CHAPTER 9
EROSION PREVENTION AND SEDIMENT CONTROL

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Synopsis

Construction and land development activities that impact existing topography, vegetative cover, and hydrologic characteristics often increase the potential for soil erosion and sediment transport. Specific control measures to mitigate adverse impacts are required by the regulations contained in Volume 1 Sections 4.2.3 and 6.10 with additional guidance and design criteria presented in Volume 4 Sections TCP and PESC. To address regulatory requirements, an erosion and sediment control plan should be prepared according to Volume 1 Section 4.2.3. The plan should provide information for each of the following items:

1. Existing and proposed contours.

2. A construction activity schedule with a plan for implementing erosion prevention and sediment control measures (EP&SC).

3. Temporary control measures that will be implemented (Volume 4 Section TCP).

4. Removal of temporary measures, when appropriate, and establishment of permanent stabilization.

5. Permanent control measures that will be implemented (Volume 4 Section PESC).

6. Maintenance requirements for temporary and permanent control measures.

7. Measures to protect adjacent areas.

8. Contingency measures in the event that planned controls are not effective.

9. Permanent stormwater conveyance facilities (Volume 4 Section PTP).

9.1 Basic Principles

The design of erosion prevention and sediment controls involve the application of common sense planning, scheduling, and control actions that will minimize the adverse impacts of soil erosion, transport, and deposition. The following five basic principles govern the development and implementation of a sound erosion prevention and sediment control plan:

1. The project should be planned to take advantage of the topography, soils, waterways, buffers, and natural vegetation at the site.

2. The smallest practical area should be exposed for the shortest possible time.

3. Onsite erosion prevention measures should be applied to reduce the suspension of soil particles.

4. Sediment control measures should be used to prevent suspended soil from leaving the site.

5. A thorough inspection and maintenance program should be implemented.

These principles should be tied together in the planning process, which identifies potential erosion and sediment transport problems before construction begins.

Vegetative control measures are required for all disturbed areas and generally include practices such as filter strips, temporary seeding, permanent seeding, sodding, and mulching. Structural control measures are required when runoff leaves a disturbed site and generally include practices such as flow diversions, sediment traps, sediment basins, and permanent detention ponds.

The erosion prevention and sediment control plan must include appropriate construction specifications for all control measures. These specifications must be developed and/or implemented by the design engineer as required for site-specific conditions. Typical design application and design criteria, specifications, inspection recommendations and maintenance requirements are provided in Volume 4 Sections TCP and PESC.

9.2 Applying Best Management Practices

Guidance for applying control measures when developing an erosion and sediment control plan is presented in Volume 4 – Best Management Practices (BMPs). Section 1.3 provides additional detail about the erosion and sedimentation processes while Sections 1.5 and 1.6 discuss types of BMPs and how to select them. Key references for this volume are the, California Stormwater Best Management Practice Handbooks (1993), Caltrans Stormwater Quality Handbooks (1996),Urban Runoff Quality Management (1998) and Tennessee Erosion and Sediment Control Handbook (1992).

The regulations presented in Volume 1 Sections 4.2.3 and 6.10 should be thoroughly reviewed and considered in selecting BMPs to present on the EP&SC plan.

9.3 Universal Soil Loss Equation (USLE)

The USLE provides an empirical approach to estimate soil loss for specific site conditions. Application of the equation to evaluate the performance of proposed erosion and sediment control measures is recommended when the disturbed area exceeds 10 acres. The USLE is expressed as:

$$A = R\ K\ LS\ C\ P \qquad (9\text{-}1)$$

where:

A = Soil loss, in tons/acre, for the time period selected for R

R = Rainfall factor

K = Soil erodibility factor, in tons/acre/R unit

LS = Length-slope factor, dimensionless

C = Cropping management factor, dimensionless

P = Erosion control factor, dimensionless

Numerical values for each of the parameters in the USLE must be determined for each problem considered. Guiding principles and data for determining these parameters in Nashville are discussed in this section.

9.3.1 Rainfall Factor (R)

The average annual R value for Nashville and Davidson County is approximately 200 (Israelson et al., 1980). The monthly distribution, or cumulative percentage, of the average annual R values for a typical year can be determined using the erosion index (EI) distribution curve presented in Figure 9-1 as follows:

1. Use the EI distribution curve to determine the percent of the annual erosion index expected to occur during the time period of concern.

2. Multiply the R value of 200 by the percentage value from Step 1 to obtain the rainfall factor expected for the specified time period.

Annual R values for return period frequencies of 2, 5, and 20 years are reported in Table 9-1. Annual R values range from 198 for a 2-year return period to 339 for a 20-year return period. Expected average R values for single storms are presented in Table 9-2.

To determine the expected average value of soil loss for a specific annual return period or a single storm, the R values reported in Tables 9-1 and 9-2 are used directly in the USLE (Equation 9-1). For example, if the expected average soil loss for a 5-year design storm is desired, an R value of 68 is used in the USLE.

9.3.2 Soil Erodibility Factor (K)

K factors are published in the Soil Survey for Nashville and Davidson County, Tennessee (USDA, SCS, 1981). K factors are generally reported for selected depth intervals of the soil profile. Soil erodibility data published in the soil survey are presented in Table 9-3.

9.3.3 Length-Slope Factor (LS)

The LS factor can be estimated by the following procedure:

1. Identify uniform slope segments and estimate the slope length, in feet, and the slope, in percent.

2. Enter the x-axis of Figure 9-2 with the slope length and move vertically to the appropriate percent-slope curve.

3. Move horizontally from the intersection point in Step 2 to the y-axis and read the LS value.

The procedure is derived from field data for uniform slopes ranging from 3 to 18 percent and from about 30 to 300 feet in length. It should not be used beyond these limits, which are delineated in Figure 9-2. If the actual slope is irregular, special considerations may be required, as discussed below.

Typical concave and convex slopes are illustrated in Figure 9-3. These irregular slopes can be analyzed using Figure 9-2 by dividing the slope into a small number of equal-length and uniform segments. If this is done, two simplifying assumptions must be valid:

1. The changes in gradient are not sufficient to cause upslope deposition.

2. The irregular slope can be divided into a small number of equal-length segments in such a manner that the gradient within each segment is uniform.

After dividing the convex, concave, or complex (composed of both concave and convex components) slope into equal-length segments, the LS factor is determined as follows:

1. List the segment gradients in the order they occur on the slope, beginning at the upper end.

2. Enter the abscissa of Figure 9-2 with the total slope length and read the LS factor for each of the gradients listed in Step 1.

3. Multiply these LS factors by the appropriate factors from Table 9-4.

4. Add the products obtained from Step 3 to obtain the LS factor for the entire slope.

The change in slope required to induce the deposition of eroded soil is somewhat variable. In practice, areas of deposition should be identified by observation. When the slope breaks are sharp enough to cause deposition, the four-step procedure described above can be used to estimate the LS factor for slope segments above and below the point of deposition.

9.3.4 Control Practice Factor (CP)

For construction sites, Chen (1974) proposed that the individual C and P factors of the USLE be evaluated with a single control-practice factor (CP), which is defined as:

$$CP = C_s\, C_r\, C_o \qquad (9\text{-}2)$$

where:

CP = Control-practice factor, or the ratio of soil loss including control practice and soil loss without control practice

C_s = Control due to surface stabilization, such as seeding, mulching, and netting

C_r = Control due to runoff reduction practices, such as diversion berms, interceptor dikes, terraces, sodded ditches, level spreaders, and sectional down drains

C_o = Control due to any erosion control practice not noted above

Detailed information for determining quantitative values of the CP factor for selected erosion control systems for various types of land use and cover conditions is presented in Section 9.4. Tables 9-5 through 9-10 present C_s factors for various site conditions. C_r can be quantified using the expression (Chen, 1974):

$$C_r = \frac{1}{\sqrt{N+1}} \qquad (9\text{-}3)$$

where:

C_r = Runoff control factor, dimensionless

N = Number of diversions placed across a uniform slope

C_o must be established by the designer.

9.3.5 Plan Evaluation

The goal of soil erosion prevention and sediment control measures should be to prevent any sediment from leaving the site. This is not say that treatment practices must be implemented to trap sediment that enters the site, but only sediment that is generated on-site. Realistically, the objective should be to provide between 90 and 95 percent control of the total suspended solids from the disturbed site. Assuming a total gross erosion rate of 200 tons/acre/year and 95 percent control, the target soil loss for an erosion and sediment control plan is approximately 10 or less tons/acre/year. Based on these assumptions, the following procedure is recommended to evaluate the need for erosion prevention and sediment control measures:

1. Estimate the sediment yield from a project site with all erosion control practices in place, A, using the USLE, Equation 9-1.

2. Estimate the sediment trapped onsite, T, using information presented in Section 9.4.

3. Estimate the sediment delivery ratio with controls, D_c, using the equation:

$$D_c = \frac{A - T}{20} \qquad (9\text{-}4)$$

where:

D_c = Sediment delivery ratio with controls

A = Sediment yield from a project site with erosion control, in tons/acre/year (calculated using USLE, Equation 9-1)

T = Sediment trapped onsite, in tons/acre/year (see Section 9.4)

4. If D_c from Equation 9-4 is greater than 1, return to Step 1 and improve the erosion and sediment control plan until D_c is 1 or less.

9.3.6 Example Problem

<u>Example 9-1. Plan Evaluation</u>

A 12-acre site on Beason soils with a 200-foot long, 10 percent slope is to be cleared for construction. No seeding or mulching is planned, and the slope will remain in a rough, irregular tracked condition for about 1 year. Evaluate the acceptability of the proposed activity using the USLE to estimate soil loss for average annual conditions.

1. The average annual rainfall factor is given in Section 9.3.1 as R = 200.

2. The soil erodibility factor from Table 9-3 for Beason soils is K = 0.32.

3. The length-slope factor from Figure 9-2 for a 200-foot, 10 percent slope is LS = 1.93.

4. The control practice factor (Equation 9-2) is determined from a single factor for surface stabilization since no runoff reduction practices are planned. The surface stabilization factor from Table 9-5 for rough, irregular, tracked conditions is $C_s = 0.90$ and, from Equation 9-2, $CP = C_s = 0.90$.

5. The soil loss is estimated as

   A = (200) (0.32) (1.93) (0.90)

   A = 111 tons/acre/year

6. The sediment delivery ratio is estimated using Equation 9-4:

   $$D_c = \frac{111 - 0}{20}$$

   $D_c = 5.6$

7. Based on estimated soil loss, with $D_c > 1$, the proposed activity is unacceptable.

8. Improve erosion control by constructing diversions along the slope to reduce the slope length to 100 feet and use mechanically tacked straw or hay mulch at 1.5 tons/acre over the disturbed area.

9. The improved length-slope factor from Figure 9-2 for a 100-foot, 10 percent slope is LS = 1.39.

10. The improved surface stabilization factor from Table 9-8 for straw or hay mulch applied at a rate of 1.5 tons/acre on a 10 percent slope is $C_s = 0.12$.

11. The runoff control factor from Equation 9-3 with one diversion across the slope is $C_r = 0.707$.

12. The improved control practice factor from Equation 9-2 is computed as

    CP = (0.12) (0.707)

    CP = 0.085

13. The improved soil loss is estimated as

    A = (200) (0.32) (1.39) (0.085)

    A = 7.6 tons/acre/year

14. The improved sediment delivery ratio using Equation 9-4 is

$$D_c = \frac{8-0}{20}$$

    $D_c = 0.4$

15. Based on estimated soil loss with improvements, with $D_c \leq 1$, the proposed activity is acceptable.

9.4 Erosion Prevention

Erosion prevention is generally the easiest and least costly way to prevent sediment from leaving the site. It is important to note that if erosion is prevented then controlling sediment is not necessary. Volume 4 Section 1.31 discusses the erosion process including water, stream and channel, wind erosion and factors that influence it. Section 1.6.4 discusses selecting erosion prevention activities.

Following a brief description of temporary and permanent considerations, factors for use with the USLE for these classifications are presented below. Remaining erosion prevention topics covered in this section include slope and channel protection, and outlet protection. All of these practices are discussed in more detail in Volume 4 Sections TCP and PESC.

9.4.1 Temporary and Permanent Considerations

To the maximum extent possible, surface stabilization measures should provide permanent protection once construction is complete. In addition, the layout for temporary runoff control measures should be consistent with the layout of permanent drainage facilities. Additional related information is available in Volume 4 Section 1.5.

9.4.2 Surface Stabilization Factors

Soil stabilization factors for natural or unprotected site conditions can be estimated from published data. For various types of bare soil conditions, C_s factors can be estimated from values reported in Table 9-5. For permanent pasture, rangeland, idle land, and grazed woodland, C_s factors can be estimated from values reported in Table 9-6. For undisturbed woodland, C_s factors can be estimated from values reported in Table 9-7.

Soil stabilization factors for mulches, seeding and vegetation, and chemical binders and tacks are discussed below.

Mulches

Table 9-8 presents mulch surface stabilization factors for selected application rates on construction sites. The principal types of mulching material are straw, hay, and wood chips. Data are also presented for crushed stones. Additional detail is provided in Volume 4 TCP-08.

Seeding and Vegetation

C_s factors for temporary and permanent seedings are presented in Table 9-9. Mechanically disturbed woodland sites with 0 to 80 percent of the site covered with residue and various levels of weed cover can be evaluated using C_s factors from Table 9-10. Suitable vegetative cover plants and plant mixtures are listed in Table 9-11 along with appropriate planting dates and application rates. Additional detail is provided in Volume 4 TCP-05 and PESC-01.

Chemical Binders and Tacks

If construction occurs at a time when conventional vegetative measures are not feasible, or immediate protection is required under adverse conditions, chemical binders and tacks may be suitable. C_s factors for selected forms of these treatments are presented in Table 9-9. Additional detail is provided in Volume 4 CP-17, TCP-08 and 10.

Other Stabilization Practices

Other stabilization practices including buffer zones, filter strips, top soil management, surface roughening, nets, mats, geotextiles, soil bioengineering, and terracing are discussed in Volume 4 TCP-04, 06, 07, 09, 10, 11, 23, PESC-02, 03, 04, and 05.

9.4.3 Exposure Scheduling Factors

The impact of exposure scheduling on the gross soil loss from a site can be determined using the monthly distribution of the rainfall erosion index, which is presented in Figure 9-1. The anticipated exposure schedule can be evaluated by the following procedure:

1. Establish the anticipated sequence of time periods with consistent surface cover conditions.

2. Determine appropriate surface stabilization cover factors (C_s) using data presented in Tables 9-5 through 9-10.

3. Determine the fraction of the annual R value for each time period, using the EI factors from Figure 9-1 (see Section 9.3.1).

4. Multiply the C_s values from Step 2 by the fractions from Step 3.

5. Sum the results from Step 4 for each time period to obtain a composite C_s value for the anticipated construction schedule.

This procedure is demonstrated in Table 9-12. Since a construction schedule is subject to unplanned changes, a worst-case scenario should be considered.

9.4.4 Runoff Control Factors

Quantitative information related to the runoff control (C_r) factor presented in Equation 9-2 is currently available only for diversion structures, since they are the principal means of reducing slope lengths and, thus, erosion. However, this should not limit the usefulness of the USLE as a planning tool for runoff control. Any structure that slows runoff or diverts it away from down-slope areas can benefit erosion prevention. The impact of diversions on gross erosion can be quantified using Equation 9-3, as proposed by Chen (1974).

9.4.5 Slope and Channel Protection

Steep slopes, both natural and cut and fill, have the potential for severe erosion. As a result, slope protection is often required to safely convey upland stormwater runoff to the toe of slopes. Slope and channel protection practices intended to reduce the potential for slope and gully erosion include temporary seeding, surface roughening, mulching, nets, mats, geotextiles, terracing, check dams, diversion: drains, swales and berms and bank stabilization. Appropriate construction specifications should be developed by the design engineer as guided by Volume 4 TCP-19, 20, 21, 22, PESC-06.

9.4.6 Outlet Protection

Design procedures for outlet protection should be consistent with the erosion prevention information for open channels presented in Chapter 3, energy dissipation methods presented in Chapter 10 and additional information provided in Volume 4 TCP-21, 24, 25, PESC-07 and 08. The design should include a plan view, profile, and cross section for each unique channel reach between the storm sewer outlet and the existing publicly maintained system or natural stream channel. The velocity should be indicated for the outlet (pipe, structure, or reinforced channel), riprap or paved apron section, and each successive channel reach from the end of the apron to the point of entry into the existing drainage system or natural stream channel. The plan should indicate the proposed method of stabilizing each channel reach, consistent with computed velocities. The velocity at the end of a structure or channel reach must not exceed the allowable velocity of the next downstream reach.

9.5 Sediment Control

Sediment control measures that can prevent the transport of detached soil from a site include sediment barriers, sediment traps, sediment basins, construction entrance stabilization and related activities. Additional information about these and other related practices for sediment control are presented in Volume 4 Sections TCP, PESC and PTP.

9.5.1 Temporary and Permanent Considerations

To the maximum extent possible, permanent facilities should be phased/scheduled to be used as temporary (construction phase) sediment control facilities. This is a more cost-effective approach than implementing many more small sediment control devices site-wide as the generally larger permanent facilities must be graded and eventually constructed. It must be noted that it may still be necessary to implement some sediment controls in other areas of the site to prevent the permanent facility from being overloaded with sediment. Furthermore, the permanent facility will generally need to be over-excavated to account for the trapped sediment. The outlet structure will need to be reconfigured to perform under the construction phase runoff sediment loadings that generally are significantly higher than post-construction (stabilized site) runoff. Additional related information is available in Volume 4 Section 1.5.

9.5.2 Sediment Barriers

Sediment barriers are intended to intercept and/or filter small volumes of sediment resulting mainly from sheet flow and rill erosion. Typical sediment barrier applications include continuous berms, brush barriers, sand bag barriers, silt fences, straw bale barriers, and inlet barriers. Check dams are similar to sediment barriers in that they slow water in small channels to the point that sediment can settle out of runoff.

In general, sediment barriers have a useful life expectancy of 3 to 6 months, depending on the construction technique. Continuous berms are strongly encouraged because of their installation ease, and minimal maintenance requirements. Straw bales are the least preferred because of the inconsistent materials qualities and very high maintenance considerations. Extreme care should be used when locating sediment barriers and application limitations must be carefully considered. Improper location and installation may result in failure of the barrier, which can cause more damage than the erosion the barrier was intended to prevent. Additional detail is provided in Volume 4 TCP-12, 13, 14, 15, 16 and 24.

9.5.3 Sediment Traps and Basins

Temporary sediment traps are generally formed by constructing a small ponding area behind an embankment and/or gravel outlet. The tributary drainage area and required service life will dictate the sizing of a small trap or temporary basin. However, it should be noted that MWS strongly encourages using permanent facilities with outlet structures configured to manage temporary (construction phase) sediment control (see section 9.5.1). Temporary sediment traps and basins are often constructed in combination with temporary diversion berms or barriers. Additional details about temporary sediment traps and basins are provided in Volume 4 TCP-17 and 18 while information about permanent detention facilities are provided in Volume 4 PTP-01 and 06.

9.5.4 Construction Road and Entrance Management

Soil tracked off the construction site by delivery and other vehicles is a significant problem. Road and entrance management is required to reduce the amount of soil transported from a construction site. At a minimum stone-stabilized entrance pads should be constructed at vehicular traffic entrances and exits to a public road or paved area. When a stabilized pad proves inadequate, a wash rack or additional road stabilization will be required. Wash water runoff should be conveyed to a sediment basin or trap. Additional information is available in Volume 4 TCP-01, 02 and 03.

Table 9-1
ANNUAL RAINFALL FACTOR (R) VALUES FOR 2-, 5-, AND 20-YEAR RETURN PERIODS FOR NASHVILLE AND DAVIDSON COUNTY

Observed R Value Annual Range (22 Years)	Annual R Value for Various Return Period Frequencies		
	2-Year	5-Year	20-Year
116-381	198	262	339

Reference: Wischmeier and Smith (1978).

Table 9-2
EXPECTED SINGLE STORM RAINFALL FACTOR (R) VALUES FOR NASHVILLE AND DAVIDSON COUNTY

Expected Single Storm R Value for Various Return Period Frequencies				
1-Year	2-Year	5-Year	10-Year	20-Year
35	49	68	83	99

Reference: Wischmeier and Smith (1978).

Table 9-3
SCS SOIL ERODIBILITY DATA

Soil Name and Map Symbol	Depth Interval (inches)	Soil Erodibility Factor, K (tons/acre/R unit)
AmB, AmC, AmC3	0-16	0.43
Armour	16-41	0.37
	41-66	0.37
Ar	0-35	0.37
Arrington	35-65	0.32
BbD,* BbE*	0-8	0.17
Barfield	8-15	0.17
	15	--
Rock Outcrop		
BcC, BcD	0-8	0.32
Baxter	8-14	0.24
	14-72	0.24
Be	0-18	0.32
Beason	18-65	0.32
BoD	0-5	0.28
Bodine	5-20	0.28
	20-65	0.28
BsE*	0-5	0.28
Bodine	5-20	0.28
	20-65	0.28
Sulphura	0-5	0.20
	5-26	0.20
BvB	0-7	0.43
Bradyville	7-18	0.28
	18-55	0.27
	55	--
ByB	0-9	0.43
Byler	9-24	0.43
	24-44	0.43
	44-65	0.24

Table 9-3
SCS SOIL ERODIBILITY DATA (continued)

Soil Name and Map Symbol	Depth Interval (inches)	Soil Erodibility Factor, K (tons/acre/R unit)
DeD, DeE	0-6	0.17
Dellrose	6-61	0.24
	61-74	0.24
DkB	0-8	0.43
Dickson	8-25	0.43
	25-44	0.43
	44-65	0.28
Eg	0-22	0.32
Egam	22-56	0.32
	56-75	0.37
GdC	0-10	0.17
Gladeville	10	--
HmC, HmD	0-5	0.37
Hampshire	5-45	0.28
	45-53	0.24
HuB	0-8	0.20
Humphreys	8-55	0.24
	55-62	0.24
Ld	0-11	0.28
Lindell	11-62	0.28
Ln*	0-11	0.28
Lindell	11-62	0.28
Urban Land		
LoB	0-9	0.43
Lomond	9-16	0.37
	16-46	0.32
	46-65	0.28

Table 9-3
SCS SOIL ERODIBILITY DATA (continued)

Soil Name and Map Symbol	Depth Interval (inches)	Soil Erodibility Factor, K (tons/acre/R unit)
McB*	0-7	0.32
Maury	7-24	0.28
	24-48	0.28
	48-65	0.28
Urban Land		
MmC, MmD	0-7	0.20
Mimosa	7-14	0.20
	14-55	0.20
	55	--
MoE3	0-6	0.20
Mimosa	6-55	0.20
	55	--
MrD,* MrE*	0-7	0.20
Mimosa	7-14	0.20
	14-55	0.20
	55	--
Rock Outcrop		
MsD*	0-7	0.20
Mimosa	7-14	0.20
	14-55	0.20
	55	--
Urban Land		
MvC		
Mountview		
Ne	0-6	0.43
Newark	6-43	0.43
	43-60	0.43

Table 9-3
SCS SOIL ERODIBILITY DATA (continued)

Soil Name and Map Symbol	Depth Interval (inches)	Soil Erodibility Factor, K (tons/acre/R unit)
Pt*		
Pits		
RtC*		
Rock Outcrop		
Talbott	0-5	0.37
	5-32	0.24
	32	--
Se	0-7	0.24
Sequatchie	7-32	0.24
	32-65	0.24
SmC	0-6	0.24
Stemley	6-20	0.28
	20-46	0.24
	46-65	0.28
StC, StD	0-8	0.24
Stiversville	8-53	0.24
	53-60	--
	60	--
SvD*	0-8	0.24
Stiversville	8-53	0.24
	53-60	--
	60	--
Urban Land		
Ta	0-7	0.43
Taft	7-22	0.43
	22-61	0.43

Table 9-3
SCS SOIL ERODIBILITY DATA (continued)

Soil Name and Map Symbol	Depth Interval (inches)	Soil Erodibility Factor, K (tons/acre/R unit)
TbC	0-5	0.37
Talbott	5-32	0.24
	32	--
TcC3	0-6	0.37
Talbott	6-32	0.24
	32	--
TrC*	0-5	0.37
Talbott	5-32	0.24
	32	--
Rock Outcrop		
TuC*	0-5	0.37
Talbott	5-32	0.24
	32	--
Wo	0-6	0.37
Wolftever	6-24	0.37
	24-55	0.37
	55-65	0.32

*See description of the map unit for composition and behavior characteristics of the map unit.
Reference: USDA, SCS (1974).

Table 9-4
ESTIMATED RELATIVE SOIL LOSSES FROM SUCCESSIVE EQUAL-LENGTH SEGMENTS OF A UNIFORM SLOPE

Number of Segments, N	Sequence Number of Segment	Fraction of Soil Loss[a] m = 0.5	m = 0.4	m = 0.3
2	1	0.35	0.38	0.41
	2	0.65	0.62	0.59
3	1	0.19	0.22	0.24
	2	0.35	0.35	0.35
	3	0.46	0.43	0.41
4	1	0.12	0.14	0.17
	2	0.23	0.24	0.24
	3	0.30	0.29	0.28
	4	0.35	0.33	0.31
5	1	0.09	0.11	0.12
	2	0.16	0.17	0.18
	3	0.21	0.21	0.21
	4	0.25	0.24	0.23
	5	0.28	0.27	0.25

[a]Derived from the equation:

$$\text{Soil loss fraction} = \frac{i^{m+1} - (i-1)^{m+1}}{N^{m+1}}$$

where:

i = Segment sequence number
m = Slope-length exponent (0.5 for slopes $\geq$ 5 percent, 0.4 for 4 percent slopes, and 0.3 for 3 percent or less)
N = Number of equal-length segments into which the slope was divided.

Reference: Wischmeier and Smith (1978).

Table 9-5
SURFACE STABILIZATION (C_s) FACTORS
FOR BARE SOIL CONDITIONS

Bare Soil Conditions	C_s Factor
Freshly disked to 6-8 inches	1.00
After one rain	0.89
Loose to 12 inches smooth	0.90
Loose to 12 inches rough	0.80
Compacted bulldozer scraped up and down	1.30
Same, except root raked	1.20
Compacted bulldozer scraped across slope	1.20
Same, except root raked across	0.90
Rough irregular tracked all directions	0.90
Seed and fertilizer, fresh	0.64
Same, after 6 months	0.54
Seed, fertilizer, and 12 months chemical	0.38
Not tilled algae crusted	0.01
Tilled algae crusted	0.02
Compacted fill	1.24-1.71
Undisturbed, except scraped	0.66-1.30
Scarified only	0.76-1.31
Sawdust 2 inches deep, disked in	0.61

Reference: Transportation Research Board (1980).

Table 9-6
SURFACE STABILIZATON (C_s) FACTORS FOR PERMANENT PASTURE, RANGELAND, IDLE LAND, AND GRAZED WOODLAND[a]

Vegetable Canopy Type and Height of Raised Canopy[b]	Canopy *Cover*[c] %	*Cover That Contacts the Surface*						
		Percent Ground Cover						
		Type[d]	0	20	40	60	80	95-100
No appreciable canopy		G	.45	.20	.10	.042	.013	.003
		W	.45	.24	.15	.091	.043	.011
Canopy of tall weeds or short brush (20-inch fall height)	25	G	.36	.17	.09	.038	.013	.033
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush (6.5-ft fall height)	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees but no Appreciable low brush (13-ft fall height)	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011

[a]All values shown assume: (1) random distribution of mulch or vegetation and (2) mulch of appreciable depth where it exists. Idle land refers to land with undisturbed profiles for a period of at least 3 consecutive years. Also to be used for burned forestland and forestland that was harvested less than 3 years before.

[b]Average fall height of water drops from canopy to soil surface.

[c]Portion of total area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[d]G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep. W: Cover at surface is mostly broadleaf herbaceous plants (such as weeds with little lateral root network near the surface) and/or undecayed residue.
Reference: Wischmeier and Smith (1978).

Table 9-7

SURFACE STABILIZATION (C_s) FACTORS FOR UNDISTURBED WOODLAND

Effective Canopy[a] (% of Area)	Forest Liter [b] (% of Area)	C_s Factor [c]
100-75	100-90	.0001-.001
70-40	85-75	.002-.004
35-20	70-40	.003-.009

[a]Where effective litter cover is less than 40 percent or canopy cover is less than 20 percent, the area should be considered as grassland or idle land, with C_s selected from Table 9-6. Where woodlands are being harvested, grazed, or burned, also use Table 9-6.

[b]Forest litter is assumed to be at least 2 inches deep over the percent ground surface area covered.

[c]The range C_s values is due in part to the range in the percent area covered. In addition, the percent of effective canopy and its height has an effect. Low canopy is effective in reducing raindrop impact and in lowering the C_s factor. High canopy, over 13 meters, is not effective in reducing raindrop impact and will have no effect on the C_s value.

Reference: Wischmeier and Smith (1978).

Table 9-8
MULCH SURFACE STABILIZATION (C_s) FACTORS AND LENGTH LIMITS FOR CONSTRUCTION SLOPES[a]

Type of Mulch	Mulch Rate (tons/acre)	Land Slope (%)	C_s Factor	Length Limit [b] (ft)
None	0	All	1.0	--
Straw or hay, tied down by anchoring and tacking equipment[c]	1.0	1-5	0.20	200
	1.0	6-10	.20	100
	1.5	1-5	.12	300
	1.5	6-10	.12	150
	2.0	1-5	.06	400
	2.0	6-10	.06	200
	2.0	11-15	.07	150
	2.0	16-20	.11	100
	2.0	21-25	.14	75
	2.0	26-33	.17	50
	2.0	34-50	.20	35
Crushed stone, ¼ to 1½ in	135	<16	.05	200
	135	16-20	.05	150
	135	21-33	.05	100
	135	34-50	.05	75
	240	<21	.02	300
	240	21-33	.02	200
	240	34-50	.02	150
Wood chips	7	<16	.08	75
	7	16-20	.08	50
	12	<16	.05	150
	12	16-20	.05	100
	12	21-33	.05	75
	25	<16	.02	200
	25	16-20	.02	150
	25	21-33	.02	100
	25	34-50	.02	75

[a]Developed by interagency workshop group on the basis of field experience and limited research data.

[b]Maximum slope length for which the specified mulch rate is considered effective. When this limit is exceeded, either a higher application rate or mechanical shortening of the effective slope length is required.

[c]When the straw or hay mulch is not anchored to the soil, C_s values on moderate or steep slopes or on soils having K values greater than 0.30 should be taken at double the values given in this table.

Reference: Wischmeier and Smith (1978).

Table 9-9
SURFACE STABILIZATION (C_s) FACTORS FOR SELECTED METHODS OF SURFACE STABILIZATION

Surface Stabilization Method	C_s Factor
Asphalt Emulsion	
1,250 gallons/acre	0.02
1,210 gallons/acre	0.01-0.019
605 gallons/acre	0.14-0.57
302 gallons/acre	0.28-0.60
151 gallons/acre	0.65-0.70
Dust Binder	
605 gallons/acre	1.05
1,210 gallons/acre	0.29-0.78
Other Chemicals	
1,000-lb fiberglass roving with 60-150 gallons/acre	0.01-0.05
Aquatain	0.68
Aerospray 70, 10 percent cover	0.94
Curasol AE	0.30-0.48
Petroset SB	0.40-0.66
PVA	0.71-0.90
Terra-Tack	0.66
Wood fiber slurry[a], 1,000 lb/acre fresh	0.05
Wood fiber slurry[a], 1,400 lb/acre fresh	0.01-0.02
Wood fiber slurry[a], 3,500 lb/acre fresh	0.10
Seedings[b]	
Temporary, 0 to 60 days[c]	0.40
Temporary, after 60 days	0.05
Permanent, 0 to 60 days[c]	0.40
Permanent, 2 to 12 months	0.05
Permanent, after 12 months	0.01
Brush	0.35
Excelsior Blanket With Plastic Net	0.04-0.10

[a]Wood fiber slurry is commonly referred to as hydromulch.

[b]Use minimum C_s values if plantings are performed with mulches.

[c]If dry weather occurs at planting and emergence is delayed, extend the 0-60 days to a period when rainfall normally occurs.

Reference: Transportation Research Board (1980).

Table 9-10
SURFACE STABILIZATION (C_S) FACTORS FOR
MECHANICALLY DISTURBED WOODLAND SITES

Percent of Soil Covered With Residue in Contact With Soil Surface	Soil Condition[a] and Weed Cover[b]							
	Excellent		*Good*		*Fair*		*Poor*	
	NC	WC	NC	WC	NC	WC	NC	WC
None								
Disked, raked, or bedded[c,d]	.52	.20	.72	.27	.85	.32	.94	.36
Burned[e]	.25	.10	.26	.10	.31	.12	.45	.17
Drum chopped[e]	.16	.07	.17	.07	.20	.08	.29	.11
10% Cover								
Disked, raked, or bedded[c,d]	.33	.15	.46	.20	.54	.24	.60	.26
Burned[e]	.23	.10	.24	.10	.26	.11	.36	.16
Drum chopped[e]	.15	.07	.16	.07	.17	.08	.23	.10
20% Cover								
Disked, raked, or bedded[c,d]	.24	.12	.34	.17	.40	.20	.44	.22
Burned[e]	.19	.10	.19	.10	.21	.11	.27	.14
Drum chopped[e]	.12	.06	.12	.06	.14	.07	.18	.09
40% Cover								
Disked, raked, or bedded[c,d]	.17	.11	.23	.14	.27	.17	.30	.19
Burned[e]	.14	.09	.14	.09	.15	.09	.17	.11
Drum chopped[e]	.09	.06	.09	.06	.10	.10	.11	.07
60% Cover								
Disked, raked, or bedded[c,d]	.11	.08	.15	.11	.18	.14	.20	.15
Burned[e]	.08	.06	.09	.07	.10	.08	.11	.08
Drum chopped[e]	.06	.05	.06	.05	.07	.05	.07	.05
80% Cover								
Disked, raked, or bedded[c,d]	.05	.04	.07	.06	.09	.08	.10	.09
Burned[e]	.04	.04	.05	.04	.05	.04	.06	.05
Drum chopped[e]	.03	.03	.03	.03	.03	.03	.04	.04

Notes for Table 9-10

[a]Excellent: Highly stable soil aggregates in topsoil with fine tree roots and litter mixed in.

Good: Moderately stable soil aggregates in topsoil or highly stable aggregates in subsoil (topsoil removed during raking), with only traces of litter mixed in.

Fair: Highly unstable soil aggregates in topsoil or moderately stable aggregates in subsoil, with no litter mixed in.

Poor: No topsoil, highly erodible soil aggregates in subsoil, with no litter mixed in.

[b]NC—No live vegetation.
WC—75 percent cover of grass and weeds, having an average drop fall height of 20 inches. For intermediate percentages of cover, interpolate between columns.

[c]Multiply Item A values by the following values to account for surface roughness:

Very rough, major effect on runoff and sediment storage, depressions greater than 6 inches	.40
Moderate	.65
Smooth, less than 2 inches	.90

[d]The C_s values for Item A are for the first year following treatment. For A-type sites 1 to 4 years old, multiply C_s value by .7 to account for aging. For sites 4 to 8 years old, use Table 9-6. For sites more than 8 years old, use Table 9-7.

[e]The C_s values for B and C areas are for the first 3 years following treatment. For sites treated 3 to 8 years ago, use Table 9-6. For sites treated more than 8 years ago, use Table 9-7.

Reference: Wischmeier and Smith (1978).

Table 9-11
GUIDELINES FOR SELECTING VEGETATIVE COVER

Plant or Plant Mixture	Application Rate Per Acre[a]	Plant Dates[b]
Temporary Plants		
1. Rye	3 bushels	Aug. 15 – Nov. 1
2. Wheat	2-3 bushels	Sept. 1 – Nov. 1
3. Annual Ryegrass	30 pounds	Aug. 15 – Nov. 1
4. Browntop or Pearl Millet	20 pounds	Apr. 15 – Jul. 15
5. Sudangrass	40 pounds	Apr. 1 – Jul. 15
Permanent Plant Mixtures		
1. Tall Fescue (Ky 31)	45 pounds	Feb. 15 – Apr. 15
White Clover[c]	3 pounds	Jul. 15 – Oct. 15
2. Crownvetch[d]	20 pounds	Feb. 15 – Apr. 15
Tall Fescue (Ky 31)	30 pounds	Aug. 15 – Oct. 15
3. Sericea Lespedeza (Scarified)	45 pounds	Mar 1. – Jul. 15
Tall Fescue (Ky 31)	20 pounds	
Annual Lespedeza (Kobe)	8 pounds	
4. Sericea Lespedeza (Scarified)	45 pounds	Apr. 15 – Jul. 15
Weeping Lovegrass	3 pounds	
5. Common Bermudagrass (Hulled)	14 pounds	Apr. 15 – Jul. 15
Annual Lespedeza (Kobe)	8 pounds	
Permanent Sprig Plants		
1. Midland or Tifton 44 Bermudagrass	30 cubic feet, machine set; 50 cubic feet, broadcast & disked	Acceptable Dates Should Be Confirmed with Local Extension Office

[a]Soil testing should be performed and evaluated by an agronomist to determine soil treatment requirements for parameters such as pH, nitrogen, phosphorus, potassium, and other factors

[b]Seed should be irrigated during dry periods.

[c]Inoculate clover.

[d]Inoculate crownvetch with special inoculant. When seeded with hydroseeder, use 10 times the amount of inoculant stated on the package for non-hydroseeder application.

Reference: USDA, SCS (1978).

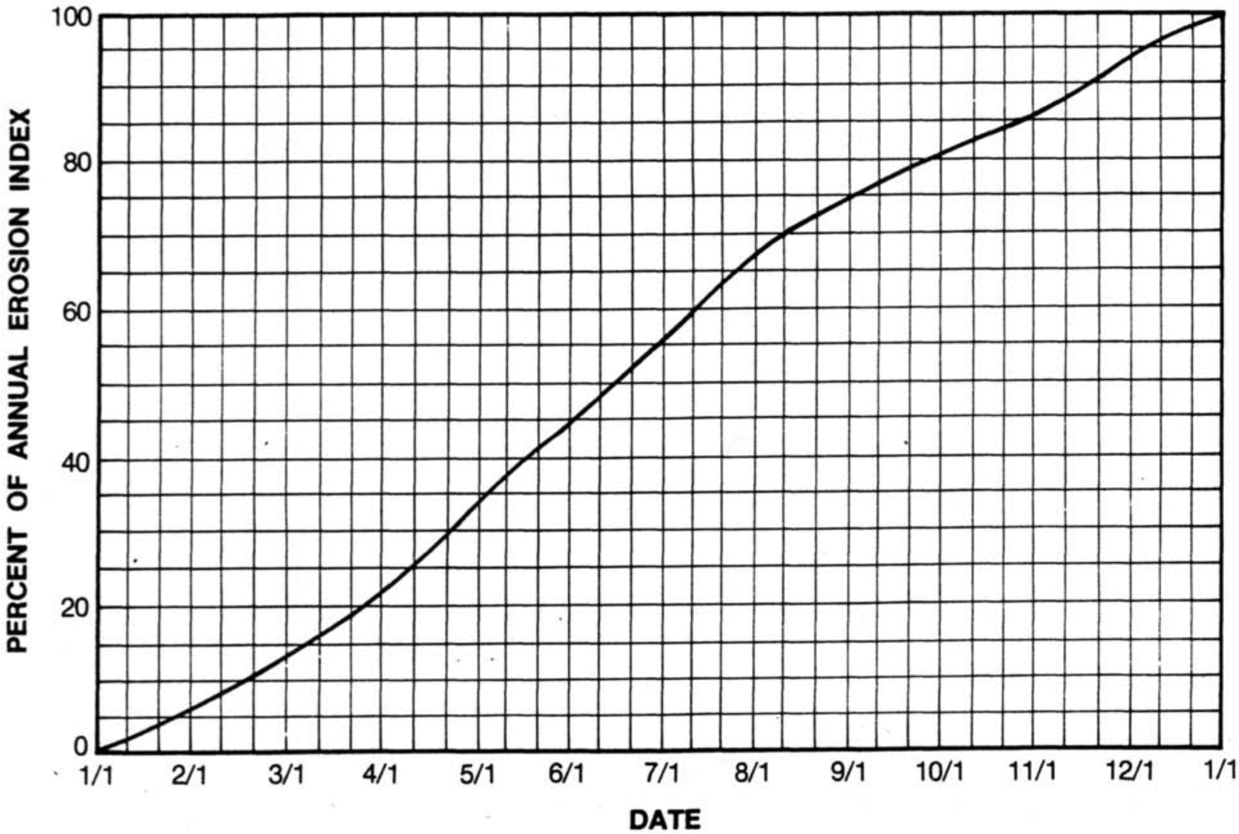
Table 9-12
EXAMPLE CALCULATION OF THE SURFACE STABILIZATION (C_s)
FACTOR FOR EXPOSURE SCHEDULING

Time Period	Surface Cover	C_S Factor	Fraction of Annual R During Time Period[a]	Weighted C_s Factor [b]
1/1 - 4/1	Undisturbed Woodland	0.003	0.22	0.0007
4/1 – 6/1	Cleared Site	1.00	0.23	0.23
6/1 – 8/1	Temporary Seeding	0.40	0.22	0.088
8/1 – 12/31	Permanent Seeding	0.05	0.33	0.017

Note: Composite C_s for exposure scheduling is the sum of each weighted C_s factor or 0.336.

[a]Obtained from Figure 9-1.

[b]Product of the C_s factor and the fraction of annual R during the specified time period.



Reference: Transportation Research Board (1980).

Figure 9-1
Erosion Index (EI) Distribution Curve
Applicable to Nashville and Davidson County

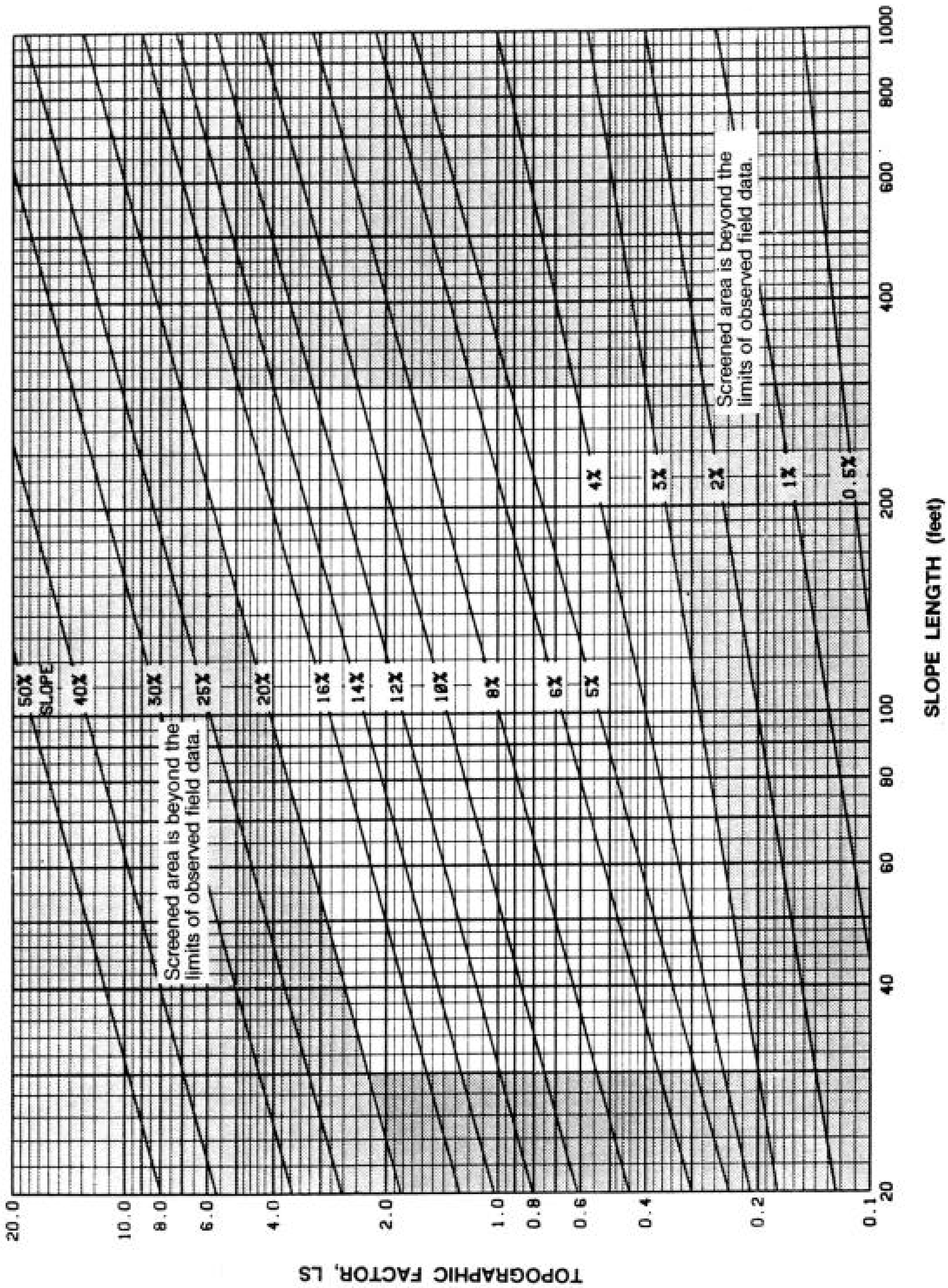


Figure 9-2
Length-Slope Factor Chart for USLE

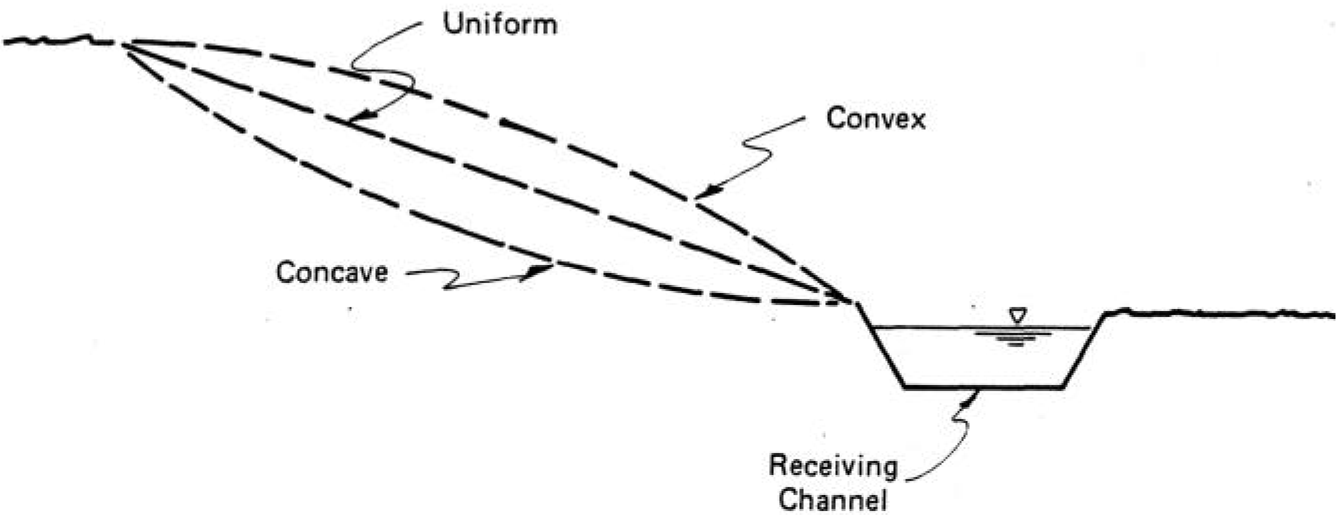


Figure 9-3
Conceptual Sketch of Typical Concave and Convex Slopes