7E-4 Grass Channel

Source: NRCS Photo Gallery.

BENEFITS

	L	M	H
Flow Control	■		
Erosion Control	■	■	■
Sediment Control	■		
Runoff Reduction	■		
Flow Diversion			

Description: Grass channels consist of ditches, swales, or waterways that are lined with vegetation to stabilize the surface from erosion.

Typical Uses: Used to carry intermittent, low to moderate concentrated flows of surface runoff.

Advantages:

- Low cost method of conveying surface runoff.
- Highly effective for controlling channel erosion for low to moderate flows.
- Aesthetically pleasing.
- Reduces flow velocity and removes sediment.

Limitations:

- Cannot withstand forces from high flows.
- There may be some difficulty establishing vegetation.
- Not suitable for channels that carry constant flows, or that remain submerged for extended periods of time.

Longevity: Permanent.

SUDAS Specifications: Refer to Section 9010 (Seeding) or 9020 (Sodding).

A. Description/uses

Grass channels consist of swales, ditches, and waterways that are lined with permanent vegetation. The purpose of the vegetation is to stabilize the surface of the channel and prevent erosion from concentrated stormwater flow.

Because these structures are lined with vegetation, they cannot be used for channels which have constant flow, or which will be submerged for extended periods of time.

Grass channels are the least costly and most aesthetically pleasing option for lining channels.

B. Design considerations

As water flows through any conduit or channel, the surface of the conduit or channel imparts drag on the flowing water. The amount of drag a particular surface will create is related to the commonly known Manning’s “n” coefficient. This drag force not only slows the flow of the water, but also imparts a corresponding force onto the lining of the channel. This force is known as shear stress.

The ability of a channel to withstand shear stress is dependent on the properties of the lining. If the shear stress imposed on the bottom and sides of a channel by the flowing stormwater exceeds the ability of the channel lining to withstand it, the lining will be moved or damaged. Various types of vegetation provide different levels of resistance to shear. Table 1 lists the various classifications of vegetation that have been established and analyzed.

Prior to movement of the lining, the underlying soil is protected from the erosive forces of the flowing water. Therefore, the erodibility of the underlying soil has little effect on the permissible shear stress of the lining. However, if the grass lining is moved or damaged, the underlying soil properties become a significant factor in determining the degree of erosion that will occur.

Calculating shear stress in a channel is a two-step process. First, the depth of flow in the channel is determined with Manning’s equation. For temporary stabilization, the channel liner should be designed to carry a two-year storm event. For permanent stabilization, the liner should be designed for a 10-year event.

For most channel lining materials, Manning’s n value does not vary significantly as the depth of flow varies, and is normally assumed to be constant. For grass channels however, the n value varies greatly with the depth of flow. This variation is caused by the reaction of the grass to the flow. As flow depth increases, the grass is bent over, thereby reducing its height and changing the resistance it imparts on the flow.

The following equations, along with the vegetation data listed in Table 2, can be used to calculate the Manning value for a given depth of flow and vegetation type. For vegetated conditions, NRCS has determined that actual Manning’s n values range only from 0.02 to 0.5. When calculated values fall outside of this acceptable range, the designer should use the upper or lower limit of the range. If the denominator of Equation 1 is zero or less than zero, a Manning’s n value of 0.5 should be used.

$$n = \frac{R^{1/6}}{19.97\left(\log\left(44.8 \times h^{0.6} \times MEI^{-0.4}\right) + \log\left(R^{1.4} \times S^{0.4}\right)\right)}$$ **Equation 1**

Where:

n	=	Manning's coefficient (dimensionless)
R	=	Hydraulic radius (ft.)
h	=	Average height of vegetation; from Table 1 (ft)
MEI	=	Stiffness factor; from Table 2 (lb.· ft^2)
S	=	Channel slope (ft/ft)

Source: Chen & Cotton, 1988 (HEC-15).

Because the Manning coefficient changes with depth, calculating the depth of flow is an iterative process. Once the flow depth is determined, the shear stress on the channel liner is determined by the following equation:

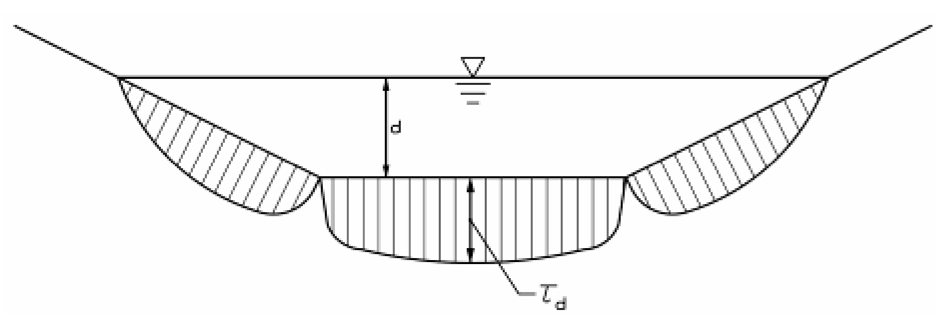
$$\tau_d = \gamma \times d \times S$$ **Equation 2**

Where:

τ_d	=	Shear stress in channel at maximum depth (lbs/ft^2)
γ	=	Unit weight of water (62.4 lbs/ft^3)
d	=	Depth of flow (ft)
S	=	Channel slope (ft/ft)

The shear stress distribution along the wetted perimeter of a channel is not uniform, as indicated in Figure 1. In a trapezoidal channel, the peak shear stress in a straight channel occurs at the center of the bottom of the channel. The stress in the corners of the channel approaches zero. The peak shear stress along the sides of a straight channel occur near the bottom third of the channel.

Figure 1: Stress distribution in a trapezoidal channel

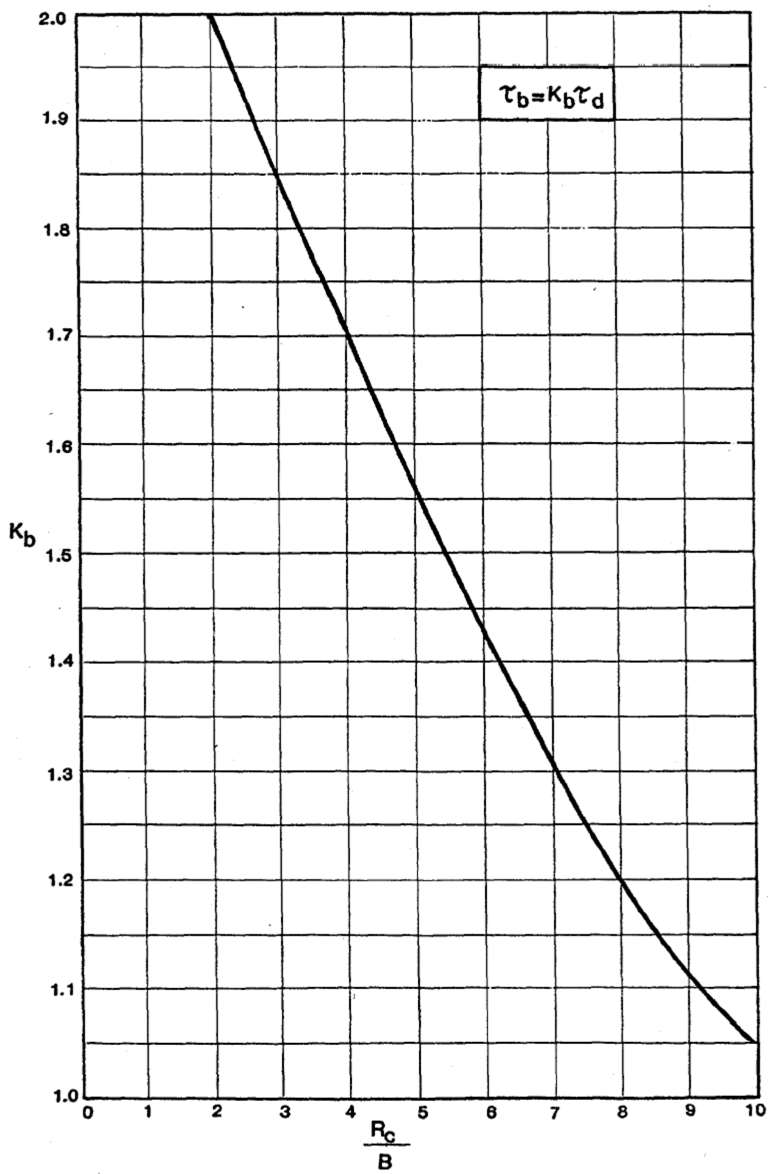


Source: Adapted from Chen & Cotton, 1988 (HEC-15).

If the flow travels around a bend, the current imposes additional forces on the channel as the flow is redirected. These forces result in increased shear stress on the bottom and sides of the channel. The additional shear stress imposed on the channel is related to the ratio of the radius of the bend, R_c, and the bottom width of the channel, b. As the bend becomes sharper, the shear stress increases. The maximum shear stress in the bend is determined by multiplying the calculated shear stress in a straight section of channel by the bend coefficient, K_b (Equation 3). K_b is determined from Figure 2.

$$\tau_b = K_b \tau_d$$ **Equation 3**

Figure 2: Bend coefficient for maximum shear stress in channel bends



Source: Chen & Cotton, 1988 (HEC-15).

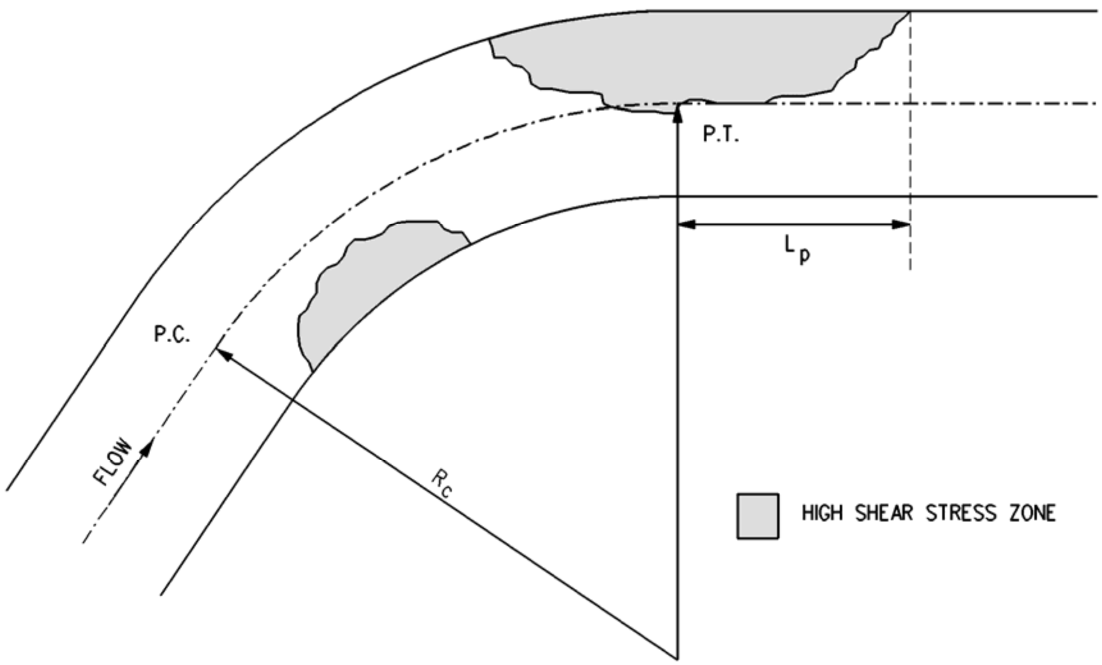
As flow travels around a bend, the increased shear stresses begin along the inside radius and move toward the outside. These increased stresses are also transmitted down the channel for a distance L_p, due to the turbulence created in the flow as it traveled around the bend (see Figure 3). This distance can be determined by Equation 4. When additional channel protection is provided in the bend, it should also be extended through this length.

$$L_p = 0.604 \frac{R^{7/6}}{n}$$ **Equation 4**

Where:

L_p	=	Length of protection required downstream of bend, ft
R	=	Hydraulic radius
n	=	Manning's coefficient

Figure 3: Shear stress distribution in a channel bend



Source: Adapted from Chen & Cotton, 1988 (HEC-15).

Once the anticipated shear stress on the channel liner is determined, it is compared to the allowable shear stress values of the proposed vegetation. If the calculated shear stress value exceeds the allowable shear stress of the liner, additional protection may be required. Depending on the level of shear stress anticipated, additional protection may be provided by an alternate type of vegetation, by reinforcing the vegetation with a turf reinforcement mat, lining the channel with rip-rap, or modifying the geometrics of the channel.

For channels where establishment of vegetation may be difficult, a rolled erosion control product may be considered. A complete discussion on RECPs can be found in Section 7E-7.

A more complete discussion on channel stabilization is provided in Chapter 2.

Table 1: Classification of vegetation

Vegetation Class	Cover	Condition
A	**Weeping lovegrass**	Excellent stand, tall (average 30")
	Yellow bluestem ischaemum	Excellent stand, tall (average 36")
B	Kudzu	Very dense growth, uncut
	Bermuda grass	Good stand, tall (average 12")
	Native grass mixture (**little bluestem**, bluestem, **blue grama,** other long and short Midwest grasses)	Good stand, unmowed
	Weeping lovegrass	Good stand, tall (average 24")
	Lespedeza serices	Good stand, not woody, tall (average 19")
	Alfalfa	Good stand, uncut (average 11")
	Weeping lovegrass	Good stand, unmowed (average 13")
	Kudzu	Dense growth, uncut
	Brome, smooth	Good stand, mowed (average 12" to 15")
	Tall fescue	Good stand, uncut (average 18")
	Tall fescue with birdsfoot trefoil	Good stand, uncut (average 18")
	Grass – Legume mixture – Timothy, Smooth bromegrass, or Orchardgrass	Good stand, uncut (average 20")
	Blue grama	Good stand, uncut (average 13")
C	Crabgrass	Fair stand, uncut (10" to 48")
	Bermuda grass	Good stand, mowed (average 6")
	Red top	Good stand, headed (15" to 20")
	Common lespedeza	Good stand, uncut (average 11")
	Grass-legume mixture - Summer (**orchard grass**, **redtop,** Italian ryegrass, and common lespedeza)	Good stand, uncut (6" to 8")
	Centipedegrass	Very dense cover (average 6")
	Kentucky bluegrass	Good stand, headed (6" to 12")
D	Bermuda grass	Good stand, cut to 2.5" height
	Common lespedeza	Excellent stand, uncut (average 4.5")
	Buffalo grass	Good stand, uncut (3" to 6")
	Grass-legume mixture fall, spring (**orchard grass, redtop,** Italian ryegrass, and common lespedeza)	Good stand, uncut (4" to 5")
	Kentucky bluegrass or Lespedeza sericea	Good stand, cut to 2" height. Very good stand before cutting.
	Red fescue	Good stand (headed (12" to 18")
E	Bermuda grass	Good stand, cut to 1.5" height
	Bermuda grass	Burned stubble

Note: covers classified have been tested in experimental channels. Covers were green and generally uniform
Items shown in **Bold** are seed varieties included in the SUDAS Specifications.

Source: Chen & Cotton, 1988 (HEC-15) and USDA NRCS, 1986.

Table 2: Vegetation properties

Vegetation Class	Permissible Shear Stress (lb/ft^2)	Average Height, h (ft)	Stiffness, MEI ($lb \cdot ft^2$)
A	3.7	3.0	725
B	2.1	2.0	50
C	1.0	0.66	1.2
D	0.6	0.33	0.12
E	0.35	0.13	0.012

Source: Chen & Cotton, 1988 (HEC-15)

C. Application

Grassed channels are an excellent low-cost stabilizing method for swales and ditches that carry intermittent low to moderate concentrated flows.

D. Maintenance

Proper maintenance of the channel is critical. For designs where vegetation is assumed to be unmowed or at a minimum height, it is important to ensure that the vegetation in the channel is maintained in the manner intended. Mowing a channel, which was not designed to be kept at a short height, could result in failure of the grass channel. If there is a possibility that the channel could be mowed, it should be designed as such.

Newly seeded or sodded areas should be maintained and watered as required to ensure establishment of the grass. See Sections 7E-6 and 7E-8.

E. Time of year

Grass channel liners require the vegetation to be well-established in order to provide maximum protection from erosion. Seeding a channel near the end of the annual seeding window may not allow enough time for the vegetation to develop sufficiently to resist flows from winter snowmelt or spring rains.

F. Design example

Assume a grass channel with a 3-foot bottom, 4:1 side slopes, and a slope of 1% is designed to carry 24 cfs. Determine if the proposed Class C vegetation is adequate.

Solution:

First, use Manning's equation to find the depth of flow. This can be done through a trial and error process, or by using various tables and charts. For grass channels, Manning's n value varies, and must be calculated based upon the depth of flow. From Table 2, the average height, h, for Class C vegetation is 0.66 ft, the stiffness, MEI, is 1.2 $lb \cdot ft^2$, and the permissible shear stress is 1.0 lbs/ft^2.

Trial 1 – Assume a trial depth of 1.2 feet.

Area of Flow, $A = (b + Z \times d) \times d = (3 + 4 \times 1.2) \times 1.2 = 9.4 \text{ ft}^2$

Wetted Perimeter, $P = b + 2 \times \sqrt{d^2 + (Zd)^2} = 3 + 2 \times \sqrt{1.2^2 + (4 \times 1.2)^2} = 12.9 \text{ ft}$

Hydraulic Radius, $R = A/P = 9.4/12.9 = 0.73 \text{ ft}$

Manning coefficient (from Equation 1):

$$n = \frac{0.73^{1/6}}{19.97\left(\log\left(44.8 \times 0.66^{0.6} \times 1.2^{-0.4}\right) + \log\left(0.73^{1.4} \times .01^{0.4}\right)\right)} = 0.092$$

Solving Manning's yields: $Q = \frac{1.49}{n} A R^{2/3} S^{1/2} = \left(\frac{1.49}{0.092}\right)(9.4)(0.73)^{2/3}(0.01)^{1/2} = 12.2 \text{ cfs}$

Since 12.2 cfs is lower than the design value of 24 cfs, a larger depth should be assumed.

Trial 2 – Assume a depth of 1.5 feet.

Following the procedure for Trial 1: A = 13.5; P=15.4; R=.88; n= 0.077; Q= 24 cfs
Now that the depth of flow is known, the shear stress on the channel bottom can be determined by Equation 2.

$$\tau_{max} = \gamma \times d \times S = 62.4 \times 1.5 \times 0.01 = 0.94 \text{ lbs/ft}^2$$

Since the maximum shear stress of 0.94 lbs/ft^2 is less than the capacity of the grass channel liner (1.0 lbs/ft^2), the design should be adequate to protect the channel from erosion.