3.0 Design of Control Measures (BMPs)

Erosion Control Measures (BMPs): Adverse impacts from construction sites can be reduced if some forethought is given to controlling the resultant erosion. One method to accomplish this is to limit the extent of native vegetation that is disturbed. This will often significantly reduce the volume of material eroded from a site. Planning the necessary locations of the disturbance and restricting construction traffic to those locations is an example of this type of planning.

Another method of reducing erosion potential is to revegetate any disturbed areas as soon as possible. To make this effective, construction activity should be planned to progress as rapidly and completely as possible. This will reduce the length of time when there is a high potential for erosion. A related method would be to revegetate between phases of a project, when there will be a delay between these phases.

Sediment control Measures (BMPs): There are several methods, structural and nonstructural, available to reduce the negative effects of sediment. Most of the common structural methods used (e.g. silt fence, rock dams, etc.) take advantage of the reduced ability of water to carry sediment when its velocity is reduced (see Figure 3.1). The reduction in velocity can be produced by constructing berms, sediment basins, or similar structural controls. The velocity can also be reduced by establishing vigorous stands of vegetation on relatively flat slopes through which the sediment-laden water must flow.

Figure 3.1 - Silt fences in series, on a relatively flat slope, pool water and decrease its velocity.

3.1 Design Methodology

The design methods for developing control measures consist of evaluating the proposed changes in erosion and sediment yields and the cost and probable effectiveness of controls for each particular site. The design of each control is not required but may be considered when dealing with very sensitive projects, evaluating control alternatives, or rating the actual effectiveness of an SW3P. A goal of reducing the sediment from disturbed areas by 70 to 80% with the use of erosion and sediment controls is considered realistic and attainable. The following sections address the technical aspects of the erosion process and the effectiveness of various controls. The procedure for designing controls is not a mandatory process but may be useful for evaluating devices or documenting the effectiveness of an SW3P.

3.2 Factors Affecting the Erosion Process

The procedures for computing the amounts of erosion are not an exact science. The processes that govern soil erosion are complicated and interact in changing and undefined ways. The complicated nature of the processes yields methodologies with many simplified assumptions in order to create a manageable problem. The Universal Soil Loss Equation (USLE) was developed using this approach. It is unlikely that any equation, statistical or otherwise, could accurately predict the response of all soil types to all the natural or man-made forces affecting the erosion process. Therefore, the USLE may be utilized as a tool, considering the limitations, to estimate erosion.

The Universal Soil Loss Equation (USLE):

Equation 1

$$A = R \times K \times L \times S \times C \times P$$

where:

A = the computed soil loss per unit area usually measured in tons per acre
R = rainfall erosion factor
K = soil erodibility factor
L = slope length factor
S = slope-gradient factor
C = cropping/management factor
P = erosion control practice factor

In adapting the USLE for use on highway projects the terms C and P are eliminated because they relate to agricultural lands and replaced with an erosion control factor VM. The L and S factors can be combined to form LS, the length-slope factor, which depends on the length and steepness of the slope. Therefore, a modified equation (Modified Universal Soil Loss Equation or MUSLE) is presented in this manual to predict soil loss due to erosion on highway construction sites and to determine the effectiveness of various erosion control devices.

Equation 2

$$A = R \times K \times LS \times VM$$

where:

A = rate of soil loss in tons per acre per year
R = rainfall erosion factor
K = soil erodibility factor
LS = length/slope factor
VM = erosion control factor (vegetative and mechanical measures)

Rainfall Erosion Factor (R): The average rainfall erosion factor (R) [often referred to as the mean annual ISO erodent (R) value] varies dependent on region and time of year. It is a measurement of the erosive force of a specified rainfall event.

Soil Erodibility Factor (K): The soil erodibility factor (K) is a numeric representation of the ability of the soil to resist the erosive forces of rain. Values of "K" range from 0.1 to 0.7 and may be found in most soil surveys. In the event the soil surveys do not contain values for K, use Appendix M which indicates more ranges of K based on location.

Topographic Factor (LS): The only portions of the soil loss equation which can be affected by construction activities are LS and VM; the R and K values are fixed by nature and cannot be altered by man. The LS factor is a numerical representation of the length-steepness combination used to estimate the erosion potential for a specific slope. Since the slope and length are determined during the design process, knowledge of the LS factor will assist in selection of erosion control devices. The equation for computing the LS is as follows:

Equation 3

$$LS = \left(\frac{1}{72.6}\right) \times \left(\frac{65.41 \times s^2}{s^2 + 10{,}000} + \frac{4.56 \times s}{\sqrt{s^2 + 10.000}} + 0.065\right)$$

where:

LS	= length/slope factor
l	= slope length (ft)
s	= slope in (ft/ft)
m	= exponent dependent on slope
	= 0.2 for s $\leq$ 1%
	= 0.3 for 1% $\leq$ s $\leq$ 3.5%
	= 0.4 for 3.5% $\leq$ s $\leq$ 4.5%
	= 0.5 for s $\geq$ 4.5%

The graph in Figure 3.2 was developed to solve Equation 3 and is used as follows:

1. Locate the slope length on the bottom.
2. Follow vertically to the correct slope gradient curve.
3. The corresponding LS value can be read from the left side.

The amount of erosion is very sensitive to the length and slope factors (e.g. cutting the slope length in half will cut the erosion by approximately one-third).

Erosion Control Factor (VM): The erosion control factor is applied to account for the effects of erosion control measures and devices used on a construction site. The lower the VM factor the more effective the device or control measure is in controlling erosion. Table 3.1 includes typical values based on the control device or measure utilized:

Table 3.1 - Erosion Control Factors (VM) for Various Erosion Control BMPs

Vegetative Management Practice	**VM Value**
Bare Soil – freshly disked to 6-8 inches	1.00
Bare Soil – after one rain	0.89
Compacted Fill	1.24-1.71
Undisturbed Soil – except for scraped	0.66-1.30
Soil Retention Blankets	0.015
Mulching (depends on application rate)	0.01-0.05
Hydromulch	0.05-0.10
Asphalt Emulsion (depends on application rate)	0.01-0.57
Silt Fence	0.25
Hay Bale	0.33
Triangular Sediment Dike	0.25
Inlet Protection	0.25-0.33*
Sediment Trap – Stone Outlet	0.15-0.30*
Sediment Basin	0.10*
Sandbag Berm	0.30*
Rock Berm	0.30*

*The VM values for structural controls listed must be adjusted for the type of cover that lies within the watershed for which they are treating runoff. Table 3.2 indicates the correction factors to use depending on the percent grass and canopy cover.

Equation 4

$$VM = VM_{Practice} \times Cover\ Factor$$

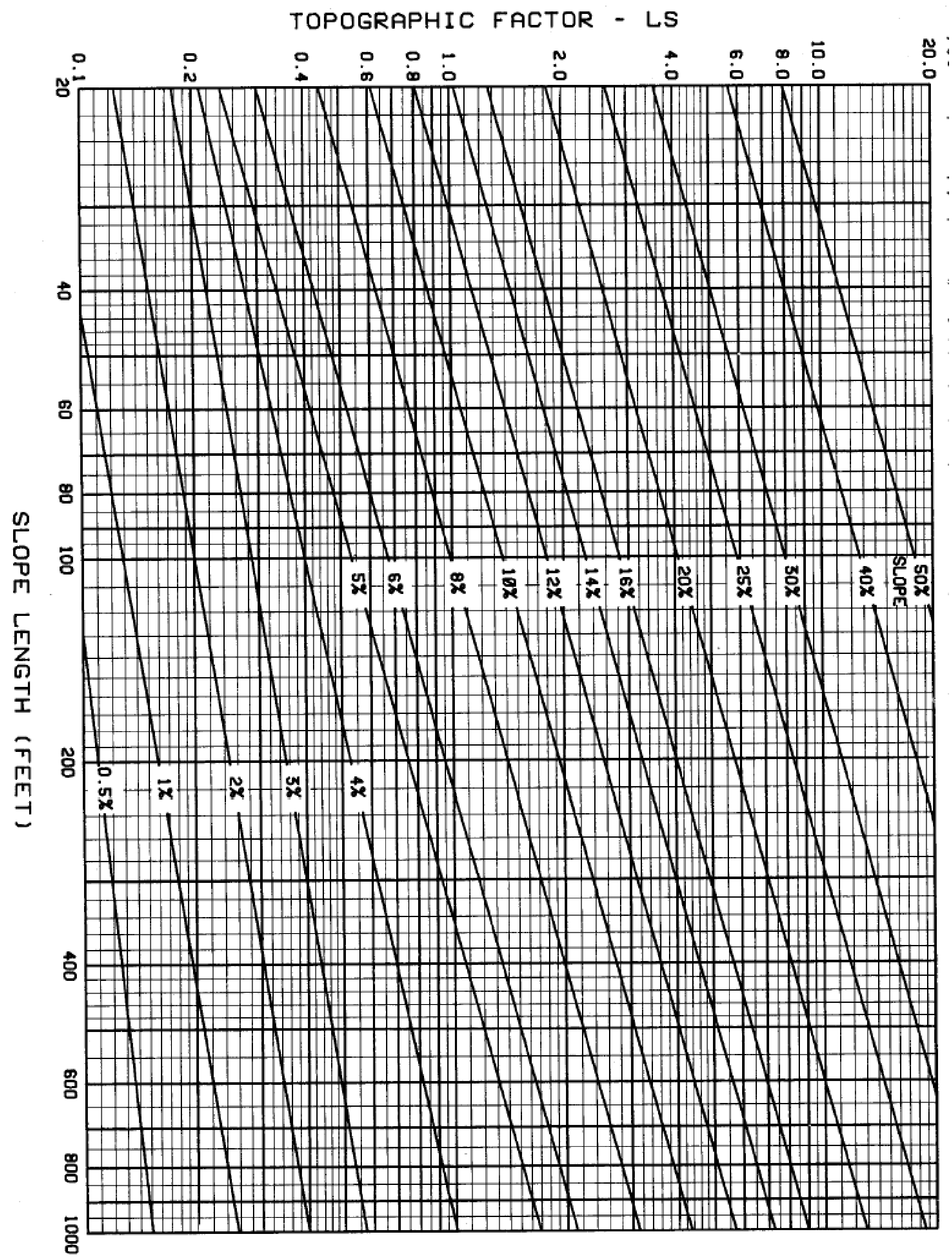

Figure 3.2 – Graphical Solution for the Slope Length Factor (LS). From Wischmeier and Smith (1978)

The cover factor considers the protection of natural ground cover in preventing soil erosion. The factor is dependent on the type of vegetation (grasses or trees) and the density of the vegetation. The canopy cover is the percent of ground cover from the trees, brush or tall weeds. For construction sites stripped of natural vegetation, a cover factor of 1.0 should be used. Note: The table will produce a cover factor of 0.45 for an area with 0% canopy and 0% cover of grass. This value represents undisturbed bare soil. On construction sites the bare soils are typically disturbed and/or compacted or otherwise altered. A value of 1.0 is recommended in the areas of disturbed bare soil.

Table 3.2 - Watershed Cover Factors

Canopy Cover, %	Undisturbed Soil Percent Ground Cover of Grass				
	0	20	40	60	>80
0	0.45	0.20	0.10	0.04	0.02
25	0.36	0.17	0.08	0.04	0.02
50	0.26	0.13	0.07	0.03	0.02
75	0.17	0.10	0.06	0.03	0.02