.) = 10', depth of flow = 0.15 ft., velocity = 0.15 fps.

4. Calculate length of channel required: Channel length = 0.15 ft/sec X 3,300 sec = 495 ft.

   Alternate Step #3 - It was decided that an orifice discharge would be 0.5 cfs - From figure 4, b=10', d=0.24', v=0.205 fps. Channel length = $0.205 \frac{ft}{sec}$ X 3,300 sec = 677'

Example #6 - Design minimum total storage for an available overland flow filter strip area

Known: Filter area - 60' wide, 0.5% slope
740 ft^3 manure storage needed
4,000 ft^2 lot area paved
$Q_i = \frac{4,000\ ft^2}{5,000\ ft^2}$ (0.6 cfs*) = 0.48 cfs

*from table 2 for 5,000 ft^2, RCN = 95

Design procedure:

1. From table 4 - Find the min. Qo (for a 60' wide, 0.5% slope filter) of 0.108 cfs.

2. Determine Qo/Q_i: (EFM, p. 11-55b)

$$Qo/Q_i = \frac{0.108 \text{ cfs}}{0.48 \text{ cfs}} = 0.225$$

3. From Table A, EFM, p. 11-55b find Vs/V_r ratio for Q ratio of 0.225:

$$\frac{Vs}{Vr} = 0.463$$

4. Determine volume of water storage needed:

   Vs = 0.463 X 3.4* watershed-inches = 1.57 w/s-inches

   *[Runoff (10-year, 24-hour storm) from RCN 95.]

5. Change 1.57 watershed-inches to cubic feet:

$$Vs\ ft^3 = 1.57 \text{ w/s-in} \times \frac{4{,}000\ ft^2}{w/s} \times \frac{1\ ft}{12\ in} = 523\ ft^3$$

6. Determine the total storage needed:

$$\begin{aligned} \text{Total storage} &= \text{water storage required + manure storage} \\ &= 523\ ft^3 + 740\ ft^3 \\ &= 1{,}263\ ft^3 \end{aligned}$$