CHAPTER SIX

P Factor: Support-Practice

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The support-practice (P) and cover-management (C) factors are very important in RUSLE soil-loss estimates for mined land and construction-site reclamation planning because these factors represent practices designed to reduce erosion. The P value in RUSLE is the ratio of soil loss with a specific support practice to the corresponding soil loss with straight-row upslope and downslope tillage.

The P factor accounts for control practices that reduce the erosion potential of the runoff by their influence on drainage patterns, runoff concentration, runoff velocity, and hydraulic forces exerted by runoff on soil. The supporting mechanical practices include tillage (furrowing, soil replacement, seeding, etc.), strips of close-growing vegetation, deep ripping, terraces, diversions, and other soil-management practices orientated on or near the contour that result in the collection and storage of moisture and reduction of runoff (AH-703, Renard et al., 1997).

Sub-factor Groupings

An overall P value is computed as a product of P sub-factors for individual support practices, which are typically used in combination. For example, contouring almost always accompanies terracing. On mined land or construction-site reclamation projects, a Towner disk or chisel plow is often used in combination with a rangeland drill. Additionally, many structures such as straw-bale barriers, gravel filters, silt fences, continuous berms, and bench terraces are used on mined land and construction sites to control or minimize sediment transport from reclamation areas.

Tillage and planting operations performed on the contour are very effective in reducing erosion from storms of low to moderate intensity that are common in many areas of the United States. However, contouring provides little protection against high-intensity, long- duration storms. Values for the contouring sub-factor in RUSLE should be near 1.0 (little effectiveness) when the 10-year frequency, single-storm index (10-yr EI) is high and infiltration into the soil is slow, and should be low (greater effectiveness) when 10-year EI is low and infiltration is high.

Terracing in combination with contouring in the Western United States is more effective as an erosion-control practice than is contouring alone. The beneficial effects of terracing are reflected in the hillslope length and gradient (LS) factor because the length of the hillslope is reduced. Contour tillage and terracing are two common practices used on mined lands and construction sites and are discussed in detail in the following two sections.

Contour Tillage

When tillage is oriented along the contour, the ridges or oriented roughness will partially or completely redirect the runoff, thereby modifying the flow pattern. When tillage leaves high ridges, runoff stays within the furrows between the ridges, and the flow direction is controlled by the tillage pattern. High ridges from tillage on the contour cause runoff to flow around the hillslope rather than directly downslope, significantly reducing the grade along the flow path and reducing the flow's detachment and transport capacity as compared to runoff flowing directly downslope. Any reclamation practice that leaves ridges sufficiently high to redirect runoff in this manner has an effect that is considered in the P factor.

The grade along the furrows between the ridges should be flat or nearly flat so runoff may spill uniformly over the entire length of the ridges. Ridges placed precisely on the contour ensure maximum runoff storage and infiltration and also minimize runoff and erosion. Contour furrowing is most effective when tillage implements create very high ridges between furrows (see **Figure 6-1**). Conversely, contour furrows are least effective when ridge height is very low. For example, under controlled conditions at Columbia, Missouri, a field with bare soil, a hillslope gradient of 9 percent, and a hillslope length of 72.6 feet would have a P value of 0.96 when the ridge height is very low (<2 inches) and a P value of 0.12 when the ridge height is very high (>6 inches). This change in ridge height, from less than 2 inches to more than 6 inches, reduces erosion by more than 80 percent (0.96 - 0.12).

After mined land and construction areas are final graded, many of the subsequent mechanical reclamation treatments can be conducted on the contour. Deep ripping, chisel plowing, disking, topsoil spreading, and seeding can be accomplished on the contour when the hillslope gradient is less than 20 to 30 percent. The P value decreases substantially when these contour tillage operations are used singularly or in combination as shown in **Tables 6-1 to 6-4**. The values contained in the tables presented in this chapter were produced using RUSLE 1.06, unless otherwise indicated. Additionally, detached sediment is often transported only a short distance and deposited locally in the roughened microtopography created by the implement.

A very low to low-height ridge (0.5 to 3 inches) is left by a typical rangeland drill or light disk operation. Medium to high ridges (3 to 6 inches) are formed by a chisel plow with twisted shanks or a heavy disk. Very high ridges (>6 inches) are created on reclaimed hillslopes by a large modified Towner disk with 36-inch diameter disks as shown in **Figure 6-2**. For example, when very high ridges are created by a large modified Towner disk, on

the contour of a 300 foot long hillslope with a 10 percent gradient, in an area near Denver, Colorado, the P value would be 0.35 (see **Table 6-4**). If a different implement, such as a light disk was used to till this same hillslope, the very low ridges would produce a P value of about 0.66. The potential for erosion would be reduced by approximately 47 percent (0.66 - 0.35) when the Towner disk was used.

Figure 6-1. Two views of Contour Furrows

Figure 6-2. Towner Disk

Table 6-1. P values for contour furrowing on a 300 ft hillslope with a 10% gradient at Lexington, Kentucky and hydrologic soil group A (low runoff potential).

Ridge Height (inches)	About 50% Cover	Nearly Bare Soil
Very low (0.5-2)	0.66	0.81
Moderate (3-4)	0.42	0.67
Very high (>6)	0.35	0.57

Table 6-2. P values for contour furrowing on a 300 ft hillslope with a 10% gradient at Lexington, Kentucky and hydrologic soil group B (moderate runoff potential).

Ridge Height (inches)	About 50% Cover	Nearly Bare Soil
Very low (0.5-2)	0.85	0.98
Moderate (3-4)	0.58	0.89
Very high (>6)	0.35	0.81

Table 6-3. P values for contour furrowing on a 300 ft hillslope with a 10% gradient at Lexington, Kentucky and hydrologic soil group D (very high runoff potential).

Ridge Height (inches)	About 50% Cover	Nearly Bare Soil
Very low (0.5-2)	1.00	1.00
Moderate (3-4)	0.70	0.95
Very high (>6)	0.41	0.89

Table 6-4. P values for contour furrowing on a 300 ft hillslope with a 10% gradient at Denver, Colorado and hydrologic soil group B (moderate runoff potential).

Ridge Height (inches)	About 50% Cover	Nearly Bare Soil
Very low (0.5-2)	0.66	0.66
Moderate (3-4)	0.42	0.42
Very high (>6)	0.35	0.35

The RUSLE program is to be used to generate P values appropriate to a specific site. The values presented in **Tables 6-1 to 6-4** are intended to illustrate the effects of ridge height, percent cover, hydrologic properties of soils, and climate on P values at Lexington, Kentucky and Denver, Colorado. **Tables 6-1, 6- 2, and 6-3** illustrate how the effectiveness of contour furrows decrease from a soil with low runoff potential (high infiltration) to a soil with moderate or very high runoff potential (slow infiltration). **Tables 6-2 and 6-4** show climate to be an important consideration when assigning P values.

The effectiveness of contour furrowing varies considerably with climate conditions.

Lastly, note that values in **Table 6-1**, Column 1 and **Table 6- 4**, Columns 1 and 2 are all identical. These values represent minimum P values for contouring within RUSLE. Once these values are achieved, further management to control erosion must occur in other ways, such as modification of hillslope shape, terracing, or changes to decrease the C value.

When tillage operations are very carefully placed on the contour, use "*zero*" for the furrow grade. When buffer strips and strips of close-growing vegetation are used, use a ratio of furrow grade to land gradient of 0.05. For example, if the land is 10 percent in gradient, use a furrow grade of 0.5 percent. When tillage operations are performed without carefully laying out contour lines, but an effort is made to stay on the contour (much as would be done for a farm field), use a ratio of furrow grade to land gradient of 0.1. Namely, use a furrow grade of 1 percent for a land gradient of 10 percent.

Contouring alone is often inadequate for effective erosion control. Runoff frequently flows along the furrows to low areas on the landscape, where overtopping and erosion of the furrows occur. A sound conservation practice or reclamation plan for mined lands and construction sites includes structures or facilities such as terraces and down-drains, or grassed channels for off-slope conveyance of runoff water. A reclaimed hillside at Peabody Western Coal Company's Black Mesa Complex in Arizona with a gradient of 20 percent is shown in **Figure 6-3** that includes terraces and rock down-drains. The terrace spacing is about 250 feet.

Contouring loses its effectiveness on long hillslopes (AH-703). Critical hillslope lengths occur when the shear stress exerted on the soil exceeds a critical shear stress and the flow erodes the soil. This critical hillslope length is a function of the hillslope gradient, ridge height, residue cover, and runoff potential. When the hillslope is longer than the calculated maximum length, the contour credit applies only to the portion of the hillslope above the critical length. The portion below has a P contour sub-factor value of 1.0.

RUSLE must be used to generate P values appropriate to a particular site. The values given in **Tables 6-5, 6-6, and 6-7** are intended only to illustrate the influence of various site-specific conditions on the value for "P". **Table 6-5** shows that the critical hillslope length is affected by the hydrologic soil group and percent cover. The critical hillslope length is considerably less for a soil that has a very high runoff potential compared to a soil with low runoff potential.

Figure 6-3. Reclaimed hillslope with terrace at the Black Mesa Mining Complex, Peabody Western Coal Company.

Table 6-5. Critical hillslope length (ft) for contour furrowing on a 300 ft long hillslope with a 10% gradient near Lexington, Kentucky.

Hydrologic Soil Group	About 50% Cover	Nearly Bare Soil
A (low runoff potential)	>1000	238
B (moderate runoff potential)	859	147
D (very high runoff potential)	589	113

Table 6-6. Critical hillslope length (ft) for contour furrowing on a hillslope with a hydrologic group B soil.

Hillslope Gradient (%)	About 50% Cover	Nearly Bare Soil
5	>1000	330
10	859	147
15	539	92
20	389	67
25	303	52
30	249	43

Table 6-7. Critical hillslope length (ft) for contour furrowing on a hillslope with a 10% gradient and a hydrologic group B soil.

Location	About 50% Cover	Nearly Bare Soil
Lexington, KY	859	147
Birmingham, AL	663	117
Grand Island, NE	>1000	181
Huron, SD	>1000	347
Dallas, TX	578	103
Denver, CO	>1000	457

Table 6-6 illustrates the effect of hillslope gradient and cover on critical hillslope length for contour furrowing of a hydrologic group B soil. The 300 foot length would be inappropriate for nearly bare hillslopes as steep as 10 percent or hillslopes with 50 percent cover that are steeper than 30 percent because the critical hillslope length is less than 300 feet. **Table 6-7** shows how climate across the United States can affect the critical hillslope length for contour furrowing of a hillslope with a 10 percent gradient and a hydrologic group B soil. The critical hillslope length for a bare soil at Denver, Colorado would be more than four times longer than at Dallas, Texas.

Terracing

Terraces reduce interrill and rill erosion on the terrace interval by breaking the hillslope into shorter hillslope lengths. Also, deposition along the terrace may trap much of the sediment eroded from the inter-terrace surface above, particularly if the terraces are level, of very low gradient, or have closed outlets. Properly designed terraces and outlet channels intercept surface runoff and convey it from the hillslopes at non-erosive velocities.

The terrace P sub-factor used in reclamation planning considers both the benefit of deposition and the amount of sediment deposited. The net soil loss is the soil loss on the inter-terrace surface minus the amount of deposited soil and is credited as helping to maintain the soil resource by retaining the soil on the terrace.

Two types of P sub-factors are applicable to terraces. One P sub-factor is for conservation planning where the role of terraces in protecting the soil resource is considered. In this P sub-factor, a portion of the deposition, if it occurs in the terrace channel, is credited as protecting the soil resource from excessive erosion. The credit given to deposition decreases as the spacing between terraces increases such that almost no credit is given for deposition where terrace spacings are greater than 300 feet.

The other P sub-factor pertains to sediment yield, and is used with RUSLE to estimate the amount of sediment leaving a particular portion of the landscape. This P sub-factor is the ratio of sediment yield to the amount of sediment produced on the inter-terrace surface and is known as the sediment-delivery ratio. The amount of deposition computed by RUSLE depends on the extent to which the sediment load reaching the terrace channel exceeds the transport capacity of the flow in the channel. No deposition occurs if the transport capacity in the channel exceeds the sediment load from the inter-terrace surface as estimated by RUSLE.

Transport capacity in RUSLE is a function of runoff and grade of the terrace channel. If deposition occurs, the amount depends on the sediment characteristics. Not much deposition occurs if the particles are very fine in texture; conversely, much more deposition occurs if the sediment is very coarse. Another important factor considered in RUSLE is that soil particles are often cohesive so in addition to primary particles, the sediment is composed of aggregates that are much larger and thus more easily deposited than the primary particles forming the aggregates. The distribution of particle classes, their size and density, are computed using equations based on the soil texture developed by Foster et al. (1985).

The RUSLE program should be used to generate P values appropriate to a particular site. The values given in **Tables 6-8, 6-9,** and **6-10** are intended only to illustrate the influence of terrace grade, soil, and climate on sediment-delivery ratios for graded terraces at Lexington, Kentucky sites**. Table 6-8** illustrates the influence of terrace grade and inter-terrace erosion rate on the effectiveness of terraces as an erosion-control practice. On a

sandy loam soil with a hillslope length of 300 feet and a gradient of 10 percent, a terrace grade of 0.5 percent would cause about 25 (1.00 - 0.78), 65, and 75 percent of the sediment to be deposited in the terrace if the inter-terrace interval soil loss was 6, 15, and 28 t/ac/yr, respectively. Nearly flat gradient terraces are very effective in retaining sediment on the hillslope surface; however, frequent maintenance will be needed to prevent terraces from filling completely with sediment. **Table 6-9** shows that finer, non-cohesive soil particles such as silt are transported more readily than coarser sand or cohesive clay particles forming aggregates. **Table 6-10** depicts the effects of climate on sediment-delivery ratios at three different locations. However, the effect of climate alone is overshadowed by the variable erosion rates at these three sites.

Table 6-8. Sediment-delivery ratios for graded terraces on a sandy loam soil with a hillslope length of 300 ft and a 10% gradient at Lexington, Kentucky.

	Soil Loss on Inter-Terrace Interval (tons/acre/year)		
Terrace Grade (%)	**6 t/ac/yr**	**15 t/ac/yr**	**28 t/ac/yr**
0.1	0.20	0.12	0.10
0.2	0.32	0.18	0.13
0.5	0.78	0.36	0.23
0.75	1.00	0.53	0.32
1.0	1.00	0.71	0.42
1.5	1.00	1.00	0.62
2.0	1.00	1.00	0.83
2.5	1.00	1.00	1.00
3.0	1.00	1.00	1.00

Table 6-9. Sediment-delivery ratios for graded terraces as a function of soil textures, which determines sediment characteristics based on a hillslope length of 300 ft and a 10% gradient at Lexington, Kentucky. Soil loss on the inter-terrace interval is 6 tons/acre/year.

	Terrace Grade (%)	
Soil Texture	**0.1**	**0.5**
Sand	0.14	0.77
Sandy loam	0.20	0.78
Silt loam	0.32	0.82
Silt	0.43	0.85
Clay	0.25	0.80

Table 6-10. Sediment-delivery ratios for the same conditions of a 300 ft hillslope with a 10% gradient and a terrace grade of 0.1% at three locations with different climates.

Soil Texture	Lexington, KY (A=6 t/ac/yr)	Huron, SD (A=1.8 t/ac/yr)	Dallas, TX (A=10.1 t/ac/yr)
Sand	0.14	0.17	0.12
Sandy loam	0.20	0.20	0.20
Silt loam	0.32	0.27	0.36
Silt	0.43	0.32	0.49
Clay	0.25	0.27	0.24

When RUSLE is used to estimate soil loss from terraced land, the hillslope length is measured from the origin of surface runoff on the upslope terrace ridge or other watershed divide to the edge of the flow in the terrace channel. To compute soil loss with RUSLE for reclamation planning, values for the terrace P sub-factor are multiplied by other sub-factor values for contouring, strips of close-growing vegetation, tillage, and ripping on the inter-terrace landscape. Occasionally, terraces may be on a non-uniform grade, and may be so far apart that concentrated flow areas develop on the inter-terrace surface. When this situation exists, terraces may have little effect on soil loss, and the hillslope length is measured in the same manner as if the terraces were not present.

Terraces or diversions on a nearly flat grade cause considerable deposition. The amount of sediment accumulated is a function of erosion between terraces and the channel grade. Sediment yield from the terrace outlets can be obtained by multiplying the RUSLE soil-loss estimate for the inter-terrace area by the sediment-delivery ratio.

The effectiveness of tillage practices decreases through time as the soil surface seals, as the furrow crests are eroded by rainsplash, and as the depressions and furrows are filled with sediment. The rate at which a practice looses its effectiveness depends on the climate, soil, topography, and cover. Estimated duration of effectiveness for various practices are listed in Table 6-11. Values for P increase over time from the minimum value immediately after treatment toward approximately 1.0 when the original practice no longer influences soil loss.

Table 6-11. Common Mechanical Practices Applied to Rangelands, Reclaimed Mined Lands, and Construction Sites (Source: AH-703).

Practice	Degree of Disturbance	Surface Configuration	Estimated Duration of Effectiveness (Years)	Runoff Reduction
Rangeland drill	Minimal tillage except in furrow	Low ridges (<2 inches) and slight roughness	1- 2	None to slight
Contour furrow/ Pitting	Major tillage 8-12 inches deep	High ridges, about 6 inches (up to 9 in)	5-10	Slight to major
Chaining	Severe surface but shallow	Slight to moderate random roughness	3- 5	Slight to moderate
Land imprinting	Moderate-sized shallow depressions	Short channels (40 inches) & small to moderate ridges	2- 3	Slight to moderate
Disk plows, offset disks	Major tillage, about 4-8 inches deep	Moderate ridges 2-4 inches	3- 4	Slight to moderate
Grader Ripping, grubbing, root plowing	Minimal but often deep, 8+ inches	Slight to very rough, especially when done both up & down the hillslope & along the contour	4- 7	Moderate to major
Dozer Ripping	Moderate surface disturbance, 2 to 3 feet deep	Very rough, especially when done both up & down the hillslope & along the contour	5-10	Moderate to major

By year five, on permanently reclaimed hillslopes much of the effects of applied erosion-control practices on P values have been greatly reduced or are eliminated. There is some speculation that a slight P factor effect may remain because established vegetation patterns on the contour exist for many years, but this has not been conclusively established. Ten-year old reclaimed areas at the Black Mesa Complex in Arizona (Peabody Western Coal Company) show residual furrows and vegetation patterns that still reduce soil loss and the P value as illustrated in **Figure 6-4**.

The effect of increased infiltration and surface roughness are considered together when selecting a value for P because the influence of runoff and surface roughness are

interrelated with hillslope gradient. The effect of surface roughness on the reduction of soil loss decreases as the hillslope gradient increases.

Figure 6-4. Residual Furrows

P factor Field Methods

As with the other RUSLE factors, the P factor differentiates between *frequently disturbed* land and *infrequently disturbed* land. Both options allow for terracing or contouring, but the *frequently disturbed* option contains a routine for the use of *permanent barriers, strips of close-growing vegetation, and concave hillslope profiles*, whereas the *infrequently disturbed* option contains an *other mechanical disturbance* routine.

Of all RUSLE factors, the P factor is the one most subject to error. Ridges and other micro-topographic features vary greatly within a field. The P factors computed by RUSLE represent the way in which these practices generally affect erosion, but the measured result for any particular field could be significantly different from that computed by RUSLE. For reclamation planning, it is highly recommended that P values be estimated conservatively.

Sediment Yield from Concave Hillslopes

Deposition occurs on concave hillslopes if the amount of sediment reaching the lower end of the hillslope is greater than the transport capacity of the runoff on that portion of the hillslope. This often happens when the gradient flattens toward the base of the hillslope. RUSLE computes this deposition and as well as a sediment-delivery ratio that can be used to estimate sediment yield from soil loss for a concave hillslope or a complex hillslope with a concave basal segment.

Sediment yield from concave hillslopes can be estimated using the *frequently disturbed* sub-factor routine within the P-factor component of the RUSLE program. Up to 10 segments can be used to characterize the hillslope shape. More segments should be used to describe the hillslope in the portion where deposition is expected than in the portion of the hillslope where soil loss is expected. The depositional area, usually at the base of the hillslope, should be described with at least four, and preferably more, segments. Also, the gradient of the last segment at the downslope end of the hillslope concavity must be very carefully delineated because it has the greatest effect on sediment yield.

The importance of accurately segmenting the hillslope is illustrated by the following example. A sediment-delivery ratio of 0.20 was computed for a concave hillslope that ranged in gradient from 19 percent at the upper end to 1 percent at the lower end. The hillslope was divided into 10 uniform segments each comprising 10 percent of the total hillslope length. To illustrate the importance of the lowest, base segment, the last three segments were then combined into one segment with a gradient of 3 percent rather than the three individual segments of 3, 2, and 1 percent respectively. The computed sediment-delivery ratio was 0.46, more than twice the original value.

The importance of accurately describing the lower portion of the hillslope cannot be over-emphasized.

In the same example, the three upper segments with gradients of 15, 17, and 19 percent were combined into a single segment with a gradient of 17%, resulting in the same sediment-delivery ratio of 0.20. This example shows that long segments in the upper eroding portion of the hillslope do not greatly affect the sediment-delivery ratio, but long segments at the lower end of the hillslope, where deposition occurs, have a substantial influence on the sediment-delivery ratio.

The gradient at the lower end of the hillslope controls the amount of sediment leaving the hillslope. The degree of concavity also is a major factor influencing the sediment-delivery ratio. The values in **Table 6-12** illustrate the effect of concavity on the sediment-delivery ratios for a particular set of conditions where the lower end of the hillslope retains a 1 percent gradient. For this example, the ratio of the gradient at the upper end of the hillslope to the average gradient for the entire hillslope is taken as a simple

measure of the degree of concavity. As the ratio increases, the concavity increases; a uniform or straight hillslope has a ratio of 1.

Table 6-12. Effect of the degree of concavity (ratio of gradient at upper end to average gradient on sediment-delivery ratio (1% gradient at lower end).

Average gradient (%)	Degree of concavity	Sediment-delivery ratio
10.0	1.90	0.20
5.5	1.82	0.32
3.7	1.73	0.42
1.8	1.44	0.65
1.5	1.33	0.78
1.0	1.00	1.00

The values in **Table 6-12** show that as the degree of concavity decreases, the sediment-delivery ratio increases. For steep concave hillslopes, sediment production (soil loss) is high, but most of the sediment is deposited in the lower concave area resulting in a low sediment-delivery ratio. For gentle straight hillslopes, sediment production is low but most of the sediment is transported from the hillslope resulting in a high sediment-delivery ratio. In another example, the same sediment-delivery ratio results when the same degree of concavity is maintained, but the gradient of all segments is uniformly increased so that the gradient of the last segment is 3 percent. This result emphasizes the importance of evaluating the degree of concavity before choosing a sediment-delivery ratio for a concave hillslope.

Sediment-delivery ratios also are affected by cover-management conditions along the hillslope. For example, if the entire hillslope has a high-percent grass cover, the sediment-delivery ratio is 0.3 (rather than the 0.2 for the comparable condition in the above table, because sediment production is less, and only a small proportion is deposited, resulting in a higher sediment-delivery ratio. When the lowest two segments have only low-percent covers, while the upper eight segments of the hillslope have high-percent cover, virtually no deposition occurs, and the sediment-delivery ratio approaches 1. Conversely, if the upper eight segments of the hillslope have low-percent cover, while the lower two segments have high-percent cover, the sediment-delivery ratio will be less than that caused by the concavity alone, because sediment production is high and a large proportion is deposited, resulting in a lower sediment-delivery ratio. The spatial variation in cover-management conditions along a hillslope can be taken into account in RUSLE.

These examples demonstrate that deposition, and hence the sediment-delivery ratio, depends not only on degree of concavity but also on the cover-management and the manner in which it varies along the hillslope. The RUSLE program must be used to capture these

interactions. If no signs of deposition are present on a concave hillslope, the deposition area representing the end of the hillslope can be estimated using the *rule of thumb* described in Chapter 4.

Sediment-Control Barriers and Structures

There are two major approaches to erosion control. One approach is on-site protection of the soil resource so that the long-term productivity of the land is maintained. The other approach is sediment control so that off-site resources are protected. Practices like buffer strips of close-growing vegetation, stiff grass hedges, straw-bale barriers, gravel filters, sand bags, silt fences, continuous berms, rock check-dams, large-scale roughness, bench terraces, and sediment basins are useful for the containment of sediment, but do little to protect the soil resource in-situ.

One of the main objectives of any reclamation plan for mined lands and construction sites is to control sediment in an efficient and economical manner. Given site conditions such as topography, climate, runoff, soil type, and post-mining or post-construction land use, a reclamation specialist or engineer must select with confidence a technique that will perform to expectations at the lowest cost. Frequently the selection of appropriate erosion and sediment-control techniques, in combination, provides the greatest opportunity for success.

Sediment-control barriers and structures cause ponding of water and sediment deposition. It is assumed by the RUSLE program that the barrier or structure is installed on the contour. The effectiveness of a barrier or basin is directly related to the length and volume of ponded water. This length and volume increase dramatically as hillslope gradient decreases. **Table 6-13** contains P values for sediment barriers constructed on hillslopes with gradients up to 15 percent. No values are given for hillslope gradients greater than 15 percent because there is much uncertainty concerning the effectiveness of these barriers on steep hillslopes. Methods other than RUSLE should be used to estimate the effects of these barriers on hillslopes steeper than 15 percent.

Barriers cause deposition by ponding runoff on the upslope side. The width used in RUSLE to represent the barrier includes the width of the barrier itself and the width of the ponded water on the upslope side. The width of the barrier can be measured in the field. The width of the ponded runoff is a function of hillslope gradient, hillslope length, runoff volume, and the hydraulic resistance of the barrier. Equations can be used to estimate the width of the ponded runoff, but the computations are imprecise. Furthermore, the performance of barriers in the field is highly variable and often do not perform as expected. The values in **Table 6-13** have been chosen to represent the overall trends of various barrier types and their relative effectiveness when properly installed and maintained.

The P value and sediment delivery ratio for sediment-control barriers and structures can be estimated using the *permanent barriers, strips and concave hillslope profile* sub-factor routine. To illustrate the RUSLE computations for sediment-control barriers, assume

that a stiff-grass hedge is placed at the toe of a 200 ft. long hillslope with a gradient of 6 percent. The *effective* width to enter in the P-factor screen is 8%, as shown in **Table 6-13**. If only one stiff-grass hedge is used on the hillslope, the RUSLE P-factor screen would appear as shown in **Figure 6-5**. The total hillslope length is divided into two strips; the area above the stiff-grass hedge and the strip of the hedge itself. According to **Table 6-13**, the width of the stiff-grass hedge is 8 percent. Therefore, the location of the upper edge of the stiff-grass hedge strip is at 92% of the total hillslope length. The upslope strip accounts for 92% of the total hillslope length and has a cover/roughness condition of *no cover and/or minimum roughness* (condition C6 on the screen). The second strip is the stiff-grass hedge and the pond on the upper side of the hedge. The second strip extends to the base of the hillslope or 100% of the length and has a cover/roughness condition of *established sod-forming grasses* (condition C1 in the screen table). This condition code is used because the hydraulic resistance of stiff-grass hedges is generally the same as that of sod grasses. If the strip width specification code "*2*" is selected, the strip widths are entered in feet. In the example above, a strip width of 16 feet (200ft x 8% = 16ft) would be entered on the screen for the grass hedge, while the upper strip would be 184 feet (200ft - 16 ft = 184 ft).

```
      File        Exit        Help        Screen
+-----------------------< P Strips & Concave 1.06 >---------------------------+
| specified soil texture: silt loam                                            |
|        number of years: 1    strip width specification code: 1               |
|    year:  +--< 1 >---+                                                       |
|  strips:  |    2     |                                                       |
| strip 1   | 6 92  6  |                                                       |
| strip 2   | 1 100 6.0|                                                       |
|           +----------+                                                       |
|                                                                              |
|                                  code  COVER/ROUGHNESS PATTERN:              |
|                            +-------------------------------------------+     |
|                            |       1. C1) estab. sod-forming grass      |     |
|                            |       2. C2) 1st year grass or cut for hay |     |
|                            |       3. C3) heavy cov. and/or very rough  |     |
|                            |       4. C4) moderate cov. and/or rough    |     |
|                            |       5. C5) light cov. and/or mod. rough  |     |
|                            |       6. C6) no cover and/or min. rough.   |     |
|                            |       7. C7) clean tilled, smooth, fallow  |     |
|                            +-------------------------------------------+     |
|                                                                              |
|                                                                              |
|      NOTE:  computed soil loss and sediment yield for strips/barriers        |
|          assume that the grade along the upper edge is < 0.5%                |
+-------------------------< F3 when done, Esc exits >-------------------------+
Tab  Esc F1   F2  F3   F9
```

Figure 6-5. RUSLE screen for barriers

Table 6-13. Width of pond used to compute P values for sediment-control barriers. Values are given as a percent of hillslope length above the barrier. The width used in RUSLE is the width of the barrier strip, plus the width of the pond obtained from this table.

	Effective width of barrier as a percent of hillslope length			
Hillslope Gradient (%)	**Close-growing grasses**	**Straw bales, Gravel, Filter barriers**	**Stiff-grass hedges**	**Silt fences and berms**
<5	5	8	12	15
5-10	3	5	8	10
10-15	2	3	4	5

The amount of deposition that occurs depends on the extent to which the sediment load arriving at the pond area exceeds the transport capacity through the pond area. If sediment production is controlled on the upslope area so that the sediment load reaching the pond area is low, no deposition will be computed by RUSLE.

Under actual field conditions, the effectiveness of these barriers varies widely, from highly effective to virtually ineffective, depending on their design, installation, and maintenance. The values computed by RUSLE assume that the barriers are properly designed, installed, and maintained.

Experience and observation, however, suggest that these three assumptions often are invalid. Barriers must be installed on the contour for optimum performance. If they are not installed on the contour, the barriers will direct the runoff to low areas where the storage capacity of water and sediment is far less than when the runoff is ponded uniformly along the barrier. If runoff flows along the barrier, it functions as a diversion rather than a barrier. If the flow passes beneath the barrier, the P value equals 1.

The proper installation is critically important. If silt fences and straw bales are not properly buried and adequately supported, runoff may pass beneath the fence, trapping little sediment, or the fence may collapse along a part of its length concentrating the flow of water and sediment at the point of failure. Straw bales must be very carefully installed with the ends tightly abutted so that runoff and sediment do not pass between the bales.

Periodic maintenance is essential to the continued operation of barriers as sediment-control structures. The storage capacity behind these barriers can be filled with sediment during one or a few storm events. If the sediment is not removed or the barrier raised, the barrier will trap little sediment during subsequent events.

Buffer Strips of Close-Growing Vegetation

Buffer strips of close-growing vegetation, either left near the edge surrounding a disturbed area, or strategically planted, can be effective sediment traps if the runoff enters them uniformly. However, if runoff is concentrated in certain places, buffer strips may be largely ineffective. In areas where the runoff or deposition inundate the grass, they also are largely ineffective.

The *frequently disturbed* routine in the P sub-factor component of the RUSLE program can be used to compute a P value for buffer strips. Enter values based on the percent coverage of the hillslope length that they occupy. In no case should the coverage be less than 5 percent. Use the recommendations for a silt fence when choosing effective widths for stiff-grass hedges. Some typical P values for sediment-control barriers are given in **Table 6-14**. The performance of installed barriers may be much less than these values. P values are not given for hillslope gradients steeper that 15% because of uncertainty in performance.

Table 6-14. Some typical P values for barriers constructed on a silt loam soil at Lexington, Kentucky.

	Structure Type			
Gradient %	**Shortgrass Strip**	**Gravel Bag**	**Stiff Grass Hedge**	**Silt Fence**
<5	0.37	0.21	0.11	0.08
5-10	0.55	0.37	0.21	0.15
10-15	0.67	0.55	0.45	0.37

Straw-Bale Barriers

Straw-bale barriers positioned on the contour intercept and detain small amounts of sediment transported by sheet and rill flow. They trap sediment by ponding water and allowing the sediment to settle. Straw-bale barriers also slow runoff velocities acting to reduce sheet, rill, and gully erosion. Straw-bale barriers may also be used to prevent sediment from moving beyond the perimeter of the disturbance area.

Straw-bale barriers can be an effective sediment-yield control practice, but the risk of failure is very high. When the bales work as expected, they may trap as much as 95 percent of the sediment. However, they often partially fail and then the amount of sediment trapped depends on the extent of failure. Therefore, the selection of a P value for straw bales is almost entirely a function of the extent of failure and the percentage of the flow that passes through the failure points. Use the permanent barriers, strips, and concave

hillslope profile P sub-factor routine to estimate the P sub-factor value and sediment delivery ratio for this practice.

Gravel-Filter and Sand-Bag Barriers

Similar to straw-bale barriers, gravel-filter and sand-bag barriers are temporary measures used along the perimeter of construction sites or within channels to trap sediments and/or reduce flow velocities. The filters or bags are usually constructed of burlap or polypropylene, filled with suitable material (sand, gravel, or sediments), and placed or stacked on the surface to create a continuous berm.

Gravel filter and sand-bag barriers can be expected to provide a level of sediment control similar to a silt fence, but like straw-bale structures, their effectiveness depends on how well they are installed, and whether or not they fail. Use an initial P value computed for silt fences as described below, and adjust this P value for the extent of failure expected. Examples of a typical P values for gravel bags are presented in **Table 6-14**.

Silt Fences

A silt fence is a temporary polypropylene sediment barrier placed on the contour or at the bottom of the hillslope to trap sediment by ponding water and allowing the sediment to settle. A silt fence is often a cost-effective practice when used for sediment and erosion control around the perimeter of a disturbed area. Some believe that silt fences can be used on hillslopes with gradients up to 50%. Others, however, believe that silt fences may be largely ineffective on steep hillslopes due to the short length and small volume of ponded water behind the fence.

Similar to straw-bale barriers, the effectiveness of silt fences is largely a function of failure rates. If the silt fences are properly installed and maintained, they can be highly effective sediment traps. For example, as shown in **Table 6-14**, typical P values range from 0.08 to 0.37 for a silt fence constructed on a hillslope near Lexington, Kentucky, with a silt loam soil with gradients ranging from less than 5 to 15 percent.

Use the *frequently disturbed* routine in the P sub-factor component of RUSLE to compute a P value for silt fences according to the following steps:

1. First, compute the P value for contouring using appropriate inputs with one exception: a *zero* furrow grade is used regardless of the actual contouring, and select vegetation strips or concave slope at the bottom of this screen.

2. Next, compute the *permanent barriers, strips, and concave hillslope profile* P sub-factor value using two strips where the width of the strip is selected according to **Table 6-13**.

3. Choose an appropriate cover-management condition for the eroding portion, and choose a cover-management condition of 1 for the lower strip that represents the silt fence.

Continuous Berms

A continuous bermis a temporary diversion or sediment barrier constructed with fill material and used to intercept and divert sheet flow. Continuous berms are useful for erosion and sediment control around the perimeter of construction sites. The berms also detain sediment-laden stormwater encouraging deposition.

Diversions can be a very important erosion-control practice by diverting runoff at critical locations on the landscape. The effect of diverting surface flow and reducing the effective hillslope length is captured by the hillslope-length component of the LS factor.

The effectiveness of the berms also depends on whether or not they fail. Assuming no failure, compute the P values as for silt fences above.

Rock Check Dams

Check dams are made of rock or brush materials, constructed across drainageways to reduce flow velocities, trap and store larger-sized sediment, and provide stabilized gradient drops. They often are temporary stabilization structures that are used until the drainageway is permanently stabilized.

Rock check dams, brush dams, and other similar porous dams slow the runoff in channels and cause deposition. The amount of deposition depends on the extent to which these structures slow the runoff and the amount of sediment in the runoff. Use a P value computed for sediment basins, as described later, and adjust upward, based on the extent of porosity and ponding induced by the dam.

Large-Scale Roughness

Large-scale roughness can be left on the surface to reduce erosion and trap sediment. Use the roughness sub-factor in the C factor component of RUSLE to reflect this effect. Do not use the rangeland P factor for mechanical disturbance of soil on mined lands or construction sites.

Bench Terraces

Bench terraces can be used on construction sites, especially for aesthetic landscaping along roads and highways. Two types of bench terraces may be used: (1) one where the bench slopes outward toward the highway, and (2) where the bench slopes backward toward the hillslope.

For outward-sloping bench terraces, the hillslope length is measured from the top of the hillslope. The procedure used to compute the P value for barriers, as described above, is again appropriate. Also, a weighted C value is needed , and the irregular hillslope procedure is used to compute the LS value. For bench terraces sloping back toward the hillslope, each inter-terrace interval or terrace face is considered to be an individual hillslope length for the purpose of computation.

Sediment Basins

Sediment basins usually are temporary ponds designed and excavated to collect and store sediment from disturbed mined land or construction sites preventing the sediment from leaving the site, and causing damage downstream. Frequently, the soil surface of these sites remains exposed for extended periods of time before permanent vegetation is re-established and permanent drainage structures are completed. Sediment basins must be maintained periodically until the disturbed area is stabilized.

The RUSLE program estimates the effectiveness of sediment basins in collecting sediment through the terracing sub-factor of the P factor. Sediment basins are treated as closed-outlet terraces for the purpose of estimation. The sediment-delivery ratio for a sediment basin is strongly influenced by the particle or aggregate size of the sediment entering them, as shown in **Table 6-15**. As the particle or aggregate size decreases, the sediment delivery ratio increases because fine-textured particles remain suspended for much longer periods of time. RUSLE computes a P value for sediment basins as a function of particle or aggregate characteristics. This P value is applicable to a newly-constructed basin with minimal sediment in storage. As the basin fills with sediment, the P value should be increased, because less sediment will be trapped subsequently.

Table 6-15. Sediment-delivery ratios for sediment basins that are well designed, constructed, and maintained with full sediment-storage capacity.

Soil texture	Sediment delivery ratio
Sand	0.01
Loamy sand	0.02
Sandy loam	0.03
Loam	0.05
Silt loam	0.06
Silt	0.07
Sandy clay loam	0.06
Clay loam	0.08

Soil texture	Sediment delivery ratio
Silty clay loam	0.09
Sandy clay	0.10
Silty clay	0.12
Clay	0.14

The RUSLE computations for sediment basins do not take into account changes in sediment-particle size resulting from upslope conditions, such as a concave hillslope segment or a sediment-control barrier. A concave segment or barrier tends to remove the coarse fractions of the sediment. As a result, the sediment reaching the basin is finer in texture than it would have been in the absence of upslope deposition. Consequently, the sediment basin is less effective, sometimes much less effective, in trapping the sediment that remains in the flow entering the basin. The extent to which the sediment-trapping effectiveness of the basin is diminished depends upon the particle or aggregate sizes produced by erosion in the upslope area and the enrichment of fine-textured particles or aggregates due to selective deposition in the concave hillslope segment or behind barriers. Of course, deposition on concave segments or behind barriers reduces the rate at which basins fill with sediment and the need for maintenance. **Table 6-16** shows upslope influences on the sediment-delivery ratio for a sediment basin. The values in this table can be used to adjust the sediment-delivery ratio computed by RUSLE for sediment basins or graded terrace channels.

RUSLE also does not account for the effects of sediment basins in series**. Table 6-16** also shows the changes in sediment-delivery ratios resulting from two sediment basins in series, with one immediately downstream from the first. The sediment leaving the first basin again is enriched in fine-textured particles or aggregates and, as a result, the second basin is able to trap only an additional 15 percent of this very fine-textured sediment. In practice, a series of basins might be used with substantial area separating the two. In this case, the second basin still is unlikely to be as effective in trapping sediment as the first basin. The effectiveness of the second basin is a function of the particle or aggregate size characteristics leaving the first basin plus the size characteristics of the sediments produced by the area between the two basins. As an approximation, the second basin can be assumed to trap only about 10 percent of the sediment from the first basin and that part of the sediment from the intervening area as determined by the sediment-delivery ratio for the soil type of that intervening area.

Table 6-16. Effect of concave hillslope segments, sediment-control barriers, and basin sequences on the effectiveness of sediment basins.

Soil texture on upslope are a producing sediment	Sediment delivery ratio of concave hillslope or barrier	Sediment delivery ratio for sediment basin	Sediment delivery ratio of second sediment basin in series
Silt loam	0.10	0.47	0.84
	0.50	0.11	0.75
High clay	0.10	0.90	0.90
	0.50	0.33	0.90
High sand	0.10	0.29	0.86
	0.50	0.06	0.84

The values computed by RUSLE for sediment basins assume that the basins are well designed, constructed, and maintained. The values computed by RUSLE correspond well with those reported in the literature (Bonta and Hamon, 1980; Fennessey and Jarrett, 1997; U.S. Environmental Protection Agency, 1976a,b)

Use of RUSLE to Compute Sediment Yield

RUSLE uses the P-factor sub-routine to compute sediment yield where deposition significantly reduces the amount of sediment leaving a hillslope. Deposition caused by erosion-control structures such as diversions, terraces, or sediment basins, is estimated using the P sub-factor for terraces within the RUSLE program. The contouring sub-factor must be computed first. If a diversion or terrace is placed on the downslope side of an erosion-control structure, such as a stiff-grass hedge, or downslope of a concave hillslope element, the terrace sub-factor should not be used because it will compute additional deposition when none would occur. The erosion-control structure or concave hillslope element would reduce the sediment load of the runoff before encountering the diversion or terrace. The values in **Table 6-16** can be used to make adjustments for a sediment basin placed downstream of an erosion-control structure or another sediment basin.

The effects of barriers, strips, and concave hillslope configurations on deposition are combined into a single P sub-factor. The information on which the effects are based include the location of the upslope edge of each strip, the cover-roughness condition for each strip, and the gradient of the strip. For narrow strips or barriers such as silt fences, gravel bags, and stiff-grass hedges, the location of the upper edge of the strip is chosen based on the effective width of the strip as provided in **Table 6-13**. The cover-roughness condition for short-growing grasses should be selected based on their stand. A cover-roughness condition of C1 (characteristic of sod) also is used for straw bales, gravel bags,

and silt fences, when well constructed and well maintained to operate at full capacity. The grasses, especially stiff-grass hedges, can be assumed to maintain their effectiveness over time, but the effectiveness of other practices will be temporary and diminish through time unless properly maintained.

The sediment delivery ratio (SDR) contained in the RUSLE worksheet screen is the product of the P sub-factor for contouring and the sediment delivery ratio based on the sediment trapping efficiency of the utilized erosion- and sediment-control practice. The sediment delivery ratios also are given on the P sub-factor screens for barriers, strips, concave hillslopes and terraces. The trapping efficiency of erosion- or sediment-control practices is equal to 1 minus the SDR.

One important modeling requirement is that each RUSLE factor be computed with the RUSLE program (because the P-factor computation for terracing uses values from all of the other factors).

Sediment-delivery ratios for the other practices are computed using the *permanent barriers, strips, and concave hillslope profile* P sub-factor option for *frequently disturbed* land. Follow the instructions below because use of this option often is not apparent or obvious:

1. Use the RUSLE program to compute values for each of the RUSLE factors including the C factor. The P factor routine is then used to compute sediment-delivery ratios.

2. Compute a P sub-factor value for contouring as you would ordinarily. Record this value so that you can re-enter the value later.

3. Repeat the P sub-factor computation for contouring, but in this case assume a "zero" furrow grade. If a "zero" furrow grade was already assumed, computation need not be repeated.

4. Move to the "permanent barriers, strips, and concave hillslope profile" P sub-factor option.

For concave and complex hillslopes:

5. Use a 1-year rotation and choose the entry method for entering locations by percentages.

6. Enter the number of hillslope segments. For each segment, enter the position of the lower edge of the segment, the cover-management condition that best represents the segment, and the gradient of the segment. These hillslope segments should match those entered in the LS factor. The cover-management condition can

differ among the individual segments.

7. Because RUSLE does not transfer the sediment-yield value back to the soil-loss computational worksheet, multiply by hand outside of the RUSLE program, values for R, K, LS, C, and the P sub-factors for contouring that you first computed, and the adjusted sediment-delivery ratio.

Strips of Close-Growing Vegetation

Strips of close-growing vegetation such as grasses can be placed on the hillslope to reduce erosion. In some agricultural-management systems, the strips of close-growing vegetation and the "clean-tilled" strips are rotated, for which multiple years of the rotation are represented on the P sub-factor screen for *permanent barriers, strips, and concave hillslope profiles*.

1. A one-year rotation is used for permanent buffer strips that are not rotated.

2. Enter the location of the lower edge of each strip and select the cover- management condition class that best represents the field situation.

3. The width of the strip need not be large to be highly effective. The widthof the ponded area is the key variable, but that variable cannot be entered into the RUSLE program. If the actual width of the strip is less than the effective widths shown in **Table 6-13**, adjust the location of the lower edge of the strips upslope of the grass strip to meet the minimum requirement shown in **Table 6-13**.

4. A cover-management condition for the short-growing grasses and stiff hedges should be selected based on their stand. Straw bales, gravel grass bags, and silt fences are assumed to be well-constructed and operating at full capacity. The grasses are assumed to maintain their effectiveness overtime,especially the stiff grass hedges. But the other practices lose effectiveness over time if not maintained; hence, their use is assumed to be temporary.

The correct procedures for the computation of all RUSLE factor values are demonstrated in Chapter 7. Users of RUSLE for soil loss estimation on mined lands, construction sites, and reclaimed lands should study this chapter carefully.