Guidelines

for the

Use of the

Revised Universal

Soil Loss Equation

(RUSLE)

Version 1.06

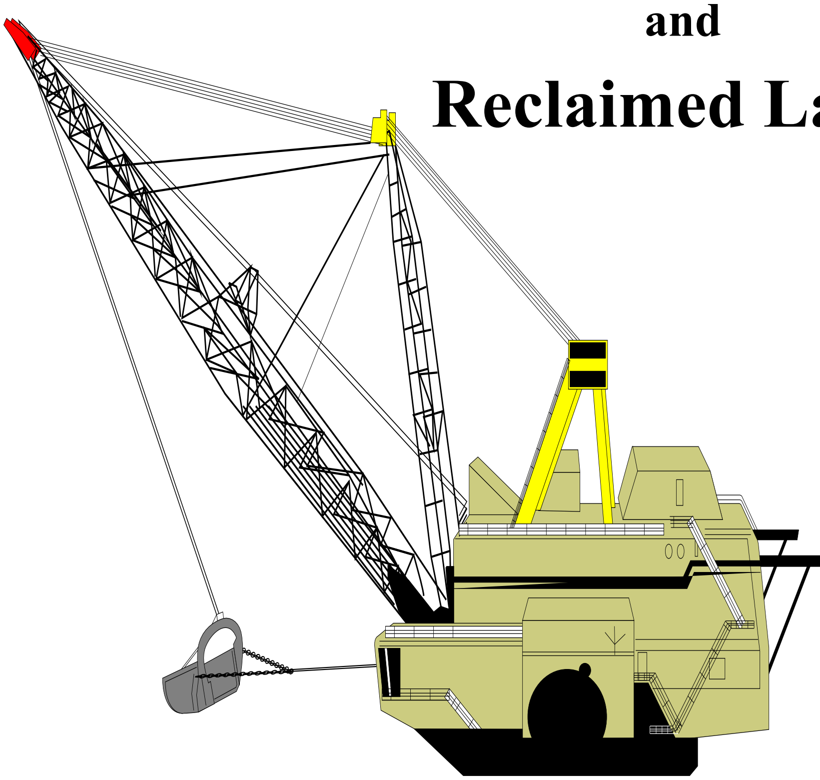
on

Mined Lands,

Construction Sites,

and

Reclaimed Lands



Terrence J. Toy and
George R. Foster
Co-editors

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Publishing Editor

Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands

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Acknowledgments

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CHAPTER ONE

Introduction

Author: T. J. Toy, K. G. Renard
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A variety of human activities disturb the land surface of the earth, and thereby alter natural erosion rates. Federal and State legislation mandate erosion control and sediment containment from lands subjected to many activities, including mining, construction, and reclamation. Effective erosion control and sediment containment begin with the project-planning process. At this time, pre-disturbance rates of soil loss and sediment discharge can be assessed, together with the rates that are likely to occur during and following land disturbance. Then, several erosion-control and sediment-containment strategies can be evaluated in terms of effectiveness and cost. The results of these evaluations may be part of a required permit application.

The Revised Universal Soil Loss Equation (RUSLE, Renard et al., 1997) is a technology for estimating soil loss from most undisturbed lands experiencing overland flow, from lands undergoing disturbance, and from newly or established reclaimed lands. RUSLE also may be used as a part of the procedures to prepare permit applications and to assess reclamation success in support of bond release.

Erosion Terminology

Several terms are used in association with the removal of soil from the land surface. Although there is not complete agreement in the connotations attributed to these terms, the following definitions are employed in this report. **Erosion** includes a group of processes by which earth materials are entrained and transported across a given surface. **Soil loss** is that material actually removed from the particular hillslope or hillslope segment. The soil loss may be less than erosion due to on-site deposition in micro-topographic depressions on the hillslope. The **sediment yield** from a surface is the sum of the soil losses minus deposition in macro-topographic depressions, at the toe of the hillslope, along field boundaries, or in terraces and channels sculpted into the hillslope.

RUSLE estimates soil loss from a hillslope caused by raindrop impact and overland flow (collectively referred to as "interrill" erosion), plus rill erosion. It does not estimate gully or stream-channel erosion.

The RUSLE Model

RUSLE is a set of mathematical equations that estimate average annual soil loss and sediment yield resulting from interrill and rill erosion. It is derived from the theory of erosion processes, more than 10,000 plot-years of data from natural rainfall plots, and numerous rainfall-simulation plots. RUSLE is an exceptionally well-validated and documented equation. A strength of RUSLE is that it was developed by a group of nationally-recognized scientists and soil conservationists who had considerable experience with erosional processes. (Soil and Water Conservation Society, 1993).

RUSLE retains the structure of its predecessor, the Universal Soil Loss Equation (USLE, Wischmeier and Smith, 1978), namely:

$$A = R\ K\ LS\ C\ P \qquad (1)$$

Where: A = Average annual soil loss in tons per acre per year
R = Rainfall/runoff erosivity
K = Soil erodibility
LS = Hillslope length and steepness
C = Cover-management
P = Support practice

The R factor is an expression of the erosivity of rainfall and runoff at a particular location. The value of "R" increases as the amount and intensity of rainfall increase. For user convenience, these data are contained in the CITY database file provided within the computer program. The basic program includes the files for numerous cities throughout the United States, but many more site-specific files are available within each state from the offices of the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS); formerly the Soil Conservation Service, (SCS). **Figure 1-1** shows a general flowchart of the RUSLE software.

The K factor is an expression of the inherent erodibility of the soil or surface material at a particular site under standard experimental conditions. The value of "K" is a function of the particle-size distribution, organic-matter content, structure, and permeability of the soil or surface material. For undisturbed soils, values of "K" are often available from soil surveys conducted by the NRCS. For disturbed soils, the nomograph equations embedded within the RUSLE program are used to compute appropriate erodibility values.

The LS factor is an expression of the effect of topography, specifically hillslope length and steepness, on rates of soil loss at a particular site. The value of "LS" increases as hillslope length and steepness increase, under the assumption that runoff accumulates and accelerates in the downslope direction. This assumption is usually valid for lands experiencing overland flow but may not be valid for forest and other densely-vegetated areas.

RUSLE

Soil Loss Estimation

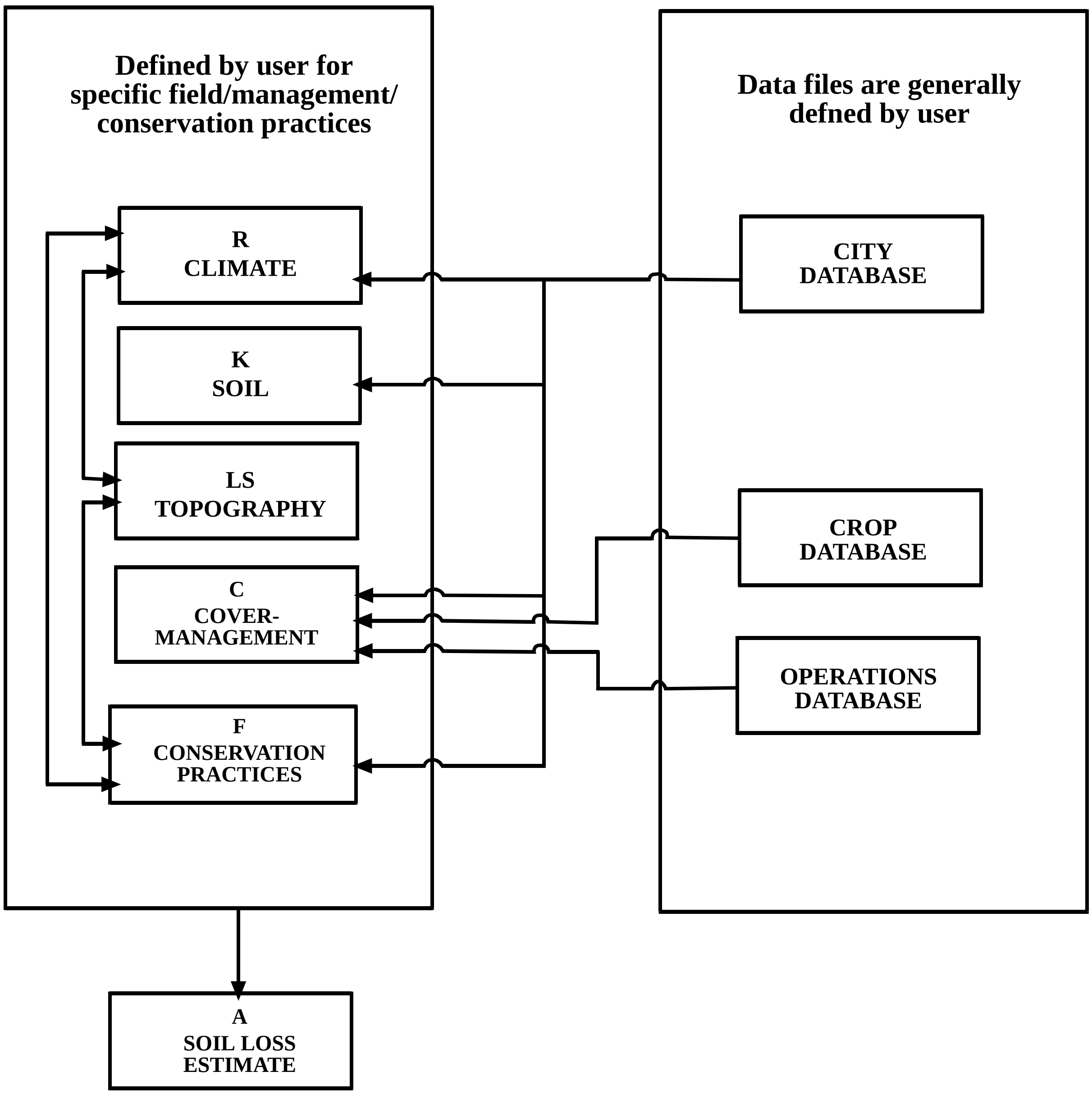

Figure 1-1. A general flowchart of the RUSLE software**.**

The C factor is an expression of the effects of surface covers and roughness, soil biomass, and soil-disturbing activities on rates of soil loss at a particular site. The value of "C" decreases as surface cover and soil biomass increase, thus protecting the soil from rainsplash and runoff. The "biological" inputs to RUSLE may not be familiar to all RUSLE users; however, the necessary values usually can be obtained through consultation of the literature and professional staff at local NRCS offices. The RUSLE program uses a sub-factor method to compute the value of "C". The sub-factors that influence "C" change through time, resulting in concomitant changes in soil protection. For user convenience, a VEGETATION database file is contained within the computer program that characterizes numerous plant types. In some cases, the plants used in reclamation may be included in these files. In other cases, files may be customized to include the desired plants and plant combinations. Likewise, the files include other types of surface treatments used as temporary covers for erosion control.

RUSLE also contains an OPERATIONS database file that characterizes the effects of various soil-disturbing activities on soil-loss rates. These operations alter the roughness, infiltration, distribution of biomass, and runoff properties of the surface. The operations usually are common tillage activities that may be used in the development of a seedbed at reclaimed sites. The files include activities specific to erosion control and disturbed-land reclamation. The effectiveness of cover-management sub-factors varies with local conditions.

Therefore, the user is strongly encouraged to calculate C values through the RUSLE equations rather than selecting values from generalized tables.

The P factor is an expression of the effects of supporting conservation practices, such as contouring, buffer strips of close-growing vegetation, and terracing, on soil loss at a particular site. The value of "P" decreases with the installation of these practices because they reduce runoff volume and velocity and encourage the deposition of sediment on the hillslope surface. The effectiveness of certain erosion-control practices varies substantially due to local conditions. For example, contouring is far more effective in low-rainfall areas than in high-rainfall areas.

Therefore, the user is strongly encouraged to calculate P values through the RUSLE equations rather than selecting values from generalized tables.

As illustrated in **Figure 1-1**, the RUSLE factors are highly interactive within the program. For example, the climate characteristics of a particular location are contained in the CITY database files; portions of these files are used in the calculation of soil erodibility (K), cover-management (C), and support practices (P) factors.

Care must be exercised to insure that all data inputs are accurate because they may affect several components of soil-loss estimation. It is often prudent to consult with qualified earth and environmental scientists to affirm the accuracy of the data inputs. Further, the soil-loss estimates produced by RUSLE rest upon the assumption that factor inputs accurately reflect field conditions. Factor adjustments are required whenever actual conditions depart from specifications.

The recommendations provided herein for the use of RUSLE on mining, construction, and reclaimed land applications represent the best judgment of the Working Group. It is the user s responsibility to determine whether or not RUSLE is applicable to a particular field situation.

These guidelines provide direction for maximizing the accuracy of RUSLE soil-loss estimates on mined lands, construction sites, and reclaimed lands.

RUSLE is a tool to estimate the rate of soil loss based on site-specific environmental conditions and a guide for the selection and design of sediment and erosion-control systems for the site. RUSLE does not determine when soil loss is excessive at a site, or when erosion-control systems have failed. The RUSLE user makes such decisions based upon numerous criteria, of which soil-loss and sediment-yield estimates are one important component.

A Brief History of Erosion Research and RUSLE

RUSLE reflects the evolutionary development of erosion-prediction technology. For nearly 100 years, erosion data have been collected, analyzed, presented, and discussed in the professional arenas of agricultural and civil engineers, agronomists, soil scientists, geologists, hydrologists, and geomorphologists.

The breadth and depth of these scientific investigations allow confidence in the application of RUSLE for the estimation of soil loss from mined lands, construction sites, and reclaimed lands.

The basic principles governing soil losses due to raindrop impact, overland flow, and rill-erosion processes remain the same for all land uses where the soil or surface material is exposed.

Most erosion research has occurred during the past 80 to 90 years, although the German scientist Ewald Wollny, writing in 1888, is generally credited as a "pioneer in soil and water conservation research." The earliest erosion measurements in the United States began in 1912 on over-grazed rangeland in central Utah. Sampson and Weyl, among others, showed that over-grazing on two 10-acre plots in the Manti National Forest accelerated erosion rates, reducing the soil's water-retention capabilities and fertility levels (Sampson and Weyl, 1918; Chapline, 1929; Stewart and Forsling, 1931). Such early rangeland research was not continued and most of the rangeland-erosion technology in use today has evolved from cropland research with limited validation for range-specific conditions (Renard, 1985; Meyer and Moldenhauer, 1985).

The concept of erosion-plot research used today generally is credited to Miller and associates at the Missouri Agricultural Experiment Station (Duley and Miller, 1923; Miller, 1926; Miller and Krusekopf, 1932). Most of the erosion plots installed for early erosion research were the now-familiar 72.6 foot long by either 6.0 or 12.0 foot wide plots (0.01 or 0.02 acres). The length dimension was chosen to ease the computation of runoff and erosion on a unit-area basis.

H. H. Bennett had substantial influence on the development of soil conservation in the United States (including soil-erosion research), and is widely recognized as the "father of soil conservation". His early efforts influenced the United States Congress to enact legislation in 1929 establishing a system of Federal erosion experiment stations that produced much of the initial erosion data in the United States. The original ten experiment stations, plus other locations added during the 1940s and 1950s through Federal and State partnerships, generated soil-loss data from a wide range of environmental conditions. Bennett served as the first chief of the Soil Conservation Service. The agency achieved considerable stature because of his speaking eloquence, prolific writing, and the quality of the scientists engaged in the research projects during his tenure. The pre-World War II years were the "golden years for soil-conservation research" (Nelson, 1958). However, rangelands, forests, mined lands, and construction sites were conspicuously absent from the early erosion research.

The collection of sufficient soil-loss data from natural rainfall events on erosion plots to permit confidence in the results of statistical analyses proved to be a long-term, expensive, and inefficient undertaking. A significant development in erosion research was the use of rainfall simulation for applying water to plots in a manner intended to emulate aspects of natural rainfall. Rainfall simulation is an important tool for erosion, infiltration, and runoff studies used to rapidly generate large volumes of data under a wide variety of controlled environmental conditions. Neff (1979) discussed several advantages and disadvantages of rainfall simulation.

In some cases, rainfall simulators have been used on short plots (about 3 feet or 1 meter in length) to study erosion processes. The results of such experiments measure only the effects of raindrop impact and not the combined effects of raindrop impact, overland flow, and rilling as estimated by RUSLE. Consequently, these data should not be used as factor-inputs to RUSLE equations. For example, it sometimes has been assumed that RUSLE soil erodibilities (K factor) are proportional to soil erodibilities measured on short plots. However, research has demonstrated conclusively that this assumption is seriously flawed; the values are not proportional (Truman and Bradford, 1995; Bradford and Huang, 1993; Meyer and Harmon, 1992).

Erosion on mined lands, construction sites, and reclaimed lands has been an important research focus for the past twenty-five years (at least five years prior to the enactment of the Surface Mining Control and Reclamation Act (SMCRA) of 1977). **Table 1-1** contains a sample of the noteworthy contributions. Discussion of this literature can be found in Toy and Hadley (1987).

Development of RUSLE

Cook's (1939) noteworthy work defined the major variables governing erosion processes and set the general structure for subsequent erosion-prediction equations. Most of the early equations resulted from regional analyses of plot data from experiment stations collected during the pre-World War II era. Because each location has site-specific soils and climate conditions, the early equations were restricted in their area of development.

Table 1-1. Sample of Literature Pertaining to the Erosion of Disturbed Lands

	Reference	Topic
Mining	Curtis and Superfesky, 1977	Erosion of mine spoils
	Gilley et al., 1977	Runoff and erosion from surface-mined sites
	Lang et al., 1983	Interrill erosion and mine-soil erodibility
	Mitchell et al., 1983	Erodibility of reclaimed surface mined soils
	Khanbilvardi et al., 1983	Erosion and deposition on mined and reclaimed areas
	Barfield et al., 1983	Applied hydrology for disturbed lands
	Toy, 1989	Reclamation assessment based on erosion rates
Construction	Diseker and McGinnis, 1967	Erosion from roadbanks
	Swanson et al., 1967	Protecting construction slopes from erosion

	Meyer et al., 1971	Erosion and runoff from construction sites
	Wischmeier et al., 1971	Soil erodibility on farm and construction sites
	Meyer et al., 1972	Mulches for construction site erosion control
	Wischmeier and Meyer, 1973	Soil erodibility on construction areas
	Israelsen et al., 1980	Erosion control during highway construction

At a 1946 workshop of SCS employees in Cincinnati, Ohio, the "slope-practice equation" devised by Zingg (1940) for farm planning in the Cornbelt States was expanded by adding a rainfall factor that facilitated the extension of the evolving technology to more diverse geographic conditions. The resulting "Musgrave Equation" (Musgrave, 1947) was widely used for estimating gross erosion from large, heterogeneous watersheds, and for flood abatement programs, whereas regional equations continued to be used to estimate soil loss from croplands.

Smith and Whitt (1948) presented a "rational" erosion-estimation equation for most soils encountered in Missouri that was very similar in structure to the USLE. During the early 1950s came the realization that the regional equations were inadequate and a standard methodology for soil-loss estimation was desirable. Thus, the National Runoff and Soil-Loss Data Center was established by the USDA, Agricultural Research Service (ARS), at Purdue University in 1954 under the direction of W. H. Wischmeier to assemble a comprehensive soil-loss data-base. These data were used in the development of the original USLE (Wischmeier and Smith, 1965, 1978). This is how Wischmeier (1972) explained the choice of the term "universal":

> "The name 'universal soil loss equation' is a means of distinguishing this prediction model from the highly regionalized models that preceded it. None of its factors utilizes a reference point that has direct geographic orientation. In the sense of the intended functions of the equation's six factors, the model should have universal validity. However, its application is limited to States and countries where information is available for local evaluation of the equation's individual factors."

In the early 1980s, the United States Department of Agriculture (USDA) used the USLE and field-collected data from more than a million sample points to estimate soil loss from all non-Federal lands throughout the United States. Based upon this analysis, a new policy was developed by the United States Congress that, in effect, required farmers to participate in there-to-fore voluntary soil conservation programs if they also were to participate in certain other government support programs (e.g. U. S. Congress, 1985). The SCS realized that improved erosion-prediction technology would be needed to implement this policy and requested an overhaul of the USLE.

RUSLE resulted from a 1985 workshop of government agency and university soil-erosion scientists. The workshop participants concluded that the USLE should be updated to incorporate the considerable amount of erosion information that had accumulated since the publication of Agriculture Handbook 537 (hereafter AH-537; Wischmeier and Smith, 1978) and to specifically address the application of the USLE to land uses other than agriculture. This effort resulted in the computerized technology of RUSLE as fully described in Agriculture Handbook 703 (hereafter AH-703, Renard et al., 1997).

The RUSLE Improvements

The development of RUSLE included several USLE modifications of importance to mined lands, construction sites, and reclaimed land applications. The climate data set in the CITY files was greatly expanded to include weather bureau stations at many more locations. The K factor was modified to account for the variability of soil erodibility during the year. Both the K and C factors now take into account the multivariate influence of rock-fragment covers within soil profiles and fragments resting upon hillslope surfaces. The equations used to estimate the LS factor were reconstituted to improve their accuracy and extended to include steeper hillslope gradients than the equations contained in the USLE. The method of determining C factor values was modified using a sub-factor approach that incorporates input values describing the main features of a cover-management system as it influences soil-loss rates. Consequently, RUSLE now can be applied to many more field conditions, and provides much more site-specific C values than does the USLE. New process-based equations were developed to estimate P values, overcoming a major limitation of the USLE. These equations accommodate a wide range of site-specific practice conditions and can estimate sediment yield for concave hillslopes.

Collectively, every factor included in the USLE and its supporting data was re-examined in the development of RUSLE. The new information compiled since 1978 was analyzed in the development of RUSLE. In every way, RUSLE is an improved erosion-estimation technology. Although perhaps convenient, the USLE no longer should be used for soil-loss estimation, as RUSLE estimates better reflect the actual field conditions.

Application of RUSLE to Mined Lands, Construction Sites, and Reclaimed Lands

Although originally developed for croplands, the USLE was used to estimate soil losses from lands disturbed by various other human activities, (i.e. disturbed forest sites, rangelands, military training sites, sanitary land fills, hazardous-waste disposal sites, surface-mined lands, and construction sites). Shown et al. (1981, 1982) stated that the equation appeared to be the best available method for evaluating soil loss from hillslopes in mined and reclaimed areas based upon studies in the disparate environments of Alabama and New Mexico. Recent refinements enhance the utility of RUSLE for soil-loss estimation from mined lands, construction sites, and reclaimed lands. For example, Peabody Western Coal Company uses RUSLE in the design of the surface-stabilization plans at its coal-mine properties in Arizona. Computer programs that used the USLE to assist in the selection of erosion-control products for hillslopes at construction sites are in the process of converting to RUSLE.

RUSLE typically is used to estimate the severity of soil loss and sediment yield from disturbed-land surfaces and to select appropriate on-site erosion-control strategies. These strategies are designed to protect soil resources so that their quality and quantity are maintained over the long-term, to provide short-term erosion control while the long-term erosion-control measures become established, and to minimize off-site sediment discharges into streams and reservoirs. RUSLE may be used as a part of the procedures to assess long-term reclamation success.

RUSLE is a very powerful tool that can be used to estimate soil loss under a wide variety of site-specific conditions. All models or equations developed to estimate the rates of geomorphic processes, including RUSLE, possess limitations. It is important to respect these limitations. Wischmeier (1976) discussed the limitations of the USLE; these generally apply to RUSLE as well: (1) RUSLE provides soil-loss estimates rather than absolute soil-loss data, (2) the soil-loss estimates are long-term average rates rather than precipitation-event-specific estimates, (3) there are hillslope-length and gradient limits for which the component RUSLE equations have been verified, (4) RUSLE does not produce watershed-scale sediment yields and it is inappropriate to input average watershed values for the computation of the RUSLE factors, and (5) utilization of RUSLE in geographic areas beyond its verification does not necessarily constitute a misuse, but caution is certainly warranted. Further discussion of the proper application of RUSLE is provided in the subsequent chapters of these guidelines.

There remains the opportunity to misuse RUSLE, especially by those without a thorough understanding of erosion processes and the RUSLE program. Many "help" screens are included within the RUSLE program that should be routinely consulted (by using the F-1 key).

It is the user's responsibility to ensure that RUSLE is applied to appropriate soil-loss problems, that inputs for the calculation of factor values accurately represent site conditions, and that interpretations of the soil-loss estimates consider the uncertainties associated with any estimating procedure. Therefore, users are expected to be familiar with AH-703 (Renard et al., 1997) that provides the scientific and technical background of RUSLE, the RUSLE User's Manual (Soil and Water Conservation Society 1993), and these guidelines specific to RUSLE application on mined lands, construction sites, and reclaimed lands.

Purposes of these Guidelines

These guidelines are based upon the premise that RUSLE will be used for estimating soil loss from mined lands, construction sites, and reclaimed lands during future years, just as the USLE was used in the past. It is the intention of these guidelines to: (1) provide guidance for maximizing the accuracy of soil-loss estimates from mined lands, construction sites, and reclaimed lands when using RUSLE, (2) recommend procedures so that soil-loss estimates are generally reproducible, and (3) identify critical areas for future research. The recommended field and laboratory procedures for the acquisition of RUSLE-input data from mined lands, construction sites, and reclaimed lands are intended to supplement the directives contained in AH-703 (Renard et al. 1997).

Structure of the Guidelines

These guidelines are divided into two parts. The first part is a discussion of each RUSLE factor in relation to mined lands, construction sites, and reclaimed lands. The concepts underlying each factor, the specific issues pertaining to lands disturbed by the aforementioned activities, the recommended field and laboratory methods, as well as other relevant information, is presented. The intent is to provide a background for the prudent use of RUSLE.

The second part is a discussion of RUSLE applications for soil-loss estimates on mined lands, construction sites, and reclaimed lands. Research design, organization of data inputs, interpretation and use of soil-loss estimates for erosion-control planning, and limitations of the RUSLE technology are presented by means of examples. The intent is to demonstrate the proper procedures for maximizing the accuracy and reproducibility of RUSLE soil-loss estimates, thereby minimizing the misuse of RUSLE.

Methods of Investigation

A working group was assembled by The Office of Technology Transfer (OTT), Western Regional Coordinating Center (WRCC), Office of Surface Mining (OSM), U.S. Department of Interior (DOI), to examine the appropriate utilization of the RUSLE technology for the estimation of soil-losses from mined land, construction sites, and reclaimed lands. The members of the working group were chosen by the OTT to include persons experienced in: (1) the development and use of RUSLE, (2) the site conditions and erosion processes resulting from mining, construction, and reclamation activities, (3) research pertaining to, and measurement of, these processes, and (4) the regulation of these activities. Each representative in the working group was encouraged to communicate extensively with colleagues and associates to gain broad insights into the germane issues, and to identify available information sources.

The fundamental question asked was whether or not the site conditions resulting from mining, construction, and reclamation activities can be accommodated within the RUSLE technology. Accordingly, each RUSLE factor was examined carefully in relation to the surface characteristics produced by these activities. For example, the processes by which precipitation produces rainsplash, runoff, and erosion from agricultural, mining, construction, and reclamation activities were compared. The validity of the nomograph approach for estimating the K values of topsoils that have been salvaged, stockpiled, redistributed, and developed into a seedbed was assessed. The use of the nomograph for estimating the K values of very coarse-textured "mine-soil," "growth-medium," or "soil-substitutes" was considered. The validity of the tables for estimating the LS factor of long and steep hillslopes, as sometimes proposed for site reclamation, was evaluated. The validity of the sub-factor approach for estimating C values was appraised. Appropriate C values for native-plant species and various mulches of natural and artificial materials were considered. The effects of management and support practices used on agricultural, mined, construction, and reclaimed lands were compared.

A determined effort was made to characterize the special site conditions resulting from mining, construction, and reclamation activities, and to critically examine the extent to which these conditions are accommodated within the RUSLE technology.

The forthcoming conclusions and recommendations were developed following a review of the available research reports, the re-assessment of the available data, and extensive discussions of the RUSLE technology, from both general and factor-specific perspectives, based upon the experiences of the working group members. Resources did not permit validation or calibration of the RUSLE model on mined lands, construction sites, and reclaimed lands. However, we are confident that the guidelines offered herein support the best use of the RUSLE technology as it presently exists. Future research will further enhance the utilization of RUSLE on mined lands, construction sites, and reclaimed lands.

CHAPTER TWO

R factor -- Rainfall/Runoff Erosivity

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Analyses of data indicated that when factors other than rainfall are held constant, soil loss is directly proportional to a rainfall factor composed of total storm kinetic energy (E) times the maximum 30-min intensity (I_{30}) (Wischmeier and Smith, 1958). The numerical value of R is the average annual sum of EI_{30} for storm events during a rainfall record of at least 22 years. Details for the calculation of R values are given in AH-703 (Renard et al., 1997; Chapter 2 and Appendix B). Individual calculations of R values were made for almost 200 stations in the Eastern United States and more than a thousand locations in the Western United States to account for climate variability due to mountains. The point values of R then were plotted on maps and contouring principles applied to construct "isoerodent" maps for all States in the conterminous United States, plus Hawaii.

Special Case: For the erosion induced by melting snow, rain on snow, and thawing soils, a procedure was developed to compute the R_{eq} (Equivalent R) as explained later in this chapter.

CITY Code Files

In RUSLE, climate data for numerous locations are stored in the CITY Database files. To select an appropriate R value for a specific location at which a soil-loss calculation is to be made, the RUSLE user must: (1) determine if a CITY Database is available for the site, or its immediate vicinity, or if not, (2) develop a database using the procedures described in AH-703. The United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) has many CITY Database files for each State in addition to those provided in RUSLE. Users of RUSLE should consult with local or State personnel of the NRCS concerning data available for an area of interest.

CITY (CLIMATE) Database

The CITY Database file contains numerous types of data as shown in **Figure 2-1.** Explanations follow for the Tombstone, Arizona data screen.

Identifier Information

A unique number is assigned to each location in the CITY file. For example, the first or first two digits represent the state location in the alphabetical array. Thus, "1" represents files from Alabama, 3" from Arizona, and "50" represents files from Wyoming. The three digit number following the State code represents the climate-gage number within the State. Thus, 999 gages can be identified and stored for any state. The city name and State abbreviation are for identification purpose only.

```
                    File        Exit        Help        Screen
+-------------------< Create/Edit City Database Set 1.06 >-----------------------+

      city code: 3004          city: TOMBSTONE___________      state: AZ
        total P: 14.1"   EI curve #: 71      Freeze-Free days/year: 237
  elevation(ft): 4540      10 yr EI: 62                   R factor: 65
 --- Mean P(") ---------- Tav (deg. F) --------------- %EI --------- %EI -------
       1: 0.86            1: 47.1                   1: 0          13: 9.1
       2: 0.82            2: 49.8                   2: 0.7        14: 18.5
       3: 0.61            3: 54.4                   3: 1.2        15: 40.6
       4: 0.29            4: 61.7                   4: 1.6        16: 59.7
       5: 0.2             5: 69.2                   5: 2.1        17: 74
       6: 0.51            6: 78                     6: 2.8        18: 86.3
       7: 3.68            7: 79                     7: 3.3        19: 91.7
       8: 3.5             8: 76.8                   8: 3.6        20: 94.7
       9: 1.53            9: 74                     9: 4          21: 96
      10: 0.64           10: 65.4                  10: 4.5        22: 96.7
      11: 0.63           11: 54.7                  11: 5.6        23: 97.3
      12: 0.87           12: 47.3                  12: 6.5        24: 98.8


+------------------< F7 Saves, Esc Returns to CITY Main Menu >------------------+
Tab  Esc F1   F2  F7   F9   Del
FUNC esc help clr save info del
```

Figure 2-1. CITY CODE Database file for station 3004, Tombstone, AZ.

Total Precipitation

As the title implies, the total precipitation is the sum of the monthly-precipitation depth (in inches) for the 12 entries shown under the column heading "Mean P". Changing any of the individual monthly values automatically changes the annual total.

EI Curve Number

The spatial variability of EI distribution zones within the contiguous United States is shown in AH-703 (**Figure 2**-7). The identifying code from **Figure 2-7** automatically identifies the percentage of the annual EI_{30} value occurring between the first and 15th day or the 16th and last day of a particular month. The 24 semi-monthly values are then automatically inserted in the appropriate position (% EI) of the CITY file. These values are used in weighting of the soil erodibility (K) value and in the weighting of soil-loss ratios (SLRs) used to calculate the seasonally-weighted K and C values as discussed in forthcoming chapters. Soil-loss ratios represent the temporal distribution of the cover-management factor used in estimating soil loss.

Freeze-Free days per year

The freeze-free days number indicates the continuous period (days) for which the minimum temperature is above freezing (32 degrees F). This information is used for determining the seasonal distribution of soil erodibility (K) in the Eastern U.S. Soil erodibility also varies seasonally in the Western U.S., but the diverse topography and climate of this region has precluded the development of satisfactory relationship upon which to base soil-erodibility adjustments. The freeze-free data were obtained from U.S. Department of Commerce, Environmental Science Service Administration, 1968.

Elevation

Although this information is not used directly in the calculations performed within RUSLE, the information often is valuable in Basin and Range physiographic provinces of the Western United States. For example, most National Weather Service (NWS) gages and the data used to calculate R are located near airports and cities in valleys that often receive less precipitation than received at higher elevations. So, where no rainfall data are available to compute the R value by standard methods, an estimate of R may be made based on the difference in elevation using the relation below:

$$R_{new} = R_{base} (P_{new}/P_{base})^{1.75} \qquad (2\text{-}1)$$

where: R_{new} = the new value for R at the desired new location when an R value is not available from a map,
R_{base} = R value at a base location where R is known (hopefully in the same general vicinity),
P_{new} = the average annual precipitation at the new location, and
P_{base} = the average annual precipitation at the base location.

A value for the average annual precipitation at the new location may not be known. An estimate of this precipitation amount can be obtained based upon a comparison of vegetative conditions at the new site and at the base location. Another way to estimate the precipitation at the new location is to adjust for the difference in elevation. As a very approximate estimate, an increase of between 2 and 3 inches of precipitation can be assumed for each 1,000 feet increase in elevation.

Similar topographic coefficients might be used to adjust the monthly precipitation and temperature data based on adiabatic temperature-elevation relations. Care must be taken using all such procedures to ensure that results seem reasonable in relation to the vegetation community at the new location. When sufficient meteorological data are accumulated at the new site, after several years that include relatively "normal" climatic conditions, the R value should be calculated using the procedures described in AH-703.

10 year frequency EI data

These data represent the single-storm maximum EI having a recurrence frequency of once in 10 years, or a 10% probability of occurring in any given year (**Figures 2-9 through Figure 2-12** of AH-703). This information is used in RUSLE to estimate a storm-rainfall depth (design storm) for the calculation of the conservation support practices (P) value, discussed in Chapter 6. The equation used is:

$$V_r = 0.255\,[(EI)_{10}]^{0.662} \qquad [6\text{-}6]\ \ (2\text{-}2)$$

where:

V_r = rainfall depth in inches.

Rainfall depth is used in the NRCS runoff-curve number method to estimate a runoff volume. This methodology is described in detail in most hydrology textbooks (e.g. American Society of Civil Engineers, 1996). Runoff-curve numbers for various climatic areas and management practices in the United States are used to convert these precipitation depths to runoff volumes and peak discharges. The runoff data are then used with fundamental sediment-transport relations to simulate the effect of conservation support practices. Although the calculations are somewhat complicated, RUSLE executes the necessary computations using specified inputs.

[ ] refers to an equation from AH-703.
( ) refers to an equation in these Guidelines.

R factor

The R-factor value is used directly in the soil-loss calculation. It is the first entry in the "Soil Loss and Sediment Yield Computation Worksheet" of RUSLE. These values were computed from recording-gage precipitation records using the mathematical relation:

$$\boldsymbol{R} = \frac{1}{n} \sum_{j=i}^{n} \left[\sum_{k=1}^{m} (E)\ (I_{30})_r \right] \qquad \text{[B-1]} \quad \text{(2-3)}$$

Where:

E = total storm kinetic energy
I_{30} = maximum 30-min rainfall intensity
j = index of number of years used to produce the average
k = index of number of storms in a year
n = number of yrs used to obtain average R (22 yrs minimum preferred)
m = number of storms in each year, and
R = average annual rainfall erosivity

This equation shows that the annual R factor is calculated by summing the product of the storm kinetic energy times the maximum 30-min intensity for each storm occurring in an "n" year period as depicted in Equation 2-4. The EI interactance term is closely related to soil loss (Wischmeier and Smith, 1958).

$$EI = (E)\ (I_{30}) = \left[\sum_{k=1}^{m} e_r \Delta V_r \right] I_{30} \qquad \text{[B-2]} \quad \text{(2-4)}$$

Where:

e_r = rainfall energy per unit depth of rainfall per unit area $ft \cdot tonf \cdot acre^{-1} \cdot in^{-1}$
ΔV_r = depth of rainfall (in) for the rth increment of the storm hyetograph which is divided into m parts, each with essentially constant rainfall intensity ($in \cdot h^{-1}$).

Equation 2-5 is used to compute the kinetic energy for each uniform increment of rainfall depth as recorded on the analog trace of a recording rain gage. When multiplied times the maximum depth of rain occurring in the storm time-depth record, it results in the estimate of storm energy and intensity (EI). The unit energy, e_r, is a function of rainfall intensity and is computed as:

$$e_r = 1099\ [1-0.72^{(-1.27 i_r)}]$$

[B-3] (2-5)

and

$$i_r = >V_r / > t_r$$

Where:

$^{a}t_r$ = duration of the increment over which rainfall intensity is considered to be constant (h), and
i_r = rainfall intensity ($in \cdot h^{-1}$)

Finally, the EI for a specified time period (such as the annual value) is the sum of the computed value for all rain periods within that time. Thus, for ease of computation:

$$\boldsymbol{R} = 3\ E\ I_{\mathbf{30}}\ (10^{-2})$$

Where:

R = average annual rainfall erosivity with the units: hundreds of $ft \cdot tonf \cdot in \cdot acre^{-1} \cdot h^{-1} \cdot yr^{-1}$

The calculation of $R = S\ E \cdot I_{30}$ is time consuming and laborious. Use of published values is encouraged. where possible (e.g. using the values provided in RUSLE, AH-703, or provided by NRCS).

Average monthly temperature

Average monthly temperatures (degrees Fahrenheit) are obtained from NWS records. These data, along with the mean monthly precipitation data, are used in the estimation of (organic) residue decomposition in the determination of cover-management

(C) values. Because residue amounts are one of the most influential parameters affecting soil loss, these data are important and soil-loss prediction is very sensitive to this value.

Special Erosion Situations

Ponded Water and Splash Erosion Reduction -- RUSLE can account for the reduction of rainfall erosivity due to ponded water. The ponded water absorbs raindrop energy. RUSLE will compute a reduced R value based on hillslope gradient and the 10-yr frequency EI. The effect of ponding is greatest on very flat hillslopes where rainfall erosivity is very large. The ponding option should not be chosen if the surface is ridged or rough so that more than half of the soil projects above the water line and is directly exposed to raindrop impact.

Erosion Resulting from Snowmelt, Rain on Snow, and Thawing Soil -- For climate and soil conditions in the northwestern part of the United States, a modified R-factor value is used for soil-loss estimation and is called R_{eq}. The pertinent geographic area includes eastern Washington, north-central Oregon, northern Idaho, southeastern Idaho, southwestern Montana, western Wyoming, northwestern Utah, and northwestern Colorado. In this region, soil erosion on cropland, mined land, construction sites, and reclaimed land frequently is dominated by Spring events. Many of the events involve rainfall and/or snowmelt on thawing soils. The thawing soil remains quite wet above the frost layer and is highly erodible until the frost layer thaws, to allow draining and soil consolidation. The frost layer near the surface limits infiltration and creates a super-saturated moisture condition causing almost all rainfall and snowmelt to become runoff. For these conditions, the R_{eq} value is used. If the land has not been disturbed within the last seven years or so, the standard R value should be appropriate. A linear interpolation is used to estimate the R value for the intervening years between soil disturbance and soil consolidation. For areas where the annual precipitation is greater than 7.5 inches, R_{eq} may be estimated as a function of precipitation (P) by means of the relation:

$$R_{eq} = -48.4 + 7.78\ P \qquad (2\text{-}7)$$

Whenever precipitation is less than 7.5 inches:

$$R_{eq} = \text{the standard R calculated by means of Equation 2-3.} \qquad (2\text{-}8)$$

When using the R_{eq} values in Washington, Idaho, Utah, Montana, Wyoming, and Colorado, it is suggested that the user consult with appropriate personnel at the appropriate State NRCS office.

Estimating R Factors from Limited Data -- In some circumstances, only annual precipitation totals are available to make estimates of the R factor. In such cases, RUSLE users are referred to Renard and Freimund (1994).

The procedure provided by Renard and Freimund (1994) for estimating R values from annual precipitation is to be used only as a last resort when there is no other alternative.

Summary

RUSLE requires the assembly of data from a variety of sources. However, most R factor data are available in AH-703, from the NRCS, or derived from published records of the NWS. A major problem in using RUSLE for soil-loss estimation in the intermountain area of the United States involves calculations of R values that reflect the orographic effects of the mountain ranges, snow accumulation (and its melting effect on erosion), effects of windward versus leeward sides of mountain ranges, as well as the effect of aspect on both snow accumulation and melting. Users of this guide will need to consider the effect of these circumstances on soil-loss estimates. Hence, conservative assumptions are warranted for soil-loss estimation and the selection and design of erosion-control practices.

CHAPTER THREE

K Factor: Soil Erodibility

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What K Represents

The soil-erodibility factor K represents: (1) susceptibility of soil or surface material to erosion, (2) transportability of the sediment, and (3) the amount and rate of runoff given a particular rainfall input, as measured under a standard condition. The standard condition is the unit plot, 72.6 ft long with a 9 percent gradient, maintained in continuous fallow, tilled up and down the hillslope. K values reflect the rate of soil loss per rainfall-runoff (R) erosion index [ton · acre · h(hundreds of acre · foot · tonf · in)$^{-1}$].   Hereafter, the term "**soil**" is used in the broad context to include true soils and other surface materials serving as a plant-growth medium, sometimes referred to as soil substitute, resoil material, or other such terms.

RUSLE requires an initial K value that is based on soil properties. This value is either hand-entered or computed using the soil-erodibility nomograph equations in RUSLE. For the eastern two-thirds of the United States, RUSLE then computes an adjusted K value based on the seasonal variation of climate.

When the soil properties are the same at two locations, the initial K is the same for both locations, but the adjusted K (the one used in the RUSLE soil-loss calculations) may be different between the two locations due to the differences in climate. Therefore, the RUSLE program should be used to compute the K value for each location rather than simply hand-entering an initial K value in the RUSLE "Soil Loss and Sediment Yield Computation Worksheet" screen.

Relationship of K Factor to Soil Properties

Fine-textured soils that are high in clay have low K values (about 0.05 to 0.15) because the particles are resistant to detachment. Coarse-textured soils, such as sandy soils, also have low K values (about 0.05 to 0.2) because of high infiltration resulting in low runoff even though these particles are easily detached. Medium-textured soils, such as a silt loam, have moderate K values (about 0.25 to 0.45) because they are moderately susceptible to particle detachment and they produce runoff at moderate rates. Soils having a high silt content are especially susceptible to erosion and have high K values, which can exceed 0.45

and can be as large as 0.65. Silt-size particles are easily detached and tend to crust, producing high rates and large volumes of runoff.

Organic matter in the soil reduces erodibility because it produces compounds that bind particles together, increasing aggregation and reducing the susceptibility of the particles to detachment by raindrop impact and surface runoff. Also, organic matter improves biological activity and increases infiltration rates, which reduces runoff and erosion. The K values published by the Natural Resources Conservation Service (NRCS), formerly Soil Conservation Service, (SCS) reflect "native" organic-matter levels, not organic matter levels that are the result of management activities, such as long-term no-till cultivation, or long-term additions of manure. The percent organic matter often is very low in disturbed soils. Coal is not considered organic matter in the context of the K factor.

Permeability of the soil profile affects K because it affects runoff rates. Soil structure affects K because it affects detachment and infiltration rates. Mineralogy has a significant effect on K for some soils, including subsoils. For example, soils dominated by kaolinite normally have greater permeability than those dominated by montmorillonite. Sodic soils seal quickly, causing the permeability to decrease.

When using the soil-erodibility nomograph for soils that seal, it is recommended that the permeability be lowered by one or two classes.

Determination of K values

Values of K for undisturbed soils should be selected from soil-survey information published by the NRCS. Values of K for disturbed soils should be computed using the soil-erodibility nomograph. Determination of any K value should be based on how a unit-plot placed on the given soil would behave over an extended period of at least 10 years. It should be kept in mind that the definition of a unit-plot includes annual tillage with a primary tool, such as a moldboard plow to a depth of about 8 inches, and periodic secondary tillage operations that break any surface crust and control weeds. Tillage operations typically disrupt a compacted zone immediately beneath the soil surface that might exist following the placement of the last lift of a fill operation.

The handling and management of soil material on mined lands, construction sites, and reclaimed lands often results in near-surface properties analogous to those of tilled agricultural soils for which the RUSLE K factor was developed. Differences in most soil properties, such as texture and organic-matter content, can be taken into account using the soil-erodibility nomograph.

After soil material is placed, deep ripping sometimes is used to alleviate soil compaction, improve water infiltration and transmission through the root zone, and enhance vegetation growth. The effects of deep ripping would be considered in the determination of a K value only if the effects of the deep ripping persist over a period of 10 years or longer.

Inputs to the soil-erodibility nomograph for undisturbed soils should be based on the long-term conditions of the near-surface soil and the soil profile that exists when the soil is managed in accordance with the unit-plot condition.

Vegetation growth, or any management operation that leaves the soil in a condition different from that of the unit-plot, is taken into account by the cover-management (C) factor, discussed in Chapter 5. It should be understood that the K value is independent of land use.

K-Factor Classes

The K values published by NRCS are based on classes. The classes are 0.02, 0.05, 0.10, 0.15, 0.17, 0.20, 0.24, 0.28, 0.32, 0.37, 0.43, 0.49, 0.55, 0.64. The range of these classes indicates the uncertainty associated with the K value for each class. For example, if a K value is 0.28, the next highest K value is 0.32, and the next lowest K value is 0.24, so the width of the class is 0.04. The uncertainty in K is therefore ±0.02 erodibility units which provides an indication of the certainty in soil erodibility for the RUSLE soil-loss estimate.

When using initial K values obtained from NRCS soil-survey information or other sources, it is necessary to determine whether or not these K values have already been adjusted for rock fragments. K values for the fine-earth fraction (K_f) obtained from NRCS data sources are based only on soil fines less than 2 mm in diameter and are unadjusted for the effect of rock fragments. K values for the whole soil (K_w), including all soil-particle sizes, have been adjusted for rock fragments.

Soil-erodibility Nomograph

K values usually are not available for the disturbed soils of mined lands, construction sites, or reclaimed lands. For those soils, a K value can be estimated using the soil-erodibility nomograph program in RUSLE, based on data obtained from soil samples and field observations by qualified soil scientists or engineers who have experience in the area. NRCS personnel can provide valuable advice.

From the "Soil Loss and Sediment Yield Computation Worksheet" screen, place the cursor on the K variable, then press *F4* to enter the *Seasonally Variable K Factor* program (**Figure 3-1**). To reach the screen used for entering inputs and displaying outputs (**Figure 3-2**), select K-factor option 1, *using Soil Interpretation Record/K-nomograph* by pressing *ENTER*. To reach the screen for the soil-erodibility nomograph (**Figure 3-3**), move the cursor to the *estimated K* and press *F4.*

The effect of rock fragments in the profile (discussed later in this chapter) can be accounted for in the soil-erodibility nomograph screen. Select *coarse fragment correction* Option 2 (**Figure 3-4**) on this screen.

The nomograph, though it is the most widely-used method for estimating K values, applies best to the medium-textured soils of the Midwest. It should not be employed beyond the limits which are programmed into the nomograph and discussed in Agricultural Handbook 703 (AH 703, Renard et al., 1997).

The nomograph also does not apply to soils of volcanic origin or organic soils, such as muck and peat. Results may be questioned for subsoils, Oxisols, low activity clay soils, calcareous soils, and soils high in mica.

```
       File        Exit        Help        Screen
+-------------------< Seasonally Variable K Factor 1.06 >----------------------+
¦        +---------------------------------------------------------+           ¦
¦        ¦ To calculate the seasonally variable K factor values    ¦           ¦
¦        ¦ for non-volcanic soils, an initial K factor value is    ¦           ¦
¦        ¦ estimated.  This value is obtained by using either      ¦           ¦
¦        ¦ the Soil Interpretation Record (SIR) or the nomograph.  ¦           ¦
¦        ¦ Option 1 continues with this procedure.                 ¦           ¦
¦        ¦ K factor values for volcanic soils in Hawaii            ¦           ¦
¦        ¦ may be obtained by using option 2.                      ¦           ¦
¦        +---------------------------------------------------------+           ¦
¦                                                                              ¦
¦            +-------------------------------------------------------+         ¦
¦            ¦     K factor options: 1                               ¦         ¦
¦            ¦-------------------------------------------------------¦         ¦
¦            ¦ -->   1. using Soil Interpretation Record/K-nomograph ¦         ¦
¦            ¦       2. for volcanic soils (Hawaii only)             ¦         ¦
¦            +-------------------------------------------------------+         ¦
¦                                                                              ¦
¦                                                                              ¦
¦                                                                              ¦
+---------------------------------< Esc exits >--------------------------------+
Tab  Esc F1   F3   F9   End
FUNC esc help cont info last
```

Figure 3-1. RUSLE screen for Seasonally Variable K Factor. This screen is entered from the Soil Loss and Sediment Yield Computation Worksheet screen by pressing *F4*. Two options for calculating K values are available on this screen.

```
       File        Exit        Help        Screen
+-------------------< Seasonally Variable K Factor 1.06 >----------------------+
¦     city code: 6001    DENVER              CO       estimated K: 0____       ¦
¦ % rock cover: 0     # yrs to consolidate: 17   hyd. group: 2                 ¦
¦ soil series:                    surface texture: silt loam                   ¦
¦                                                                              ¦
¦                                                                              ¦
¦                                                                              ¦
¦                                                                              ¦
¦                                                                              ¦
¦                                                                              ¦
¦                                                                              ¦
+--------------< F4 to calculate K Nomograph value, F3 when done >-------------+
Tab  Esc F1   F2  F3   F4   F9
FUNC esc help clr cont call info
```

Figure 3-2. RUSLE screen for entering inputs and displaying outputs for non-volcanic soils. This screen can be used for entering K values obtained from soil surveys or tables, or for calculating K values using the soil-erodibility nomograph.

```
       File        Exit        Help        Screen
+-------------------< Seasonally Variable K Factor 1.06 >----------------------+
¦   % of silt and very fine sand  (e.g. 66): 20                                ¦
¦                           % clay  (e.g. 17): 20                              ¦
¦           % of organic matter  (e.g. 2.8): 0.5                               ¦
¦                     soil structure code #: 4                                 ¦
¦                 soil permeability class #: 2                                 ¦
¦              coarse fragment correction #: 2                                 ¦
¦                                                                              ¦
¦                          +--------------------------------------------+      ¦
¦                          ¦       1. permeability already includes the ¦      ¦
¦                          ¦         effect of fragments in the soil    ¦      ¦
¦                          ¦         profile per NSH.                   ¦      ¦
¦                          ¦       2. the effect of fragments in the    ¦      ¦
¦                          ¦         soil profile on permeability will  ¦      ¦
¦                          ¦         be considered per Chapter 3, AH703.¦      ¦
¦                          +--------------------------------------------+      ¦
¦                                                                              ¦
¦                                                                              ¦
¦                                                                              ¦
¦                                                                              ¦
+---------------------------------< Esc exits >--------------------------------+
Tab  Esc F1   F2  F3   F6   F9
FUNC esc help clr cont list info
```

Figure 3-3. RUSLE screen for estimating K values using the soil-erodibility nomograph. To reach this screen, move the cursor to the *estimated K* input field and press *F4*. After inputs have been made, press *F3* to display the calculated K factor from the nomograph..

```
       File        Exit        Help        Screen
+-------------------< Seasonally Variable K Factor 1.06 >---------------------+
¦   % of silt and very fine sand  (e.g. 66): 20                               ¦
¦                              % clay  (e.g. 17): 20                          ¦
¦           % of organic matter  (e.g. 2.8): 0.5                              ¦
¦                     soil structure code #: 4                                ¦
¦                 soil permeability class #: 2                                ¦
¦              coarse fragment correction #: 2                                ¦
¦                                                                             ¦
¦                           +---------------------------------------------+   ¦
¦                           ¦       1. permeability already includes the ¦   ¦
¦                           ¦         effect of fragments in the soil    ¦   ¦
¦                           ¦         profile per NSH.                   ¦   ¦
¦                           ¦       2. the effect of fragments in the    ¦   ¦
¦                           ¦         soil profile on permeability will  ¦   ¦
¦                           ¦         be considered per Chapter 3, AH703.¦   ¦
¦                           +---------------------------------------------+   ¦
¦                                                                             ¦
¦                                                                             ¦
¦                                                                             ¦
¦                                                                             ¦
+---------------------------------< Esc exits >-------------------------------+
Tab  Esc F1   F2  F3   F6   F9
FUNC esc help clr cont list info
```

Figure 3-4. The effect of rock fragments in the soil profile can be accounted for on the soil-erodibility nomograph screen. Select coarse fragment correction option 2 on this screen. The effect of these rock fragments, when selecting Option 2, is to decrease permeability and may result in an increase in K values. Rock fragments are discussed later in this chapter with detailed documentation in Chapter 3 of AH-703.

Other Sources of K Values

Soils on lands that have been mined or subjected to construction and reclamation activities have been altered so that the K values in the NRCS soil surveys or databases are no longer applicable. Use the soil-erodibility nomograph to estimate the initial K for these conditions. Where K values are not available and the nomograph does not apply, other relationships may be useful for estimating K values of soils in disturbed areas. Special regression equations are available in AH-703 for specific soil conditions, such as the soils of the upper Midwest that are high in montmorillonite, for clay subsoil in the Midwest, and for volcanic soils in Hawaii, A program for calculating K values for volcanic soils in Hawaii is available in RUSLE (**Figure 3-5**). After *CALL*ing the K-factor routine, select option 2 *for volcanic soils for Hawaii*. Inputs can be made on the *Volcanic Soils K Factor* screen and the calculated K value is displayed by pressing *F3* (**Figure 3-6**).

```
       File        Exit        Help        Screen
+-------------------< Seasonally Variable K Factor 1.06 >---------------------+
¦        +---------------------------------------------------------+          ¦
¦        ¦ To calculate the seasonally variable K factor values    ¦          ¦
¦        ¦ for non-volcanic soils, an initial K factor value is    ¦          ¦
¦        ¦ estimated.  This value is obtained by using either      ¦          ¦
¦        ¦ the Soil Interpretation Record (SIR) or the nomograph.  ¦          ¦
¦        ¦ Option 1 continues with this procedure.                 ¦          ¦
¦        ¦ K factor values for volcanic soils in Hawaii            ¦          ¦
¦        ¦ may be obtained by using option 2.                      ¦          ¦
¦        +---------------------------------------------------------+          ¦
¦                                                                             ¦
¦            +-------------------------------------------------------+        ¦
¦            ¦     K factor options: 2                               ¦        ¦
¦            ¦-------------------------------------------------------¦        ¦
¦            ¦       1. using Soil Interpretation Record/K-nomograph¦        ¦
¦            ¦ -->   2. for volcanic soils (Hawaii only)             ¦        ¦
¦            +-------------------------------------------------------+        ¦
¦                                                                             ¦
¦                                                                             ¦
¦                                                                             ¦
+---------------------------------< Esc exits >-------------------------------+
Tab  Esc F1   F3   F9   Home
FUNC esc help cont info 1st
```

Figure 3-5. RUSLE screen for selecting K-factor option for volcanic soils in Hawaii.

```
       File        Exit        Help        Screen
+----------------------< Volcanic Soils K Factor 1.06 >-----------------------+
¦                                                                             ¦
¦                                                                             ¦
¦                    unstable aggregates (%): 10                              ¦
¦                        base saturation (%): 40                              ¦
¦                   silt-sized particles (%): 40                              ¦
¦                     sand > 100 microns (%): 5                               ¦
¦                         very fine sand (%): 10                              ¦
¦                                                                             ¦
¦                    +-------------------------------------+                  ¦
¦                    ¦ K Factor for volcanic soils: 0.108 ¦                  ¦
¦                    ¦                                     ¦                  ¦
¦                    ¦ (press Esc to dismiss)              ¦                  ¦
¦                    +-------------------------------------+                  ¦
¦                                                                             ¦
¦                                                                             ¦
¦                                                                             ¦
¦                                                                             ¦
+---------------------------------< Esc exits >-------------------------------+
Tab  Esc F1   F9
FUNC esc help info
```

Figure 3-6. RUSLE screen for volcanic soils in Hawaii, showing sample inputs and output. The calculated K-factor value for volcanic soils is displayed by pressing *F3*.

Examples of Measured K Values from Reclamation Sites

Data for the erodibility of spoils from 38 reclamation sites at the Black Mesa Mine Complex in northern Arizona (Peabody Western Coal Company, PWCC, 1995) indicate that K values for dominantly clay loam spoils range from 0.04 to 0.21, with a mean of 0.12. The volumetric rock fragment content for these sites ranged from 15 to 70 percent, with a mean of 40 percent. At another reclamation site, K values for dominantly very fine sandy loam, and sandy clay loam soils averaged 0.33, with 0 to 20 percent rock fragments. In comparison, K values for cultivated soils having these textures would generally fall in the range of 0.24 to 0.37.

In another study of K values from Appalachian coal mine spoil in Ohio, K values averaged 0.18 for undisturbed topsoil, and 0.12 for subsoil and resoil material (Warner, 1996). For a similar study in Kentucky, K values averaged 0.27 for undisturbed topsoil, 0.18 for recently placed spoil, and 0.19 for spoil after 6 months of weathering (Warner, 1997). Other examples can be found in the references cited in **Table 1-1** of Chapter 1.

During construction or reclamation, the soil-erodibility (K) value should represent the upper 6 inches of the final fill material re-spread as the last lift. When K values on construction sites or reclaimed lands are known to be low (K_f values <0.1), use the permeability portion of the nomograph, but do not use the structure portion. A general rule to follow on mined land and construction sites -- if a K value is 0.08 or less, use a value of 0.08.

Rock Fragments

Rock fragments are unattached pieces of rock 2 mm in diameter or larger that are strongly cemented or resistant to fracturing. Rock fragments can have a major effect on soil erosion. Rock fragments on the soil surface and in the soil profile require special considerations.

Only the effects of rock fragments within the soil profile are considered in the estimation of the K value. Rock fragments resting upon the soil surface that protect the soil from raindrop impact and runoff are taken into account in the Cover-management (C) factor.

Although the percent rock cover on the surface is entered on a screen in the K-factor program, the effect of those rocks in reducing soil-loss rates is computed in the C factor.

While soil scientists consider a rock fragment to be an unattached piece 2 mm in diameter or larger, the smallest of these rocks may not reduce runoff and erosion, especially on steep hillslopes. It is generally agreed that rocks with a diameter of 5 mm or larger will not move due to rainsplash or overland flow, even on steep and long hillslopes, and therefore do provide protection from runoff and erosion processes. Hence, the 5 mm diameter may be the appropriate size to use in estimating the percent rock fragment cover on hillslopes with gradients of 20% or more. The minimum fragment size that effectively reduces erosion rates in a particular situation requires careful consideration.

Effects of Rock Fragments in the Profile: Rock fragments in undisturbed soil tend to be small, and it is generally believed that their presence reduces the infiltration rate, increasing runoff and erosion rates. Research reported in AH-703 indicates that rocks in the profile of sandy soils tend to increase K factor values by reducing the permeability and increasing runoff, thus increasing erosion (increasing the K value). The adjustment in RUSLE for the effects of rock fragments in the soil profile is based on this research.

Rocks at mine reclamation and construction sites generally are large in size and volume. A soil-profile description from a typical mine reclamation site in northern Arizona is shown in **Table 3-1**.

Table 3-1. Typical pedon of a reclaimed mine soil in northern Arizona. The amount and size distribution of rock fragments is mentioned in each horizon in this soil profile description.

0-12 inches	Topsoil, brown (7.5YR 4/4, moist) sandy loam; moderate medium to coarse subangular blocky parting to moderate medium to coarse granular structure; friable; 5% gravel; many fine and very fine roots; gradual, smooth boundary.
12-24 inches	Topsoil, brown (7.5YR 4/4, moist) sandy loam; massive; 5% gravel; common fine and very fine, and few medium and coarse roots; abrupt, smooth boundary.
24-40 inches	Spoil, dark grayish brown (10YR 4/2, moist) and dark gray (10YR 4/1, moist) sandy clay loam; massive; few fine, medium, and coarse roots; firm; 25% gravel, 10% cobble, and 5% stone-sized rock fragments; clear, smooth boundary.
40-60 inches	Spoil, dark grayish brown (10YR 4/2, moist) and dark gray (10YR 4/1, moist) sandy clay loam; massive, firm; 25% gravel, 10% cobble, and 5% stone-size rock fragments; clear, smooth boundary.

Many soil scientists (USDA, SCS, National Soils Handbook, 1983) and mined-land reclamation experts agree that, in general, with high percentages of rock in the profile ($\geq$50-75% by volume) infiltration will increase and K values will decrease. However, insufficient data are available to document this premise.

The increase in infiltration due to coarse rock fragments in the soil profile depends on the properties of the topsoil and its thickness. If the topsoil controls infiltration, the amount of rock fragments in the underlying material will have little effect on infiltration and thus K values. The following recommendations can be used as a guide to account for rock fragments in the soil profile. These recommendations are based exclusively on experience and judgment.

For sandy soils, having K_f values (before adjusting for rock fragments) of less than 0.15, the user should adjust K values upward according to the K-factor program in RUSLE. For soils with K_f values of 0.15 or greater, the user should ignore the rock effects in the K factor. The RUSLE program does not make this adjustment automatically; the adjustment must be made external to the program by the user. In both instances, the user should include the percentage of rock cover on the soil surface in the C - factor calculation. This will reduce the RUSLE soil-loss estimate.

Temporal Variability in K

Soil erodibility varies during the year. In many areas where freeze-thaw conditions persist, erodibility tends to be high early in the spring, during and immediately following thawing, and during periods when moisture is above average for the soil. Values for K tend to be low in the fall, partially because the soil is drier than at other times and because biological activity is greater during the warm seasons than during the cold seasons. This variability is shown in **Figure 3-7**.

The adjustment of K values to account for temporal variability is applicable only in the eastern United States, generally east of the 105° W. longitude. The areas for which time-varying K should not be applied are shown in **Figure 3-5** of AH-703. Soil erodibility varies during the year in the western United States as well, but acceptable relationships have not yet been developed to describe these variations due to the diverse and complex topography and its influence of climate conditions.

RUSLE computes K values that vary by "half-month" periods, as shown in **Figure 3-8**. These time-varying K values are computed using the published, or initial K value and climate information for the number of freeze-free days and temperature. The K value used in RUSLE to compute soil loss is the sum of the product of all half-month K values multiplied by each corresponding half-month EI value.

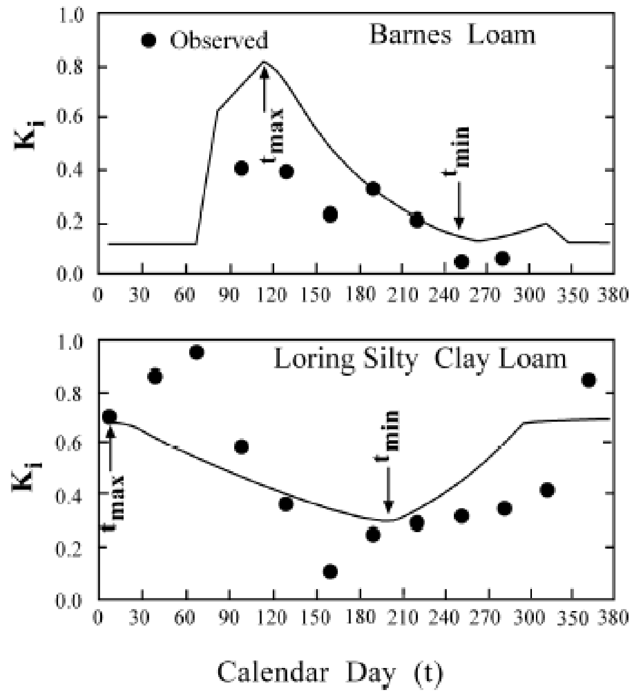

Figure 3-7. Seasonal variability of K is shown for the Barnes soil near Morris, MN and the Loring soil near Holly Springs, MS. Values for K_i tend to be high early in the spring and immediately following thawing, and during periods when soil moisture is above average. Values for K_i will be low in the fall if the soil is dry and undisturbed.

Soils on mine lands, construction sites, and reclaimed lands experience periods of vulnerability to erosion processes, both during freeze-thaw cycles and when soils are left bare. Keep sites covered with vegetation or mulch material whenever possible during these periods.

In addition to calculating the average annual K value adjusted for temporal variability, RUSLE also calculates the maximum and minimum K value (see **Figure 3-8**). The ratio of maximum to minimum K is computed as a function of rainfall-runoff erosivity, R. This ratio decreases as the R value increases. That is, RUSLE will compute a greater variation in K at locations where the R value is low than at locations where the R value is high.

The date when the maximum K value occurs also varies with R. In general, the date of maximum K is later in the year at locations having low R values. The date of minimum K is determined by adding the length of the freeze-free days to the date of the maximum K.

The dates and values for maximum and minimum K have important implications for erosion and sediment control on mined lands, construction sites, and reclaimed lands, because soil cover or lack thereof during these periods greatly affects erosion rates.

```
       File        Exit        Help        Screen
+------------------< Seasonally Variable K Factor 1.06 >----------------------+
¦     city code: 14001   EVANSVILLE           IN       estimated K: 0.28_     ¦
¦ % rock cover: 0     # yrs to consolidate: 17   hyd. group: 2                ¦
¦ soil series:                    surface texture: silt loam                  ¦
¦                                                                             ¦
¦  1/1-1/15        1.0      0.359     ¦  7/1-7/15          7.0       0.193    ¦
¦  1/16-1/31       2.0      0.411     ¦  7/16-7/31         7.0       0.17     ¦
¦  2/1-2/15        3.0      0.475     ¦  8/1-8/15          7.0       0.148    ¦
¦  2/16-2/28       3.0      0.544     ¦  8/16-8/31         6.0       0.13     ¦
¦  3/1-3/15        3.0      0.55      ¦  9/1-9/15          4.0       0.12     ¦
¦  3/16-3/31       4.0      0.484     ¦  9/16-9/30         4.0       0.137    ¦
¦  4/1-4/15        5.0      0.422     ¦  10/1-10/15        3.0       0.157    ¦
¦  4/16-4/30       5.0      0.371     ¦  10/16-10/31       3.0       0.18     ¦
¦  5/1-5/15        5.0      0.326     ¦  11/1-11/15        2.0       0.208    ¦
¦  5/16-5/31       6.0      0.287     ¦  11/16-11/30       2.0       0.238    ¦
¦  6/1-6/15        6.0      0.25      ¦  12/1-12/15        2.0       0.272    ¦
¦  6/16-6/30       7.0      0.22      ¦  12/16-12/31       3.0       0.311    ¦
¦                                                                    -----    ¦
¦   EI DIST.: 105        FREEZE-FREE DAYS: 216    AVERAGE ANNUAL K:   0.27     ¦
¦    R VALUE: 200    Kmin = 0.117 on 9/5     Kmax = 0.56 on 3/6               ¦
+--------------------------------< Esc exits >--------------------------------+
Tab  Esc F1   F2  F3   F4   F9
FUNC esc help clr cont call info
```

Figure 3-8. RUSLE screen for displaying the seasonally variable K value. The initial K value (estimated K = 0.28) is entered in the upper right of this screen. The calculated seasonally variable K value (AVERAGE ANNUAL K = 0.27) is displayed in the lower right of the screen. The minimum (K_{min} = 0.12 on 9/5) and maximum (K_{max} = 0.56 on 3/6) K values are displayed on lower portion of the screen. The half-month periods and the corresponding EI and K values are also displayed.

Soil Properties Affecting Erosion Not Included in the K Factor

Rocks on the surface act as surface mulch, much like crop residue and plant litter. These surface covers reduce soil loss and are accounted for in the C factor. Increases in organic matter that are related to management activities, such as long-term cover of grass or other full vegetation, are also accounted for in the C factor. Finally, compaction or disturbance caused by machinery also is a management effect that must be accounted for in the C factor.

Do not adjust K values to account for rocks on the soil surface or increases in soil organic matter related to management activities. The effects of surface rock cover and management practices are taken into account by the Cover-management (C) factor discussed in Chapter 5.

CHAPTER FOUR

LS factor: Hillslope Length and Gradient

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K. G. Renard, T. J. Toy

The effect of topography on erosion is accounted for by the LS factor in RUSLE, which combines the effects of a hillslope-length factor, L, and a hillslope-gradient factor, S. Generally speaking, as hillslope length and/or hillslope gradient increase, soil loss increases. As hillslope length increases, total soil loss and soil loss per unit area increase due to the progressive accumulation of runoff in the downslope direction . As the hillslope gradient increases, the velocity and erosivity of runoff increases. The following sections of this chapter describe the effects of L and S on soil-loss rates, the interactions between L and S, and their combined effects on soil loss, and the ability of RUSLE to estimate soil loss from non-uniform, complex, hillslopes.

A RUSLE screen showing the LS estimate for a hillslope composed of two distinct profile segments is shown in **Figure 4-1**. The first segment at the top of the hillslope is 250 feet in length with a gradient of 3%, while the lower segment is 50 feet in length with a gradient of 33%. The first entry shows that this hillslope is composed of two segments. The next entry to the right shows that the lengths of the segments are measured horizontally rather than along the hillslope surface (in which case a 1 would have been the correct input). The second entry in the left column indicates that the segment lengths are not equal (versus an entry of 2 for segments of equal lengths). The third entry in this column indicates that the texture of the hillslope soil is "silt loam." The last entry in this column indicates that the soil surface is made of disturbed topsoil fill without a rock cover.

The use of soil texture and general land use in the computation of the LS value is a major change and improvement in RUSLE version 1.06 as compared with earlier versions. The effect of hillslope length on soil loss depends on the ratio of rill to interrill erosion on the hillslope. This ratio is a function of soil texture and general land use. Soils with a high percentage of silt (>85%) are assumed to have a high rill to interrill erosion ratio. Soils with a textural classification of silt loam are assumed to have a high to moderate rill to interrill erosion ratio. Soils with a high percentage of sand are assumed to have a moderate to low rill to interrill erosion ratio. Soils with a high percentage of clay (>35%) are assumed to have a low rill to interrill erosion ratio.

The general land use also is used to estimate the ratio of rill to interrill erosion Recently disturbed mine or construction lands are assumed to have a high rill to interrill erosion ratio. Croplands and disturbed forests are assumed to have a moderate rill to interrill erosion ratio. Land uses such as no-till cropland, pasture land, and range land that have not been recently disturbed by mechanical operations usually have a low rill to interrill erosion ratio because the soil exists in a consolidated condition, and consolidation is assumed to have a greater effect on rill erosion than interrill erosion.

Once the user has entered the information on the screen and pressed the *F3* key, RUSLE estimates the LS value. Thus, not only are the LS estimates for the two individual hillslope segments calculated, but a LS value for the entire hillslope is estimated for use in other parts of RUSLE. An equivalent hillslope gradient (that would result in the same LS estimate if the gradient was uniform for the entire 300 feet) is also estimated.

```
      File        Exit        Help        Screen
+-----------------------------< LS Factor 1.06 >--------------------------------+
|                                                                               |
|   number of segments: 2          segment lengths are measured: 2              |
|         segments are: 1                                                        |
|         soil texture: silt loam                                                |
|     general land use: 8                                                        |
|-------------------------------------------------------------------------------|
|                               1        2                                       |
| Gradient (%) of Segment     3       33                                        |
| Length of Segment (ft)    250       50                                        |
| Segment LS               0.59      22.95                                      |
|----+-----------------------------------------------------------------+--------|
|    | overall LS = 4.32; equiv. slope = 14.2 %; horiz. length = 300 ft |        |
|    +-----------------------------------------------------------------+        |
|                                                                               |
|                                                                               |
+---------------------------------< Esc exits >--------------------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 4-1. LS-factor screen from the RUSLE program.

Hillslope-Length Factor (L)

The hillslope length factor, L, reflects the effect of hillslope length on soil loss. The L factor has a value of 1 for a unit plot 72.6 feet in length with a gradient of 9 percent. However, the L value is less than 1 for hillslope lengths less than 72.6 feet and greater than 1 for lengths greater than 72.6 feet.

If soil loss is entirely generated by interrill erosion, which is nearly always uniform along a hillslope, the L value will be 1 for all lengths. However, if the soil loss is generated entirely by rill erosion, the L value will increase linearly with length because rill erosion increases in the downslope direction as runoff accumulates. Soil loss is usually a combination of both interrill and rill erosion; L values remain nearly constant as hillslope lengths increase when interrill erosion predominates along hillslopes, or increase when rill erosion predominates.

When soil loss estimates are used for conservation planning and the protection of a soil resource, hillslope length is defined as the distance from the origin of the overland flow to a point along the hillslope profile where either the gradient decreases to the extent that soil deposition occurs, or where the overland flow becomes concentrated in a well-defined channel (AH-703, Renard et al., 1997). However, in the field this distance can be difficult to determine due to insufficient evidence to identify the place where overland flow begins upslope and insufficient evidence of the place where deposition begins downslope. Deposition occurring in micro-topographic depressions as a result of tillage or animal traffic along a hillslope is not the same as sedimentation in hillslope-ending depositional areas, and would not be considered in measuring the downslope terminus of the hillslope length.

The main areas of deposition that terminate hillslope length for RUSLE occur on concave hillslopes. This depositional area can be estimated from the following "rule of thumb": if no signs of deposition are present on a concave hillslope profile, it can be assumed that deposition begins where the gradient is one-half of the average gradient for the concave profile (Soil and Water Conservation Society, 1993).

For example, assume a concave hillslope decreases from 18 percent gradient at the upper end to a 2 percent gradient at the lower end. The average gradient is 10 percent, and one-half of the average gradient is 5 percent. Thus, deposition is assumed to begin at the location where the hillslope has flattened to a gradient of 5 percent, and this would mark the endpoint for this particular length segment. On the other hand, consider a concave hillslope that decreases from a gradient of 4 percent on the upper hillslope to a gradient of 2 percent on the lower end. In this case the average gradient is 3 percent and one-half of that is 1.5 percent. Because the gradient at the lower end of the hillslope profile (2 percent) is greater than the gradient where deposition would occur (1.5 percent), no deposition is assumed to take place on this hillslope. This latter example reinforces the fact the deposition does not always occur as a hillslope flattens.

When the RUSLE soil-loss values are used to estimate off-site sediment delivery, the hillslope length is measured from the origin of overland flow through the depositional area. The P factor, to be discussed in Chapter 6, is used to compute the amount of deposition and sediment from the hillslope.

Fortunately, however, estimated soil-loss values from RUSLE are not as sensitive to inaccurate estimates of hillslope length as they are to inaccurate estimates of hillslope gradient. In fact, differences in lengths of ±10 percent are not important for most hillslopes, especially flat gradients.

Diversion channels installed as part of a conservation-system design on mined lands or construction sites conduct water to an outlet for controlled drainage from the landscape. These diversions reduce hillslope length, thereby reducing soil loss, because hillslope length is measured from the place where overland flow begins to the beginning of the diversion on the hillside. However, if contouring alone is employed on the mined lands or construction sites, hillslope length is measured as though the contours do not exist. Contouring effects on soil loss are taken into account by the Support Practice, P factor, discussed in Chapter 6.

Terraces also reduce the influence of hillslope length on soil loss. **Figure 4-2** shows three possible terrace configurations. Outward-sloping terrace benches, such as that illustrated in **Figure 4-2A**, are constructed to increase hillslope stability. If the edge of the bench is very close to the contour, so that the overland flow continues across the bench without concentrating, the hillslope length extends from the place near the top of the hillslope where overland flow originates, across the bench, to the hillslope below. In this case, the hillslope consists of three segments included in the estimation of the LS value.

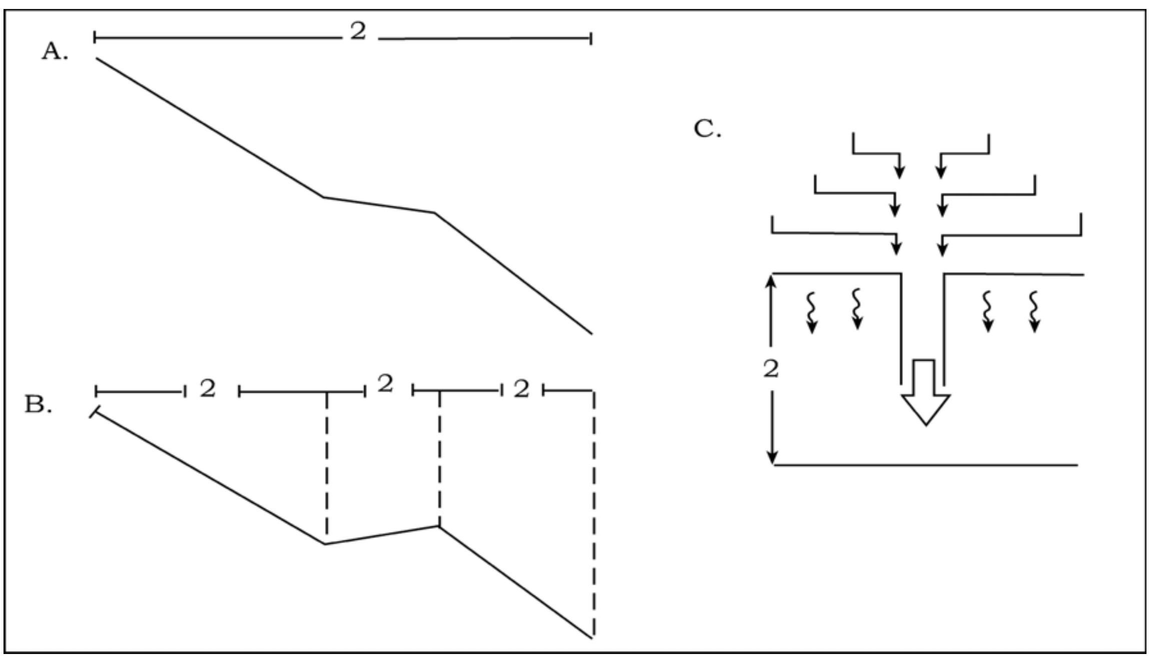


Figure 4-2. Effect of terraces on hillslope length

Back-sloping benches, such as that illustrated in **Figure 4-2B**, function as diversions, ending the hillslope length as described above. Three separate RUSLE analyses should be used to estimate soil loss from the hillslope depicted in **Figure 4-2B**.

Sometimes the berm along the front edge of a bench is uneven in height. The runoff collected behind the berm may be directed to several "breakovers" locations along the berm, concentrating the flow at these locations. In those areas of the hillslope where runoff is diverted, a new hillslope length begins below the diversion and extends to the bottom of the hillslope, as depicted in Figure **4-2C**.

The accuracy of estimates for the L value is the highest for hillslope lengths of 35 to 300 feet because most experimental-plot lengths occurred within these limits. However, the L value estimates for lengths from 20 to 50 and 300 to 600 feet are moderately accurate. Because the relationships for longer lengths have been extrapolated from shorter experimental-plot lengths, the accuracy of L values is probably poorest for lengths from 600 to 1000 feet. RUSLE should not be used to estimate soil loss from hillslope longer than 1000 feet.

Hillslope lengths usually do not exceed 400 feet under natural conditions. Overland flow usually becomes concentrated into concentrated flow paths or rills in less than 400 feet. Although natural hillslopes can occur that are longer than 1,000 feet under certain environmental conditions, RUSLE should not be used to estimate soil loss from hillslopes longer than 1000 feet, and indeed, the RUSLE program will not accept values for lengths that total more than 1000 feet.

The hillslope-length values used in RUSLE can be either horizontal measurements or measurements along the hillslope. In the field, it is easier and more accurate to measure length along the hillslope rather than horizontally, especially for longer hillslopes. Hillslope-segment data are entered into the RUSLE program from the top to the bottom of the hillslope profile as shown in the earlier example. For gradients of less than 20 percent (5:1), the difference between the calculated L value for lengths measured along the hillslope or measured horizontally is small. **Figure 4-3** illustrates some typical lengths in the field (AH-703).

Horizontal hillslope-length measurements can, in some cases, be obtained from topographic maps. However, because accuracy decreases as scale decreases, great care should be employed when taking length data from topographic maps with contour intervals greater than 2 feet. Usually, length is overestimated when topographic maps, such as USGS 7½ minute quadrangle maps (20-foot intervals), are used because the origin of the overland flow where the length should begin and especially concentrated flow areas or deposition area where length should be terminated are difficult to ascertain from such maps. One example where the USGS 7½-minute quadrangle maps with 20-foot contour intervals can be used with fair accuracy is a small concave watershed with a relatively straight, closely-spaced rill pattern on most of the hillslope profile and a flow pattern from the top to the bottom of the hillslope or to a flow concentration at the bottom of a swale (AH-703). Likewise, fair accuracy could be expected for similar topographic situations based on maps with 5 to 10-foot contour intervals.

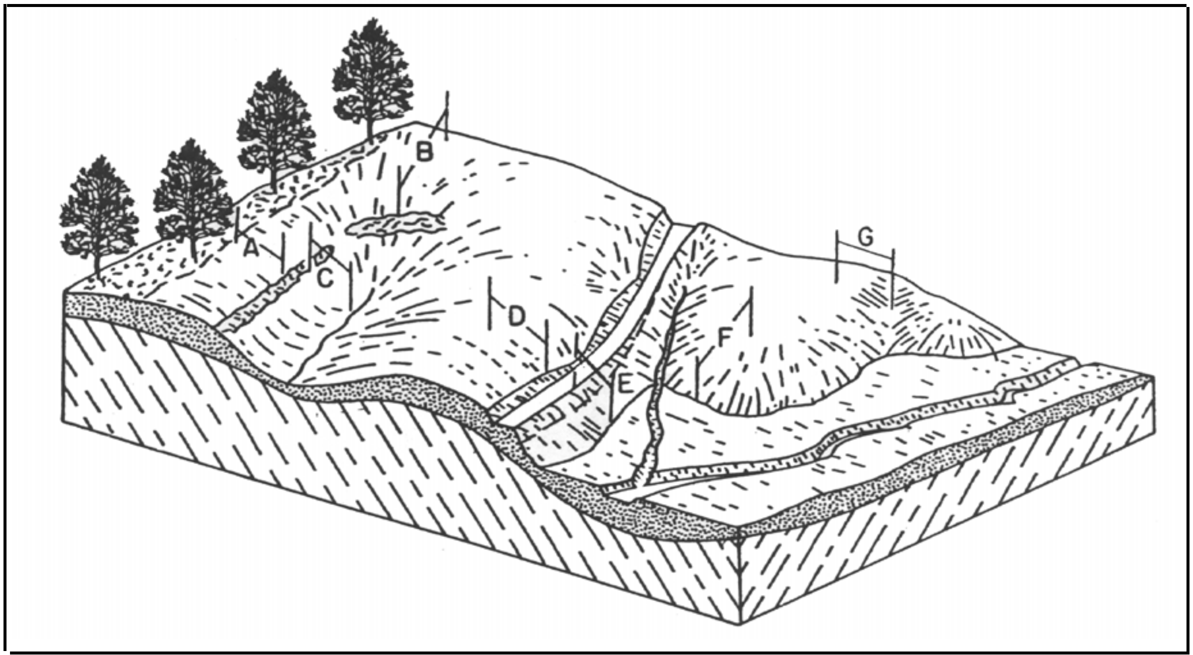


Figure 4-3. Typical hillslope lengths (Dissmeyer and Foster 1980). Hillslope A -- If undisturbed forest soil above does not yield surface runoff, the top of hillslope starts with edge of undisturbed forest soil and extends downslope to windrow if runoff is concentrated by windrow. Hillslope B -- Point of origin of runoff to windrow if runoff is concentrated by windrows. Hillslope C -- From windrow to flow concentration point. Hillslope D -- Point of origin of runoff to road that concentrates runoff. Hillslope E -- From road to flood plain where deposition would occur. Hillslope F -- On nose of hill, from point to origin of runoff to flood plain where deposition would occur. Hillslope G -- Point of origin of runoff to slight depression where runoff would concentrate

.

Hillslope-Gradient Factor (S)

The hillslope-gradient factor, S, reflects the effect of hillslope-profile gradient on soil loss. For a unit plot, with a 9 percent gradient as described earlier, the S value is equal to 1. The S values vary from above to below 1, depending on whether the gradient is greater than or less than that of the unit plot. Soil losses increase more rapidly as gradient increases than as length increases. Also, rill erosion is affected more by hillslope gradient than is interrill erosion.

The gradient of a hillslope profile is defined as the change in elevation per change in horizontal distance, expressed in percent. The gradient of a particular hillslope can be measured in the field using a rod and Abney or hand level, electronic survey level, or a GPS unit, at the same time that length is measured. Hillslope gradients may also be estimated from digital aerial surveys or specific site maps but, again, accuracy decreases as the map scale decreases.

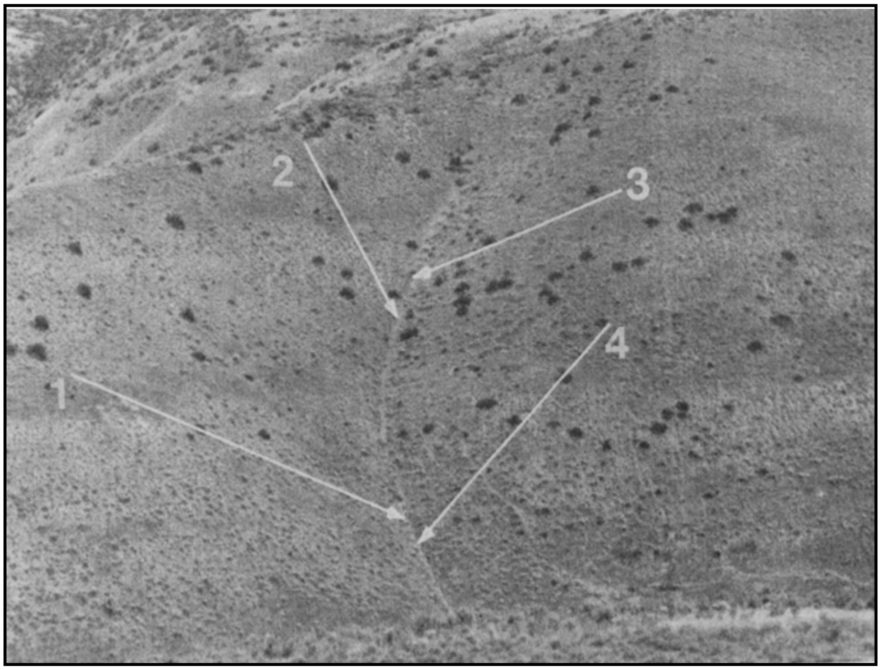
Accuracy of estimates for the S value is the highest for hillslope gradients from 3 to 20 percent. The accuracy is moderate for gradients of 1 to 3 and 20 to 35 percent. The accuracy of S is less for gradients exceeding 35 percent. Gravitational soil movement (such as slumps and slides) may be the dominant mode of soil loss when gradients exceed 50 percent (2:1).

Usually, the area of the field having the greatest potential erosion is where the hillslope gradient and S value are the greatest. This area is used to compute soil loss in order to estimate the highest probable rate. If an average soil-loss value is desired, soil loss should be estimated for several sites with varying lengths and gradients and a weighted average used to represent the soil loss from the area.

Interaction of Hillslope Length and Gradient

Within RUSLE, the hillslope length (L) and gradient (S) terms are combined into a single topographic factor (LS) representing the ratio of soil loss from a given hillslope length and gradient to soil loss from the unit plot (72.6 ft in length and 9 percent in gradient). Thus, LS values are not absolute values but are based upon a value of 1 for unit plot conditions (AH-703).

Individual values describing the hillslope length and gradient are entered into RUSLE, as shown earlier in **Figure 4-1**, and a single LS value is estimated for the hillslope profile. Examples of the LS calculations for hillslope segments of various lengths and gradients on small hillslopes in a rangeland watershed are shown in **Figure 4-4.**



Transect	Hillslope length (ft)	Hillslope steepness(s) (%)	LS
1	225	61	13.27
2	135	53	9.34
3	150	45	8.58
4	375	60	16.82

Figure 4-4. Examples of LS calculations hillslopes in a rangeland watershed.

It should be noted that an estimated LS value is used to describe a single hillslope profile within a landscape and does not apply to an entire watershed. Three-dimensional effects of hollows that concentrate overland flow, and spur-ends which disperse overland flow, require special consideration within RUSLE. If the average watershed soil loss is required, several representative combinations of RUSLE factors (including LS) should be used to estimate soil loss. Then, an areally-weighted average soil loss should be calculated outside of RUSLE based on the proportion of the watershed that each factor combination represents.

When entering the data for hillslope length and gradient, RUSLE requires the user to select one of several general land uses . The choices for disturbed lands assume that rill erosion is greater than interrill erosion for the surface and soil conditions. Hillslope length, therefore, is assumed to have a greater effect on soil loss than for undisturbed conditions where the topsoil is fully consolidated. Also, for disturbed sites, the effect of hillslope length on soil loss is influenced by the "cut" or "fill" nature of the surface material. A topsoil surface is assumed to be less susceptible to rill erosion than a subsoil of the same soil texture. Once the time since material placement and reclamation extends beyond the "years to consolidation" given in the estimation of the K-factor, discussed in Chapter 3, the land use should be considered as cropland, pastureland, or rangeland.

The proper choice of general land use is very important in the computation of accurate LS values by the RUSLE program. Research has shown that some graded spoil materials are highly erodible due to high bulk densities, crusting, and low porosities, resulting in low permeabilities and infiltration capacities (Gilley et al., 1977; Schroeder, 1987). **Table 4-1** illustrates the influences of land use and hillslope gradient on LS values for hillslopes of 100 and 600 ft lengths. As expected, LS values increase with increasing hillslope length and gradient. For short hillslopes (100 ft. or less), the LS values are similar for the three land uses, especially when the hillslope gradients are small. For long hillslopes (600 ft or more) of the sort often created by land-disturbing activities or included in reclamation plans, the differences in the LS values for the three land uses increase as the hillslope gradient increases. For a hillslope that is 600 ft in length and 20% in gradient, the LS value of disturbed land with subsoil fill is 14.1, while the LS value of pastureland is 6.23. Other factors being equal, the soil loss from the disturbed land would be more than twice (2.26 times) that of the pastureland. The influence of land use on LS values is greater for long hillslopes than for short hillslopes because of the greater downslope accumulation of runoff on long hillslopes than on short hillslopes.

Care must be taken in determining not only the most appropriate values entered for hillslope length and gradient, but also the appropriate land use. This is especially critical as hillslope lengths and gradients increase, as shown in Table 4-1.

Table 4-1. Hillslope length-gradient (LS) values for hillslopes of 100 and 600 ft lengths with various gradients and land uses.

Hillslope Length = 100 ft, silt loam soil	**Land Use**		
Slope Gradient (%)	**Disturbed Land, Subsoil Fill**	**Regularly Tilled Cropland**	**Pastureland**
0.5	0.088	0.086	0.085
1	0.15	0.14	0.14
3	0.41	.039	0.37
6	0.82	0.77	0.73
10	1.46	1.38	1.29

Slope Gradient (%)	Disturbed Land, Subsoil Fill	Regularly Tilled Cropland	Pastureland
15	2.25	2.38	2.22
20	3.57	3.39	3.16
30	5.59	5.32	4.96
50	9.15	8.74	8.16

Hillslope Length = 600 ft, silt loam soil	Land Use		
Slope Gradient (%)	**Disturbed Land, Subsoil Fill**	**Regularly Tilled Cropland**	**Pastureland**
0.5	0.12	0.099	0.090
1	0.24	0.19	0.16
3	0.98	0.66	0.48
6	2.47	1.64	1.09
10	5.04	3.38	2.17
15	9.49	6.53	4.12
20	14.1	9.91	6.23
30	23.4	16.9	10.6
50	40.4	29.9	19.1

Non-Uniform Hillslope Profiles

In many cases, hillslope profiles are complex, consisting of several segments of differing lengths, gradients, and shapes which necessitate special handling in the RUSLE program. RUSLE computes an LS value for non-uniform hillslope profiles by estimating an “effective LS value”. The hillslope profile is divided into segments of uniform length and gradient characteristics and each segment is entered into the program individually. Five segments often define the hillslope profile, although RUSLE will allow up to 10 segments.

The shape of the hillslope profile affects soil loss rates due to the changes in the length and gradient characteristics along the hillslope. This effect on soil loss, however, is not related to the proximity of the sediment-receiving channel. These various hillslope-profile forms are characterized as uniform, concave, convex, and complex (convex -

concave). Meyer and Romkens (1976) described the soil loss tendencies on these hillslope-profile forms in the following manner:

> "A convex slope is more erodible than a uniform slope, because it is steepest near the toe where runoff is greatest. A uniform slope will yield more sediment than a concave one, because the concave slope is steepest where the flow is least and because some of the sediment eroded from the upper portions of the concave slope may deposit as it flattens near the toe …. A complex slope that is convex along its upper portion and concave along its lower portion will generally yield less sediment than a uniform slope. A flat section at the toe of a slope will also reduce sediment yield."

The segment data are entered sequentially from the top to the bottom of the hillslope profile. As stated earlier, the total length of all the segments must not exceed 1000 feet.

Examples of LS-factor screens for uniform, convex, concave, and complex hillslope profiles are shown in **Figures 4-5 through 4-8**. All characteristics, with the exception of the gradients for the various segments, are the same for all profiles. The difference between hillslope-profile forms can be seen in the gradients entered for the 10 segments that define the particular hillslope-profile shape. As can be seen from the estimates of the LS values for these examples, all other factors being equal, the order of soil loss (from least to greatest) for these hillslope profiles is: complex < concave < uniform < convex. Although the construction of complex or concave hillslope profiles may offer grading challenges, these shapes can substantially reduce soil-loss rates.

These LS values emphasize the importance of correctly identifying the configuration of the hillslope profile in question. Accurate measurements of the field characteristics will produce the most accurate estimates of the LS value, especially for non-uniform hillslope profiles consisting of more than one segment.

```
       File        Exit        Help        Screen
+-----------------------------< LS Factor 1.06 >------------------------------+
|                                                                              |
|   number of segments: 10         segment lengths are measured:  2           |
|         segments are: 2          uniform segment length (ft) : 30           |
|         soil texture: silt loam                                              |
|     general land use: 6                                                      |
 -----------------------------------------------------------------------------
|                             1         2         3         4         5        |
|  Gradient (%) of Segment   11        11        11        11        11       |
|  Length of Segment (ft)    30        30        30        30        30       |
|  Segment LS              1.021     1.502     1.759     1.95      2.106      |
 -----+---------------------------------------------------------------+--------
|     | overall LS = 2.06; equiv. slope = 11 %; horiz. length = 300 ft|        |
 -----+---------------------------------------------------------------+--------
|                             6         7         8         9         10       |
|  Gradient (%) of Segment   11        11        11        11        11       |
|  Length of Segment (ft)    30        30        30        30        30       |
|  Segment LS              2.239     2.357     2.462     2.558     2.646      |
 -----------------------------------------------------------------------------
|                                                                              |
+----------------------------------< Esc exits >------------------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 4-5. LS values for a uniform hillslope profile.

```
       File        Exit        Help        Screen
+-----------------------------< LS Factor 1.06 >------------------------------+
|                                                                              |
|   number of segments: 10         segment lengths are measured:  2           |
|         segments are: 2          uniform segment length (ft) : 30           |
|         soil texture: silt loam                                              |
|     general land use: 6                                                      |
 -----------------------------------------------------------------------------
|                             1         2         3         4         5        |
|  Gradient (%) of Segment   11        11        11        11        11       |
|  Length of Segment (ft)    30        30        30        30        30       |
|  Segment LS              1.021     1.502     1.759     1.95      2.106      |
 -----------------------------------------------------------------------------
|     | overall LS = 2.06; equiv. slope = 11 %; horiz. length = 300 ft|        |
 -----------------------------------------------------------------------------
|                             6         7         8         9         10       |
|  Gradient (%) of Segment   11        11        11        11        11       |
|  Length of Segment (ft)    30        30        30        30        30       |
|  Segment LS              2.239     2.357     2.462     2.558     2.646      |
|                                                                              |
+----------------------------------< Esc exits >------------------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 4-6. LS values for a convex hillslope profile.

```
      File        Exit        Help        Screen
+-----------------------------< LS Factor 1.06 >------------------------------+

   number of segments: 10         segment lengths are measured:  2
         segments are: 2          uniform segment length (ft) : 30
         soil texture: silt loam
     general land use: 6
 -----------------------------------------------------------------------------
                            1         2         3         4         5
 Gradient (%) of Segment   20        18        16        14        12
 Length of Segment (ft)    30        30        30        30        30
 Segment LS               1.998     2.827     2.943     2.763     2.403
 ----+-----------------------------------------------------------------+-------

      overall LS = 1.84; equiv. slope = 10.1 %; horiz. length = 300 ft
 ----+-----------------------------------------------------------------+-------
                            6         7         8         9        10
 Gradient (%) of Segment   10         8         6         4         2
 Length of Segment (ft)    30        30        30        30        30
 Segment LS               1.924     1.461     1.073     0.681     0.318
 -----------------------------------------------------------------------------

+---------------------------------< Esc exits >-------------------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 4-7. LS values for a concave hillslope profile.

```
      File        Exit        Help        Screen
+-----------------------------< LS Factor 1.06 >------------------------------+

   number of segments: 10         segment lengths are measured: 2
         segments are: 2          uniform segment length (ft) : 3
         soil texture: silt loam
     general land use: 6
 -----------------------------------------------------------------------------
                           1         2          3         4         5
 Gradient (%) of Segment   2         6         12        12        12
 Length of Segment (ft)    30        30        30        30        30
 Segment LS               0.223     0.743     1.994     2.219     2.403
 -----------------------------------------------------------------------------
      overall LS = 1.3; equiv. slope = 8.17 %; horiz. length = 300 ft
 -----------------------------------------------------------------------------
                            6         7         8         9        10
 Gradient (%) of Segment   10         8         6         4         2
 Length of Segment (ft)    30        30        30        30        30
 Segment LS               1.924     1.461     1.073     0.681     0.318
 -----------------------------------------------------------------------------

+---------------------------------< Esc exits >-------------------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 4-8. LS values for a complex hillslope profile.

CHAPTER FIVE

C factor: Cover-Management

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**Technical Resource: G. R. Foster, W. Agnew
S. Davis, J. W. Spotts, T. J. Toy**

The cover-management factor (C) represents the effects of vegetation, management, and erosion-control practices on soil loss. As with other RUSLE factors, the C value is a ratio comparing the existing surface conditions at a site to the standard conditions of the unit plot as defined in earlier chapters.

The C factor represents the effect of plants, soil covers, soil biomass (roots and incorporated residue), and soil-disturbing activities on soil loss. RUSLE uses a sub-factor method to compute soil-loss ratios (SLR), which are the ratios of soil loss at any given time in the cover-management sequence to soil loss from the standard condition. The sub-factors used to compute a soil-loss ratio value are prior land use, canopy cover, surface cover, surface roughness, and soil moisture. The C value is the average soil-loss ratio weighted by the distribution of rainfall EI (energy x intensity) during the year.

C-Factor Options

There are two C-factor options in RUSLE, a time-invariant option and a time-variant option. The time-invariant option is used when the conditions described by the C factor remain constant or do not change sufficiently over time to change soil-loss rates, such as on most rangeland or pastureland.

The time-variant option is used when there are changes in vegetation and soil conditions that significantly affect soil-loss rates. Such conditions may occur in at least three ways. For reclaimed prime agricultural lands, crop rotation may be utilized consisting of a particular sequence of operations and crops that are repeated on an annual or longer cycle. The number of years in the rotation is entered into the RUSLE program, together with the operations and crops in chronological order. RUSLE computes sub-factor values for 15-day periods throughout the period of rotation and provides and overall rotational C value.

The time-variant option for rotation also may be used for a pasture or range land where the vegetation varies significantly during the year. In the Spring, the canopy and new roots systems develop, while in late Summer, the canopy decreases due to the leaf-fall that adds litter to the soil surface and the roots slough that adds biomass to the soil. A one-year rotation captures this natural annual cycle of vegetation changes. The time invariant option cannot account for the accumulation of litter on the surface or the accumulation of biomass in the soil.

The time-variant option also may be used to account for changes in conditions during the first few years after revegetation of a reclaimed site. Here, "zero" years is designated as the period of rotation. With a "zero" years rotation, the initial surface and soil conditions must be carefully set using an appropriate operation, such as a tandem disk to create a freshly-disturbed soil. No soil-disturbing operation is used for a "cut" soil condition. However, for a "cut" soil the root biomass remains in the soil if the depth of the cut is not below the root zone. This condition can be simulated by the establishment and killing of a plant cover that provides no cover, but leaves a root biomass in the soil following the killing operation.

Both the time-invariant and the time-variant options can be used when developing a reclamation plan for surface mining or construction sites. The time-invariant option would be used to document the conditions prior to disturbance, when mining or construction is planned on rangeland or permanent pasture. To develop a reclamation plan, the time-variant option would be used to describe conditions during the first few years following reclamation. During this period, the conditions affecting soil loss, such as canopy cover, surface cover, surface roughness, and soil consolidation will be changing. Soil consolidation is to the result of physical and biological processes that cause aggregation of soil particles that, in turn, reduce soil erodibility. After a few years, when these conditions become relatively stable, the time-invariant option could be used to describe post-reclamation conditions.

C Sub-factors

Data from the three databases (VEG, OPERATIONS, and CITY) and from user inputs, are used by the RUSLE program to derive the five C sub-factor values. These five values are then multiplied together by the RUSLE program to arrive at the C value for a specified management period. The sub-factors are prior land use (PLU), canopy cover (CC), surface cover (SC), surface roughness (SR), and antecedent soil moisture (SM). Each sub-factor value can range from slightly greater than 1 (indicating no reduction in soil-loss rates) to 0 (indicating that no soil loss will occur). Only prior land use, canopy cover, surface cover, and surface roughness will be discussed here because the soil-moisture sub-factor applies only to lands in the Northwest Wheat and Range Region of the U.S.; detailed discussion of the particular characteristics of this region and the manner by which they are addressed in RUSLE are available in AH-703 (Renard et al., 1997).

Prior Land Use

The prior land-use sub-factor (PLU) reflects the effects of soil loosening by tillage or other deep disturbance, and soil biomass (incorporated residue and plant roots) on soil-loss rates. These variables interact to give the PLU factor. For example, land that is plowed from meadow or pasture is only about 25 percent as erodible as land under continuous cropping. This is due to the effects of the vegetation incorporated by tillage and the stable soil aggregates formed under sod. Conversely, for reclaimed prime agricultural lands in a corn-soybeans rotation, the soil is about 40 percent more erodible in the year following soybeans than if it had been planted to corn due to lower soil biomass.

The PLU factor would be high (approaching 1) during and immediately following mining and construction because the topsoil is often stripped and stockpiled during mining operations, causing a decrease in the incorporated biomass. Tillage or other soil disturbance makes the soil more erodible because the soil is less consolidated, and stable aggregates are reduced in size. Soil disturbance associated with mining or construction activities also reduce stable-aggregate size and reduce the soil s ability to resist erosive forces. This reduction of aggregate size is offset somewhat by increases in the surface roughness, that slows runoff, increases infiltration, and traps sediment transported by overland flow. Maintaining or creating roughness is an effective method of reducing soil-loss rates, which is accounted for in the roughness sub-factor. Biomass and organic-matter losses are minimized when topsoil and the upper subsoil material is handled separately, not mixed with deeper soil material, and hauled directly to and spread on the final-graded reclamation surface. After soil-disturbing activities cease, the soil begins to consolidate again. If no further disturbance takes place, the soil is assumed to be fully consolidated after approximately seven years in the Eastern United States while consolidation may take longer in the Western United States, perhaps 20 years. The time required for consolidation is largely a function of rainfall amount and characteristics. Annual rainfall totals are low in many parts of the West, and so more time is required to achieve consolidation.

Canopy Cover

Canopy cover is the vegetative cover above the soil surface that intercepts raindrops but does not contact the soil surface. Any portion of a plant touching the soil surface is considered surface cover as discussed below. The two characteristics of canopy are utilized in the RUSLE calculations: (1) the percent of surface covered by the canopy, and (2) the height within the canopy from which intercepted rain drops re-form into water droplets and fall to the ground; this fall distance is known as the "effective fall height." Open spaces in a canopy, whether within the perimeter of a plant canopy or between adjacent plants, are not considered as canopy. When measuring or estimating canopy cover, planners should try to get a birds-eye view of the area.

The effective fall height is measured from the ground up to the level within the canopy from which the majority of water droplets fall. The effective fall height of a canopy varies with the vegetation type, the density of the canopy, and the architecture of the plants. **Figure 5-1** illustrates different canopy shapes and shows where the average fall height occurs in these canopies. If the plant canopy has a pyramid shape, with most of the leaves toward the bottom of the canopy, then the average drop fall occurs toward the bottom of the pyramid. If the plant canopy is round or oval, then the average drop fall occurs toward the center of the canopy. If the plant canopy has an inverted pyramid shape, with most of the leaves toward the top of the canopy, then the average drop fall occurs toward the top of the canopy.

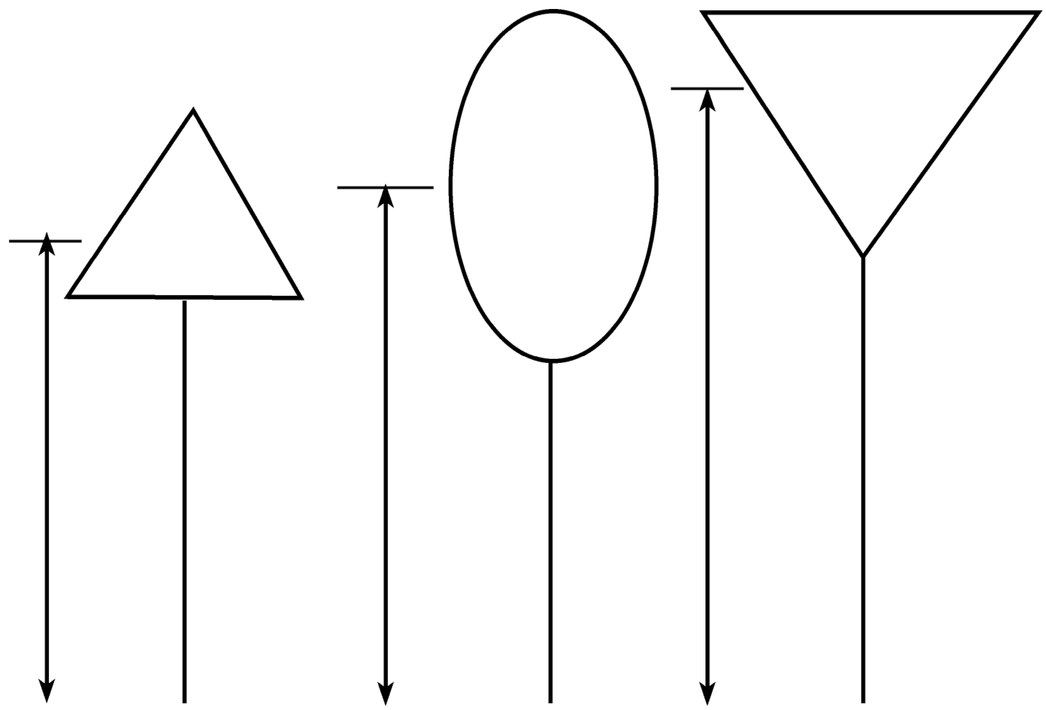

Figure 5-1. Fall heights from canopies of different shape

In plant communities that have more than one type of vegetation composing the canopy, such as on rangeland with a mixture of grasses, shrubs, and trees, the user should try to visualize the height from which most of the water drops would fall. If the majority of the canopy is composed of grasses and forbs, then that would be the type of canopy to use in estimating the effective fall height. If shrubs and small trees dominate and grasses are sparse, then the shrub and tree canopy would be used to estimate the effective fall height.

The canopy cover of reclaimed lands can vary throughout the year, especially on pasture or rangeland, or on lands revegetated with a large percentage of deciduous trees and shrubs. Leaf loss from these plants can significantly reduce canopy cover. The canopy-cover sub-factor for various combinations of percent cover is illustrated in **Figure 5-2**.

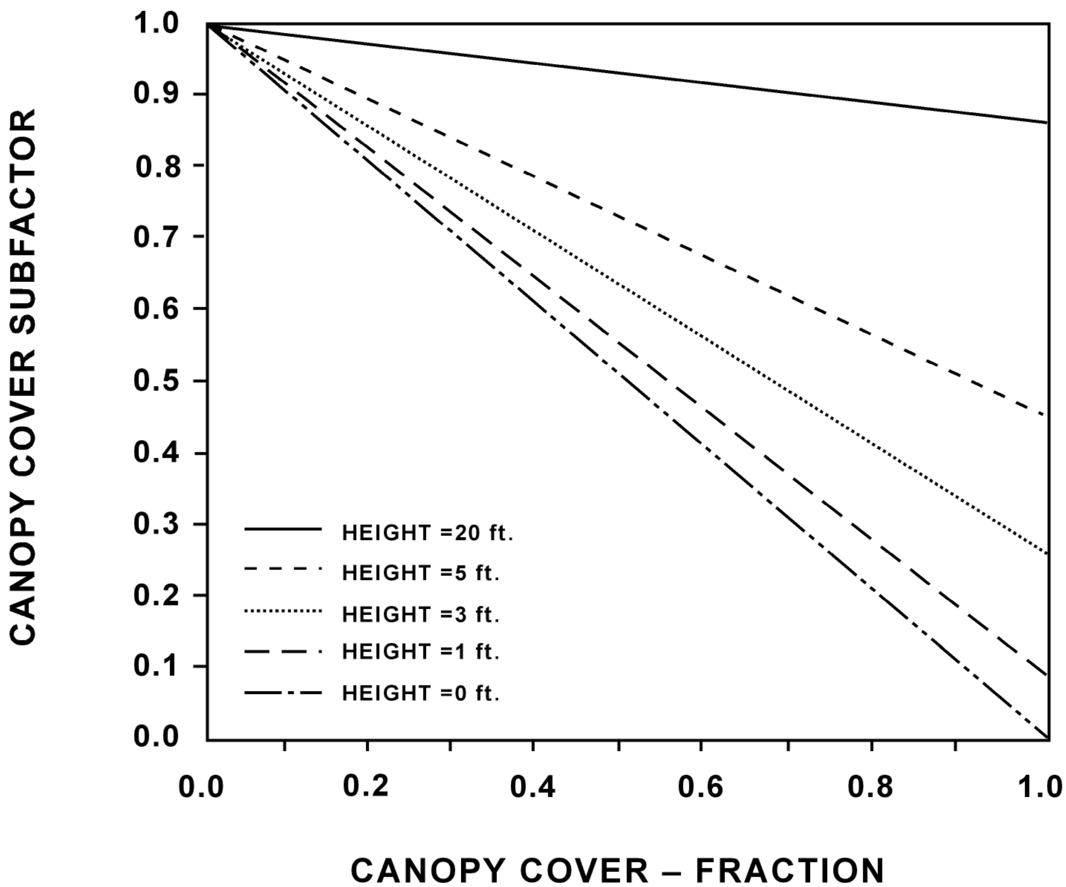

Figure 5-2. Relationship of percent canopy cover to the RUSLE canopy cover sub-factor

Surface Cover

Surface cover is material in contact with the soil that both intercepts raindrops and slows surface runoff. It includes all types of cover, such as mulches and rock fragments, live vegetation in contact with the soil surface, cryptogamic crusts (which are formed by mosses or fungi in the soil), and plant litter. To be effective, surface cover must be anchored to the surface or of sufficient size so that it is not blown away by wind or washed away by runoff. RUSLE takes into account the overlap of surface covers and rock, if both are present. The percent rock cover is entered through the K-factor screen and transferred to the C-factor computations.

The effectiveness of surface cover, such as mulch, varies depending on several factors, including the dominant type of soil erosion occurring on the slope, the slope gradient, the extent of contact between the surface cover and the soil, and the type of surface-cover material itself. In general, surface cover does a better job of reducing rill erosion rates than it does in reducing interrill erosion rates (Foster, 1982). Therefore, if erosion of a bare soil is primarily due to rilling, the addition of a given amount of cover material will reduce erosion more than if the same amount of cover material were placed on a soil that erodes primarily by interrill erosion processes.

On steep hillslopes (greater than 10% gradient) more of the total erosion often results from rill rather than interrill processes. Conversely, on flatter hillslopes (less than 3% gradient), more of the total erosion often results from interrill rather than rill processes. Again, because surface cover reduces the rill erosion rates more than the interrill erosion rates, a given amount of cover material results in a greater reduction in soil loss on steep slopes than on flat hillslopes.

The RUSLE user is asked to select a land use from which RUSLE computes a "b value" that reflects the effectiveness of the surface cover in reducing soil-loss rates. As the effectiveness of the surface cover increases, the b value increases. Because rilling often is the major erosion process on steep hillslopes, and surface cover is more effective in reducing rill erosion than interrill erosion, b values generally increase for most land uses as hillslope gradient increases. The exception to this generalization is for disturbed land where the surface cover is not in full contact with the soil surface or is not anchored to the soil surface by growing vegetation, by stems from previous vegetation. In this case, the effectiveness of surface cover is assumed to increase with hillslope gradient up to a maximum value and then to decrease with additional increases in gradient. Although RUSLE allows direct input of b values, the program should be used to compute the b value based on hillslope gradient, surface cover, and general land use**.** **Table 5-1** provides typical b values for various situations. Further discussion of b values is provided in AH-703.

The effectiveness of the surface cover depends on good contact between the soil and the cover material, and on the cover remaining in place. If the cover, whether straw mulch or manufactured materials, does not make full contact with the soil, is perched above the soil by clods, or stays suspended above depressional areas, severe rill erosion can occur beneath it. Therefore, mulch must be placed to ensure maximum contact with the soil.

Based on research by Meyer et al., 1971, 1972, mulch on construction sites is less effective than on agricultural land. Therefore, a relatively low b value is used in the program when mulch is placed on subsoil, even when properly applied, because the contact and bonding between the mulch and subsoil is assumed to be less effective than the contact and bonding between the mulch and topsoil. The smallest b value is used when the contact is fair, but not good, between the mulch and the soil, because there remains vulnerable soil beneath the cover. Mulch should always be anchored to the soil to ensure that runoff or wind does not remove the material.

As noted above, mulch consisting of long fibers, such as straw, may bridge above the soil surface by resting on clods or over depressions, thus reducing contact with the soil. Gravel mulches tend to fit into depressions and around clods, resulting in better contact with the soil than straw mulch. Therefore, a higher b value is used for gravel materials on construction sites than is used for straw. Of course, the use of gravel materials precludes virtually all post-reclamation land uses.

Table 5-1. General situations represented by b values used in RUSLE

b = 0.025	Situations where **bare-soil** rill erosion is low relative to interrill erosion, such as: flat slopes (<2%), short slopes (<15 feet), and soils that are so highly cohesive that little rill erosion occurs. This would also apply to permanent pasture on fine-textured soils where runoff is unaffected by cover or biomass. This value is also used on steep construction sites where the contact between the mulch and the soil surface is less than optimal with rill erosion occurring beneath the mulch, but the mulch does not fail entirely.
b = 0.035	A mid-range value that should be used for typical medium-textured soils that are regularly disturbed or tilled, for typical construction and for permanent pasture on coarse-textured soils.
b = 0.045	Coarse rangeland soils in areas with low rainfall.
b = 0.050	Situations where the bare-soil rill erosion is high relative to interrill erosion, such as: steep slopes, long slopes, and soils easily eroded by overland flow, e.g., thawing soils, soils high in silt, highly-disturbed soils, coarse-textured soils, and the soils of no-till agricultural lands.

Wind and water can displace mulch, leaving much less surface cover than was originally applied. The mulch cover input for RUSLE must reflect the actual mulch cover that remains in place. Crimping, netting, or tackifiers can be used to help secure the mulch.

Another important consideration is that organic mulch materials, such as straw, decompose through time. The loss of cover by decomposition is calculated within RUSLE as discussed in AH-703. Adjustments should be made based on the amount of cover that exists during the critical period when the R values are the highest.

Sometimes mulch is not evenly spread, resulting in some areas with reduced cover. The conservative way to apply RUSLE is to estimate the soil loss for the area having the lowest cover and to use that estimated soil loss for the entire area. An average soil-loss rate may be obtained for the site by computing the soil loss separately for areas with different amounts of surface cover. A weighted soil-loss rate is then computed based on the percentage of the total area that each sub-area represents. The reason that average surface cover is not used to estimate an average erosion rate is that the equation describing the effect of surface cover on soil loss is non-linear, so that the average surface cover does not give an accurate representation of the actual soil loss.

Table 5-2 provides C values for several combinations of mulch type, percent slope, and soil conditions. Because of the interactive nature of the variables in RUSLE, the program always should be used to compute C values for specific applications; the values in **Table 5-2** are intended only as examples. The placed topsoil and subsoil are direct-hauled or stockpiled soil spread on the surface much like fill material. The stripped topsoil is the remaining topsoil horizon following partial removal by grading operations. In this case, the topsoil has not been stripped down to the subsoil horizon and still contains some organic matter and rootlets. These soils are assumed to be well-prepared to ensure optimum contact between the soil and the mulch material. It also is assumed that the mulch is uniformly distributed on the hillslope, and it is assumed that the mulch is effectively anchored by crimping, netting, or tackifier so that it is not displaced by wind or water.

The C values in **Table 5-2** were computed for a site near Lexington, KY with a 150 foot hillslope. The "placed topsoil" and "placed subsoil" were assumed to be dumped and bladed on March 15 followed immediately by a surface cover. It is assumed that there was no initial vegetation on the site. The C values in the table represent the first three-month period during which time a vegetation cover was established on the surface. If no vegetation cover was established for the entire year, a C value of 0.08 for the first three months becomes a value of 0.14 for the year.

Also, the C values depend on when the mulch is applied to the surface. For example, if the surface material is dumped and bladed with the mulch applied on June 15, the C value for the first three months is 0.09, slightly higher than the C value when the mulch is applied in March. The value for the year is 0.12, slightly lower than the C value when the mulch is applied in March. The differences reflect the climatic regime of the location. These C values and those in **Table 5-2** will vary with location. Hence, the RUSLE program should be used to provide customized C values for a particular site.

The potential for mulch failure can be estimated using the procedure described by Foster, et al., 1982. When the shear stress imposed by a surface flow exceeds the shear strength of a mulch material, the mulch may be displaced or rilling begins beneath the mulch; in either case, the mulch ceases to protect the soil surface. A properly designed erosion-control system is one in which the mulch does not fail to protect the soil. Graphs provided by Foster et al., 1982 can be used to estimate the conditions under which mulch failure may occur. The relations upon which those graphs are based have not been included in the RUSLE program because they have not been extensively tested under actual field conditions. The procedure provided by Foster et al., 1982 employs the data inputs used by the RUSLE program and simple graphs and so could provide valuable guidance in situations where the potential for mulch failure must be evaluated.

Table 5-2. C factor values for mulch under disturbed-land conditions

Type of Mulch	Gradient (%)	Placed Topsoil	Subsoil	Stripped Topsoil
Straw, 2 tons/acre, 91% cover at placement, 84% cover at 3 months	1	0.10	0.10	0.09
	6	0.07	0.08	0.06
	15	0.06	0.08	0.04
	30	0.07	0.10	0.04
	50	0.08	0.11	0.03
Straw, 1 ton/acre. 69% cover at placement, 50% cover at 3 months	1	0.24	0.24	0.23
	6	0.18	0.20	0.16
	15	0.18	0.20	0.14
	30	0.18	0.24	0.12
	50	0.20	0.26	0.12
Straw, ½ ton/acre, 36% cover	1	0.35	0.35	0.34
	6	0.29	0.31	0.26
	15	0.28	0.32	0.23
	30	0.29	0.35	0.22
	50	0.30	0.38	0.21
Straw, 2 tons/acre, 20% rock fragment on soil before placement of mulch	1	0.09	0.09	0.09
	6	0.06	0.07	0.05
	15	0.06	0.08	0.04
	30	0.06	0.09	0.03
	50	0.07	0.10	0.03
Straw, 1/2 tons/acre, 20% rock fragment on soil before placement of mulch	1	0.24	0.24	0.23
	6	0.18	0.20	0.16
	15	0.18	0.20	0.14
	30	0.18	0.24	0.12
	50	0.20	0.26	0.12
Gravel, 135 tons/acre, 90% cover	1	0.08	0.08	0.08
	6	0.05	0.05	0.05
	15	0.04	0.04	0.04
	30	0.03	0.03	0.03
	50	0.03	0.03	0.03

Notes:
Soil is assumed to have been placed as a fill or to have been disturbed. Values would be lower for a cut slope.

The soil is assumed to have been well prepared to ensure optimum contact between the soil and the mulch and the mulch is assumed to have been anchored by crimping or a similar operation. A netting, tackifier, or something similar has been used to keep in the mulch in place so that it is blown away by wind.

The mulch is assumed to have evenly and uniformly placed.

The mulch is assumed not fail even by mulch movement or erosion beneath the mulch. The potential for mulch failure can be determined using the procedure described in Foster, G. R., C. B. Johnson, and W. C. Moldenhauer. 1982. Hydraulics of failure of unanchored cornstalk and wheat straw mulches for erosion control. Trans. ASAE. 940-947.

There are several ways to estimate the percent surface cover. **Figure 5-3** shows a graphic representation of percent cover. This can be used to help you visualize the amount of mulch or rock cover for a particular site. Your local NRCS office may have sets of photographs that show varying levels of vegetation covers. Surface cover can be measured quickly in the field using the line-transect or point-frame methods.

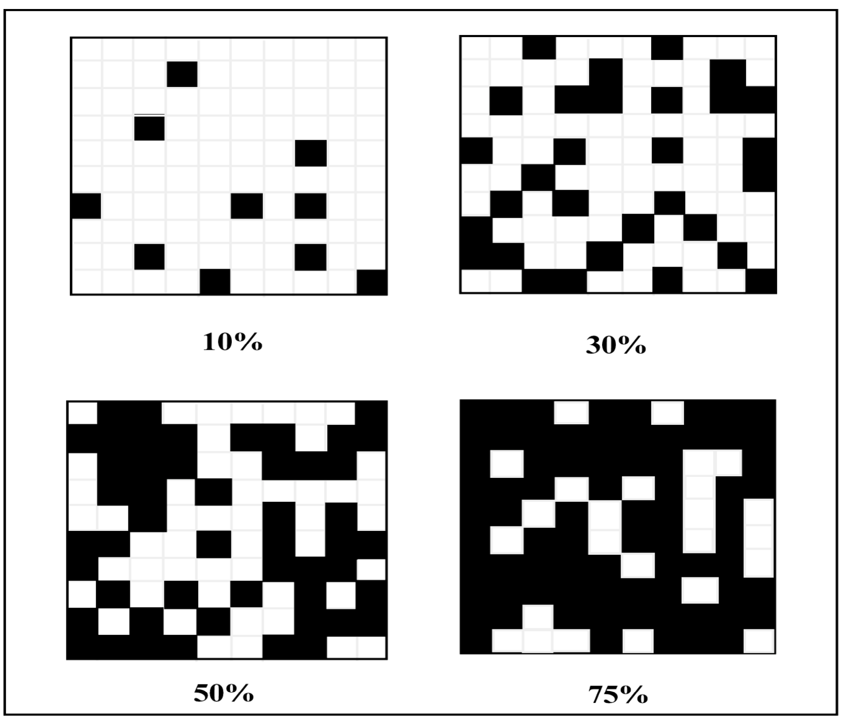

Figure 5-3. Graphic representation of varying percent surface cover

Measuring surface cover by the line-transect method: For ease of calculation and adequate accuracy, use a 100-foot measuring tape or a cord with 100 points marked on it with knots or other easily-visible marks. If the cover has any obvious orientation, stretch the cord or tape along the ground at a 45° angle to that orientation. Then walk along the cord and look directly down on each mark. Count the number of marks that have a piece of plant residue or other cover under it, and total them for the transect. Only count cover that is larger than 0.25 - 0.40 in size. If you are using a tape, look at the edge of the tape at each foot mark for cover. Always look on the same side of the tape. Repeat this procedure four or five times over the area, choosing locations that are representative of the area as a whole. The average number of cover hits is the percent cover for the area.

Figure 5-4 shows surface-cover, sub-factor values for varying cover levels. The three curves in this figure also illustrate how the effectiveness of surface cover in reducing soil-loss rates varies with the relative amounts of rill and interrill erosion as represented by the three different b values. The curve with a b value of 0.025 represents the effectiveness of a surface cover when the ratio of rill to interrill erosion is low for bare soil conditions. The curve with a b value of 0.050 represents the effectiveness of a surface cover when the ratio of rill to interrill erosion is high for bare soil conditions.

RUSLE can add cover after a harvest operation on reclaimed agricultural land, using the residue yield ratio in the VEG database. RUSLE can also accommodate the "external" addition of mulch materials, such as straw, in the computations of C values.

During the reclamation process, surface cover could be added as straw mulch, excelsior blankets, or other types of mulching materials. Unfortunately, there is a paucity of systematically collected field data relating applications of these products to soil loss that can be used to calibrate sub-factor values for RUSLE. In many cases, the RUSLE users must rely on their professional judgement based upon experience. Additional research is greatly needed to establish the soil-loss rates for various manufactured products, various application rates, and various site conditions.

Manufactured erosion-control products affect rill and interrill erosion processes in the same way as covers of natural materials. The same properties considered in an evaluation of straw mulch, for example, should be considered when using RUSLE to compute a C value for manufactured products. The important material properties are: (1) the percent of the soil surface covered, (2) the mass of the applied material, and (3) the rate at which the material decomposes. Another important variable is the nature of the contact between the mulch material and the soil surface. If the material bridges across the microtopography of the surface, a *disturbed land use with no rock cover* should be chosen from the general land use menu. If the material closely conforms to the soil surface, following the microtopography, then choose the *disturbed land use with rock cover* option from the menu.

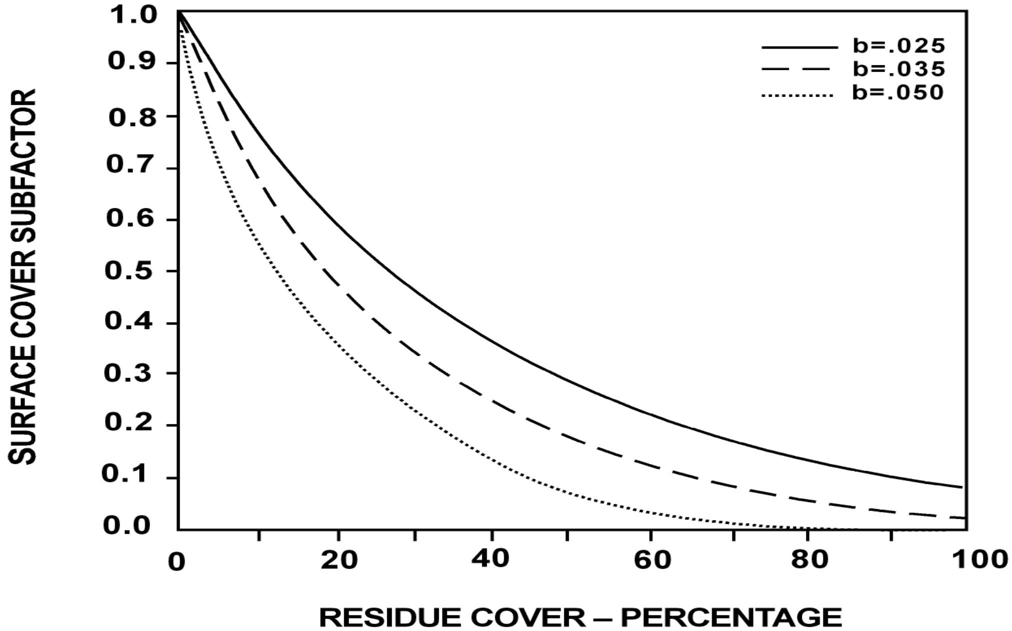

Figure 5-4. Relationship between percent residue cover and the RUSLE surface cover sub-factor.

On reclaimed mined lands and construction sites, losses of mulch cover can occur due to removal by wind and water, grazing animals, or decomposition. In stable plant communities, such as rangelands, pasturelands, or successfully reclaimed lands, surface cover is lost primarily by decomposition, although some loss of surface cover may result from livestock trampling. In these types of plant communities, surface cover tends to remain relatively constant, because the cover that is lost by decomposition is replaced by additions of plant litter to the soil surface.

On mined lands and construction sites, highly erodible conditions exist during site preparation, mining, and construction periods when the soil is bare and highly disturbed. High C values are used to represent these conditions. **Table 5-3** gives some C values for soil loss from bare-soil conditions. Again, because of the interactive nature of the variables in RUSLE, the program always should be used to compute C values for specific applications; the values in **Table 5-3** are intended only as examples. Notice that the C value varies for "cut" or "fill" surface materials due to differences in the material characteristics. The C values are lower for the cut materials because the soil is still consolidated and more resistant to erosion. For fill materials, the soil has been loosened and soil-aggregation size has been reduced, making the soil much more susceptible to erosion processes. The "packed, smooth" condition represents a soil surface that has been bladed smooth but the traffic from the blading operation has compacted the soil. This condition differs from the highly-compacted layers resulting from motorscraper traffic during the placement of several fill material lifts. Such a highly-compacted surface should be treated as a "cut" condition rather than a "fill" condition.

The C values in **Table 5-3** were computed for a site near Lexington, KY assuming that the operation occurred on March 15. The C values are for the first three months following the operation. The C values of the "fill" practices are due almost entirely from the random roughness resulting from fill placement. There is some loss of roughness during the three months caused by erosion of the microtopographic peaks and sedimentation in the microtopographic basins.

No soil disturbing activity is assumed for the "cut" practices. The C value of 0.45 is based on the assumption in RUSLE that a consolidated soil is about 45% as erodible as a freshly disturbed soil. The difference between the value of 0.45 and the other C values for the "cut" conditions reflect the effect of "dead" root biomass on soil-loss rates. The density of the root system and biomass for the sod is assumed to be much greater than for the "weeds." These differences are taken into account in the RUSLE program.

Table 5-3. C values for bare soil at construction site

Condition	Practice	Factor
Fill	Packed, smooth	1
	Freshly disked	0.95
	Rough (Offset disk)	0.85
Cut	Below root zone	0.45
	Scalped surface (some roots remain from sod)	0.15
	Scalped surface (some roots remain from “weeds”)	0.42

After the mining or construction activity is completed, the reclamation process usually begins. Along with the application of mulch, permanent vegetation often is established by seeding. The effectiveness of the vegetative cover in reducing soil loss increases through time as the stand develops. **Table 5-4** provides some typical C values for different types and growth stages of vegetative cover. Once again, because of the interactive nature of the variables in RUSLE, the program always should be used to compute C values for specific applications; the values in **Table 5-4** are intended only as examples. Small grain cover crops (nurse crops) give quick cover and help to protect the soil until the permanent vegetation is established. Even weeds give some protection. Any type of cover will help protect the soil from the erosive forces of rainfall and runoff.

The C values in **Table 5-4** were computed for a site near Lexington, KY. The C values illustrate the difference in the effect on soil-loss rates of a cover crop, such as oats, compared to permanent vegetation, such as weeds. It is assumed that the oats are seeded into a freshly disturbed soil with no initial root biomass present in the soil. Thus, the root biomass for the first four months of oat growth is much less than for the permanent weed cover with a comparable annual above-ground production. Soil consolidation also differs between the oats and the weed covers. The soil is assumed to be fully consolidated for the weeds, whereas no consolidation is assumed for the oats. The canopy cover also differs between the oats and the weeds. The canopy develops through time for the oats, whereas the canopy cover is constant for the weeds. Even after the canopy for the oats is fully developed, the weeds are assumed to provide a higher percent canopy that the oats and the fall height for the oats is about three times that of the weeds. Finally, a litter cover is assumed for the weeds that is not assumed to exist for the oats. When all of these differences are taken into account, the C value for the permanent cover of weeds is much less than that of the newly planted oats. Of course, this does not mean that weeds are a desirable surface cover for reclaimed lands, but their presence does affect soil-loss rates. The C values in **Table 5-4** show that the grasses are much more effective in reducing soil-loss rates.

Table 5-4. C values for various types of vegetation cover

Type	Production Level (lb/acre)	C-value
Sod (bluegrass)	4000	0.001
Bromegrass	4000	0.002
Weeds	2000	0.01
	1000	0.04
	500	0.11
Oats (first four months)	5000 lb/acre at maturity	0.27
	2500 lb/acre at maturity	0.44
Oats (annual)	5000 lb/acre at maturity	0.17

Surface Roughness

Soil-disturbing operations leave two types of surface roughness: oriented and random. Oriented roughness has a recognizable pattern. The ridges and furrows left by "cat-tracking" or a chisel plow used in the preparation of a seedbed are examples of oriented roughness. Oriented roughness redirects surface runoff, and may trap some sediment. When the ridges and furrows are very nearly on the contour, runoff flows around the slope, rather than directly downslope, thus reducing the erosivity of the runoff. Oriented roughness is considered in the P factor. Random roughness is considered in the C factor.

Random roughness is defined as the standard deviation of the elevation from a plane across a tilled area after oriented roughness is taken into account. It has no recognizable pattern and is the result of clods and aggregates produced by various soil-disturbing activities. The depressions between the clods cause water to pond, slows runoff, increases infiltration, and stores sediment, all of which helps to reduce erosion rates. The amount of random roughness created by a particular operation varies with the initial condition of the site, the tillage implement and its use, soil texture, and soil moisture at the time of disturbance.

CAUTION: If any oriented roughness is present, take random-roughness measurements parallel to the oriented roughness. For example, take measurements along the top of a ridge or the bottom of a furrow, rather than perpendicular to the ridges and furrows.

A random roughness value for RUSLE can be obtained by simple field measurements. Measure the distance between the highest and lowest points on the soil surface along a furrow or ridge. The average range, determined from the average high and average low elevation measurements, is used together with **Figure 5-5** to estimate the

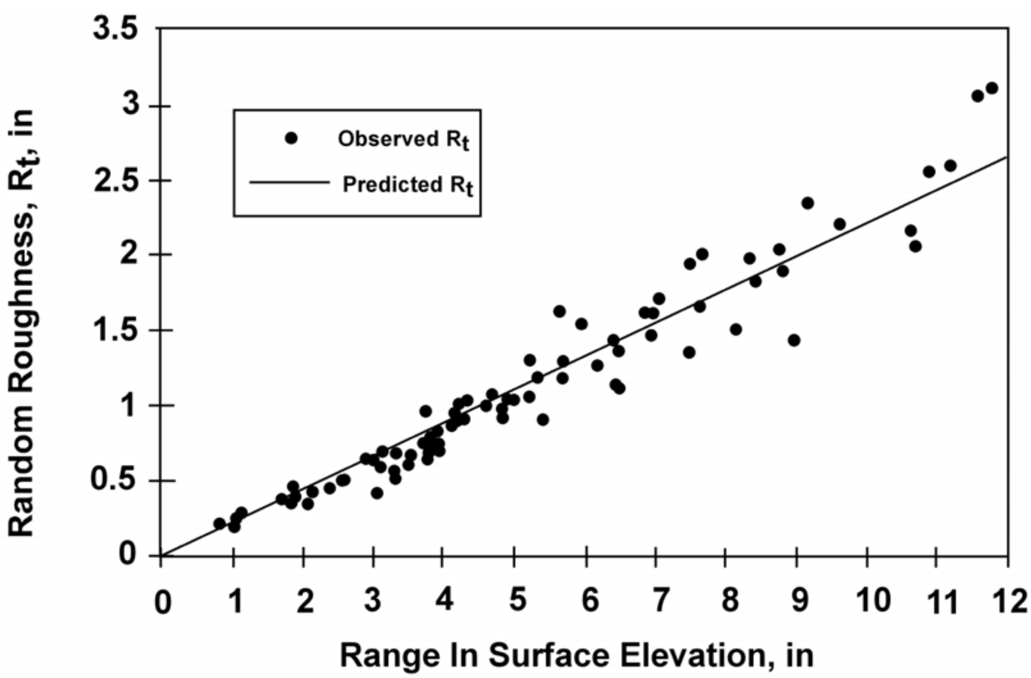

Figure 5-5 Random roughness versus range in surface elevation (Soil and Water Conservation Society, 1993)

random-roughness value. For example, if the average difference between the high and low points is 9 inches, the random-roughness value for RUSLE is 1.75 inches. **Table 5-5** provides random-roughness values for different types of rangeland communities, and

Table 5-6 provides some typical random-roughness values for various tillage implements. The values in these two table are intended only as examples; field measurements and **Figure 5-5** should be used to obtain the random-roughness values for C-factor inputs.

Table 5-5. Roughness values for rangeland field conditions (Soil and Water Conservation Society, 1993).

Condition	Random Roughness (in)
California annual grassland	0.25
Tallgrass Prairie	0.30
Clipped and bare	0.60
Pinyon/Juniper interspace	0.60
Cleared	0.70
Natural shrub	0.80
Seeded rangeland drill	0.80
Shortgrass,desert	0.80
Cleared and pitted	1.00
Mixed grass, prairie	1.00
Pitted	1.10
Sagebrush	1.10
Root-plowed	1.30

Table 5-6. Attributes of Typical Tillage Implements[1]

Field operations	Random roughness (in)	Fraction of residue left on surface (%)	Depth of incorporation (in)	Soil surface disturbed (%)
Chisel, sweeps	1.2	70	6	100
Chisel, straight point	1.5	60	6	100
Chisel, twisted shovels	1.9	45	6	100
Cultivator, field	0.7	75	3	100
Cultivator, row	0.7	80	2	85
Cultivator, ridge till	0.7	40	2	90

Field operations	Random roughness (in)	Fraction of residue left on surface (%)	Depth of incorporation (in)	Soil surface disturbed (%)
Disk, 1-way	1.2	30	4	100
Disk, heavy plowing	1.9	35	6	100
Disk, tandem	0.8	50	4	100
Drill, double disk	0.4	90	2	85
Drill, deep furrow	0.5	70	3	90
Drill, no-till	0.4	80	2	60
Drill, no-till into sod	0.3	90	2	20
Fertilizer applicator, anhydrous knife	0.6	80	2	15
Harrow, spike	0.4	80	2	100
Harrow, tine	0.4	85	2	100
Lister	0.8	20	4	100
Manure injector	1.5	50	6	40
Moldboard plow	1.9	5	8	100
Mulch treader	0.4	75	2	100
Planter, no-till	0.4	85	2	15
Planter, row	0.4	90	2	15
Rodweeder	0.4	90	2	100
Rotary hoe	0.4	85	2	100
Vee ripper	1.2	80	3	20

[1] From AH-703 - Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation

Both oriented and random roughness decrease through time. Depressions fill with sediment, and rainsplash erodes the clods, aggregates, and ridges created by tillage implements. RUSLE automatically diminishes surface roughness through time as a function of accumulated rainfall volume and rainfall energy.

Cover-Management Systems

A set of plant types, surface covers, and operations constitutes a cover-management system. The complete list of plant types, surface covers, and operations, together with the dates of planting or implementation, must be assembled for the computation of C values. For complex reclamation and production systems on reclaimed prime agricultural lands, RUSLE will accept crop-rotation sequences up to ten years in length. Additional information pertaining to the development of cover-management systems is available in Chapter 7 and in AH-703.

Caution: Developing a cover-management system for RUSLE can be a complicated task. It is imperative that plant types and operations be entered in the proper sequence to insure accurate calculation of C values. The user is strongly encouraged to participate in a RUSLE training course given by qualified instructors before trying to develop elaborate multi-step sequences for reclaimed prime agricultural lands. Check with your local NRCS office for information on available training and assistance in developing C values.

A reclamation plan may be quite simple or quite complex, depending on the reclamation objectives and future land uses. It is impractical to attempt to include in the RUSLE program all of the possible plant types, erosion- and sediment-control materials, and operations that might be utilized in reclamation programs throughout the United States. Furthermore, the data frequently do not exist specifically relating various plant types, materials, or operations to soil-loss rates, in which cases it is not possible to develop C values for inclusion in RUSLE. Therefore, recourse often must be given to the use of analogies based on user judgement and experience. For example, the plant types used in revegetation at a particular location may be expected to affect soil-loss rates much like coastal bermudagrass. An erosion-control material may be expected to affect soil-loss rates much like straw much applied at a rate of 2 tons per acre. An operation may be expected to affect soil-loss rates much like the use of a heavy offset disk. When new data become available relating additional plant types, materials, and operations to soil-loss rates, new C sub-factors can be added to RUSLE. The user is advised to consult with State NRCS Office to obtain existing plant type, material, and operation information for the particular area of interest and for assistance in identifying the best possible analogies for use in the C-value computations.

The C-value computations for two disturbed-land cover-management systems are provided in **Figures 5-6** and **5-7**. The site characteristics for these example are provided for comparison in **Table 5-7**. Note that the soil and topographic characteristics are the same for each site but the climatic conditions differ considerably and cover-management systems differ somewhat. For the Eastern U.S. location (Charleston, WV) the C value is 0.085, indicating that the soil-loss rate would be 8.5% of that from a bare, unit plot under the other conditions described in **Table 5-7**. For the Western U.S. location (Flagstaff, AZ) the C value is 0.07, indicating that the soil-loss rate would be 7% of that from a bare unit plot under the other conditions described in **Table 5-7**. The difference in the C values is due to the differences between the climate characteristics at these two locations and the differences in the cover-management systems.

```
                    File        Exit        Help        Screen
+-----------------< C Factor: results by operations 1.06 >--------------------+
 veg. # 1/1: winter small gr cvr        prev. veg.: winter small gr cvr
                     % res. cover    op.          date
---operation------------after op.----date---------next op.-----SLR-----%EI----
 place (dump) fill         0        3/5/1         3/6/1       0.847    0.1
 blade fill matl           0        3/6/1         3/7/1       1.06     0.1
 broadcast planter         0        3/7/1         3/7/1       0        0.0
 add straw mulch           70       3/7/1         3/5/2       0.084   99.9
---------- Rotation C Factor = 0.085 -------- Veg. C Factor = 0.085 ----------




+-----------------------< Esc Returns to C Result Menu >----------------------+
Tab  Esc F1   F3   F9   PgUp PgDn Home End
FUNC esc help cont info pgup pgdn 1st  last
```

Figure 5-6. Example C-factor value for a site in the Eastern U.S.

```
             File        Exit        Help        Screen
+-----------------< C Factor: results by operations 1.06 >--------------------+
 veg. # 1/1: grama-1st yr        prev. veg.: grama-1st yr
                     % res. cover    op.          date
---operation------------after op.----date---------next op.-----SLR-----%EI----
 place (dump) fill         0        3/15/1        3/17/1      0.846    0.0
 blade fill matl           0        3/17/1        3/18/1      1.06     0.0
 heavy offset disk         0        3/18/1        3/20/1      0.793    0.1
 range drill               0        3/20/1        3/22/1      0.896    0.1
 add straw mulch           70       3/22/1        3/15/2      0.072   99.8
--------- Rotation C Factor = 0.073 -------- Veg. C Factor = 0.073 -----------



+-----------------------< Esc Returns to C Result Menu >----------------------+
Tab  Esc F1   F3   F9   PgUp PgDn Home End
FUNC esc help cont info pgup pgdn 1st  last
```

Figure 5-7. Example C-factor value for a site in the Western U.S.

Table 5-7. Comparison of site characteristics

RUSLE Factor	Eastern United States	Western United States
Rainfall - Runoff Erosivity (R)	Charleston, WV Slope gradient = 8.65 Adjust ponding = yes (R = 140)	Flagstaff, AZ Slope gradient = 8.65 Adjust ponding = yes (R = 30)

RUSLE Factor	Eastern United States	Western United States
Soil Erodibility (K)	Silt loam Si + vfs = 65% Clay = 15% Organic matter = 0.5% Structure = 2 Permeability = 4 % Rock cover = 0 Consolidation = 7 Hydrologic group = 3 (K = 0.471)	Silt loam Si + vfs = 65% Clay = 15% Organic matter = 0.5% Structure = 2 Permeability = 4 % Rock cover = 0 Consolidation = 15 Hydrologic group = 3 (K = 0.444)
Topographic Factor (LS)	Segments = 3 Measured downslope Segments vary in length Soil texture = Silt loam General land use = 8 Gradients = 10, 15, 5% Lengths = 100, 200, 300 ft (LS = 3.50)	Segments = 3 Measured downslope Segments vary in length Soil texture = Silt loam General land use = 8 Gradients = 10, 15, 5% Lengths = 100, 200, 300 ft (LS = 3.50)
Cover - Management (C)	No Adjust for soil moisture % Rock cover = 0 b-value code = 1 Years in rotation = 0 Long-term rough = 0.24 Consolidation = 7 Winter small grain Place (dump) fill Blade fill material Broadcast planter Add straw mulch (2000lbs) (C = 0.085)	No adjust for soil moisture % Rock cover = 0 b-value code = 1 Years in rotation = 0 Long-term rough = 0.24 Consolidation = 7 Grama - 1st year Place (dump) fill Blade fill material Heavy offset disk Range drill Add straw mulch (2000lbs) (C = 0.073)

In the Midwestern part of the U.S., surface mining often takes place on prime agricultural lands. There are very specific requirements for the reclamation of these lands. Further, the post-mining land use may involve various crop-rotation patterns. It is essential that the data inputs for the computation of the C value include all of the required reclamation and cropping steps in precisely the correct sequence. The regulatory authority for mining activities and NRCS personnel can assist in the selection of the appropriate data inputs.

Sources of Information

The RUSLE program accompanying these Guidelines includes limited data sets in the CITY, OPERATIONS, and VEG databases**.** Many additional data sets have been developed by NRCS personnel during the implementation of RUSLE at the field level. Contact your State NRCS office for the latest versions of these databases.

CHAPTER SIX

P Factor: Support-Practice

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Technical Resource: G. R. Foster
T. J. Toy

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 berm is 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.

CHAPTER SEVEN

Applications of RUSLE

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Benefits of Using RUSLE

What can RUSLE do for you? Numerous erosion-control and reclamation activities are integral parts of a thoroughly planned design that collectively contribute to the reduction of soil loss, but are not accounted for in the original Universal Soil Loss Equation (USLE). For years, permit applicants and erosion-control and reclamation specialists have encouraged concurrent reclamation, leaving the soil/spoil surface in a roughened state, using mulch or a temporary cover crop, contouring, and terracing, and establishing sustainable vegetation. These erosion-control measures have become standard operating procedures on many mined lands and construction sites resulting in long-term stabilized areas, reduced sediment basin clean-out costs, and reduced potential off-site impacts. With RUSLE the benefits of these and other erosion-control measures can be estimated and alternative reclamation plans can be readily compared. Other advantages of using RUSLE include: (1) assessment of alternative hillslope configurations (convex, uniform, concave, and complex), (2) obtaining erosion-control or erosion-reduction credit for the surface rock fragment covers that exists on many mine sites, and (3) analyses of the effects of straw mulch, random roughness, soil consolidation, sediment deposition, and changes through time due to mulch decomposition and deterioration of surface roughness due to rainfall.

The RUSLE program facilitates analyses associated with permitting and bond release through comparison of pre- and post-mining scenarios. Soil loss can be estimated with respect to the influence of plant growth, canopy development, residue cover, and below-ground root development as a function of time and geographical region. Decreases in random roughness through time, which decrease the resistance of disturbed soils to erosion, and increases in soil consolidation through time, which increase the resistance of disturbed soils to erosion, can be estimated using the RUSLE program.

RUSLE is a powerful program that is capable of predicting soil loss from fields or hillslopes that have been subjected to a full spectrum of land manipulation and reclamation activities. RUSLE can accommodate undisturbed soil, spoil, and soil-substitute (growth medium) material, percent rock cover, random surface roughness, mulches, vegetation types, and mechanical equipment effects on soil roughness, hillslope shape, and surface manipulation including contour furrows, terraces, and strips of close-growing vegetation and buffers.

Application Overview

The purpose of this chapter is to demonstrate how to use RUSLE. Several scenarios, including mining and construction cases, are provided as examples using RUSLE to account for the effectiveness of specific erosion-control measures. Alternative design scenarios illustrate: (1) embankment stabilization during highway construction, (2) hillslope reconstruction during back-filling and grading of reclaimed outslopes, highwalls, and ramps, (3) deposition on multi-segmented concave hillslopes, (4) establishment of terraces and contour furrows in conjunction with mechanical surface manipulation including deep ripping and disking during minesoil reconstruction, and (5) comparison of pre- and post-mining soil loss with emphasis on the effects of vegetation and soil consolidation. Scenarios were selected for various geographical areas including the southeastern U.S. for highway construction; the Appalachian coal region for outslope reconstruction; Lexington, KY for deposition and sediment-delivery estimations; the semi-arid U.S. for terracing, contour furrows, and mechanical surface manipulation; and the Mountain States for pre- and post-mining comparisons focusing on vegetation assessment. It should be noted that these examples do not provide a comprehensive assessment of an entire erosion-control or reclamation plan, but are intended to provide the user with an understanding of the capabilities of the RUSLE program and how to utilize it in specific situations.

RUSLE fundamentally is a DOS program. Users running the program as a DOS program, or as a DOS program within Windows 3.1 or Windows 95, should experience no difficulties. Users running RUSLE within Windows NT environment have experienced problems. The easiest solution to these problems is to use RUSLE on a computer with Windows 3.1 or Windows 95. Users attempting to run RUSLE on a computer with Windows NT may require expert assistance.

The five examples, with alternative design scenarios, provide the user of these Guidelines with step-by-step inputs and procedures. The examples constitute a sequence of lessons. The first example enables the user to learn the basic functions of RUSLE version 1.06. All inputs, and even key strokes, are given in a detailed format. The remaining four examples provide the user with additional and advanced capabilities. In subsequent examples, it is assumed that the user has acquired the skills explained in previous examples; therefore, only new concepts are introduced in the detailed step-by-step manner. The series of examples were developed to enable the user to gain knowledge comfortably about the extensive capabilities of the RUSLE program. Also, explanation and evaluation of outputs, given in each example, should provide the user with insights to the effectiveness of alternative design options. Finally the section entitled 'What the User Will Learn' helps the user rapidly find the section that gives detailed information on a specific topic.

Using RUSLE Software

Make a directory for RUSLE 1.06. Copy all files from the disk to the hard drive. Commands or input values to be entered are shown in brackets, [ ]. Also note that comprehensive HELP tables and information are always available by selecting the context-sensitive help key [F1].

Change the Directory to RUSLE 1.06, i.e. [CD\RUSLE 1.06].

Type [RUSLE] and then press [Enter] to execute the program.

The main program screen, as shown in **Figure 7-1**, appears.

```
             File        Exit        Help        Screen
+-------------------------------< RUSLE 1.06 >---------------------------------- +


             +---------------------------------------------+
                  program choice:  1
              ---------------------------------------------
               -->   1. RUSLE Soil Loss Prediction Table
                     2. R Factor
                     3. K Factor
                     4. LS Factor
                     5. C Factor
                     6. P Factor
                     7. Database Utilities (City, Veg., Op)
                     8. RUSLE Information and Maintenance
             +---------------------------------------------+


+---------------------------------< Esc exits >-------------------------------- +
Tab  Esc F1   F3   F9   End
FUNC esc help cont info last
```

Figure 7-1. Primary Program Option Screen

Select [1] RUSLE Soil Loss Prediction Table by pressing the [Enter] key.

Example 1: Fill Embankment Stabilization During Highway Construction

Problem Statement: An interstate highway is to be constructed near Charleston, South Carolina. An assessment of alternative fill-slope embankment stabilization scenarios is conducted using RUSLE.

Scenario 1 - no erosion control
Scenario 2 - two tons per acre straw mulch
Scenario 3 - broadcast seeding with tall fescue grass
Scenario 4 - rock mulch

What Will the User Learn?

This is an introductory problem that will first teach the RUSLE user how to install version 1.06. RUSLE version 1.06 has been developed to incorporate various mining- and construction-design options.

In Scenario 1 the user will learn how to create an input file, select a CITY code, enter inputs, progress through input screens, run the program, and save a file.

Scenario 2 shows the user how to recall a previously saved file and modify the file. The user is introduced to the time-varying option, long-term random roughness, number of years needed for soil consolidation, the field operations display, entering a basic sequence of field operations, (i.e. site disturbance and addition of crop residue), and ending a sequence of operations. Understanding the output is emphasized through display and discussion of half-month sub-factors. The user will gain insight into temporal residue decay, changes in previous land-use, and seasonal EI (R-factor) distributions.

Scenario 3 expands the user's knowledge of the vegetation display and provides additional field-operation capabilities. Result interpretation, illustrated by the half-month sub-factors values, is expanded to encompass canopy sub-factor changes due to establishment and growth of a grass cover. The interplay between mulch decomposition and grass growth is evident to the user from the half-month display. The relationships among mulch, grass growth, and temporal erosion potential is discussed.

The substitution of a rock cover, to stabilize a fill outslope, is illustrated in Scenario 4. The user's knowledge of the field-operations data base is enhanced through this scenario. Again, complete rock cover precludes post-reclamation land uses.

Design information:

Location - near Charleston, SC.

Soil - topsoil, sandy loam, K = 0.24 (from soil survey report).

Refer to county soil series publications obtained from the Natural Resources Conservation Service, NRCS (formerly Soil Conservation Service).

Grass - tall fescue.

Planting method - broadcast seeding.

Mulch - straw applied at 2 tons per acre. Held in place by netting.

Gradient - 4:1 (Horizontal : Vertical).

Vertical height of fill-slope is 28 ft.

A road berm is located above the fill -slope to direct road runoff to a protected downdrain.

Duration of assessment - 1 year.

Scenario 1 - Fill embankment stabilization during highway construction, no erosion control**.** Now we can begin to create a file for the first scenario.

The R factor is discussed in Chapter 2.

As displayed near the bottom of the screen, the function key F4 is used to call a factor.

[F4] to obtain a listing of the CITY codes.

Page down until the SC listings are displayed and then arrow down until Charleston, SC is highlighted. It is shown as CITY code 40001.

[Enter] to select the highlighted city.

The next screen shows an Average Annual R of 400. This is the R value for Charleston, SC. The relatively high value is due to the number and severity of storms that occur, on the average, in Charleston.

The LS factor is discussed in Chapter 4.

The embankment gradient is 25 % for the 4:1 fill-slope.

To enter this value, first go to the LS-factor routine [F4]. The LS-factor routine is now displayed.

Because this is a single uniform hillslope simply [Enter] [2] indicating that segment lengths are measured horizontally.

The program shows a soil texture of silt loam, which is the default. The actual soil texture is sandy loam for this example, which only can be entered on the K-factor screen. To select soil texture, move to the K-factor screen by pressing [F4].

The soil texture options are listed. Chose [3] to select sandy loam, the texture for the soil in this example. Additional entries are needed on the K-factor screen. We will make those entries later. Press [F3] to accept the sandy loam selection, and then [Esc] to return to the LS-factor screen.

Use the down arrow or [Enter] to move the cursor to the next entry for general land use. [8] [Enter] chooses "disturbed fill, topsoil, no rock cover," appropriate for this example.

Rock cover is a factor in determining general land use. A hillslope is assumed to have rock cover when the rock cover is greater than 35 percent for the purpose of choosing the land use.

The gradient % is [25]. [Enter].

The horizontal projection of hillslope length is [112] ft, (28 x 4).

[F3]. The calculated LS value is 4.74.

[Esc] [Esc] returns to the R-factor screen. The hillslope gradient has now been entered in the R-factor screen. [Enter].

The adjustment for ponding is only used where the soil is very rough or in ridges so that soil projects above the waterline during an intense storm. The adjustment for ponding is a function of hillslope gradient and the 10-year storm EI, which is contained in the CITY file for each location. For flat hillslopes, high-intensity rainfall events create ponded conditions. The ponded water dissipates the energy of the raindrop impact. For this situation, the R value over-predicts soil loss. An adjustment corrects the R-factor for these conditions. The flatter the hillslope and the higher the 10-year storm EI, the greater the R value correction.

Because the soil surface for this fill embankment is smooth, adjustment for pondage should be entered, [2], [Enter]. As the results show, the adjustment for pondage has no effect on this steep hillslope.

R-factor information has now been completed. [F3]. [Esc]. [Esc]. [Enter] or [right arrow] to proceed to the K factor.

The K factor is discussed in Chapter 3.

Even though the K value is known for this example, (i.e. 0.24), the K screen must be executed. [F4]. [Enter] to select Option 1 and [Enter] to move to the estimated K section of the seasonally variable K-factor screen.

Execution of the K screen is necessary to compute the time-variable K and to activate key variables such as hydrologic soil group that will be needed in the P-factor computations. [0.24] [Enter].

The percent rock cover is "0" so accept the default value of zero, [Enter].

The default value of 7 years to consolidation is also accepted, [Enter].

The hydrologic soil group for a sandy loam, on a fill-slope constructed by a dozer, should be relatively compacted such that infiltration is reduced. Thus, either a 3 or 4 would be applicable.

Select [3]. [Enter].

The value selected for permeability is chosen to reflect the soil condition that would exist if the soil was maintained in continuous tillage for growing a crop like corn. The reason for this consideration is that K is defined for soil loss measured from the unit-plot condition, which is a continuous, clean-tilled fallow condition.

Soil series information is used primarily for review purposes because a great deal of information can be readily obtained from the National Resources Conservation Service (NRCS) based simply on the soil series. Such information includes soil texture, K values for undisturbed various soil horizons, permeability class, soil classification under USDA and NRCS methods, etc.

Because the soil series name is unknown for this example, [Enter].

As given in the problem statement the surface texture is a sandy loam, [3]. [Enter]. [F3]. The bi-monthly %EI and K values are now displayed. The K values are constant for the entire year because of climatic conditions at this location, which experiences a long freeze-free period. [Esc]. [Esc]. [Enter]. [Enter].

C and P factors are discussed in Chapters 5 and 6, respectively.

Because this is a smoothly-graded hillslope that was back-bladed by a dozer, and Charleston receives high intensity rainfall events, no credit can be taken for contour ridges left by a dozer tracking up and down the hillslope. Back-blading removed these small ridges.

Thus the C value and P value are entered as [1], [Enter], [1], [Enter].

The estimated average annual soil loss for Scenario 1 - no erosion control is 450 tons per ac/year. To put this in perspective 450 tons/ac/year is equivalent to approxi-mately a 2.5 inch loss of soil over the entire hillslope length.

Saving the created file:
[tab].
[arrow down to 2]. [Enter].
Type filename. [EX1SCNO1]. [Enter].
Type in a description of the scenario.
[6/10/97

Charleston, SC
Fill embankment stabilization during highway construction
Ex. 1, Scenario 1-no controls]
[F3].

Scenario 2 - Fill-embankment stabilization during highway construction, two tons per acre straw mulch.

The only difference between Scenarios 1 and 2 is the application of 2 tons per acre of straw mulch. Initial grading is assumed to be conducted March 1 and straw mulch with netting is placed that afternoon, with the mulch anchored to the soil surface.

The previous file can be reused so that data needed for the R , K, and LS factors do not have to be reentered. To accomplish this:

[arrow down to the next line] on the Soil Loss and Sediment Yield Computation Worksheet.
[tab].
Select loadfile [Enter].
[Arrow down] to highlight "EX1SCNO1". [Enter].
The factor values from the first scenario are now listed on the second line.
[Arrow] to the C factor. [F4].
The time-varying option will be illustrated.
[Highlight it] and [Enter].
The Charleston CITY code is displayed. [Enter].
The default for adjusting soil moisture is highlighted and a dialog box appears.
[Enter].

Use the default of zero because no rock fragments are present on the soil surface. The effect of rock fragments will be illustrated later in Example 4. [Enter].

The land use has already been specified on the LS-factor screen as being disturbed land with fill topsoil, with no rock cover. This information can be used by RUSLE to automatically select a b value.

To select this option, which is the preferred option, [1], [Enter].

As an alternative, a b value can be selected based on the information in the RUSLE help screens or from information in Chapter 5. The RUSLE help screen can be reached by pressing the F1 key with the cursor at the point where the b value is entered.

Because this is a single disturbance [0] and not a crop rotation, [Enter].

The final long-term roughness defaults to 0.24 inches, but will be changed to 0.15 inches because that is the roughness left by the blade fill material operation, which is smoother than the default.

If the initial roughness left by an operation is greater than 0.24 inches, a final roughness is chosen that represents the long-term roughness of the surface after the surface has been smoothed by rainfall assuming the surface is not disturbed again. [0.15] [Enter].

The number of years to consolidation is used to reduce the erosion potential of the site as soil aggregates develop. Research has shown that soil that has been disturbed and then is left undisturbed becomes less erodible through time. The consolidation effect ranges from 4 to 20 years and averages 7 years for the Eastern U.S. but may be considerably longer in the Western U.S.

Accept the default value of [7] because the site is located in the Eastern U.S. [Enter].

A dialog box listing grasses, crops, etc. now appears. [Arrow down] to "no vegetation" and highlight it. [Enter]. [F3]. [F3]. Refer to **Figure 7-2**.

```
              File        Exit        Help        Screen
+  ------------------< Time-varying C: general inputs 1.06 >---------------------+
|                            city code: 40001  CHARLESTON            SC          |
|  adjust for soil moistured depletion: 1                                        |
|   % surface covered by rock fagments: 0                                        |
| surface cover function; B  value code: 1     landuse shown in LS:   8          |
|          number of years in rotation: 0                                        |
|         long term rand +--------------------------+      #   Veg.             |
|                # years |     alfalfa, spring seed |   +--------------------+  |
|                        |     bermudagrass; coastal|   | 1 no vegetation    |  |
|                        |     bromegrass seedling  |   +--------------------+  |
|                        |     corn; 125 bu         |                           |
|                        |     grama    1st yr      |                           |
|                        |     grama    2nd yr      |                           |
|                        |     grama    3rd yr      |                           |
|                        | -  > no vegetation       |                           |
|                        |     orchardgrass; seed yr|                           |
|                        |     Red clover: spr seed |                           |
|                        |     sorghum              |                           |
|                        +--------------------------+                           |
|                                                                                |
+-------------------------<F3 When don enter Veg. Names >----------------------- +
Tab  Esc F1  F2  F3  F4  F8  F9  F10  Ins  Del  PgUp  PgDn  Home  End
FUNC esc help clr cont call dupe info desc ins del pgup pgdn lst last
```

Figure 7-2. Vegetation Inputs

Field operations are now displayed. [Enter].

The question about senescence is not applicable for this example so select the default answer of [no]. [Enter].

Enter the beginning date of the first operation. [3/1/1]. [Enter]. The sequence is Month/Day/Year with year one being the first year. A two-digit year can also be used (e.g. 98)

Another dialog box appears that lists equipment such as disk, chisels, blade cut matl (dozer blading a cut), drills, harrows, and rippers as well as additions of other crop residue, e.g. straw mulch and rock mulch.

Prior to adding mulch we must disturb the soil. [blade fill matl] is selected. [Enter]. [Enter].

The next operation is the addition of 2 tons/ac straw mulch. [3/1/1]. [Enter]. Highlight "add straw mulch". [Enter]. [Enter].

Input the quantity of mulch addition in lbs/ac. The amount entered for the mulch should reflect the mulch remaining if some is blown away by the wind. In this example, netting is used to retain the mulch in place. Also, the mulch is assumed to be well anchored to minimize runoff flowing between the soil and mulch and to minimize mulch movement by runoff.

[4000]. [Enter]. [Enter]. [F3]. We will assume that there is no additional operations, so "no operation" [Enter]
We are now finished with the data entry [F3].

Display options are now listed. Highlight number [1]. [Enter]. [Esc], and then highlight number [2] to display Rotational C (by vegetation) and Operational C tables, respectively, as shown in **Figure 7-3**.

```
      File        Exit        Help        Screen
+------------------< C Factor: results by veg. types 1.06 >--------------------- +
|                                                                                 |
|                                                                 veg. C          |
|   veg.                        start date     end date     %EI       factor      |
| ------------------------------------------------------------------------------- |
|  no vegetation                3/1/1          3/1/2       100.0      0.159       |
| -------------------------------------------------- Rotation C Factor = 0.159 -----|
|       File        Exit        Help        Screen                                 |
+------------------< C Factor: results by operations 1.06 >--------------------- +
|  veg. # 1/1: no vegetation        prev. veg.: no vegetation                     |
|                        % res. cover    op.          date                        |
| ---operation------------after op.----date---------next op.-----SLR-----%EI----- |
|  blade fill matl           0        3/1/1         3/1/1       0         0.0     |
|  add straw mulch           91       3/1/1         3/1/2       0.159  100.0      |
+---------- Rotation C Factor = 0.159 -------- Veg. C Factor = 0.159 ----------- +
```

Figure 7-3. Results by Vegetation and by Operations

Highlight number [3] to display half-month sub-factors, **Figure 7-4**.

```
      File        Exit        Help        Screen
+------------------< C Factor: 15-day SLR subfactors 1.06 >--------------------- +
|                    % res.                                                       |
|                    cover  plu  *  cc  *  sc  *  sr  *  sm  =  slr    %EI       |
 -------------------------------------------------------------------------------
*********** BEGINNING/END OF ROTATION *** Rotation C Factor = 0.159 ***********
  3/1/1         no vegetation       blade fill matl
  3/1/1         no vegetation       add straw mulch
  3/1 - 3/15/1         90     1       1       0.066  1.06    1       0.07       1.0
  3/16 - 3/31/1        89     0.999   1       0.069  1.06    1       0.073      2.0
  4/1 - 4/15/1         87     0.997   1       0.072  1.06    1       0.076      2.0
  4/16 - 4/30/1        85     0.994   1       0.076  1.06    1       0.08       2.0
  5/1 - 5/15/1         83     0.991   1       0.08   1.06    1       0.084      3.0
  5/16 - 5/31/1        80     0.988   1       0.086  1.06    1       0.09       3.0
  6/1 - 6/15/1         77     0.984   1       0.096  1.06    1       0.1        5.0
  6/16 - 6/30/1        73     0.979   1       0.106  1.06    1       0.11       9.0
  7/1 - 7/15/1         69     0.975   1       0.119  1.06    1       0.123     11.0
  7/16 - 7/31/1        64     0.97    1       0.134  1.06    1       0.138     12.0
  8/1 - 8/15/1         60     0.965   1       0.151  1.06    1       0.155     11.0
  8/16 - 8/31/1        56     0.96    1       0.171  1.06    1       0.174      9.0
  9/1 - 9/15/1         52     0.955   1       0.192  1.06    1       0.194      9.0
  9/16 - 9/30/1        48     0.95    1       0.213  1.06    1       0.214      6.0
  10/1 - 10/15/1       45     0.945   1       0.232  1.06    1       0.232      3.0
  10/16 - 10/31/1      43     0.94    1       0.248  1.06    1       0.247      3.0
  11/1 - 11/15/1       41     0.935   1       0.261  1.06    1       0.258      2.0
  11/16 - 11/30/1      40     0.929   1       0.273  1.06    1       0.269      1.0
  12/1 - 12/15/1       38     0.924   1       0.285  1.06    1       0.279      1.0
  12/16 - 12/31/1      37     0.919   1       0.297  1.06    1       0.289      1.0
  1/1 - 1/15/2         36     0.913   1       0.308  1.06    1       0.298      1.0
  1/16 - 1/31/2        35     0.908   1       0.32   1.06    1       0.308      1.0
  2/1 - 2/15/2         33     0.903   1       0.333  1.06    1       0.318      1.0
  2/16 - 2/28/2        32     0.897   1       0.345  1.06    1       0.328      1.0
*********** BEGINNING/END OF ROTATION *** Rotation C Factor = 0.159 ***********
```

Figure 7-4. Results by 15-day Period

What can be learned from **Figure 7-4**? The time increments are given in 15-day intervals. The percent residue cover decreases from 90% to 32% during the year. This is not a C sub-factor, and is simply listed to provide information.

The prior land use (PLU), C sub-factor accounts for soil consolidation, i.e., the soil becomes less erodible through time. On 3/1/1 C-PLU is initialized at a value of "1" because the soil was disturbed during fill-slope construction.

Other construction situations can exist. If the soil is scraped or cut without loosening the remaining soil, and the cut is below the root zone, (which is the most likely case), then a consolidation sub-factor (PLU) value of 0.45 should apply. For the fill-slope situation, sub-factor PLU reduces to 0.897 after one year of consolidation.

The RUSLE program allows the creation of a specific operational file for various operation scenarios. If only the vegetation and the near surface soil is cut, most of the roots would remain to help bind the soil. A construction operation could be created to begin the sequence of operations with the roots remaining in the soil. In this case PLU would include the effects of roots and the effect of consolidation, thus the PLU value would be less than 0.45.

The canopy sub-factor (CC) value is 1.0 because no vegetation is present that forms a canopy to intercept rainfall and reduce its erosivity.

The surface cover sub-factor, (SC), is the predominant mechanism of soil-loss reduction. On 3/1/1 SC was initiated at a value of 0.066, and through time the mulch became less effective because of decomposition. For example, the SC value increased to 0.096, 0.19, and 0.28 for 6/1/1, 9/1/1, and 12/1/1, respectively. After a full year, the mulch effectiveness was reduced to a SC value of 0.34.

The value of the surface roughness sub-factor (SR) is 1.06, (which means that the smooth surface left by the grading is six percent more erodible than the base condition of the unit-plot condition in RUSLE that is assigned a value of 1.0, as previously described).

The other information that can be found in **Figure 7-4** is the % EI that occurs throughout the year for Charleston, SC. Historically the most erosive storm period is from 6/16 through 9/15, which accounts for 61 % of the total average erosion. The Fall and Winter seasons have a very small erosion potential, suggesting preferable times for site disturbance. The overall rotational C value is 0.16. Thus, the mulch provided substantial soil protection.

[Esc] to return to the prior screen where the option for C factor output is chosen.

Highlight "Operational C". [Enter]. The overall C-factor is 0.16.

[Esc] [Esc] [Esc] [Esc] to return to the Soil Loss and Sediment Yield Computation Worksheet.

Although RUSLE displays several decimal places in the output, these decimal places are not always significant. Generally the number of significant decimal places that should be reported is two, which is the way that the decimal places are reported in this chapter, even though RUSLE screens show additional places.

As can be seen, the C value of 0.16 has been calculated and entered. The total estimated average annual soil loss has been reduced from 450 to 72 tons/ac/year, comparing Scenarios 1 and 2, respectively.

Saving the created file:
[tab].

[arrow down to 2]. [Enter].
Type filename. [EX1SCNO2]. [Enter].
Type in description of the scenario.
[6/11/97 Charleston, SC
Fill embankment stabilization during highway construction
Ex. 1, Scenario 2- 2 tons/ac
straw mulch. 1 yr simulation]
[F3].

Scenario 3 - Fill embankment stabilization during highway construction, broadcast seeding of tall fescue grass followed by 2 tons per acre straw mulch.

We expand on Scenario 2 by adding the broadcast seeding of tall fescue grass which also begins the growth cycle on March 1 followed by the placement of mulch and netting.

To use the previous file:
Arrow down to the next line on the computation worksheet.
[tab]
Select [loadfile] [Enter]
Arrow down to highlight "EX1SCNO2" [Enter].
The factors are now listed on the third line.
Arrow to the C factor. [F4].

We will follow the same sequence of steps as in Scenario 2; only the new changes will be discussed herein.

Move the cursor to the area where vegetation is entered.
"No vegetation" will be highlighted.
[F6] will display the list of vegetation choices.
Use the arrow key to move the cursor so that "tall fescue, 1st year" is highlighted.
[F3]. [F3]. [F3].

The field operations screen is now displayed.
[Enter] until the 3/1/1 date for the "add mulch operation" is highlighted
[ins] key
[3/1/1] [Enter]
From the dialog box select "broadcast planter" . [Enter]
The input C factor figure is shown in **Figure 7-5**.

The sequence of operations is important. The seed is planted before the mulch is applied. If the add mulch operation precedes the planting operation, the planter buries a portion of the mulch, resulting in less cover and more erosion than when the planting occurs before adding mulch. Also, some of the seed will rest on the mulch so that the expected vegetation cover may not be realized.

[F3].
Highlight "Rotational C". [Enter].
Highlight "Operational C". [Enter]. Refer to **Figure 7-6**. [Esc]
Highlight "Half-Month Sub-factor Values". [Enter]. Refer to **Figure 7-7**.

```
         File            Exit        Help        Screen
+---------------------< Time-varying C: operations 1.06 >---------------------- +
|
 1/1     veg.: tall fescue, 1st yr_   senescence code :1
 -Date-------Field Operation-------Res. Add   (#/A)----New Growth Set-----------
 3/1/1           blade fill matl
 3/1/1           broadcast planter
 3/1/1           add straw mulch        4000
+------------------------<F3 when Questions Answered >------------------------- +
Tab  Esc F1  F2  F3  F4  F8  F9  F10  Ins  Del  PgUp  PgDn  Home  End
FUNC esc help clr cont call dupe info desc ins del pgup pgdn 1st last
```

Figure 7-5. C-factor Inputs

```
   File            Exit        Help        Screen
+------------------< C Factor: results by veg. types 1.06 >--------------------- +
|
                             veg. C
 veg.                          start date     end date     %EI       factor
--------------------------------------------------------------------------------
 tall fescue, 1st yr           3/1/1          3/1/2       100.0      0.009
----------------------------------------------- Rotation C Factor = 0.009 ------

+------------------< C Factor: results by operations 1.06 >---------------------+
|
 veg. # 1/1: tall fescue, 1st yr         prev. veg.: tall fescue, 1st yr
          % res. cover                 op.          date
---operation------------after op.----date---------next op.-----SLR-----%EI------
 blade fill matl            0        3/1/1         3/1/1       0         0.0
 broadcast planter          0        3/1/1         3/1/1       0         0.0
 add straw mulch            91       3/1/1         3/1/2       0.009  100.0
---------- Rotation C Factor = 0.009 -------- Veg. C Factor = 0.009 ------------
|
|
+------------------------< Esc Returns to C Result Menu >---------------------- +
Tab  Esc F1   F3   F9   PgUp PgDn Home End
FUNC esc help cont info pgup pgdn 1st  last
```

Figure 7-6. Results by Vegetation Operations

So what is the effect of the planting and establishing of a grass cover along with the 2 tons/ac straw mulch on the erosion rate:

1. The percent residue cover decreases from 90 % to 32 %, as it did in the previous scenario.

2. The prior land use (PLU) factor changes from 1.00 to 0.33 during the year reflecting the effect of root biomass and consolidation of the soil on soil loss.

3. The canopy sub-factor (CC) decreases from 1.00 to 0.11 to account for the development of the grass cover, which is established by 6/1 as shown by a sub-factor CC of 0.11.

4. The surface cover sub-factor (SC) is initiated at 0.066 and increases the same as in Scenario 2.

5. The surface roughness sub-factor (SR) is 1.056, essentially the same as in Scenario 2.

The overall C factor is 0.009.

```
  File            Exit        Help        Screen
+------------------< C Factor: 15-day SLR subfactors 1.06 >---------------------+
         % res.
         cover              plu  *  cc  *  sc  *  sr  *  sm  =  slr    %EI
--------------------------------------------------------------------------------
*********** BEGINNING/END OF ROTATION *** Rotation C Factor = 0.009 ***********
 3/1/1         tall fescue, 1st yr  blade fill matl
 3/1/1         tall fescue, 1st yr  broadcast planter
 3/1/1         tall fescue, 1st yr  add straw mulch
 3/1 - 3/15/1          90     0.954  0.908  0.066  1.056  1      0.061     1.0
 3/16 - 3/31/1         89     0.857  0.644  0.069  1.056  1      0.04      2.0
 4/1 - 4/15/1          87     0.754  0.4    0.072  1.056  1      0.023     2.0
 4/16 - 4/30/1         85     0.63   0.254  0.076  1.056  1      0.013     2.0
 5/1 - 5/15/1          83     0.514  0.182  0.08   1.056  1      0.008     3.0
 5/16 - 5/31/1         80     0.414  0.129  0.086  1.056  1      0.005     3.0
 6/1 - 6/15/1          77     0.38   0.109  0.096  1.056  1      0.004     5.0
 6/16 - 6/30/1         73     0.378  0.109  0.106  1.056  1      0.005     9.0
 7/1 - 7/15/1          69     0.375  0.109  0.119  1.056  1      0.005    11.0
 7/16 - 7/31/1         64     0.373  0.109  0.134  1.056  1      0.006    12.0
 8/1 - 8/15/1          60     0.37   0.109  0.151  1.056  1      0.006    11.0
 8/16 - 8/31/1         56     0.368  0.109  0.171  1.056  1      0.007     9.0
 9/1 - 9/15/1          52     0.365  0.109  0.192  1.056  1      0.008     9.0
 9/16 - 9/30/1         48     0.363  0.109  0.213  1.056  1      0.009     6.0
 10/1 - 10/15/1        45     0.36   0.109  0.232  1.056  1      0.01      3.0
 10/16 - 10/31/1       43     0.357  0.109  0.248  1.056  1      0.01      3.0
 11/1 - 11/15/1        41     0.354  0.109  0.261  1.056  1      0.011     2.0
 11/16 - 11/30/1       40     0.352  0.109  0.273  1.056  1      0.011     1.0
 12/1 - 12/15/1        38     0.349  0.109  0.285  1.056  1      0.011     1.0
 12/16 - 12/31/1       37     0.346  0.109  0.297  1.056  1      0.012     1.0
 1/1 - 1/15/2          36     0.343  0.109  0.308  1.056  1      0.012     1.0
 1/16 - 1/31/2         35     0.34   0.109  0.32   1.056  1      0.013     1.0
 2/1 - 2/15/2          33     0.337  0.109  0.333  1.056  1      0.013     1.0
 2/16 - 2/28/2         32     0.334  0.109  0.345  1.056  1      0.013     1.0
*********** BEGINNING/END OF ROTATION *** Rotation C Factor = 0.009 ***********
```

Figure 7-7. Results by 15-day Period

We can see in the Soil Loss Ratio (SLR) column in Scenario 3 that as the mulch is decomposing, the grass is becoming established and the combination of these two factors results in the low estimated soil loss. The grass growth during the highest erosion-potential period of 6/1 through 9/15 is especially critical in reducing estimated soil loss.

The estimated soil loss is 4.0 ton/ac/year. This is a major reduction in soil loss from the 72 tons/ac/year estimated for the straw mulch alone. The results reflect our expectations and experience that grass planted at the right time of year and protected by anchored mulch will readily become established, protecting the surface from erosion, and protecting the contractor from potential costs of re-treating a portion or the entire job. The contractor's vulnerability to potentially detrimental off-site impacts is likewise reduced by proper planning and implementation of erosion controls.

[Esc] from program and save as [EX1SCNO3].

Scenario 4 - Fill embankment stabilization during highway construction using rock mulch.

We will again modify the file used in Scenario 2 by substituting rock mulch for straw mulch.

Follow the previously detailed procedure to load file EX1SCNO2.
Proceed to the C factor and highlight "% surface cover by rock fragment".

We could use this field to enter a value for the rock cover, but that would be an improper use of this field. This entry is used to designate coverage of rock fragments on soils that also include rock fragments in the profile. It is not used to enter rock added as a mulch. Leave this entry at zero.

However, the land use designation will need to be changed to show disturbed land, topsoil fill, with rock cover.

Use the arrow keys to place the cursor on the land-use designator.
[F4] to reach the LS screen where the land use can be changed.
[12] [Enter] to select the land use of "disturbed land, topsoil fill, rock cover".
[F3] to compute a new LS value with the new land use.
[Esc] to return to the C-factor screen.

The entries on the C-factor screen are now complete,

[F3] to move to the next C-factor screen to change operations to "add rock mulch" rather than straw mulch.
Use the arrow keys or [Enter] to reach and highlight add straw mulch. .
[F6] to obtain the list of field operations.
Arrow up to display add rock mulch.
Let s see the assumed values for this operation. [F4].
Select Option 1 to add/edit/delete operations from the OPERATIONS Database Set.
[Enter].

The field operation is "add rock mulch" and the assumptions are shown on the displayed screen (**Figure 7-8**). The effect of adding rock mulch is 4, which is simply other residue added to the site. At 90% surface cover, 200,000 lbs/acre were added.

```
      File        Exit        Help        Screen
+--------------< Create/Edit Site Operation Database Set 1.06 >----------------- +
                operation: add rock mulch______
   Effect #1:4 %sur 100  Dsr 0      Dsu 0      #/A@30%:0  60%:15000090%:200000
   Effect #2:1
   Effect #3:1
   Effect #4:1
   Effect #5:1

                      +-------------------------------------------------+
                        1. no effect
                        2. soil surface disturbed
                        3. current vegetation residue added to surface
                        4. other residue added to the site
                        5. residue removed from site
                        6. current vegetation harvested
                        7. vegetation growth begins
                        8. current vegetation is killed                  .
                        9. call in a new vegetation growth set
                      +-------------------------------------------------+



+--------------------< F7 Saves, Esc Returns to OP Main Menu >------------------- +
Tab  Esc F1   F2  F6   F7   F9   F10  Ins Del
FUNC esc help clr list save info desc ins del
```

Figure 7-8. Field Operation Data Base

One of the advantages of using rock is that it naturally conforms to the soil surface and provides greater protection than does a mulch like straw that tends to bridge low areas where runoff can concentrate and cause rill erosion beneath the mulch. However, rock mulch precludes post-reclamation land use.

[Esc] [Esc] [Esc] to return to the field operations screen.
Arrow to the right.
[200,000]. [Enter]. [F3].

View the half-month sub-factor values, as shown in **Figure 7-9**.

The surface cover C sub-factor has been reduced to 0.055, and remains constant throughout the year because the rock mulch does not decompose like the straw mulch.

Return to the Soil Loss and Sediment Yield Computation Worksheet

```
+-----------------< C Factor: 15-day SLR subfactors 1.06 >-------------------- +
                      % res.
                      cover  plu  *  cc  *  sc  *  sr  *  sm  =  slr    %EI
 ------------------------------------------------------------------------------
 *********** BEGINNING/END OF ROTATION *** Rotation C Factor = 0.055 ***********
   3/1/1        no vegetation       blade fill matl
   3/1/1        no vegetation       add rock mulch
   3/1 - 3/15/1        83     1      1      0.054  1.06   1      0.057     1.0
   3/16 - 3/31/1       83     0.999  1      0.054  1.06   1      0.057     2.0
   4/1 - 4/15/1        83     0.997  1      0.054  1.06   1      0.057     2.0
   4/16 - 4/30/1       83     0.994  1      0.054  1.06   1      0.057     2.0
   5/1 - 5/15/1        83     0.992  1      0.054  1.06   1      0.056     3.0
   5/16 - 5/31/1       83     0.989  1      0.054  1.06   1      0.056     3.0
   6/1 - 6/15/1        83     0.985  1      0.054  1.06   1      0.056     5.0
   6/16 - 6/30/1       83     0.981  1      0.054  1.06   1      0.056     9.0
   7/1 - 7/15/1        83     0.978  1      0.054  1.06   1      0.056    11.0
   7/16 - 7/31/1       83     0.974  1      0.054  1.06   1      0.055    12.0
   8/1 - 8/15/1        83     0.969  1      0.054  1.06   1      0.055    11.0
   8/16 - 8/31/1       83     0.965  1      0.054  1.06   1      0.055     9.0
   9/1 - 9/15/1        83     0.961  1      0.054  1.06   1      0.055     9.0
   9/16 - 9/30/1       83     0.956  1      0.054  1.06   1      0.054     6.0
   10/1 - 10/15/1      83     0.951  1      0.054  1.06   1      0.054     3.0
   10/16 - 10/31/1     83     0.946  1      0.054  1.06   1      0.054     3.0
   11/1 - 11/15/1      83     0.941  1      0.054  1.06   1      0.054     2.0
   11/16 - 11/30/1     83     0.936  1      0.054  1.06   1      0.053     1.0
   12/1 - 12/15/1      83     0.931  1      0.054  1.06   1      0.053     1.0
   12/16 - 12/31/1     83     0.926  1      0.054  1.06   1      0.053     1.0
   1/1 - 1/15/2        83     0.921  1      0.054  1.06   1      0.052     1.0
   1/16 - 1/31/2       83     0.916  1      0.054  1.06   1      0.052     1.0
   2/1 - 2/15/2        83     0.91   1      0.054  1.06   1      0.052     1.0
   2/16 - 2/28/2       83     0.905  1      0.054  1.06   1      0.052     1.0
 *********** BEGINNING/END OF ROTATION *** Rotation C Factor = 0.055 ***********
```

Figure 7-9. Results by 15-day Period The estimated soil loss, based on a C value of 0.055, is 26 tons/ac/year. Thus, 80% rock cover reduced soil loss much more than the straw mulch, but not as much as the straw mulch and grass combined, which illustrates the value of vegetation for controlling soil erosion.

Example 2: Reclaimed Outslope Reconstruction

Problem Statement: An Appalachian coal mine must reconstruct an outslope. Four alternative hillslope-profile configurations are considered: (1) uniform, (2) concave, (3) convex, and (4) complex. The alternative configurations are shown in Figure 7-10. An assessment of the alternative outslope configurations uses the RUSLE program.

Scenario 1 - Uniform hillslope.
Scenario 2 - Concave hillslope.
Scenario 3 - Convex hillslope.
Scenario 4 - Complex hillslope.

What Will the User Learn?

The RUSLE capability demonstrated through Example 2 is the ability to input and evaluate the hillslope-profile configurations of uniform, concave, convex, and complex. In Scenario 1 the user learns how to calculate the K value based on inputs of the soil-particle size percentages. The user will learn to account for the effect of percent rock fragments and the effect of specifying a roughened soil-surface condition. A method to estimate surface roughness is illustrated. Scenarios 2, 3, and 4 illustrate inputs and results interpretations for concave, convex, and complex hillslope configurations, respectively.

Design information

Location - Eastern Kentucky.

Soil-substitute material: From a particle size analysis; % silt and very fine sand = 28, % sand minus very fine sand = 64, % clay = 8, and from an organic material analysis the % organic material (non-coal) = 1.2. % sand = 67, % silt = 25, and % clay = 8, i.e. a sandy loam.

Hillslope-profile configurations -

(1) uniform 35 %, and 400 ft,

(2) concave 44 %, 250 ft and 20 %, 150 ft,

(3) convex 31.4 %, 350 ft and 60 % 50 ft, and

(4) complex 60 %, 150 ft, 13.3 %, 150 ft and 30 %, 100 ft.

Refer to Figure 7-10.

A terrace is located above the highwall to divert storm water away from the outslope. Thus no runoff will enter from above the highwall on to the hillslope.

Regraded Slope Shape	Segment 1			Segment 2			Segment 3		
	Slope (%)	Horizontal Distance (ft)	Vertical Drop (ft)	Slope (%)	Horizontal Distance (ft)	Vertical Drop (ft)	Slope (%)	Horizontal Distance (ft)	Vertical Drop (ft)
Uniform	3.5	400	140						
Concave	44	250	110	20	150	30			
Convex	31.4	350	109.9	60	50	30			
Complex	60	150	90	13.3	150	19.95	30	100	30

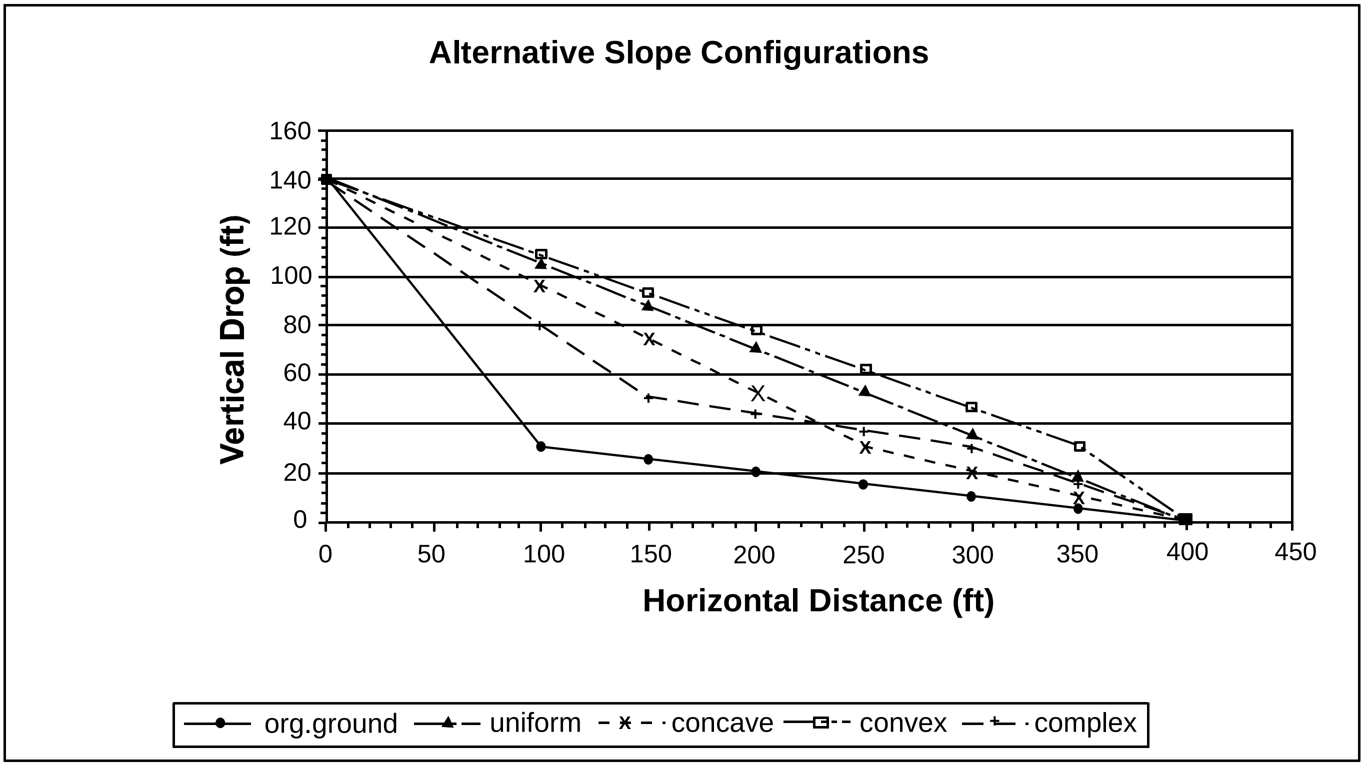

Fig 7-10. Alternative Hillslope Configurations

Scenario 1 - Uniform reclaimed outslope configuration.

Start a new file on the Soil Loss and Sediment Yield Computation Worksheet screen.

At the R factor. [F4].
Select [Charleston, WV] as the best climate station
[F4] to transfer to the LS value.
[1] hillslope segment,
[2] measured horizontally,
[3] sandy loam soil texture entered through the K-factor screen, and
[10] a land use of disturbed fill, subsoil, no rock cover is entered.

A gradient of [35] and length of [400] results in a LS = 17.9 and the equivalent slope = 35 % is the same as the actual hillslope steepness because the hillslope shape is uniform.

If the hillslope shape is nonuniform, the equivalent slope is not the same as the average steepness because the relationship between erosion and hillslope length is nonlinear.

[Esc]. returns you to the R-factor screen
R = 140.
No adjustment for ponding.

K-factor input:

Arrow to the K factor. [F4].
Select using the Soil Interpretation Record/ K Nomograph.
Arrow to estimated K. [F4].
% silt and very fine sand [28].
% clay [8]
% organic material [1.2].

Soil-structure code: The soil-substitute material is granular in structure and predominantly 1 to 2 mm, so select "fine granular". [2]

Soil structure can be determined by a soil scientist or other qualified scientist or engineer.

In the Appalachian region, soil-substitute material is expected to be slow to moderate in permeability. [4].

To define the permeability, a laboratory permeability analysis could be conducted using standard or modified Proctor compaction. Care should be taken to accurately mimic the in-field compaction. An alternative is to use a double-ring infiltrometer in the field. A difficulty in using this apparatus is obtaining a good seal along the infiltrometer walls and may require the use of kaolinite or bentonite clay for this purpose. Nevertheless, the permeability code represents the permeability of the soil profile.

Although additional specific information is gained through field and laboratory investigations, the RUSLE user is cautioned to balance the cost of gaining additional data with the anticipated increase in soil-loss estimation accuracy. The simplest way to determine this trade-off is to test the sensitivity of an input parameter with respect to output. For instance, to determine if it is worthwhile to invest time and money to conduct a field investigation of regraded soil-substitute permeability, the user should enter one higher and one lower permeability class to see how these changes affect the estimated K value. Of course, each of the input parameters need to be kept in perspective. Although we may be able to "fine tune" one parameter, the overall accuracy of the soil-loss estimate may be limited if some of the other parameters are input with lesser accuracy,

Refer to the Rock Fragments in the Profile section of Chapter 3 of these Guidelines or Chapter 3 of (Renard et al., 1997) for a detailed discussion of this variable.

Because the K value is anticipated to be greater than 0.15 no correction will be made to the K value. [1]. [F3].

A K value of 0.2 is calculated.
[Esc] to the Seasonally Variable K-factor screen. [Enter].
% rock cover. [20].

This is a sensitive parameter with respect to soil-loss estimations. A method to estimate percent rock cover is provided in Chapter 5.

For the number of years to consolidation, use the default value because no data exists for soil-substitute material, but such material should respond similarly to disturbed soils. [7]. [Enter]

Most soil-substitute materials in Appalachian coal fields are highly compacted and, depending on the mix of shale to sandstone, may weather rapidly which may further reduce permeability. Most soil-substitute material in these areas will be in hydrologic soil group 3 or 4. [3]. [Enter]

Entry of the soil series is for informational purposes, whereas the soil texture is used in the terrace P-factor computation. Leave soil series blank. Soil texture is based on the United States Department of Agriculture (USDA) soil textural classification system.

[3] for Sandy Loam. [F3]

The seasonally Variable K-Factor screen is now displayed showing an average annual K value of 0.19 as shown in **Figure 7-11**. Also listed are the maximum and minimum K values of 0.46 and 0.078, respectively. The maximum value occurs at the end of the annual freeze-thaw period which is April 2 for this area. The minimum value occurs on October 2, corresponding to a period when the soil is the driest and least likely to produce runoff. This is also at the end of the period of biological activities in the soil, which reduces soil loss.

The LS value has already been calculated and so proceed to the C factor. We need to account for the effect of percent rock fragment on the surface and the roughened state of the soil- substitute material on soil-loss rates

```
      File        Exit        Help        Screen
+------------------< Seasonally Variable K Factor 1.06 >---------------------- +
     city code: 48001   CHARLESTON          WV       estimated K: 0.2
  % rock cover: 20    # yrs to consolidate: 7    hyd. group: 3
  soil series:                    surface texture: sandy loam

   1/1-1/15         1.0      0.187        7/1-7/15         13.0       0.179
   1/16-1/31        1.0      0.215        7/16-7/31        11.0       0.155
   2/1-2/15         1.0      0.248        8/1-8/15          9.0       0.133
   2/16-2/28        1.0      0.284        8/16-8/31         8.0       0.115
   3/1-3/15         1.0      0.319        9/1-9/15          5.0       0.098
   3/16-3/31        1.0      0.365        9/16-9/30         5.0       0.085
   4/1-4/15         2.0      0.435        10/1-10/15        2.0       0.082
   4/16-4/30        3.0      0.376        10/16-10/31       2.0       0.094
   5/1-5/15         4.0      0.325        11/1-11/15        1.0       0.108
   5/16-5/31        5.0      0.281        11/16-11/30       1.0       0.124
   6/1-6/15         8.0      0.24         12/1-12/15        1.0       0.142
   6/16-6/30       13.0      0.207        12/16-12/31       1.0       0.162
                                                                      -----
    EI DIST.: 111        FREEZE-FREE DAYS: 193    AVERAGE ANNUAL K:   0.189
     R VALUE: 140    Kmin = 0.078 on 10/2    Kmax = 0.461 on 4/2
+---------------------------------< Esc exits >-------------------------------- +
Tab  Esc F1   F2  F3   F4   F6   F9
FUNC esc help clr cont call list info
```

Figure 7-11. Seasonally Variable K Factor

[F4].
Highlight the time-invariant method to explore this method. [Enter].
Vegetation data will be entered directly. [3]. [Enter].

The values for the effective root mass, % canopy cover, and average fall height are set to zero because no vegetation is present.

The roughness value for the field condition is a moderately sensitive parameter that accounts for the roughened condition of a ground surface on soil-loss rates. A rough surface provides opportunities for runoff to pond and subsequently infiltrate, and provides numerous deposition sites. All of these effects reduce soil loss. A method to estimate random roughness in the field is detailed in Chapter 3. Refer to **Figure 7-12** which shows the relationship between the random roughness factor, and the range in elevation in inches. For example, the surface-elevation range for the soil-substitute material on this outslope will be 6 to 9 inches based on previous measurements of similar areas.

Select 7.5 inches and from **Figure 7-12**, a random roughness value of 1.6 is estimated. [1.6]. [Enter].

Yes, there has been mechanical disturbance. [2]. [Enter].
Number of years needed for consolidation. Use the default value of 7.
Number of years since last disturbance.
Because this outslope will be further reclaimed for Phase II bond release in about 1 year enter [1].

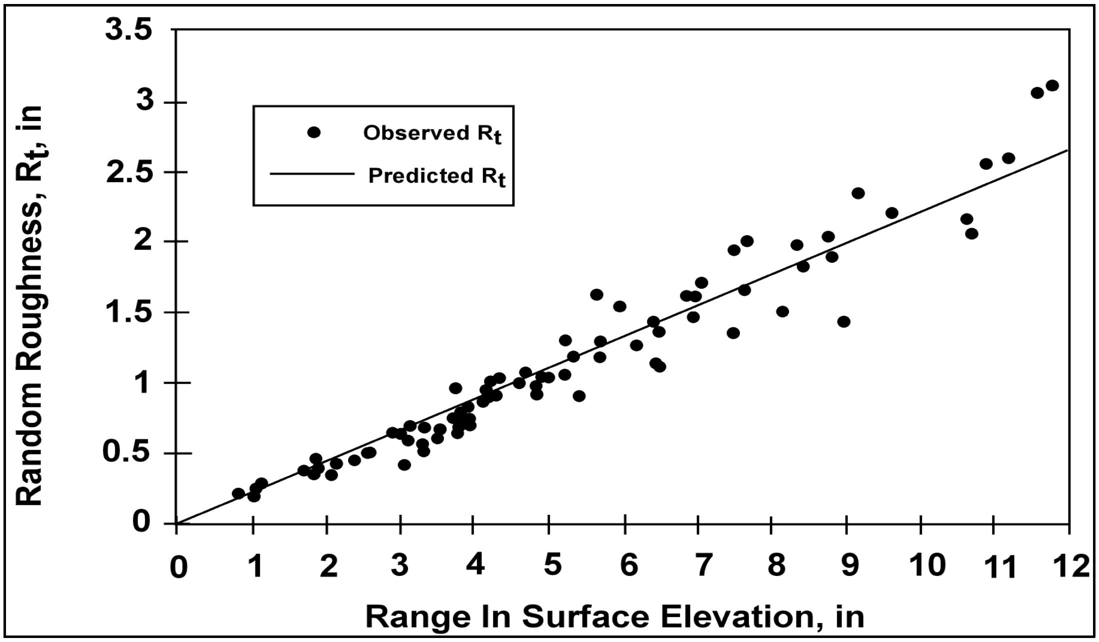

Figure 7-12. Relation between the range in surface elevation and random roughness

Note that this option for the C factor gives an estimate of the C value at the time since the last disturbance (e.g. 1 year), rather than an average for the period since consolidation. Because the spoil has been graded and left untreated for a period of one year, using "zero" or "one year" will compute a C value for the time immediately following grading. When seeding is completed to start Phase II bond release, the time since disturbance is reset, and time zero begins following the seeding operation. However, some consideration must be given to operations where only a portion of the surface is disturbed. For those situations, a separate RUSLE calculation should be made and the time should not be set to zero, but rather a proportional adjustment between 0 and 7 years, or the appropriate total number of years for soil consolidation, based on the percent of land disturbance.

The next three cover values have been previously entered in the K-factor input section.

The surface-cover function; b-value code is [1] to allow the program to automatically compute a b value. [F3]

A C value of 0.22 is calculated.

This value differs from the value that would be estimated for the C factor using the original USLE. Thus, one of the distinct advantages of using RUSLE is obtaining a C value that accounts for both surface rock-fragment cover and surface roughness.

The P factor has two options: (1) one for frequently disturbed land, and (2) one for infrequently disturbed land. The option for infrequently disturbed land is used for conditions such as pasture and rangelands where infrequent disturbance generally is for renovation of the vegetation. Use the option for frequently disturbed land for mining, construction, and reclaimed lands when the time since the last disturbance is less than the time to consolidation.

A P value of 1 is entered for this example after returning to the Soil Loss and Sediment Yield Computation Worksheet. [1].

The estimated soil loss is 100 tons/ac/year for the uniform reclaimed outslope configuration.

Save the file as EX2SCNO1.

Scenario 2 - Concave reclaimed outslope configuration.

The only change is with the LS factor:

Load the saved file and proceed as follows for the LS factor.
[2] hillslope segments and [1] varying in length are the input changes.
Segment 1 gradient [44], length [250] ft.
Segment 2 gradient [20], length [150] ft.
Resultant LS = 15.0, Equivalent LS-factor gradient is 29.3%. The actual overall gradient is 35 %.

Because of the concave hillslope-profile configuration the equivalent uniform LS gradient is reduced to 29.3%. That is to say that a 29.3 % hillslope, which is 400 ft in length, will result in a LS value of 15.0. Refer to **Figure 7-13**.

Note that a LS value is given for each hillslope segment. The LS value of a given hillslope segment depends, in part, upon the hillslope length above that segment but the LS value does not depend upon the rate of erosion upslope.

The estimated soil loss is 86 tons/ac/year.

Save as EX2SCNO2.

```
      File        Exit        Help        Screen
+-----------------------------< LS Factor 1.06 >-------------------------------+
|                                                                              |
|   number of segments: 2          segment lengths are measured: 2             |
|         segments are: 1                                                      |
|         soil texture: sandy loam                                             |
|     general land use: 10                                                     |
 ------------------------------------------------------------------------------
|                          1         2                                          |
| Gradient (%) of Segment   44        20                                       |
| Length of Segment (ft)    250       150                                      |
| Segment LS               15.99     13.257                                     |
 -----+---------------------------------------------------------------+---------
|     | overall LS = 15; equiv. slope = 29.3 %; horiz. length = 400 ft|         |
|     +---------------------------------------------------------------+         |
|                                                                              |
+---------------------------------< Esc exits >--------------------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 7-13. Hillslope Segment Input Screen for Concave Hillslope

Scenario 3 - Convex reclaimed outslope configuration

Re-load EX2SCNO2, then [Enter]
Segment 1 [31.4], [350]
Segment 2 [60], [50].
Resultant LS = 19.0, Equivalent LS-factor gradient is 37.3 % as shown in **Figure 7-14**.

The influence of the hillslope-segment sequence can be readily seen in this example. The long upper hillslope segment transfers runoff to the shorter and steeper lower hillslope segment, thereby significantly increasing the LS value of this portion of the convex hillslope.

The estimated soil loss is 110 tons/ac/year.

The soil loss from this convex hillslope is somewhat more than that from the uniform hillslope. However, the soil loss from the lower segment of the convex hillslope is much higher than from the similar lower segment for the uniform hillslope. The LS value for the lower 50 ft on the convex hillslope is 51.7, which is 74 percent greater than the 29.7 value for this equivalent segment on the uniform hillslope. Establishing and maintaining vegetation on the convex hillslope will be more difficult than on the uniform hillslope because of the much higher erosion rate on the lower segment of the convex hillslope than on the uniform hillslope. The LS value for the lower segment on the uniform hillslope was obtained by dividing the uniform hillslope into two segments, 350 and 50 ft in length, respectively.

Save as EX2SCNO3.

```
      File        Exit        Help        Screen
+-----------------------------< LS Factor 1.06 >-------------------------------+
|                                                                              |
|   number of segments: 2          segment lengths are measured: 2             |
|         segments are: 1                                                      |
|         soil texture: sandy loam                                             |
|     general land use: 10                                                     |
 ------------------------------------------------------------------------------
|                             1         2                                      |
| Gradient (%) of Segment   31.4      60                                      |
| Length of Segment (ft)    350       50                                      |
| Segment LS              14.354    51.653                                     |
 -----+---------------------------------------------------------------+---------
|     | overall LS = 19; equiv. slope = 37.3 %; horiz. length = 400 ft |        |
|     +---------------------------------------------------------------+         |
|                                                                              |
+---------------------------------< Esc exits >--------------------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 7-14. Hillslope Segment Inputs Screen for Convex Hillslope

Scenario 4 - Complex reclaimed outslope configuration.

Proceed as before, then [enter]:
[3] for the number of segments
Segment 1 [60], [150]
Segment 2 [13.3], [150]
Segment 3 [30], [100].
Resultant LS = 13.4, Equivalent LS-factor gradient is 26.4 %.
The estimated soil loss is 77 tons/ac/year.
Save as EX2SCNO4.

The complex hillslope configuration reduces estimated soil loss to less than any of the other profile configurations.

So which is the best hillslope configuration?

To summarize, the uniform, concave, convex, and complex hillslope shapes resulted in estimated soil loss of 100, 86, 110, and 77 tons/ac/year, respectively. Based on these data the complex configuration is most desirable. An examination of **Figure 7-10**, shows that the complex shape nearly approximates the original ground surface, thus requiring the least amount of earthwork. This has major cost implications. Regrade earthwork often requires extensive hauling of spoil and bulldozer work. The haulage cost is the largest cost variable. Examining alternative hillslope configurations can help operators to realize both reduced rates of soil loss and savings in haulage and earthwork cost. There are major cost savings that can be achieved by the engineer or reclamation specialist through a complete analysis of alternative hillslope-profile configurations.

Example 3: Sediment Yield and Deposition Along a Hillslope

Problem Statement: The deposition potential for alternative hillslope-profile configurations are evaluated. Assessment is made of both the soil loss from a hillslope and the quantity of sediment that will be transported away from the bottom of the hillslope and transported downgradient. The soil-loss is important when we are concerned with retaining adequate soil on the hillslope for revegetation, and the quantity of soil transported downgradient is a concern with respect to potential off-site impacts, such as sediment discharge into a waterway or sediment-control structure, e.g. a sediment basin.

Scenario 1 - no erosion controls, a uniform hillslope of 5 %.
Scenario 2 - no erosion controls, a concave hillslope proceeding from 10 to 1 %.
Scenario 3 - no erosion controls, a convex hillslope proceeding from 1 to 10 %.

What Will the User Learn?

Sediment yield at the end of a hillslope can now be predicted with RUSLE version 1.06. This is a significant addition to the program's capabilities. The advantage of estimating the sediment yield is that off-site assessments can now be made. The quantity of sediment, on an average annual basis, that exits a hillslope can be determined and used to estimate the sediment-storage requirements for sediment-control structures.

Design information

Location - Lexington, KY

Soil - silty clay loam, B-horizon, % sand = 10, % silt = 55, % clay = 35, % silt + % very fine sand = 57, % sand - % very fine sand = 8, % organic material = 1.8.

Hillslope gradient and length - Scenario 1, ten 10 ft-segments all at 5%. Scenario 2 - a concave hillslope consisting of ten 10 ft-segments ranging from 10 % to 1 % in increments of 1 %. Scenario 3 - a convex hillslope consisting of ten 10 ft-segments ranging from 1 % to 10 % in increments of 1 %.

Duration of assessment - 1 year.

Scenario 1 - One hillslope segment at 5 % uniform gradient, 100 ft in length.

Select Lexington, KY from the CITY file. The R value is 165.

Proceed to the hillslope gradient. One hillslope segment measured horizontally, silty clay loam soil texture, disturbed fill of topsoil with no rock cover, 5 % gradient and 100 ft in length.
Resulting in a LS value of 0.65.

No adjustment for ponding.

K-factor inputs:

Use the nomograph. Other input values from the preceding design information are used.

The silty clay loam sublayer is expected to be blocky in structure and the soil permeability will be slow to very slow.

Select [6] very slow.
No significant rock fragments exist [1].
An approximate K value of 0.391 is estimated.
The % rock cover is [0].
Use the default of [7] years for consolidation
The hydrologic soil group is [4], highest runoff potential.
The soil-surface texture is [9], a silty clay loam.

From the Seasonally Variable K Factor it can be seen that K values range from 0.16 to 0.85.
The average K value is 0.37.

C and P values are entered as [1].

The estimated soil loss is 39 tons/ac/year.

Save as [EX3SCNO1].

Scenario 2 - Concave hillslope-profile configuration ranging from 10 % to 1 % in 1 % increments and 10 ft lengths.

Recall EX3SCNO1.
Start with the R factor and proceed to the "field slope" to alter the LS-factor calculations.
Enter [10] hillslope segments.
Horizontally measured.
Select equal hillslope-segment lengths, [2].
The uniform hillslope segment length is [10] ft.
Enter hillslope gradient from 10 % to 1 % in 1 % increments proceeding from the first to the tenth segment. To save time use the right arrow key to proceed from gradient to gradient.

The results are very useful. As the hillslope flattens the segment LS values change from 0.48, 0.58, 0.78, 0.82, 0.79, 0.72, 0.61, 0.48, 0.32, to 0.17, respectively. Refer to

Figure 7-15. It can be readily seen that although the uppermost gradient is the steepest (10 %), the LS value for this segment is only 0.48 and LS values increase to 0.82 at the fourth segment. The interplay among hillslope segments becomes evident in the LS values. As we proceed downgradient, the quantity of runoff increases, the transported sediment increases, and the hillslope flattens. The ability to transport sediment is a function of runoff and hillslope gradient. So as we proceed downslope, the quantity of runoff increases, which for a constant gradient, increases the erosivity of the runoff. For the concave hillslope profile, the gradient decreases downslope, which reduces the erosivity of the runoff. The interrelationship between runoff represented by distance and hillslope gradient determine LS values for each segment. At the final downslope hillslope segment, number 10, the LS value is lowest due to the flatter gradient. The highest soil loss occurs at Segment 4 where the LS value is 0.82.

```
      File        Exit        Help        Screen
+-----------------------------< LS Factor 1.06 >-------------------------------+

   number of segments: 10         segment lengths are measured: 2
         segments are: 2          uniform segment length (ft) : 10
         soil texture: silty clay loam
     general land use: 8
--------------------------------------------------------------------------------
                           1         2         3         4         5
  Gradient (%) of Segment   10        9         8         7         6
  Length of Segment (ft)    10        10        10        10        10
  Segment LS               0.484     0.584     0.782     0.817     0.792
 ---+---------------------------------------------------------------+---------
    | overall LS = 0.576; equiv. slope = 4.36 %; horiz. length = 100 ft|
 ---+---------------------------------------------------------------+---------
                           6         7         8         9         10
  Gradient (%) of Segment   5         4         3         2         1
  Length of Segment (ft)    10        10        10        10        10
  Segment LS               0.72      0.612     0.476     0.323     0.167
 -------------------------------------------------------------------------------

+---------------------------------< Esc exits >--------------------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 7-15. LS Values by Hillslope-Profile Segment

Values for LS represent the potential for erosion. Deposition occurs on concave hillslopes where the gradient near the end of the hillslope is sufficiently flat. Deposition occurs when the transport capacity of the runoff becomes less than the sediment load produced by upslope erosion. This deposition is estimated within the P-factor.

How can this information be used?

The effect of hillslope shape on soil loss is evident from the above and now shape can be incorporated as a design factor using RUSLE 1.06. Where should a limited quantity of straw mulch or increased seeding be used? In the case of this concave hillslope and with respect to the LS factor, it is most effective when placed along Segments 3, 4, and 5.

The deposition that occurs on the toe of concave hillslopes can now be estimated using the RUSLE 1.06. To accomplish this proceed to the P-factor inputs.

Select "frequent-disturbance P factor", [1].
Select "contoured". [F4].
For the ridge-height use code [1] because no contours actually exist.
A [0] furrow grade is entered, but it has no effect on the computations because no ridges was specified. No ridges means that contouring gets no erosion-control credit.

The equivalent LS factor for a uniform hillslope was forwarded from the LS-factor calculation. Likewise the soil hydrologic class was forwarded.

The cover/management code of [6] is selected because this is a bare soil with minimal roughness.

Select [2] because a concave hillslope profile now exists. [F3]. [Esc]. [Esc]. [Enter] to proceed to the concave hillslope calculations. [F4].

The silty clay loam soil texture was forwarded and will be used to estimate depositional properties of the sediment.

Because we are modeling this scenario in a single timeframe an entry of 0 or 1 is appropriate, [0].

We will enter the location of the bottom of the strip as a % of hillslope length, [1]. Enter [10] strips.

The cover/roughness code is 6 throughout all hillslope segments.

Enter [10] and [10] for Strip 1.
The first 10 indicates that the lower edge of the most upgradient hillslope segment is located at a distance of 10 % from the top of the hillslope. The second 10 indicates that this upgradient segment has a 10 % gradient.

Continue entering 20, 30 ..., 100 for the second column and 9, 8, ...,1 for the % slope column as shown in **Figure 7-16**. [F3].

The conservation practice P sub-factor value is 0.84 and the sediment-delivery ratio value is 0.37. What does this mean? The P value of 0.84 is used to compute the soil loss when selecting practices to protect the soil resource against excessive degradation by erosion. The sediment delivery ratio (SDR) of 0.37 means that 63% of the sediment produced is trapped on the hillslope by deposition and that 37% of the sediment moves off the hillslope as sediment yield with the potential for downstream impact. The difference between the 0.84 P value for conservation planning and the 0.37 P value for sediment yield is that full credit is not taken for all of the deposition because most of the deposition occurs on the lower portion of the hillslope and does not benefit the upper portion of the hillslope.

Escape to the Soil Loss and Sediment Yield Computation Worksheet.

```
       File        Exit        Help        Screen
+------------------------< P Strips & Concave 1.06 >----------------------------+
| specified soil texture: silty clay loam                                       |
|        number of years: 0    strip width specification code: 1                |
|    year:  +--< 1 >---+                                                        |
|  strips:  |     10   |                                                        |
|  strip 1  |  6 10  10|                                                        |
|  strip 2  |  6 20  9.0                                                        |
|  strip 3  |  6 30  8.0                                                        |
|  strip 4  |  6 40  7.0                                                        |
|  strip 5  |  6 50  6.0                                                        |
|  strip 6  |  6 60  5.0                                                        |
|  strip 7  |  6 70  4.0                                                        |
|  strip 8  |  6 80  3.  +--------------------------------+                     |
|  strip 9  |  6 90  2.  | horiz. slope length (ft): 100  |                     |
|  strip 10 |  6 100 1.  +--------------------------------+                     |
|  +-----------------------------------------------------------------------+   |
|     veg. strip, concave slope sub. P = 0.841,  (sed. del. ratio = 0.368)      |
|                                                                               |
|     (press Esc to dismiss)                                                    |
|  +-----------------------------------------------------------------------+   |
+---------------------------------< Esc exits >---------------------------------+
Tab  Esc F1   F9
FUNC esc help info
```

Figure 7-16. Input Screen for P-factor Strips

The estimated soil loss is 29 tons/ac/year which is less than the 39 tons/ac/year estimated for the uniform hillslope. The sediment yield is only 13 tons/ac/year; that is, only 13 tons/ac/year was transported beyond the lowest hillslope segment. This 13 tons/ac/year is calculated by multiplying $165 \times 0.36 \times 0.58 \times 1.00 \times 0.37$. Notice the P value of 0.84 is not used in the sediment-yield estimation.

Save as EX3SCNO2.

Scenario 3 - Convex hillslope - 1 % to 10% in 1 % increments of 10 ft each.

Follow the same sequence as in Scenario 2.
For the LS-factor the gradient % will increase from 1 to 10 %.

The resultant LS values continuously increase from 0.11 to 2.09 as we proceed from the uppermost to the lowest segment.

The C and P factor are both 1.

The result is an estimated soil loss and sediment yield of 54 tons/ac/year. This is nearly twice as high as the soil loss from the concave hillslope, namely 29 tons/ac/year. The sediment yields from the two hillslope configurations are 13 tons/ac/year for the concave hillslope and 54 tons/ac/year from the convex hillslope.

Save as EX3SCNO3.

RUSLE 1.06 is a powerful design tool enabling the estimation of off-site impacts resulting from alternative hillslope configurations.

Example 4: Terraces, Deep Ripping, and Contour Furrows.

Problem Statement: Steep and long hillslopes are created during spoil grading, during reclamation of selected box cuts, final pits, highwalls, and areas that blend into adjacent natural topography. After spoil grading is completed, supplemental plant-growth medium is placed and terraces constructed. Contour ripping with multi-shanked deep rippers spaced 3 feet apart, followed by the construction of contour furrows using a modified offset disk. The contour furrows will be 9 to 14 inches deep.

Scenario - 1 No erosion control measures.
Scenario - 2 Terraces.
Scenario - 3 Ripping, contour furrows, and terraces.

What Will the User Learn?

Scenario 1 of Example 4 introduces the user to the time invariant C factor. Terrace systems are examined in Scenario 2. P values for conservation planning, and for estimating the amount of sediment that leaves a terrace are contrasted in Scenario 2. In Scenario 3 the effects of contour furrows and deep ripping on soil-loss rates are demonstrated in conjunction with a system of terraces.

Design Information

Location - semi-arid southwestern U.S.

Supplemental plant-growth medium - sandy loam. Clay = 16 %, silt = 25 %, sand = 59 %, % silt and very fine sand = 31, % sand minus % very fine sand = 53, % organic material = 1.4.

Landform - uniform gradient hillslope at 20 %, hillslope length is 800 ft.

Deep Ripping

Contour furrows - spaced 3 ft apart along the contour and 10 inches in height.

Terraces - spaced 200 ft apart, 800 ft in length, placed on a 0.5 % gradient, and 4 ft in height.

Scenario 1 - No erosion control measures except a roughened surface.

Start from the Soil Loss and Sediment Yield Computation Worksheet screen.

R-factor inputs:

Albuquerque, NM, and no adjustment for ponding.

LS-factor inputs:

A single hillslope, measured on the horizontal,
sandy loam soil texture, disturbed fill, topsoil, no rock cover,
20 % gradient, and 800 ft in length.
The result is LS = 12.5.

K-factor inputs:

From a standard particle-size analysis, the nomograph inputs are silt and very fine sand = 31 % and clay = 16 %.
Percent organic material = 1.4.
Soil structure = very fine granular.
Permeability = slow to moderate.
Coarse fragment correction = 1.
The resultant K factor from the nomograph = 0.17.
Percent surface rock cover = 8.
Number of years to consolidate = 20. This value is computed by pressing F4.
Hydrologic soil group = 3.
Soil Series [leave blank].
Surface Texture is a sandy loam [3].

The K-factor does not change through time for locations in the Western U.S.

The time-invariant C factor will be used in this example. Even though the K factor does not vary with time in the Western U.S., either the time-invariant or time-variant C factor can be used to estimate the C value in either the Eastern or Western U.S. We will use the time-invariant option in this example.

C-factor inputs:

The C-factor information will be entered directly, [3],
No plant information will be applicable. The effective root mass, % canopy cover, and average fall height do not apply for bare soil conditions.
[Enter], [Enter], [Enter] to accept the default values of zero.

The roughness value is the result of rough grading using a large dozer with a wide span reclamation blade. From field observations, the range in surface roughness will be approximately 4 inches, which is the roughness immediately following the operation.

From **Figure** 7-12, the corresponding random-roughness value is [0.85].

Through time, rainfall and other processes wear down the surface so that surface roughness decreases. A roughness value appropriate for the conditions represented at the time since last disturbance is used. The site has been mechanically disturbed and the erosion computation is for the time immediately after the last disturbance.

Enter [0] to represent this time.
The surface rock % cover has been previously entered as 8%.
[Enter] [Enter] [Enter] to accept the transferred values.
The surface-cover function (b value) will be determined from the land use, together with the soil characteristics, hillslope gradient, and surface cover.
A C-factor value of 0.50 results as shown in **Figure 7-17**.
A P value of 1 will be used.
The resultant soil loss estimate is 27 tons/ac/year.

Save as EX4SCNO1.

```
             File        Exit        Help        Screen
+-------------------------< Time-invariant C 1.06 >-----------------------------+
|       where get vegetation information?: 3                                    |
|                                                                               |
|                                                                               |
|                                                                               |
|    effective root mass (lb/ac) in top 4": 0                                   |
|                              % canopy cover: 0                                 |
|                 average fall height (ft): 0        +-----------+               |
|   roughness (in) for the field condition: 0.85     | C = 0.504 |               |
|    has there been mechanical disturbance: 2        +-----------+               |
| # of years needed for soil consolidation: 20                                  |
|   number of years since last disturbance: 0                                   |
|  total % ground cover (rock and residue): 8                                   |
|      % surface covered by rock fragments: 8                                   |
|       % vegetative residue surface cover: 0                                   |
|   surface cover function; B-value choice: 1        landuse shown in LS: 8     |
|                                                                               |
| enter avg. annual values!                                                     |
+------------------------------< Esc to continue >------------------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 7-17. Time Invariant C Factor Inputs

Scenario 2 - Terraces.

Two changes to file EX4SCNO1 will be necessary, one in the LS factor to reflect the change in hillslope length caused by the terraces and one in the P factor to reflect the effect of deposition in the terrace channels. With terraces located every 200 ft horizontally along the hillslope, the hillslope length is reduced from 800 to 200 ft. The effect of terraces on deposition is taken into account by the gradient along the terrace as entered through the P factor.

Start with the EX4SCNO1 file and go to the LS factor.
Change the hillslope length from 800 to 200.
The LS value changes from 12.5 to 5.27.

One major function of terraces is to reduce the hillslope length, thereby significantly reducing the LS value. The addition of terraces, with the shorter hillslope length, reduces the estimated soil loss to about 40 percent of the original rate.

Go to the P factor. Highlight "calculate frequent-disturbance P-Factor". [Enter].
Arrow to Terraced . [F4].
Enter a graded terrace, [2].

The screen message reminds the user that to use the terrace-design procedure the contouring sub-factor is first required to determine an estimate of runoff which is used, along with the soil texture and inter-terrace soil loss, to estimate sediment deposition along the terrace.

The contouring P sub-factor must be run to determine the contouring effect, if any. If no ridges are present that produce a contouring effect, the contouring P sub-factor still must be run to compute runoff values needed in the terrace sub-factor computations.

[Esc] and arrow to "contoured." [F4]
Ridge height code, [1], for no ridges.
Furrow grade, [0].
The equivalent slope has been transferred from the LS factor. [Enter].
The hydrologic soil group has likewise been transferred and will not be changed. [Enter].

Because no vegetal cover exists, and the roughness is minimum input, [6] will be used.
No strip cropping or concave hillslope configuration exists, [1].
[Esc] and arrow to "terraced." [F4]
[F3]

Terrace inputs:

This will be a graded terrace with an open outlet. [2]. [Enter].
The distance between terraces is 200 ft. [200]. [Enter].
The specified soil texture was originally input in the K factor as a sandy loam and this response appears at the input prompt. [Enter].
The gradient of the terrace is 0.5 %. [0.5]. [F3].

The estimated annual soil loss above the terrace is 11.4 tons/ac/year. [F3].

The resultant terraced P sub-factor is 0.84 and the sediment-delivery ratio is 0.14 as shown in **Figure 7-18**. If the major concern is soil loss from the hillslope surface, between terraces because of potential depletion of the soil as a productive growth medium, then the 0.84 P value is used. If we are concerned with potential off-site impacts of sediment-laden water decreasing water quality downstream, then the sediment delivery ratio should be entered as the P value.

Return to the Soil Loss and Sediment Yield Computation Worksheet.

The estimated soil loss has been reduced to 9.6 tons/ac/year and the sediment yield is 1.7 tons/ac/year.

```
      File        Exit        Help        Screen
+------------------------< P Factor - Terraced 1.06 >--------------------------+
|                                  terrace type code: 2                        |
|        horizontal interval between terraces (ft): 200                       |
|                             specified soil texture: sandy loam               |
|               graded outlet has a percent grade of: 0.5                      |
|    est. annual soil loss above the terrace (T/A): 11.4                      |
|                                                                              |
|                                                                              |
|                                                                              |
|             +-----------------------------------------------------------+    |
|             | Terraced P subfactor = 0.843  (sed. del. ratio = 0.145)   |    |
|             |                                                           |    |
|             | Takes credit for deposition as a benefit for soil saved.  |    |
|             | See help screen for additional information.               |    |
|             +-----------------------------------------------------------+    |
|                                                                              |
+-------------------------< F3 When Questions Answered >-----------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 7-18. Terrace Input Screen and Result

The graded-terrace system was effective in reducing off-site sediment delivery from 27 to 1.7 tons/ac/year . This reduction occurred for two reasons. The terraces shortened the hillslope length from 800 ft to 200 ft, which reduced soil loss by about 60 percent. In addition, the terraces trapped about 86 percent of the sediment eroded from the inter-terrace area. Thus the graded terrace had an average annual sediment trap efficiency of 86 % (1-sediment delivery ratio). Through use of a terrace system, the off-site soil loss was decreased by an order of magnitude, 27 to 1.7 tons/ac/year, compared to the "no erosion controls" of Scenario 1.

Save as EX4SCNO2.

Scenario 3 - Ripping and contour furrows added to the inter-terrace areas of Scenario 2

The expected impact of deep ripping is to increase the infiltration rate until the openings become filled with rainsplashed soil and deposited sediment. Because this site is located in the semiarid southwest with low precipitation, such deposition may take many years. The contour furrows will also significantly increase ponding of runoff, thereby further increasing infiltration to provide the moisture needed to establish vegetation, and reducing the erosivity of runoff. Changes will be required in the C and P values.

The K-factor is adjusted in this case. The definition of K is based on the standard unit-plot condition, and the K value represents a single specific condition unaffected by management. Parameter values for estimating K are selected based on how the soil would behave through the long term if it were regularly tilled as an agricultural soil. Deep ripping is assumed to have a long-term effect on the soil that persists during the 20 years to consolidation. The effect of deep ripping on the K value is to change the permeability rating of the soil from "slow to moderate" to "moderate." The adjusted K value is now 0.14 rather than the original 0.16. The other change due to deep ripping is to assume that there is also a long-term effect on the hydrologic group for the soil, namely from group [3] to group [2].

C-factor inputs:

The field roughness value increases due to the ripping operation. Based on field observations from other sites, the range in surface elevation is 12 inches, resulting in a Random Roughness value of 2.5.
The time since last disturbance is set to [0] to represent soil loss immediately after the disturbance.
It is important to note here that the roughening effect of ripping is considered to be temporary for the C factor. The roughness disappears through time as the peaks are eroded by rainfall and surface flow and the depressions are filled with sediment.

Even though contour furrows decrease the flow path of runoff to just a few feet along a uniform hillslope, the hillslope length is selected as if the surface is smooth.

The C value changes from 0.50 in Scenario 2 to 0.17 as a result of the ripping.

P-factor inputs:

Select "calculate frequent-disturbance P factor".
Select contouring. [F4].
Because the ridge height is greater than 6 inches, select [6].
Furrow grade - The furrows are designed to be on a zero gradient, but some deviation can be expected. [0.5].
The cover/management roughness code at the time of disturbance is considered to be very rough [3].
Do not have vegetative strips or concave hillslope, [1].
No other changes are needed.

The P sub-factor for conservation planning with the terrace is 0.90 and the sediment-delivery ratio is 0.48. The overall P value for conservation planning is 0.21.

Be sure to recompute the terrace sub-factor after changes in other parts of RUSLE. The program does not automatically update this computation after a change in the contouring sub-factor.

Note that the sediment delivery ratio greatly increased with the change in the contouring. The reason for the increase in the sediment delivery ratio is that deposition only occurs in the terrace channel when the transport capacity of the flow is less than the sediment load arriving at the terrace channel. The addition of contouring reduced the sediment load much more than the transport capacity of the flow was reduced in the terrace channel. Sediment yield from a terrace channel where deposition is occurring is controlled by the transport capacity in the terrace channel.

Average annual soil loss is estimated to be 0.7 tons/ac/year.
The sediment-delivery ratio is 0.48 for the terrace system.
The sediment yield is 0.34 tons/ac/year based on 0.7 x 0.48

Comparing Scenarios 2 to 3 (i.e. the addition of contour furrow and deep ripping to the terrace design), there is about an order of magnitude reduction in soil loss, from 9.6 to 0.7 tons/ac/year. Sediment yield decreased from 1.7 to 0.3 tons/ac/year resulting in a 82% reduction in the transport of sediment to a stream channel or sediment-control structure.

Save as EX4SCNO3.

Example 5: Pre- and post-mining soil loss emphasizing effects of vegetation.

Problem Statement: Estimates of soil loss during pre-mining conditions are based on the undisturbed plant community. After mining and before phase III bond release, the disturbed surface will be in transition with respect to plant development and soil conditions, experiencing a reduction in initial soil-surface roughness, with deposition of soil along contours and terraces, and soil consolidation. Soil consolidation is a key factor in determining soil loss during the phase III bond-release period. The use of the RUSLE program is illustrated for pre-mining and post-mining soil-loss estimates.

Scenario 1 - Estimating pre-mining soil loss
Scenario 2 - Estimating soil loss at Phase III bond release

What Will the User Learn?

C-factor plant-community inputs for pre-mining conditions are emphasized in Scenario 1. Scenario 2 illustrates the method to evaluate an established plant community, 10 years after reclamation, for phase III bond release.

Design information

Location - Northern Mountain States

Soil - Soils used in this example are typical of many soils on ridgetops and upland sideslopes in the mountain states. Soils are deep (40 to 60 inches) and develop from colluvium and some alluvium derived from interbedded sandstone. Subsoils are generally clayey and have a weak structure. Permeability of this soil is moderate as is the available-water holding capacity. The example soil is a clay loam with a moderate medium subangular blocky structure. The percent sand, silt, and clay is 36, 32, and 32, respectively. The % silt and very fine sand = 37, % sand minus very fine sand = 31, percent organic material = 2.6.

Landform - hillslopes are generally convex to uniform. The pre-mining hillslope is slightly convex with an overall gradient of approximately 9.5 percent.

Vegetation - grasses, forbs, and scattered shrubs at an elevation of 7000 to 7600 ft. Pre-development vegetation consists of wheatgrass, serviceberry, sagebrush, chokecherry, snowberry, gambel oak, and various forbs. During reclamation the vegetal mix consists of grasses, forbs, and shrubs.

Scenario 1 - Pre-mining soil loss estimation

Start from the Soil Loss and Sediment Yield Computation Worksheet screen.

R-factor inputs:
Select Grand Junction, CO with no adjustment for ponding.

LS-factor inputs:

A convex hillslope measured on the horizontal, clay loam soil texture, with the land use as range, except coarse textured soil [5] is input.
Segment 1 - hillslope gradient 6 %, 370 ft in length
Segment 2 - hillslope gradient 12 %, 220 ft in length
LS = 1.45

K-factor inputs:

% silt and very fine sand = 37
% clay = 32
% organic material = 2.6
soil structure = blocky
permeability = moderate

no significant rock fragments within the soil matrix
Percent surface rock cover = 0.
15 years to consolidate in the Western United States
hydrologic soil group 3
soil texture, clay loam.
K = 0.214

C-factor inputs:

Information source will be a plant scientist in the reclamation department, the NRCS state agronomist, Bureau of Land Management (BLM) range scientist, or other qualified plant specialist.

Time-invariant.
Vegetation information from plant community and site potential, [1].
Plant community - chaparral, [10].
Annual site production potential - [700] lb/ac.
The effective root mass in top 4 inches - a value of 350 lbs/ac is derived from the plant community data within RUSLE.
Canopy cover - [85] %.

Average fall height -- There are essentially two kinds of vegetation. The tall mountain brush will be approximately 7 ft in height with an average fall height of approximately 4 ft.
The sagebrush is about 2 ft in height and the fall height is assumed to be about 12 inches. Because there is about a 50-50 mix of these two types of vegetation an average fall height of [2.5] ft will be used.
Roughness value for natural shrub is .8 and sagebrush is 1.1; so select [.95].
No previous mechanical disturbance, [1].
Total % ground cover (rock and residue) - leave at 0.
% surface covered by rock - [0]. (From the K factor).
% vegetative residue surface cover - [60].
The total % of ground cover is calculated within the program as 60 %.
Surface cover function - computed from the land use, [1].
The resultant C value is 0.012.

P-factor inputs:

Because no disturbance occurred prior to mining, a P factor of 1 is entered.
The estimated soil loss from this pre-development site is 0.04 tons/ac/year.

Save as file EX5SCNO1

Scenario 2 - Reclaimed Mined Land

This scenario estimates soil loss 10 years after initial reclamation. To be very conservative, terraces are assumed to be nonfunctional, contour furrows are non-functional, and the positive effect ripping and disking are not considered. This scenario focuses on the effectiveness of revegetation and soil consolidation.

Load EX5SCNO1

R-factor inputs:

No changes except for linked changes to the LS value.

Ls-factor inputs:

The reclamation landform will be slightly less convex than that of the pre-mining hillslope shape.

Segment 1 - 8 %, 340 ft.
Segment 2 - 10 %, 250 ft.
The LS value changed only slightly from 1.45 for the pre-mining condition to 1.43 for the post-mining condition.

K-factor inputs:

The only change is to the number of years to soil consolidation, which will be changed to [10].
Resultant K = 0.21 which is the same as the pre-mining condition.

C-factor inputs:

The proposed seed mix for reclamation is approximately 16 pure live seeds per square ft of grasses, predominantly wheatgrass, bluegrass, fescue and redtop, 15.5 pure live seeds per square ft consisting of a variety of forbs, and 12.6 pure live seeds per square ft of shrubs dominated by rabbitbrush, sagebrush, and bitterbrush.

During reclamation there is a plant community shift from chaparral to a Northern mixedgrass prairie with some chaparral-type vegetation.

Select [2], N mixedgrass prairie, because this will be the dominant vegetation type.

The annual site potential production of a reclaimed site is much greater (based on extensive measurements) than the natural condition so increase this parameter from 700 to [2000] lb/ac.

The effective root mass will also be increased by the RUSLE program to 3000 lb/ac.
The % canopy is approximately the same so leave at 85 %.
The average fall height will be reduced from 2.5 ft to 1.5 ft based on the reclaimed vegetation.
Roughness will be slightly higher than the natural state. Change from 0.95 to [1.0].

When the time of interest for the C factor is beyond the time required to reach consolidation, no mechanical disturbance option should be chosen; no, [1].

Because this area receives about 15 inches of precipitation per year and a portion of this is in snowfall the number of years for soil consolidation is [10] rather than the average of 7.

The total percent ground cover will be calculated by the program based on the next two inputs so enter [0].
The percent rock fragments will remain nearly equal, [0].
The % vegetative residue will increase to [80].
The resultant C value is 0.0008.
P-factor inputs:

Assign a [1] to the P factor.
The estimated soil loss is 0.0 tons/ac/year.

The results of both analyses suggests that no significant erosion will occur during the pre-mining period or 10 years after mine reclamation.

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