2.3 Grass Swale

Description

A grass swale is a wide, dry permanent stormwater conveyance channel specifically engineered to provide limited water quality treatment for short duration flow. Do not confuse a grass swale with a ditch or other waterway designed to efficiently convey runoff. Surface runoff flows slowly through a grass swale at or below the height of the grass lining. The grass blades within the swale remain upright, promoting deposition of suspended sediment and to a lesser extent, infiltration. A grass swale dries quickly following a storm event without prolonged or intermittent flow.

A grass swale does not provide sufficient pollutant removal, detention time, or infiltration to serve as a primary post-construction stormwater management practice but can function as pretreatment while conveying runoff to the primary practice. A grass swale may reduce peak discharges by increasing the time of concentration of the drainage area.

Planning and Feasibility

A grass swale may be an option if elevations and space allow for a surface conveyance in place of surface inlets and storm sewer pipe. It can be easily blended into lawn or other open space.

The design criteria usually constrain the contributing drainage area to one acre or less.

Do not site a grass swale:

- where overflow from the swale could cause flooding of existing or proposed buildings, roads, or adjacent properties,
- within underground utility easements,
- where a tree canopy will inhibit grass growth through continuous shading or lead to excessive accumulation of leaf litter, or
- where sharp changes in lateral direction may lead to erosion problems.

If a swale accepts runoff from more than one property, place the swale in a permanent drainage easement granting access for maintenance or in a public right-of-way.

This practice does not apply to defined streams with perennial, intermittent, or ephemeral flow, or any channel expected to have prolonged runoff flow such that grass cover cannot be established and maintained. Small, ephemeral drainageways provide many hydrologic and environmental benefits not duplicated by a constructed grass swale. A grass swale is an upland conveyance practice. Construction in surface waters such as streams may require authorization from the U.S. Army Corps of Engineers and Ohio EPA.

Credits

Table 2.3.1 Credits for a Grass Swale Meeting the Criteria in this Chapter

Objective	Credit
Runoff Reduction Volume (RRv)	0.20 inches over the drainage area contributing to a grass swale constructed on Hydrologic Soil Group A or B soil. 0.10 inches over the drainage area contributing to a grass swale constructed on Hydrologic Soil Group C or D soil. Use the Ohio EPA Runoff Reduction Spreadsheet to calculate RRv credits. RRv credit may not exceed the WQv for the practice.

Design Criteria

Design a grass swale to slowly convey stormwater runoff at a very shallow depth through the blades of grass lining the bottom of the swale. This allows the blades and stems to remain upright, providing resistance to the flow that increases hydraulic retention time to promote deposition of suspended solids. Carefully coordinate a grass swale's shape, length, and slope to develop 1) capacity for the water quality flow (WQf); 2) the necessary hydraulic residence time at the WQf; and 3) a non-erosive, stable channel boundary at all flows.

Water Quality Flow Capacity

A grass swale conveys the WQf calculated for the contributing drainage area. Refer to Chapter 2.18 for guidance on calculating the WQf to the grass swale. Do not include flow through the swale as part of the time of concentration. Design the cross-sectional geometry and longitudinal grade to convey the WQf at a flow depth of 4 inches or less. Equations 2.3.1 and 2.3.2 (Manning Formula) give the standard relationship between open channel flow and channel geometry.

$$\mathrm{WQf} = \mathrm{A_{WQf}} \times \mathrm{V_{WQf}} \qquad \text{(Equation 2.3.1)}$$

and

$$\mathrm{V_{WQf}} = \frac{1.49}{\mathrm{n}} \times \mathrm{R}^{\frac{2}{3}} \times \mathrm{S}^{\frac{1}{2}} \qquad \text{(Equation 2.3.2)}$$

where WQf = water quality flow,

A_{WQf} = cross-sectional area of flow (ft^2) at the WQf,

V_{WQf} = average velocity (ft/s) at the WQf,

n = Manning's coefficient of roughness [see note 1],

R = hydraulic radius or the depth of flow (ft) [see note 2], and

S = channel grade or longitudinal slope (ft/ft).

Note 1: A Manning's coefficient (n) in the range of 0.20 to 0.25 is often cited for shallow flow through grass as is expected to occur within a grass swale. A coefficient value of 0.35 is recommended by Kirby, et. al. (2005) for low flow through Kentucky Bluegrass. A much lower coefficient value of 0.025 to 0.035 is typical for higher flow rates where the depth exceeds the grass height.

Note 2: Where the design flow depth is very shallow (four inches) compared to the bottom width (≥four feet), the hydraulic radius can be approximated as the depth of flow.

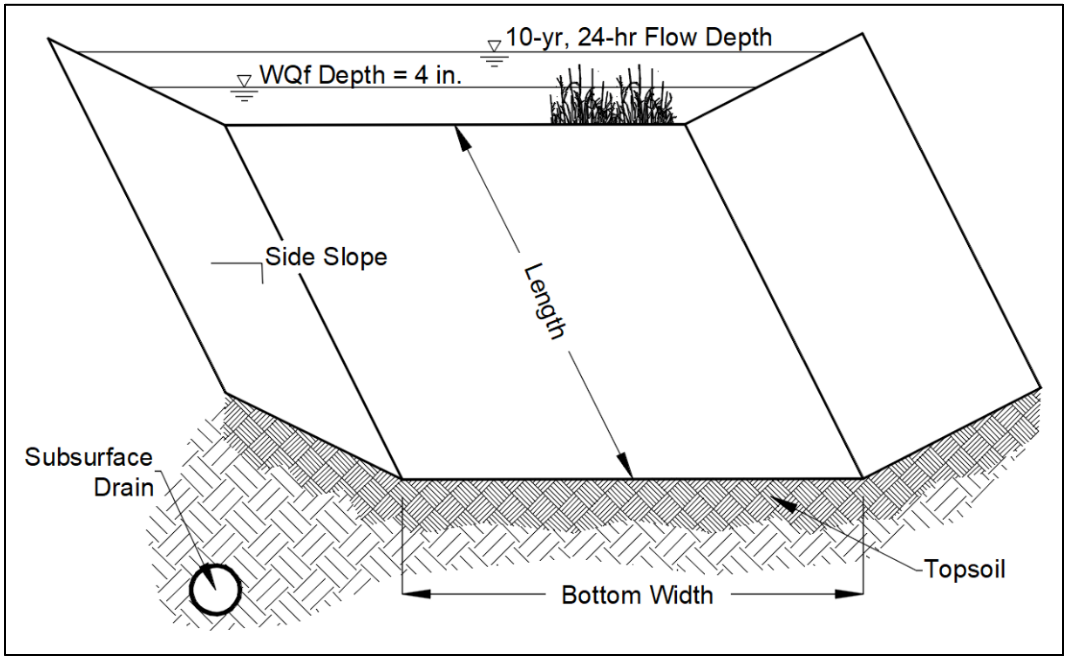


Figure 2.3.1 Grass Swale Geometry and Components

Cross-Sectional Geometry

A grass swale must be trapezoidal in shape with an even, uniformly graded bottom that is a minimum of four feet in width (see Figure 2.3.1). A bottom width greater than eight feet is not recommended without rock checks or other measures to prevent flow from channelizing within the swale. Side slopes shall be no steeper than 3:1. Flatter side slopes are recommended to facilitate mowing.

Longitudinal Grade

Design a longitudinal grade of at least one percent to prevent standing water from damaging the grass. To prevent erosive flow, the maximum allowable grade of a grass swale is seven percent. Terracing a swale with drop structures (weirs) can reduce the channel grade to develop acceptable stability and retention time.

Length

Given the cross-sectional shape and longitudinal grade, the length of a grass swale must achieve a hydraulic retention time (HRT) of five minutes or longer at the WQf. Calculate the HRT as:

$$HRT = \left(\frac{L_{flow}}{V_{WQf}}\right) \div 60 \qquad \text{(Equation 2.3.3)}$$

where HRT = hydraulic retention time (minutes),

L_{flow}= average flow length of swale (ft), and

V_{WQf} = average velocity (ft/s) at the WQf (see Equation 2.3.2).

The average flow length is dependent upon where and how runoff from impervious surface enters the swale and may not equal the full constructed length. Figure 2.3.2 illustrates the average flow length for two common grass swale configurations. Area-weight multiple or continuous inflow points to develop the average flow length.

Stability

Grass swales are on-line practices that do not include provisions for overflow. A grass swale must convey the 10-year peak flow without eroding. For grass lined channels, the effective soil stress method of verifying stability described in NRCS (2007) is recommended. Design the swale with an erosional effective stress less than the allowable effective

effective stress Table 2.3.2 indicates for the soil the swale will be constructed within such that

$$\tau_e < \tau_a \qquad \text{(Equation 2.3.4)}$$

and

$$\tau_e = \gamma DS(1 - C_f)\left(\frac{n_s}{n}\right)^2 \qquad \text{(Equation 2.3.5)}$$

where τ_e = erosional effective stress (lb/ft^2),

τ_a =allowable effective stress (lb/ft^2) [see Table 2.3.2]

Υ = unit weight of water (62.4 lb/ft^3),

D = maximum depth of flow in the cross-section (ft),

C_f = vegetal cover factor (recommend 0.75 for grass mix),

n_s = roughness associated with grain size (recommend 0.0156),

n = Manning's roughness coefficient (recommend 0.025 to 0.035), and

S = channel bed slope (ft/ft).

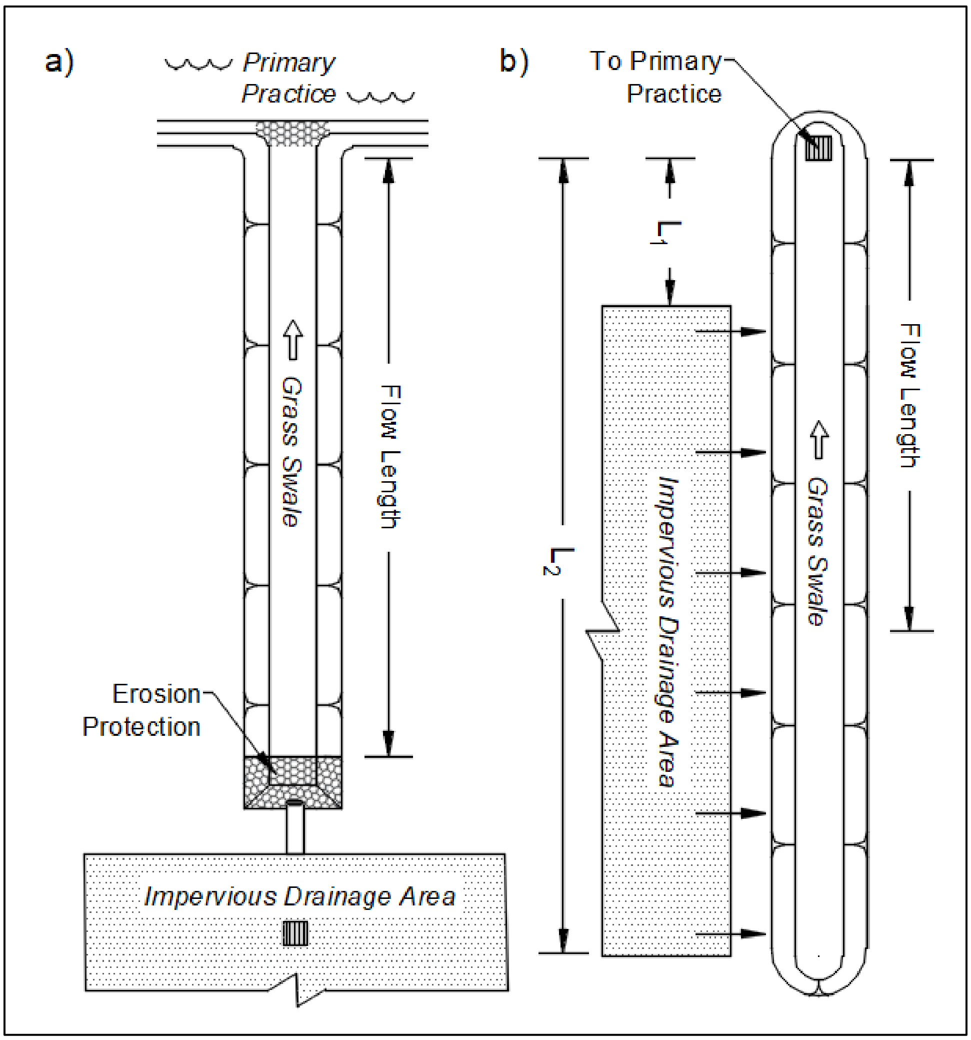


Figure 2.3.2 a) Flow Entering a Swale at a Defined Point or L_{flow} = L, b) Sheet Flow Entering Along the Swale Length Represented as an Average of the Shortest (L1) and Longest (L2) Paths or L_{flow} = (L1 + L2) ÷ 2

Turf reinforcement products (geogrid or geocells) may increase the allowable effective stress per the product design requirements. Alternatively, an allowable velocity approach may be used as documented in civil engineering texts and design manuals.

Although usually not the governing factor, conduct a second check to assure the vegetal effective stress is less than the allowable vegetal effective stress such that

$$\tau_v < \tau_{va} \qquad \text{(Equation 2.3.6)}$$

and

$$\tau_v = \gamma DS \qquad \text{(Equation 2.3.7)}$$

where τ_{va} is 3.33 lb/ft^3.

Soil

Healthy soil conditions support a dense, deep-rooted grass lining that both protects the swale from erosion and filters suspended solids. Avoid constructing a grass swale into overly compacted soil or dense subsoil. This will lead to a poor stand of grass cover that reduces the effectiveness of the practice. Chapter 1.4 explains the interdependent relationship between plants, soil, and hydrologic function.

Table 2.3.2 Allowable Effective Stress in a Grass Swale (NRCS, 2007)

Soil Textural Classifications	Allowable Soil Effective Stress (τ_a) in lb/ft^2
Clays	0.05
Silts	0.03
Sands	0.02

Inlet and Outlet Stability

Dissipate energy and disperse flow from concentrated inlet points with a rock pad or other measures. A rock plunge pool or forebay may be necessary for larger pipe inlets. Use a gravel verge along the edge of pavement to ensure runoff enters a swale as sheet flow.

All grass swales shall have a stable outlet with adequate capacity to prevent both erosion of the receiving channel from outflow and damage to the grass swale by tailwater ponding.

Subsurface Drain

A swale must completely drain within hours of the end of the storm event to maintain its grass cover. A subsurface drain of perforated pipe decreases wetness in the swale between storm events. Offset a subsurface drain two feet from the top edge of the swale. The drain's flowline should be at least 12 inches below the swale centerline grade with at least two feet of cover. A single subsurface drain parallel to the swale is usually sufficient. The installer must ensure that mounding or settling of trench backfill does not divert surface flow from the grass swale. Where possible, place the drain opposite the bank that receives inflow.

Separation from the Seasonal High-Water Table and Bedrock

The grass swale bottom must be at least 12 inches above the seasonal high-water table and bedrock. Install subsurface drains on both sides of a grass swale if the seasonal high-water table is a concern.

Grass Establishment

Seed a grass swale with a non-clumping, turf-forming perennial grass mix appropriate for the regional climate and local site conditions (for example, full sun, partial sun) immediately after reaching final grade. Plan to seed a grass swale between March 15 through June 1 or August 1 through October 15 to assure proper germination and plant growth. Seeding between June 1 and August 1 is possible but will require frequent watering and erosion control blankets to retain moisture. Allow time for a dense grass cover to grow prior to discharging stormwater runoff into a grass swale. Refer to the permanent seeding specifications in Chapter 7 for further guidance.

Sod can accelerate establishment but is to be avoided if excessive clay (> 20 percent) in the root mass will prevent infiltration. Seeding produces deeper plant roots with a better species mix.

The grass swale is considered established when both (1) plants can no longer be pulled free from the soil by hand; and (2) 90 percent cover is achieved which may take multiple growing seasons.

Construction Considerations

A grass swale is highly vulnerable to soil erosion until the protective grass cover has grown. Construct a grass swale early, during optimal seeding timeframes and allow the grass cover to grow prior being placed in service. Protect all seeded grass swales with erosion control matting throughout the germination period.

To prevent soil compaction, construct a grass swale using excavating equipment with adequate reach to grade the swale from the sides without sitting inside the footprint of the channel. Protect the grass swale from disturbance throughout the construction process.

Upgradient sediment and erosion controls should remain in place until the drainage area is permanently stabilized. Place additional sediment controls at inlets to the swale (sediment barrier, rock check, etc.). Accumulated construction sediment will be difficult to remove without damaging the freshly grown grass and costly reconstruction or reseeding.

Maintenance Considerations

A grass swale may not be as identifiable as traditional stormwater management infrastructure. The designer and developer must decide how to best inform current and future owners of the practice's purpose and how to safeguard it. A drainage easement allowing inspection and maintenance of the conveyance is recommended.

Detail the purpose, location, and maintenance expectations of a grass swale in the post-construction operation and maintenance plan developed as part of the stormwater pollution prevention plan (SWP3) and presented to the landowner.

Consider the ease of mowing when designing the swale geometry.

Example Calculation 2.3.1 Basic Grass Swale Design Calculations

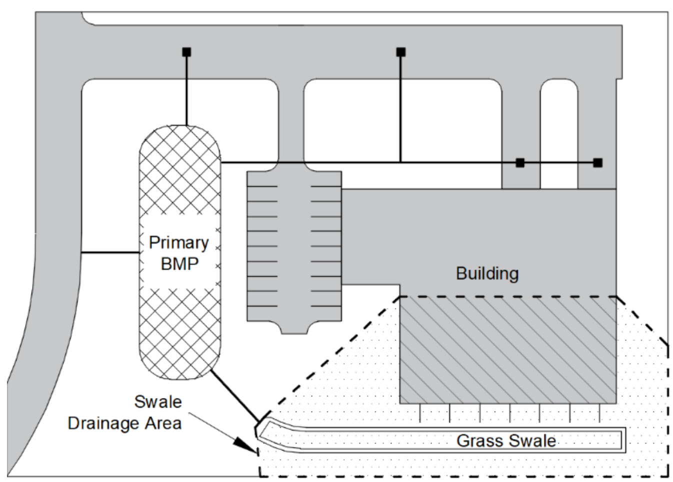
Scenario: A small industrial building is planned for a 4-acre disturbance. A grass swale will be used to convey stormwater runoff from 0.96 acres of the site (includes a portion of the building and lawn) to the primary stormwater management BMP.

<u>Swale Drainage Area</u>

Hydrologic soil group:	D
Drainage area:	0.96 ac
Impervious drainage area:	0.27 ac
Rv:	0.30

<u>Planned Grass Swale Geometry</u>

Bottom width:	6 ft
Side slopes:	3:1
Longitudinal slope:	1.0 %
Total length:	265 ft



Site Plan (not to scale)

Calculations:

1. **Calculate the WQf for the drainage area to the grass swale.**

$$WQf = CiA_{swale} = 0.34 \times 1.68 \text{ in/hr} \times 0.96 \text{ ac} = 0.55 \text{ cfs}$$

Where $C = (0.27 \text{ ac} * 0.90) + (0.66 \text{ ac} * 0.15) = 0.34$

$i = 1.68$ in/hr [See Chapter 2.18 Water Quality Flow] for a t_c of 12 minutes.

Or checking the impervious sub-area only,

$$WQf = CiA_{swale} = 0.90 \times 2.37 \text{ in/hr} \times 0.27 \text{ ac} = 0.58 \text{ cfs}$$

Where C = 0.90

i = 2.37 in/hr [see Chapter 2.18 Water Quality Flow] for a t_c of <5 minutes.

∴ Use a design flow of 0.58 cfs.

2. **Given the design geometry, use equation 2.3.2 to calculate the velocity at the 4-inch flow depth.**

$$V_{WQf} = \frac{1.49}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}} = \frac{1.49}{0.25} \times (0.333 \text{ ft})^{\frac{2}{3}} \times (0.010 \text{ ft/ft})^{\frac{1}{2}} = 0.29 \text{ ft/s}$$

3. **Use equation 2.3.1 to verify the swale capacity at the 4-inch flow depth exceeds the WQf.**

$$Q = VA = 0.29 \text{ ft/s} \times 2.33 \text{ ft}^2 = 0.68 \text{ cfs}$$

$$0.68 \text{ cfs} \geq 0.58 \text{ cfs WQf}$$

NOTE:
$A_{Trapezoid} = y(b+yz)$

y = depth of flow
b = bottom width
z = side slope (z:1)

4. **Verify the HRT meets or exceeds 5 minutes.**

Given the entire length receives flow, the average flow length is

$$L_{flow} = 265 \text{ ft} \div 2 = 132.5 \text{ ft}$$

From Equation 2.3.3, the HRT for the designed swale design is

$$HRT = \left(\frac{L_{flow}}{V_{WQf}}\right) \div 60 = \left(\frac{132.5 \text{ ft}}{0.29 \text{ ft/s}}\right) \div 60 = 7.6 \text{ minutes}$$

7.6 minutes provided ≥ 5 minutes required

5. **Given the 10-yr peak flow to the swale was determined to be 2.4 cfs and correspond to a flow depth of 0.55 ft, check the stability of the channel using Equations 2.3.5 and 3.3.7.**

$$\tau_e = \gamma DS(1 - C_f)\left(\frac{n_s}{n}\right)^2 = (62.4 \text{ lb/ft}^3)(0.55 \text{ ft})(0.01 \text{ ft/ft})(1 - 0.75)\left(\frac{0.0156}{0.03}\right)^2 = 0.02 \text{ lb/ft}^2$$

0.02 lb/ft2 < 0.05 lb/ft^2

and

$$\tau_{vegetation} = \gamma DS = (62.4 \text{ lb/ft}^3)(0.55 \text{ ft})(0.01 \text{ ft/ft}) = 0.34 \text{ lb/ft}^2$$

$$0.34 \text{ lb/ft}^2 < 3.33 \text{ lb/ft}^2$$

6. **With design criteria met, the runoff reduction credit of 0.1 inches (HSG D) over the swale's drainage area is applied to the WQv (normally calculated by the Runoff Reduction Spreadsheet, it is written out below for informational purposes).**

The WQv required for the 4-acre project is: 0.58 × 0.9 in × 4.0 ac ÷ 12 = 0.175 ac-ft (7,622 ft^3)

$$RRv = RR_{credit} \times Rv_{swale} \times DA_{swale} \div 12 = 0.10 \text{ in} \times 0.30 \times 0.96 \text{ ac} \div 12 = 0.0024 \text{ ac-ft } (105 \text{ ft}^3)$$

The primary practice must now be sized for

$$WQv_{adjusted} = WQv - RRv_{swale} = 7{,}622 \text{ ft}^3 - 105 \text{ ft}^3 = 7{,}517 \text{ ft}^3$$

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