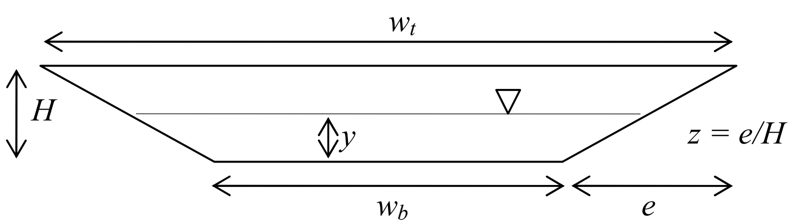
Trapezoidal Grassed Swale Sample Design

Task

Design a vegetated swale to filter the 6-month, 24-hour storm at a design flow depth of 3 inches. The available site is 200 feet in length and 8 feet wide on a longitudinal slope of 2 percent. Find the appropriate swale dimensions for sufficient capacity and stability. Assume a flow rate (*Q*) from the 6-month, 24-h storm is 0.014 m^3/s (0.5 ft^2/s). The winter grass height is determined to be 125 mm (5 in) and the design flow depth of the swale is 0.076 m (3 in). Since the swale will be mowed regularly, a Manning's n value of 0.2 should be used. Assume soil analysis has established soils at the site as erosion resistant and the maximum velocity is 1.5 m/s.

Trapezoid Swale Hydraulics



$$Q = \frac{R_h^{0.667} S^{0.5}}{n} A \qquad (1)$$

Finds flow (*Q*) based on Manning's equation given hydraulic radius (R_h), slope (*S*), friction factor (*n*) and cross sectional flow area (*A*).

$$w_b \cong \frac{Qn}{y^{1.67} s^{0.5}} - zH \qquad (2)$$

Approximates bottom width (w_b) given flow (*Q*), Manning's n (*n*), flow depth (*y*), longitudinal slope (*s*), and side slope (*z*).

$$w_t = w_b + 2zH \qquad (3)$$

Finds top width (w_t) given bottom width (w_b) and side slope (*z*).

$$A_x = (w_b + zH)H \qquad (4)$$

Finds the cross sectional area () for the trapezoid given the length of its base (w_b),side slope (*z*), and height (*H*)

$$U = \frac{Q}{A_x} \qquad (5)$$

Calculates channel velocity (*U*) given flow (*Q*) and cross sectional area (A_x).

$$L = Ut_r(60\ \text{s/min}) \qquad (6)$$

Finds swale length (*L*) given channel velocity and hydraulic residence time (t_r).

$$R_h = \frac{UR_h}{U_{max}} \qquad (7)$$

Finds trial velocity x hydraulic radius (UR_h) values given maximum velocity (U_{max}) determined from figure 1.

$$UR = \frac{R_h^{1.667} S^{0.5}}{n} \qquad (8)$$

Finds actual velocity (*U*) given hydraulic radius (R_h), longitudinal slope (), and Manning's n (*n*).

$$U = \frac{UR_h}{R_h} \qquad (9)$$

Finds the actual velocity for the final design (*U*) given hydraulic radius (R_h)

$$A_x = \frac{Q}{U} \quad (10)$$

Finds the cross sectional area required for stability (A_x) given flow (Q)and actual velocity (U).

$$R_h = \frac{A_x}{WP} \quad (11)$$

Finds hydraulic radius (R_h) given flow area (A_x) and wetted perimeter (WP).

$$R_h = \frac{A_x}{w_b y + 2y\sqrt{z^2 + 1}} \quad (12)$$

Finds hydraulic radius (R_h) given glow area (A_x), trapezoid base (w_b), depth of flow (y), and side slope (z).

Table 1. Criteria for optimum swale performance.

Parameter	***Optimal Criteria***	***Minimum Criteria***
Hydraulic Residence Time	9 min	≥ 5 min
Average Flow Velocity	≤ 27 m^3/s (0.9 ft/s)	
Swale Width	2.4 m (8 ft)	0.6 m (2 ft)
Swale Length	61 m (200 ft)	30 m (100 ft)
Swale Slope	~ 2 - 6%	~ 1%
Side Slope Ratio (horizontal:vertical)	4 : 1	2 : 1

Table 2. Guide for selecting maximum permissible swale velocities for stability.

		Maximum Velocity (m/s [ft/s])	
Cover Type	***Slope (%)***	***Erosion-resistant soils***	***Easily eroded soils***
Kentucky bluegrass Tall fescue	0 - 5	1.8 (6)	1.5 (5)
Kentucky bluegrass Ryegrasses Western wheat-grass	5 - 10	1.5 (5)	1.2 (4)
Grass-legume Mixture	0 - 5 5 - 10	1.5 (5) 1.2 (4)	1.2 (4) 0.9 (3)
Red fescue	0 - 5	0.9 (3)	0.8 (2.5)

Table 3. Grass coverage, height, and degree of retardance

Average Grass Height (mm [inches])	***Degree of Retardance***
Coverage = "Good"	
> 760 (30)	A. Very high
280 - 610 (11 -24)	B. High
150 - 270 (6 - 10)	C. Moderate
50 - 150 (2 - 6)	D. Low
> 50 (>2)	E. Very low
Coverage = "Fair"	
> 760 (30)	B. High
280 - 610 (11 -24)	C. Moderate
150 - 270 (6 - 10)	D. Low
50 - 150 (2 - 6)	D. Low
> 50 (>2)	E. Very low

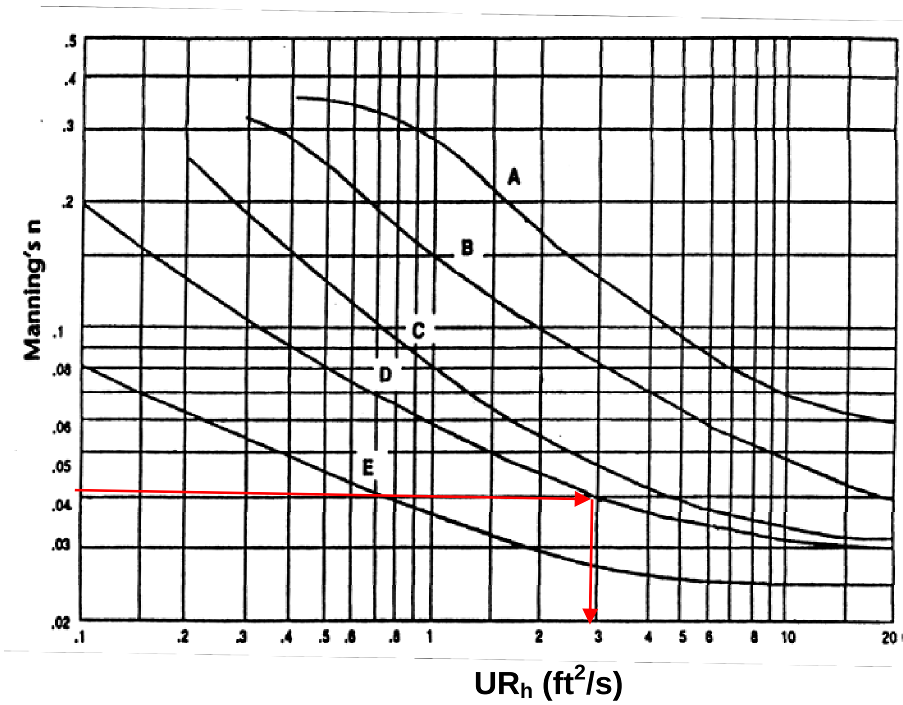


Figure 1. Relationship of Manning's n with UR_h (in ft^2/s) for farious degrees of flow retardance. (m^2/s = 0.09290 ft^2/s)