4.2.5. Grass Swale (GS)

GS-1. Introduction

Grass Swales are vegetated open channels that are designed to manage the runoff by reducing the depth of flow and velocity through the channel.

Grass Swales can be used to:

- Partially manage the first one inch of rainfall on-site using a Grass Swale designed to the required geometry and slope to maintain the Design Volume flow depth and velocity. Grass Swales can be used in all Hydrologic Soil Groups (HSGs); Soil Amendments can be used to enhance performance in HSGs C and/or D. (See **Table GS-1**)
- Reduce pollutant loads to meet water quality targets (total maximum daily loads or TMDLs; See **Table GS-2**)
- Retrofit existing developed areas and existing drainage channels.

Grass Swales can be blended into the landscape and drainage infrastructure design for many sites. The left photo above shows a Grass Swale collecting runoff along its length from the adjacent parking lot, and the right photo shows a Grass Swale designed to manage runoff that enters at a single location at the upstream end.

Figure GS-1 further illustrates typical Grass Swale applications. **Figure GS-2** is a schematic of a typical Grass Swale. **Tables GS-1 and GS-2** describe two levels of Grass Swale design and associated volume reduction and pollutant removal performance rates. **Table GS-3** is a Design Checklist to help guide the design process for Grass Swales.

GS-1.1. Planning This Practice

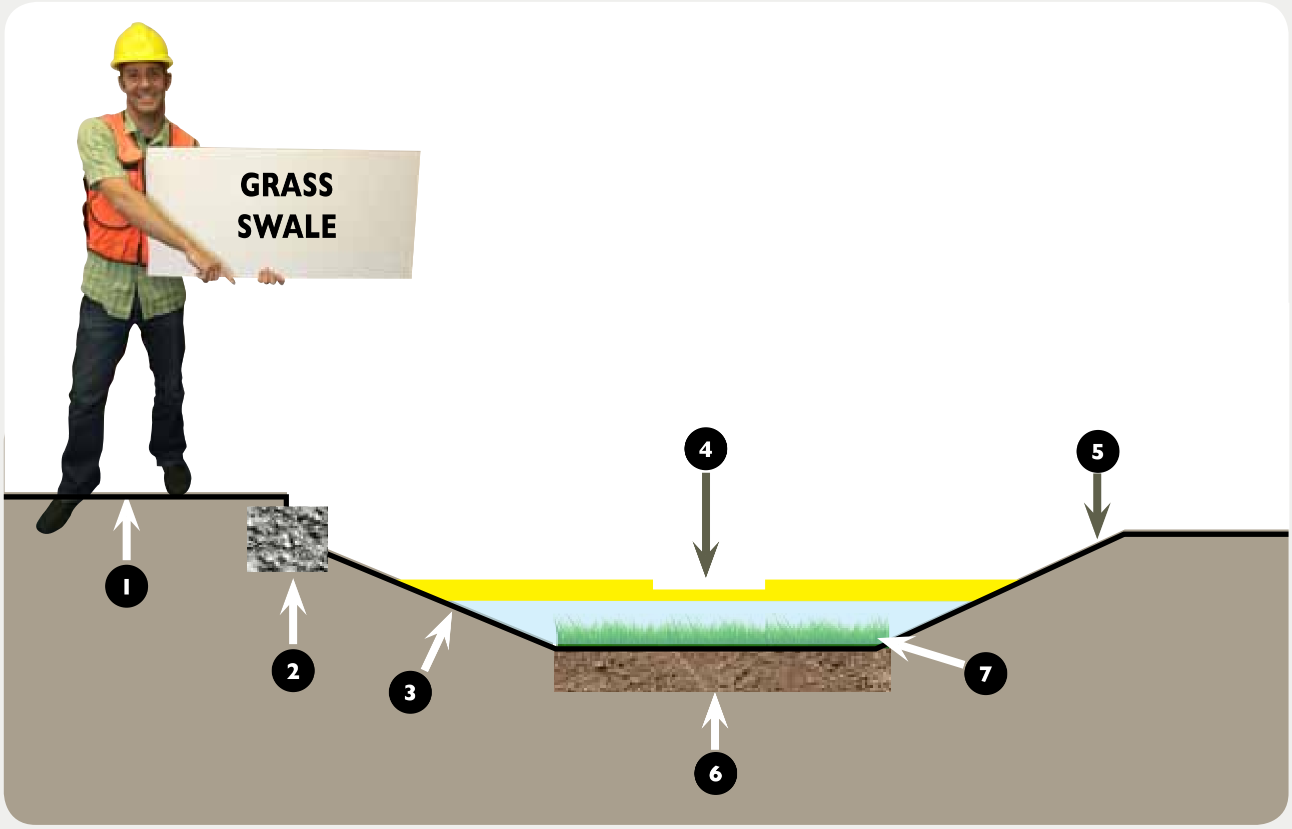
Figure GS-1. Typical Applications of Grass Swales

Edge of a Roadway

Roadway Median

Residential Application

Figure GS-2. Schematic Section for Typical Grass Swale



1. **Contributing impervious or pervious area (e.g., roadway)** – Section GS-3
2. **Pretreatment (typical gravel diaphragm)** – Sections GS-4.2
3. **Swale sizing, conveyance, geometry** – Table GS-1, Sections GS-4.1, GS-4.3 & GS-4.4
4. **Check dam with notch weir; ponding depth** – Sections GS-4.5 & GS-4.6
5. **Side slopes** – Section GS-4.7
6. **Soil Amendments (options)** – Section GS-4.8
7. **Grass swale planting** – Section GS-4.9

GS-1.2. Grass Swale Design Options & Performance

Table GS-1 describes the design and site constraints that are directly related to Grass Swale performance in terms of reducing the volume associated with one inch of rainfall on the site. Grass Swales are one of the few practices that do not use a Level 1 and Level 2 designation. Rather, the designer can implement Soil Amendments (described in detail in **Appendix D**) to overcome the basic site constraints of soil types (HSGs C or D) that would otherwise limit the performance of the practice. In addition, regardless of the soil types, the designer can manipulate the design geometry by adjusting the swale dimensions and/or adding check dams to achieve the key design criteria related to performance. **Table GS-2** summarizes pollutant removal performance values for different designs. This is for the purpose of calculating site-based pollutant load reductions in the context of TMDLs and/or watershed plans.

Table GS-1. Grass Swale Design Levels: Descriptions & Performance

Hydrologic Soil Group	Description	Applications	Performance[1]
A /B	**Standard Design** – Swale Geometry: • Trapezoid • Bottom width ≥ 2 ft. • Side Slopes 3:1 maximum • Combined slope and geometry to maintain max Design Volume[2] flow velocity: ≤ 1 ft/s • Inflow energy dissipation/ pre-treatment	Generally low to moderate density development projects Sites with steep slopes can utilize check dams to break up longitudinal slope and control flow velocity.	0.20 inches for the contributing drainage area and land cover types draining to the swale[3], when designed according to minimum criteria[4]
C /D	**Standard Design** – Same as A/B soils	See above	0.10 inches for the contributing drainage area and land cover types draining to the swale[3], when designed according to minimum criteria[4]
	Standard Design w Soil Amendments (Appendix D of Manual)	See above	0.20 inches for the contributing drainage area and land cover types draining to the swale[3], when designed according to minimum criteria[4]

[1] *Performance achieved toward reducing one inch of rainfall*

[2] *The Design Volume is based on the size and land cover types of the contributing drainage area to the Grass Swale, and is used to determine a peak flow used for swale design. See* **Section GS-4** *for sizing details.*

[3] *0.20 inches x size of contributing drainage area x volumetric runoff coefficient for the drainage area. This volume can be determined by using the Design Compliance Spreadsheet. See* **Chapter 3 of this Manual** *for the calculation methodology and* **Section GS-4** *for sizing details.*

[4] *Minimum criteria address multiple design geometry characteristics related to flow depth, velocity, length, width, and residence time of water in the swale. Check dams in the channel help to reduce the effective velocity and depth of flow so as to meet the minimum criteria on steep sites, but do not provide additional volume reduction (additional storage behind check dams may be able to provide storage benefits for single storm event modeling). See* **Section GS-4** *for sizing details.*

Table GS-2. Total Pollutant Load Reduction Performance Values for Grass Swales

Hydrologic Soil Group	Total Suspended Solids (TSS)[1]	Nutrients: Total Phosphorus (TP) & Total Nitrogen (TN) [1]
A/B	TSS = 60%	TP = 32% TN = 36%
C/D	TSS = 35%	TP = 23% TN = 28%

[1] Total Pollutant Load Reduction = combined functions of runoff reduction and pollutant removal. Pollutant removal refers to the change in event mean concentration as it flows through the practice and is subjected to treatment processes, as reported in Hirschman et al. (2008).

GS-1.3 Grass Swale Design Checklist

Table GS-3. Grass Swale Design Checklist

CHECKLIST

This checklist will help the designer through the necessary design steps for Grass Swales

- ☐ Check feasibility for site – **Section GS-3**
- ☐ Evaluate site constraints and determine HSGs present on site and evaluate feasibility of achieving design goals: swale geometry and slope to meet maximum allowed flow depth and velocity.– **Table GS-1**
- ☐ Verify Grass Swale sizing guidance and ensure adequate footprint on the site for Grass Swale(s) – **Section GS-4.1**
- ☐ Complete Design Compliance Spreadsheet and confirm if additional practices are needed for overall site compliance – **Spreadsheet & Chapter 3 of Manual**
- ☐ Check design adaptations appropriate to the site – **Section GS-6**
- ☐ Design Grass Swale in accordance with design criteria and typical details – **Sections GS-2 & GS-4**
- ☐ Provide all necessary plan view, profile, and cross-section details along with elevations, materials specifications, grading, construction sequence, and notes

4.2.5. Grass Swale (GS)

GS-2. Typical Details

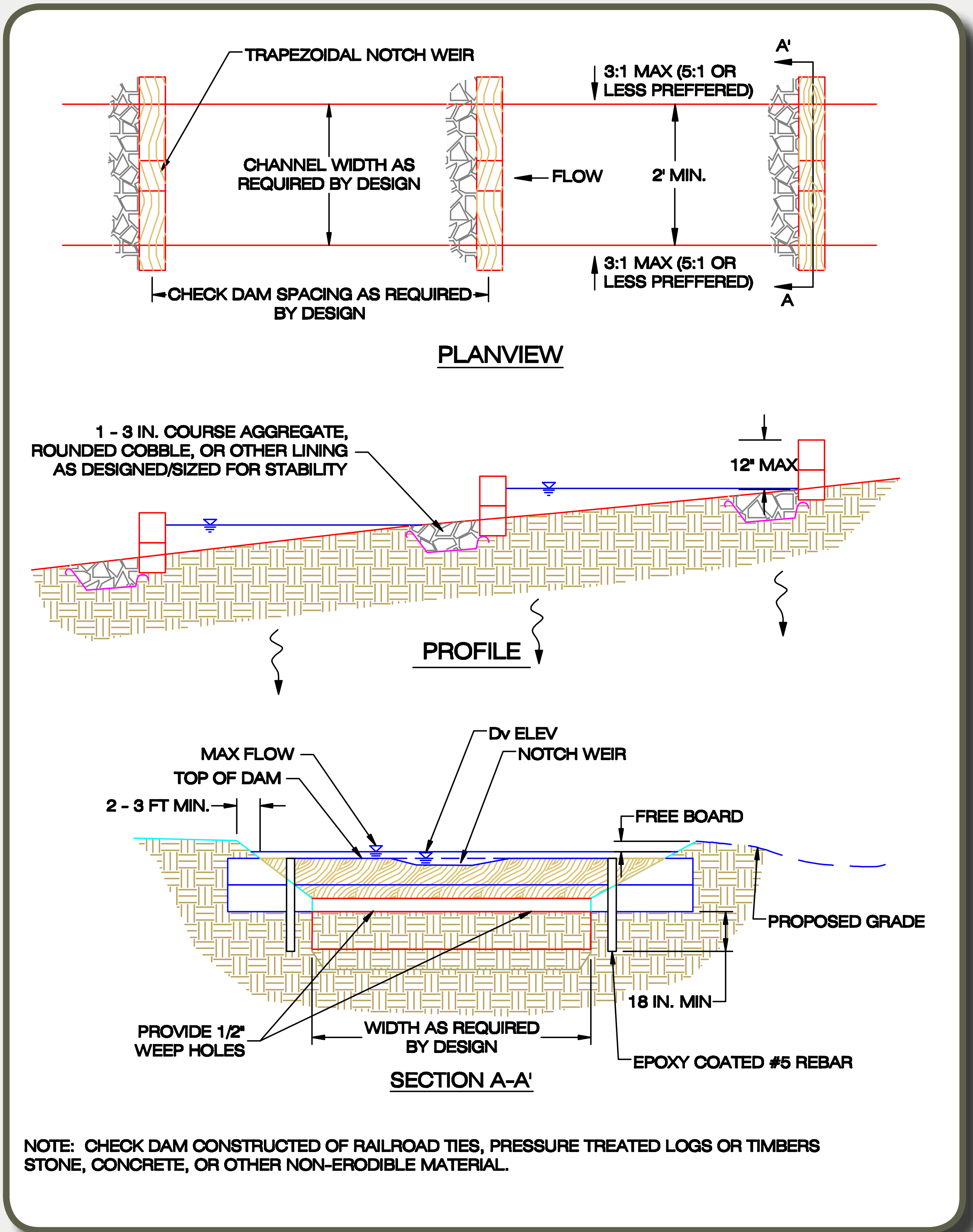


Figure GS-3. Typical Detail for Grass Swale with Check Dams

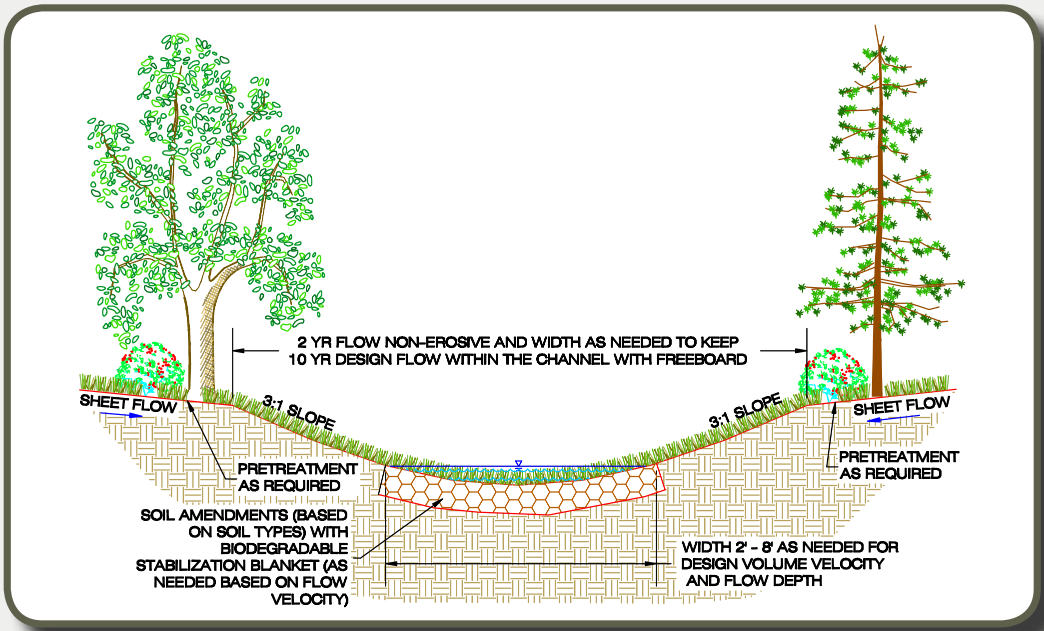


Figure GS-4. Typical Detail for Grass Swale with Soil Amendments

4.2.5. Grass Swale (GS)

GS-3. Feasibility Criteria and Design Considerations

Grass Swales are primarily applicable for land uses such as roads, highways, and residential development. Key constraints with Grass Swales include the following:

Available Space. Grass Swales can be incorporated into linear development applications (e.g., roadways) by utilizing the footprint typically required for an open section drainage system. The footprint required will likely be greater than that of a typical conveyance channel because of the limitations on velocity and depth of flow. However, the benefit of the runoff reduction may reduce the footprint requirements for stormwater management elsewhere on the development site.

Site Topography. Grass Swales must be constructed at relatively flat grades, so they are most effective on sites with mild to moderate post-construction grades (less than 5%). Check dams can be used to reduce the effective slope of the channel and lengthen the contact time to enhance filtering and/or infiltration. Longitudinal slopes of less than 2% are ideal and may eliminate the need for check dams. However, channels designed with longitudinal slopes of less than 1% should be monitored carefully during construction to ensure a continuous grade, in order to avoid flat areas with pockets of standing water.

Available Hydraulic Head. A minimum amount of hydraulic head is needed to implement Grass Swales in order to ensure positive drainage and conveyance through the channel. The hydraulic head is measured as the elevation difference between the channel surface inflow and outflow point.

Water Table. Designers should ensure that the bottom of Grass Swales is at least 1 foot above the groundwater table to ensure that the seasonally high groundwater does not intersect the swale flow line (which would likely render the design a "wet swale" – refer to Design Specification 4.2.11, Stormwater Wetlands).

Soils and Underdrains. Grass channels are suitable for most soil types as long as they can support a good stand of vegetation. Soil Amendments are recommended in HSGs C and D (see Section GS-4.8 of this Specification and Appendix D)

Contributing Drainage Area. The maximum recommended contributing drainage area (CDA) to Grass Swales is 5 acres, and preferably less. Grass Swales managing runoff from drainage areas greater than 5 acres must still address conveyance design criteria for larger storms which will often overwhelm the design elements intended to manage the

Design Volume. The larger storm events will require significant channel cross sections in order to keep velocities down and prevent erosion in the channel. The design criteria for maximum channel velocity and depth are applied along the entire length (See Section GS-4).

Hotspot Land Uses. Grass Swales can typically be used to convey runoff from stormwater hotspots, but do not qualify as a hotspot treatment mechanism.

For a list of potential stormwater hotspots, please consult Chapter 5 of the Manual.

Use of Grass Swales in Fill Sections or On Marginal Soils

In areas of fill, soil slips can result from saturating sections of different soil types. While Grass Swales are not necessarily designed to infiltrate runoff, they can attenuate flows so as to encourage infiltration where soils allow. Grass Swales can be used in either cut or fill, however a clear note should address proper fill material preparation in order to minimize any differential soil conditions.

Further, Grass Swales depend on dense vegetation to promote filtering and abstraction. Construction of Grass Swales in fill material or in a disturbed soil profile may require Soil Amendments in order to establish vegetation and achieve even basic performance. A soil test should be performed to evaluate the organic content and fertilization requirements.

Floodplains. Grass Swales should be constructed outside the limits of the mapped 100-year floodplain, unless a waiver is obtained from the local authority.

Baseflow and Non-stormwater Discharges. Grass Swales should be located so as to avoid inputs of springs, chlorinated wash-water, or other dry weather flows. Periodic irrigation runoff is permissible, however too much discharge may impact the vegetation.

Setbacks. Grass Swales should be set back at least 10 feet down-gradient from building foundations. Similarly, setbacks from septic system fields and private wells are typically needed only to avoid impacting the function of those systems during construction and potential maintenance of the swale. Generally, minimum setbacks of 10 to 20 feet from the perimeter of drain fields and well heads is recommended.

Proximity to Utilities. Approval from the applicable utility company or agency is required if utility lines will run below or through Grass Swale areas. Typically, utilities can cross linear channels perpendicular if they are protected (e.g., double-casing or conduit). Locating utilities (especially water and sewer lines) in a parallel alignment under a Grass Swale is not recommended.

Community Factors. The main concerns of adjacent residents are perceptions that Grass Swales will create nuisance conditions or will be hard to maintain. Common concerns include the continued ability to mow grass, landscape preferences, weeds, standing water, and mosquitoes. All of these concerns can be fully addressed through the design and construction process and proper on-going operation and routine maintenance. Grass Swales should be placed in a drainage or maintenance easement in order to ensure long term maintenance (see Section GS-8 Maintenance)

Underground Injection Permits. Grass Swales are not considered to be Class V wells subject to permits under the Underground Injection Control (UIC) Program (U.S. EPA, 2008).

4.2.5. Grass Swale (GS)

GS-4. Design Criteria

GS-4.1. Grass Swale Sizing Guidelines for Water Quality & Volume Reduction

A Note on Terminology Describing Volume

There are two types of volumes that the designer should consider when designing a best management practice (BMP) plan:

Target Treatment Volume (Tv) = Volume associated with managing 1" of rainfall based on the size and land cover of the CDA, as determined by the Design Compliance Spreadsheet. Any given BMP may treat the full Tv or only part of it if used in conjunction with other practices as part of a treatment train.

Design Volume (Dv) = The volume designed into a particular practice based on storage (or peak flow in the case of Grass Swales), as prescribed in the BMP specification. Grass Swales are often part of a treatment train BMP design, with possible upgradient (e.g., Impervious Surface Disconnection) and downgradient (e.g., Bioretention) practices. In these cases, the Dv of the Grass Swale may be a portion of the overall Tv for the contributing drainage area. In such cases, the sum of the Design Volumes in the Grass Swale plus that of the other practices in the treatment train should equal the total drainage area Tv. On the other hand, when Grass Swales are the last practice in a treatment train, the designer may have to accommodate all the flow from the CDA, including large storm bypass from the upstream practices. In these cases, the swale is likely oversized and the Dv will be at least equal to the CDA Tv, and the credit will be 0.2 watershed inches as described in Table GS-1.

See **Chapter 3** for more information on the runoff reduction design methodology.

For the purposes of this sizing section, the sizing relates to the Dv of the Grass Swale being designed.

Unlike other stormwater practices, Grass Swales are designed based on a peak rate of flow. Designers must demonstrate both channel conveyance and treatment capacity in accordance with the following guidelines:

- Hydraulic capacity should be verified using Manning's Equation or an accepted equivalent method, such as erodibility factors and vegetal retardance.
  - The flow depth for the peak flow generated by the Design Volume should be maintained at 4 inches or less, with a flow velocity ≤ 1 ft/s.
  - Manning's "n" value for Grass Swales should be 0.2 for flow depths up to 4 inches, decreasing to 0.03 at a depth of 12 inches and above (which would apply to the 2-year/24 hour storm. and 10-year storms if an on-line application as noted in Haan et. al, 1994).
  - Peak flow rates for the 2-year frequency storm must be non-erosive, in accordance with **Table GS-5** below (see **Section GS-4.9 Grass Swale Landscaping Criteria**), or subject to a site-specific analysis of the channel lining material and vegetation; and the 10-year peak flow rate must be contained within the channel banks (with a minimum of 0.3 feet of freeboard).
- Calculations for peak flow depth and velocity should reflect any increase in flow along the length of the swale, as appropriate. If a single flow is used, the flow at the outlet should be used.
- The hydraulic residence time (the time for runoff to travel the full length of the channel) should be a minimum of 9 minutes for the peak flows from the Design Volume storm (Mar et al., 1982; Barrett et al., 1998; Washington State Department of Ecology, 2005). If flow enters the swale at several locations, a 9 minute minimum hydraulic residence time should be demonstrated for each entry point, using **Equations GS-1 – GS-5** below.

The Grass Swale geometry is designed according to the recommended steps provided below to maintain the appropriate flow depth and velocity.

Using Available Swale Design Tools

Designers may choose to utilize available hydraulic design software to optimize the swale geometry for treatment and large storm conveyance.

1. Establish the peak flow rate for the one-inch rainfall event (Refer to **Appendix F** for guidance on the recommended calculation procedure). This will be the design peak flow rate for the entire drainage area. If the flow enters the swale at intermediate points or continuously along the length, the designer may choose to establish the maximum section at the downstream end of the swale and then work upstream establishing an incrementally smaller cross section corresponding to the incrementally smaller drainage area and peak flow rate.

Verify Modeling Approach with Local Authority

Designers should verify through the local plan approving authority if they intend to utilize a different hydrologic modeling tool or computational procedure other than that referenced in **Appendix F.**

2. Use the Manning equation (**Equation GS-1**) to calculate the velocity for the maximum flow depth of four inches (0.3 ft.) and the design longitudinal slope of the swale.

Equation GS-1: Manning's Equation

$$V = \left[\left(\frac{1.49}{n}\right) D^{2/3} s^{1/2}\right]$$

V = flow velocity (ft./sec.)
n = roughness coefficient (0.2, or as appropriate)
D = flow depth (ft.) (NOTE: D approximates hydraulic radius for shallow flows)
s = channel slope (ft./ft.)

3. Calculate the minimum bottom width (W) required to accommodate the design peak flow velocity (based on the four inch depth as calculated in Step 2 above) using the rearranged Continuity Equation (**Equation GS-2**):

Equation GS-2: Continuity Equation

$$Q_{Dv} = VA$$

$$Q_{Dv} = V(W \times D)$$

Rearranged Continuity Equation

$$W = Q_{Dv}/(V \times D)$$

Where:
Q_{Dv} = Design Volume design peak flow rate (cfs)
V = swale flow velocity (ft./sec.)
A = swale cross sectional flow area = $W \times D$
W = channel width (ft.)
D = flow depth (ft.)
(NOTE: channel width (W) x depth (D) approximates the cross sectional flow area for shallow flows.)

An alternative direct solution for the minimum swale bottom width is through combining **Equations GS-1 and GS-2**, and re-writing them as follows:

Equation GS-3: Minimum Width

$$W = \left[\frac{nQ_{Dv}}{\left(1.49D^{5/3}s^{1/2}\right)}\right]$$

Solving **Equation GS-2** for the corresponding velocity provides:

Equation GS-4: Corresponding Velocity

$$V = Q_{Dv}/WD$$

The width, slope, or Manning's "n" value can be adjusted to provide an appropriate channel design for the site conditions. However, if a higher density of grass is used to increase the Manning's "n" value and decrease the resulting channel width, it is important to provide material specifications and construction oversight to ensure that the more dense vegetation is actually established. Equation GS-5 can then be used to ensure adequate hydraulic residence time.

In addition, the designer should evaluate the use of check dams and the impact on the flow velocity. The velocity and resulting travel time will be lengthened based on the distance between the check dams and the ponding depth behind the check dams.

Equation GS-5: Grass Channel Length for Hydraulic
Residence Time of 9 minutes (540 seconds)

$$L = 540 * V$$

Where:
L = minimum swale length (ft.)
V = flow velocity (ft./sec.)

The runoff reduction credit is applied to the Design Volume used to establish the design of the swale.

GS-4.2. Pretreatment

Pre-Treatment is Essential

Pre-treatment is required for Grass Swales to dissipate energy and runoff velocity at concentrated inflow points and trap sediments and other particulate pollutants. Pre-treatment is essential to prolong the life of the practice and ensure long-term performance. Pre-treatment for Grass Swales can be simple practices, such as a grass strip or gravel diaphragm.

Several pre-treatment measures are feasible, depending on the type of the Grass Swale practice and whether it receives sheet flow or concentrated flow. **Figure GS-5** shows typical pretreatment options for Grass Swales. For pre-treatment structures at the edge of pavement (e.g., grass filter strips, gravel diaphragms, flow splitters), it is important that there be a 2 to 4 inch drop from the edge of pavement to the top of the grass or stone in the pre-treatment structure. This is to prevent accumulation of debris and subsequent clogging at the point where runoff is designed to enter the pre-treatment structure (see **Figure GS-6**).

Figure GS-5. Examples of Pre-Treatment Applicable to Grass Swales

Grass filter strips *that are perpendicular to incoming sheet flow extend from the edge of pavement (with a slight drop of 2 to 3 inches at the pavement edge) to the bottom of the Grass Swale at a 5:1 slope or flatter.*

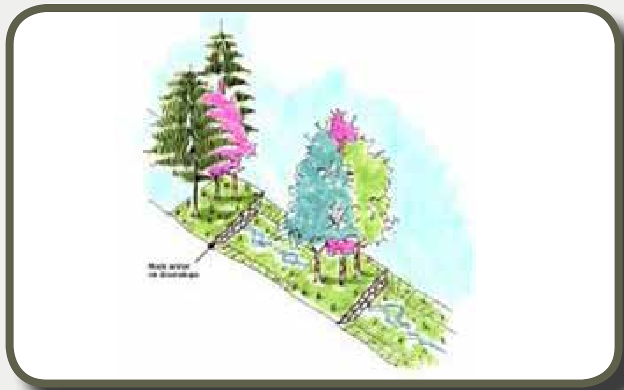
This Pre-Treatment Cell is located at piped inlets or curb cuts leading to the Swale. The cell may be formed by a wooden or stone check dam or an earthen or rock berm.

Figure GS-5 (continued)

Check Dams are energy dissipation devices that can be used on small Grass Swales with drainage areas of less than 1 acre. The most common form is the use of wooden or stone check dams. The pretreatment volume stored must be 10% of the Design Volume.

A Gravel Diaphragm located at the edge of the pavement should be oriented perpendicular to the flow path to pre-treat lateral runoff, with a 2 to 4 inch drop from the pavement edge to the top of the stone. The stone must be sized according to the expected rate of discharge.

The Gravel or Stone Flow Spreader is located at curb cuts, piped inlets, downspouts, or other concentrated inflow points. The gravel or stone should extend the entire width of the opening and create a level stone weir at the bottom of the swale.



Tree Check Dams are tree mounds that are placed within the bottom of Grass Swales up to an elevation of 9 to 12 inches above the channel invert. One side has a gravel or river stone bypass to allow runoff to percolate through (Cappiella et al, 2006). The pretreatment volume stored must be 10% of the Design Volume.

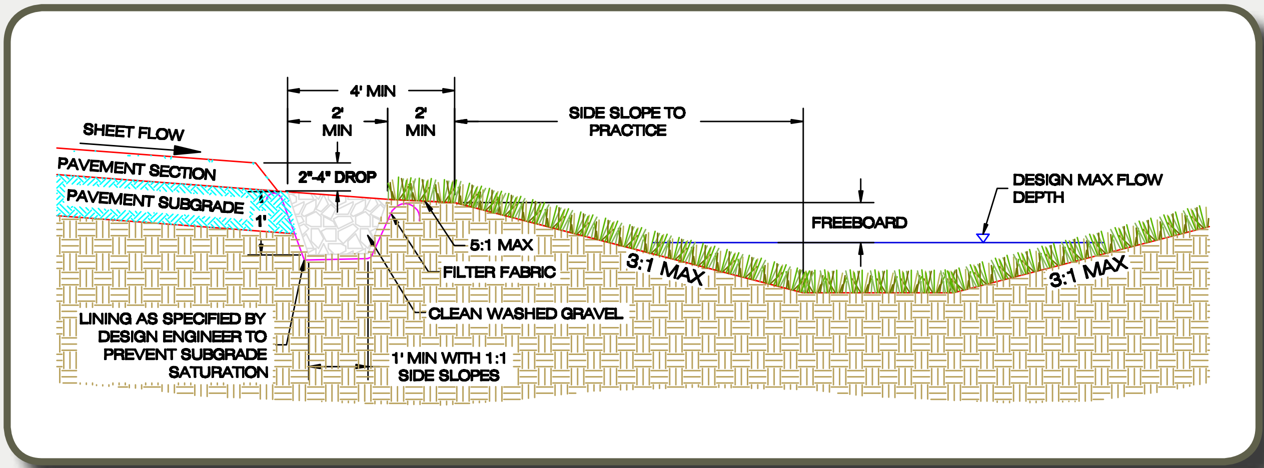


Figure GS-6. Typical Detail for Pre-Treatment at Pavement Edge – A 2 to 4 inch drop from the pavement to the top of stone helps to prevent clogging.

GS-4.3. Conveyance and Overflow

The bottom width and slope of a Grass Swale is designed to achieve the required flow depth, velocity, and travel time of the Tv for the full length of the channel. Grass Swales must also be designed to convey the 2- and 10-year storms at non-erosive velocities for the soil and vegetative cover provided (**Table GS-5**). The final swale design shall have a minimum of 0.3 ft. freeboard above the design 10-year water surface profile of the channel. The analysis should evaluate the flow profile through the channel at normal depth, as well as the flow depth over top of the check dams.

In order to avoid the additional swale cross section needed to accommodate the larger storms, designers may choose to construct the swale in an off-line configuration. This will generally require some form of a diversion structure that is specifically designed to only allow the design Tv peak flow rate into the swale.

An alternative off-line configuration incorporates a check dam design that when full (water is backed up to the maximum ponding depth) prevents additional flow from entering the swale and forces it to bypass into a large storm conveyance system. This configuration is especially useful in an edge of pavement application where the overflow can be diverted along the edge of pavement to an alternative conveyance. A single inflow design will be complicated by the need to ensure that the downstream check dams have had a chance to fill before diverting flow at the upper end.

It should be noted that both types of design approaches require attention to safe conveyance of larger flows in adequate conveyances and with adequate freeboard to a receiving waterbody. Drainage design should be based on expected peak discharges assuming that upstream stormwater BMPs are full and typically provide marginal storage during larger events. Large storm overland-flow paths should be identified and labeled in the project's overall drainage map.

GS-4.4. Design Geometry

Design guidance regarding the geometry and layout of open channels is provided below:

- Edge of pavement Grass Swales should generally be aligned adjacent to and the same length as the CDA identified for treatment.
- Grass Swales should be designed with a trapezoidal cross section. It is very common for a trapezoidal cross section to take on a parabolic shape within the first year after construction due to the margin of error related to construction and erosion and sedimentation of the side slopes during the first year of vegetation establishment.
- The bottom width of the swale should be a minimum of 2 feet wide. Typical design (depending on drainage area and longitudinal slope) will be between 2 and 8 feet wide to ensure that an adequate surface area exists along the bottom of the swale for filtering. If a swale will be wider than 8 feet, the designer should incorporate benches, check dams, level spreaders or multi-level cross sections to prevent braiding and erosion along the swale bottom.

GS-4.5. Check Dams

Check dams may be used for pre-treatment, to reduce the effective slope and flow velocity, and thereby increase the hydraulic residence time in the swale. Design requirements for check dams are as follows:

- Check dams should be spaced based on the swale slope, as needed to increase residence time, provide design storm storage volume, or any additional volume attenuation requirements. In typical spacing, the ponded water at a downhill check dam should not touch the toe of the upstream check dam.
- The maximum desired check dam height is 12 inches (for maintenance purposes). However, for some sites, a maximum of 18 inches can be allowed, with additional design elements to ensure the stability of the check dam and the adjacent and underlying soils.
- The swale should have a continuous grade between check dams.
- Armoring may be needed at the downstream toe of the check dam to prevent erosion.
- Check dams must be firmly anchored into the side-slopes to prevent outflanking; check dams must also be anchored into the swale bottom so as to prevent hydrostatic head from pushing out the underlying soils.
- Check dams must be designed with a center weir sized to pass the swale design storm peak flow (typically the 10-year storm event).
- Each check dam should have a weep hole or similar drainage feature so it can dewater after storms.

- Check dams should be composed of wood, concrete, stone, or other non-erodible material. Individual swale segments formed by check dams or driveways should generally be at least 25 to 40 feet in length.

Check dams for Grass Swales should be spaced to reduce the effective slope to 2% or less, as provided in **Table GS-4** below.

Table GS-4. Typical Check Dam (CD) Spacing to Achieve Effective Channel Slop

Swale Longitudinal Slope	Spacing [1] of 12-inch High (max.) Check Dams [3, 4] to Create an Effective Slope of 2%	Spacing [1] of 12-inch High (max.) Check Dams [3, 4] to Create an Effective Slope of 0 to 1%
0.5%	–	200 ft. to –
1.0%	–	100 ft. to –
1.5%	–	67 ft. to 200 ft.
2.0%	–	50 ft. to 100 ft.
2.5%	200 ft.	40 ft. to 67 ft.
3.0%	100 ft.	33 ft. to 50 ft.
3.5%	67 ft.	30 ft. to 40 ft.
4.0%	50 ft.	25 ft. to 33 ft.
4.5% [2]	40 ft.	20 ft. to 30 ft.
5.0% [2]	40 ft.	20 ft. to 30 ft.

Notes:

[1] The spacing dimension is half of the above distances if a 6-inch check dam is used.

[2] Grass Swales with slopes greater than 4% require special design considerations, such as drop structures to accommodate greater than 12-inch high check dams (and therefore a flatter effective slope), in order to ensure non-erosive flows.

[3] All check dams require a stone energy dissipater at the downstream toe.

[4] Check dams require weep holes at the channel invert. Swales with slopes less than 2% will require multiple weep holes (at least 3) in each check dam.

GS-4.6. Ponding Depth

Check dams should be used in Grass Swales to create ponding cells along the length of the channel. The maximum ponding depth in a Grass Swale should not exceed 18 inches. It may be necessary or desirable to space check dams more frequently than is shown in **Table GS-**4 in order to decrease the ponding depth.

Limit Applications of 18" Ponding

Designers should evaluate the community acceptance (safety, aesthetics, etc.) and maintenance factors when considering the use of 18 inch ponding depths in a residential setting. The 18" ponding depth may be appropriate for larger-scale commercial, industrial, or institutional settings. The depth of ponding should never exceed 18".

GS-4.7. Side Slopes

Grass Swale side slopes should be no steeper than 3H:1V for ease of mowing and routine maintenance. Flatter slopes are encouraged where adequate space is available, to enhance pre-treatment of sheet flows entering the swale.

GS-4.8 Soil Amendments

Soil Amendments serve to increase the runoff reduction capability of a Grass Swale constructed on HSGs C and/or D. The following design criteria apply when Soil Amendments are used:

- The compost-amended strip should extend over the length and width of the swale bottom, and the compost should be incorporated to a depth as outlined in **Appendix D**.
- The amended area will need to be rapidly stabilized.
- It may be necessary to install a temporary or permanent erosion control blanket to protect the compost-amended soils. Care must be taken to consider the erosive characteristics of the amended soils when selecting an appropriate geotextile. Refer to the WVDEP (2006)
- For redevelopment or retrofit applications, the final elevation of the Grass Swale (following compost amendment) must be verified as meeting the original design hydraulic capacity.

GS-4.9. Grass Swale Planting Criteria

All Grass Swales must be stabilized to prevent erosion or transport of sediment to receiving practices or drainage systems. Several appropriate types of grasses appropriate for Grass Swales are listed in **Table GS-5**. Designers should consider the following when choosing grass cover:

- Tall and high stem density grasses that can withstand the flow velocity anticipated in the swale (designers should ensure that the maximum flow velocities do not exceed the values listed in **Table GS-5** for the selected grass species and the swale slope).
- If roadway salt will be applied to the CDA, Grass Swales should be planted with salt-tolerant plant species.
- Landscape design shall specify proper grass species based on specific site, soils and hydric conditions present along the channel.
- Grass Swales should be seeded at such a density to achieve a 90% vegetated cover after the second growing season.
- Grass Swales should be seeded and not sodded. Seeding establishes deeper roots and sod may have muck soil that is not conducive to infiltration. (Wisconsin DNR, 2004)

- Grass channels should be protected by a biodegradable erosion control fabric to provide immediate stabilization of the channel bed and banks.

For a list of grass species suitable for use in grass channels, consult WVDEP (2006) . Also, consult **Appendix F** of this manual for a comprehensive plant list for stormwater BMPs.

Table GS-5. Recommended Vegetation and Maximum Flow Velocities for Grass Swales.

Vegetation Type	Slope (%)	Maximum Velocity (ft/s)	
		Erosion resistant soil	Highly Erodible Soil[1]
Bermuda Grass	0-5	6	4.5
	5-10	5	4
	>10	4	3
Kentucky Bluegrass Reed Canary Grass Tall Fescue Grass Mixture	0-5	5	4
	5-10	4	3
	>10	3	2.5
Red Fescue Redtop	0-5	5	4

[1]*An erodibility factor (K) greater than 0.35 would indicate a highly erodible soil. Erodibility (K-factors) can be obtained from local NRCS offices.*

Source: WVDEP (2006)

GS-5. Materials Specifications

Recommended material specifications for Grass Swales are shown in **Table 6**.

Table 6. Grass Swale Material Specifications

Component	Specification
Grass	A dense cover of water-tolerant, erosion-resistant grass. The selection of an appropriate species or mixture of species is based on several factors including climate, soil type, topography, and sun or shade tolerance. Grass species should have the following characteristics: a deep root system to resist scouring; a high stem density with well-branched top growth; water-tolerance; resistance to being flattened by runoff; an ability to recover growth following inundation; and, if receiving runoff from roadways, salt-tolerance.
Check Dams	• Check dams should be constructed of a non-erosive material such as wood, gabions, riprap, or concrete. All check dams should be underlain with filter fabric conforming to local design standards. • Wood used for check dams should consist of pressure treated logs or timbers, or water-resistant tree species such as cedar, hemlock, swamp oak or locust.
Diaphragm	Pea gravel used to construct pre-treatment diaphragms should consist of washed, open-graded, course aggregate between 3 and 10 mm in diameter and must conform to local design standards.
Erosion Control Fabric	Where flow velocities dictate, biodegradable erosion control netting or mats that are durable enough to last at least two growing seasons must be used, conforming to WVDEP (2006)

4.2.5. Grass Swale (GS)

GS-6. Design Adaptations

GS-6.1. Karst Terrain

Grass Swales are an acceptable practice in karst terrain, as long as they do not treat hotspot runoff. The following design adaptations apply to grass channels in karst terrain:

- Soil compost amendments may be incorporated into the bottom of Grass Swales to improve their runoff reduction capability.
- Check dams are generally discouraged for Grass Swales in karst terrain, since they pond too much water (although flow spreaders that are flush with the ground surface and spaced along the channel length may be useful in spreading flows more evenly across the channel width).
- The minimum depth to the bedrock layer is 12 inches.

- A longitudinal slope greater than 0.5% must be maintained to ensure positive drainage.
- The Grass Swale may have off-line cells and should be tied into an adequate discharge conveyance system.

GS-6.2. Steep Slopes

Grass Swales are not practical in areas of steep terrain, although terracing a series of Grass Swale cells may work on slopes from 5% to 10%. The drop in elevation between check dams should be limited to 18 inches in these cases, and the check dams should be armored on the down-slope side with suitably sized stone to prevent erosion.

GS-6.3. Cold Climate and Winter Performance

Many different kinds of salting and sanding materials are applied to roads and highways during winter months. Grass Swales can store snow and treat snowmelt runoff when they serve road or parking lot drainage. If roadway salt is applied in their CDA, Grass Swales should be planted with salt-tolerant species.

GS-6.4. Stormwater Retrofitting

Grass Swales can be readily used in retrofit situations. Most swale retrofits require that an existing open channel be widened, deepened, reduced in gradient, or some combination of all three. Swales are particularly well suited to treat runoff from low and medium density residential streets and small parking lots.

For more information on retrofitting, see the Center for Watershed Protection's manual, ***Urban Stormwater Retrofit Practices*** (Schueler et al., 2007).

4.2.5. Grass Swale (GS)

GS-7. Construction & Installation

GS-7.1. Construction & Installation

Grass Swale alignments may be utilized during construction as diversion dikes. However, specific plan notes regarding the clean out and conversion to a water quality swale must be specific in removing the accumulated sediment as well as minor excavation down into undisturbed soils.

A Grass Swale used to convey clean water around or through a construction should be fully protected by silt fence or diversion and protected from construction traffic crossing the swale. Ideally, Grass Swales should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment. However, this is seldom practical, given that the channels are a key part of the drainage system at most sites. In these cases, temporary erosion and sediment controls such as dikes, silt fences and other erosion control measures should be integrated into the swale design throughout the construction sequence.

GS-7.2. Grass Swale Installation

The following is a typical construction sequence to properly install Grass Swales, although steps may be modified to reflect different site conditions or design variations. If possible, Grass Swales should be installed at a time of year that is best to establish turf cover without irrigation.

The timing of the installation of Grass Swales is dependent on whether the swale is to be used as a conveyance during construction. It may be preferable to construct the swale prior to the CDA being directed to the swale in order to help establish vegetation in the swale bottom. If this is not feasible based on the construction sequencing of the site, then the

CDA should be stabilized with vegetation before attempting to establish vegetation in the channel.

Any accumulation of sediment that does occur within the channel must be removed during the final stages of grading or establishing vegetative cover in order to achieve the design cross-section.

Step 1. Grade the Grass Swale to the final dimensions shown on the plan. Excavators or backhoes should work from the sides to grade and excavate the swale to the appropriate design dimensions. Excavating equipment should have scoops with adequate reach so they do not have to sit inside the footprint of the open channel area. The final grading should rake or scarify the bottom as needed for seed preparation.

Step 3 (Optional). Add Soil Amendments as needed. Till the bottom of the Grass Swale to a depth of 1 foot and incorporate compost amendments according to Appendix D.

Step 4. Install check dams, driveway culverts and internal pre-treatment features as shown on the plan. The top of each check dam should be constructed level at the design elevation.

Step 5. Seed (or Hydro-seed) the bottom and banks of the open channel, and peg in erosion control fabric or blanket where needed. After initial planting, a biodegradable erosion control fabric should be used, conforming to WVDEP (2006).

Step 6. Conduct the final construction inspection and develop a punchlist for facility acceptance.

GS-7.3 Construction Inspection

Inspections during construction are needed to ensure that the Grass Swale is built in accordance with these specifications. An example construction phase inspection checklist is available in Appendix A of the Manual.

Some common pitfalls can be avoided by careful construction supervision that focuses on the following key aspects of Grass Swale installation:

- Make sure the desired coverage of turf or erosion control fabric has been achieved following construction, both on the channel bed and side-slopes.
- Inspect check dams and pre-treatment structures to make sure they are at correct elevations, are properly installed, and are working effectively.
- Check that outfall protection/energy dissipation measures at concentrated inflow and outflow points are stable.

The real test of a Grass Swale occurs after the first big storm. The post-storm inspection should focus on whether the desired sheet flow, shallow concentrated flows or fully concentrated flows assumed in the plan actually occur in the field. Minor adjustments are normally needed as part of this post-storm inspection (e.g., spot reseeding, gully repair, added armoring at inlets, or realignment of outfalls and check dams).

4.2.5. Grass Swale (GS)

GS-8. Maintenance Criteria

Maintenance is a crucial element that ensures the long-term performance of Grass Swales. Once established, Grass Swales have minimal maintenance needs outside of the spring clean up, regular mowing, periodic repair of check dams and other measures to maintain the hydraulic efficiency of the channel and a dense, healthy grass cover. Additional effort may be needed to stabilize inlet points and remove deposited sediment from pre-treatment cells.

Periodic maintenance should be integrated into routine landscape maintenance tasks:

- If landscaping contractors will be expected to perform maintenance (as is likely on commercial, business, or high density residential land uses), their contracts should contain specifics on unique Grass Swale landscaping needs.
- If maintenance is conducted by a homeowner, they should be:
  (1) educated about their routine maintenance needs;
  (2) understand the long-term maintenance elements; and
  (3) be subject to modified maintenance agreements (as described below).

Consider Maintenance during the Design Process

A critical maintenance factor is the many design choices made during the swale design. The context of the site and maintenance capabilities of the owner(s) should be considered during the design process such as including adequate access for mowing and trash and debris removal.

As with all BMPs, maintenance agreements must be executed between the owner(s) and the local authority to ensure that the practices are maintained and function properly. The agreements will specify the property owner's primary maintenance responsibilities and authorize local agency staff to access the property for inspection or corrective action in the event that proper maintenance is not performed.

Grass Swales must be covered by a drainage easement to allow inspection and maintenance by local authority staff.

Table GS-7. Suggested Maintenance Activities and Schedule for Grass Swales

Maintenance Activity	Frequency
• Mow grass channels and dry swales during the growing season to maintain grass heights in the 4" to 6" range.	As needed
• Ensure that the CDA is clear of debris. • Ensure that the CDA is stabilized. Perform spot-reseeding if or where needed. • Repair undercut and eroded areas as needed at swale inflow and outflow structures. • Inspect upstream and downstream of check dams for evidence of undercutting or erosion, and remove and trash or blockages at weepholes.	Quarterly
• Reseed as needed during fall seeding season to maintain 90% turf cover. • Remove any accumulated sand or sediment deposits behind check dams. • Examine channel bottom for evidence of erosion, braiding, excessive ponding or dead grass. • Check inflow points for clogging and remove any sediment. • Inspect side slopes and grass filter strips for evidence of any rill or gully erosion and repair.	Annual inspection

Annual inspections are used to trigger maintenance operations such as sediment removal, spot revegetation and inlet stabilization. Example maintenance inspection checklists for disconnection can be found in **Appendix A of the Manual**.

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