RUSLE for mining, construction and reclamation lands

T.J. Toy, G.R. Foster, and K.G. Renard

ABSTRACT: The Revised Universal Soil Loss Equation (RUSLE) is a practical and increasingly popular choice to provide soil-loss estimates in the preparation of environmental impact assessments, reclamation plans, and post-reclamation site evaluations for land subjected to mining and construction. A factor-by-factor comparison of the Universal Soil Loss Equation (USLE) and RUSLE versions 1.04 and 1.06 illustrates the ways in which version 1.06 has been modified and improved to accommodate the special conditions of mining, construction, and reclamation lands. The effects of several erosion- and sediment-control materials and practices are included in the C and P factors. The program computes sediment-delivery ratios that include consideration of sediment characteristics. Despite its limitations, we believe that RUSLE 1.06 is the best currently available technology for soil-loss estimation on mining, construction, and reclamation lands. The USLE and RUSLE version 1.04 no longer should be used for this purpose.

Key words: erosion, soil loss, RUSLE, USLE, mining, construction, reclamation, disturbed land.

Earth scientists have worked for decades to create methods for accurately estimating soil loss from land surfaces. The early soil-loss estimation technologies were often based on small data sets collected in just a few locations which limited their geographic range of applicability. In response to the need for a standard, versatile method for estimating soil loss, the National Runoff and Soil-Loss Data Center was established in 1954 by the United States Department of Agriculture, Agricultural Research Service (USDA, ARS). The Center's mission was the assembly and analysis of all the available soil-loss data collected by the ARS and the agricultural experiment stations. This project resulted in the Universal Soil Loss Equation (Wischmeier and Smith, 1965, 1978) that served as the most commonly used soil-loss estimation model worldwide for more than 30 years.

Until 1970, the USLE was limited to cropland applications. At a meeting with the USDA, Soil Conservation Service (SCS; now the Natural Resources Conservation Service, NRCS) and the Forest Service, a sub-factor approach was developed by the ARS representatives so that the USLE could be used for undisturbed lands (Wischmeier, 1975). In the early 1970s, the USLE was modified for use on highway (Farmer and Fletcher, 1977) and other construction sites. Often, the equation was employed under inappropriate conditions (Wischmeier 1976). Despite its limitations, the USLE remained the best choice for soil-loss estimation on mining lands (Shown et al, 1982) and construction lands (Israelsen et al, 1980).

The development of RUSLE

Erosion research progressed following the release of Agricultural Handbook 537 (Wischmeier and Smith, 1978), and a significant disparity emerged between our knowledge of erosion processes and the methods and equations for soil-loss estimation within the USLE. At a 1985 workshop, government agency and university erosion scientists decided that it was time for a major overhaul of the USLE: (1) to incorporate the results of current erosion research, (2) to increase the versatility to accommodate applications on various non-agricultural lands, and (3) to offer the technology as an integrated computer program to facilitate the calculations and the examination of several soil-conservation alternatives. The project resulted in the Revised Universal Soil Loss Equation (RUSLE) as documented in Agriculture Handbook 703 (Renard et al., 1997).

The team commissioned to revise the USLE recognized the inevitability of RUSLE applications under a wide variety of environmental and land-use conditions (Renard et al., 1991). Environmental laws, such as the Clean Water Act (U.S. Congress, 1972) and the Surface Mining Control and Reclamation Act, (U.S. Congress, 1977) require the management of the processes and products of erosion

from non-agricultural lands. RUSLE often was the soil-loss prediction technology of choice because of its simplicity, availability of parameter values, adequate accuracy of soil-loss estimates, and available expertise to assist in the use of RUSLE. There are alternative technologies, such as the Water Erosion Prediction Project (WEPP; Lane and Nearing, 1989), and users should consider the strengths and weaknesses of these technologies before selecting one for a particular application. The purpose of this report is to illustrate the development of RUSLE by comparing the USLE, RUSLE 1.04, and RUSLE 1.06, and to describe the modifications made to adapt version 1.06 for mining, construction, and reclamation lands. Herein, "RUSLE" refers to characteristics or features generic to all versions, while the RUSLE version number (1.04 and 1.06) is given when referring to particular characteristics or features of particular versions.

RUSLE 1.06 for mining, construction, and reclamation lands

Since the release of RUSLE 1.02 in 1993 (Soil and Water Conservation Society, 1993), it became clear that some users were struggling with the transition from the USLE to RUSLE. Some users were misusing RUSLE or making inappropriate input choices resulting in inaccurate soil-loss estimates. Additionally, there was no specific guidance for mining, construction, and reclamation land applications. Therefore, a working group was formed under the auspices of the U. S. Department of Interior, Office of Surface Mining, Reclamation, and Enforcement in 1997 to evaluate the ability of RUSLE 1.04 to provide satisfactory soil-loss estimates under the site conditions resulting from mining, construction, and reclamation activities and to prepare a guidebook of recommendations for RUSLE 1.04 applications. Following extensive review, discussion with industry representatives, and deliberations, the working group concluded that RUSLE 1.04 possessed the versatility needed for these applications and was likely to continue as the preferred choice. Additionally, it was concluded that modifications of the existing technology would enhance the utility of RUSLE 1.04 by making it more "user-friendly" and able to produce more accurate and consistent soil-loss estimates than the earlier versions. These modifications are included in the new RUSLE version 1.06, specifically tailored for min-

Terrence J. Toy is a professor in the Department of Geography at the University of Denver. George R. Foster is a retired research hydraulic engineer at the USDA-Agricultural Research Service, National Sedimentation Laboratory, in Oxford, MS. Kenneth G. Renard is a retired research hydraulic engineer at the USDA-Agricultural Research Service in Tucson, AZ.

ing, construction, and reclamation lands (Toy and Foster eds., 1998).

Comparison of USLE, RUSLE 1.04 and 1.06

A factor-by-factor comparison of the USLE and RUSLE versions 1.04 and 1.06 is presented to illustrate the progressive development of RUSLE and highlight the modifications included for mining, construction, and reclamation land applications.

Rainfall/runoff erosivity (R). The current rainfall/runoff-erosivity maps and the values in the RUSLE CITY code files are based on a much larger set of meteorological data for the western U.S. than was used in the development of the USLE. The maps for the eastern U.S. were re-contoured to improve their accuracy. The equations in RUSLE compute higher erosivity for high-intensity storms than the equations used in the USLE. However, RUSLE decreases the erosivity determined by precipitation characteristics and hillslope gradient when the raindrops impact on flat surfaces of ponded water. RUSLE computes erosivity at 15-day intervals allowing project planners to identify the most potentially erosive times of the year. The soil surface should be adequately protected during these periods. The computation of erosivity is the same for RUSLE 1.04 and 1.06. A method based on research by Renard and Freimund (1994) is suggested in the guidelines accompanying version 1.06 for estimating erosivity at higher-elevation sites when the *only* available climate data are for lower-elevation stations. RUSLE also includes improved procedures to account for rainfall on frozen or partially frozen soil in the Northwest Wheat and Range Region (NWRR).

Soil Erodibility (K). A review of the available literature (e.g. Stein et al., 1983 and Mitchell et al., 1983) indicated that the nomograph method (Wischmeier and Smith, 1978) provides satisfactory estimates of soil erodibility for mining, construction, and reclamation lands. Especially important, however, is the capability of RUSLE to account for: (1) the presence of rock fragments in the soil profile, and (2) the consolidation of soil structure in the months and years following disturbance. In RUSLE 1.04 and 1.06, soil erodibility increases as the proportion of rock fragments in the profile increases. This relationship merits further examination because the large rock fragments on drastically disturbed lands may "bridge" within the soil causing infiltra-

tion to increase, runoff to decrease, and erosion to decrease.

Following disturbance, pedogenic processes begin to regenerate soil aggregation and structure. In the humid eastern U.S., the time to consolidation is estimated to average about seven years. In the arid and semiarid western U.S., the time to consolidation is substantially longer, perhaps 15-25 years. The time of consolidation for disturbed soils is entered as a part of the soil-erodibility factor inputs because it is a soil property but is transferred to and used in the computation of the cover-management (C) factor. In RUSLE 1.04, the user directly inputs the time to consolidation. In RUSLE 1.06, the time to consolidation is estimated by the program, although the flexibility for direct user input, based upon site-specific information or experience, is retained in the program.

RUSLE computes soil erodibility at 15-day intervals for the eastern U.S. allowing project planners to identify when the surface material is the most erodible, when erosion-control practices are most important. Soil erodibility also varies during the year in the western U.S., but the relationships upon which to base appropriate adjustments await development. RUSLE includes the capability to compute soil erodibility for volcanic Hawaiian soils. The computation of soil erodibility is fundamentally the same in RUSLE 1.04 and 1.06.

Topography (LS). The USLE equations used to compute the effect of hillslope length (L) on soil-loss rates are modified in RUSLE to reflect the differential influence of hillslope length on rill and interrill erosion rates by means of a rill to interrill erosion ratio. The RUSLE equations used to compute the effect of hillslope gradient (S) on soil-loss rates are based on much larger data sets than were used in the USLE. Taken together, the RUSLE equations now accommodate short (a few inches in length) and steep (to about 100%, where soil slips are not occurring) hillslopes. An important improvement for mining, construction, and reclamation lands is the capability of RUSLE 1.06 to compute LS values within the program for convex, straight, concave, or complex hillslope shapes. The equations compute a LS value for each hillslope segment defined by inputs of specific length and gradient and from these an "effective" value for the entire hillslope is computed. This capability allows project planners to examine the effect of various hillslope shapes on soil-loss rates. Therefore, hillslope shape be-

comes an operational variable in erosion-control design. Further, the hillslope segments with the highest LS values are those most susceptible to soil loss, other factors being equal. This allows project planners to identify those segments of the hillslope where shape characteristics should be altered or cover-management practices intensified to protect the soil resource and maximize the prospect of long-term reclamation success.

The effect of hillslope length (L) on soil loss is adjusted for the prevalence of rill erosion on the hillslope that markedly alters the hydrologic behavior of the surface. In version 1.04, the user selected a table of LS values that reflected the rill to interrill erosion ratio and the choice often seemed speculative. With RUSLE 1.06, an improved method is provided to estimate the prevalence of rill erosion based upon soil texture, hillslope gradient, percent surface cover, and land use. Generally, a clay-textured soil is the most resistant to rill erosion. A silt-textured soil is the least resistant. A sand-textured soil is moderately resistant to rill erosion. Generally, disturbed soils are considered to be less resistant to rill erosion than undisturbed soils. Topsoil is more resistant to rill erosion than subsoils of the same texture. Land uses that affect the soil and hydrologic properties of a hillslope also affect L values due to the accumulation of runoff in the downslope direction. As surface cover increases, rill erosion decreases more rapidly than interrill erosion. (Foster, 1982). The equations in RUSLE 1.06 also adjust the LS value for the decreased effectiveness of erosion-control practices on steep hillslopes. Collectively, the equations in RUSLE 1.06 better represent the actual influence of topography on soil-loss rates from mining, construction, and reclamation lands than either USLE or RUSLE 1.04. With RUSLE 1.06, an opportunity exists to treat topography as a design variable for the protection of the soil resource.

Cover-management (C). The C-factor is perhaps the most important factor in RUSLE because: (1) it represents surface conditions that often are easily managed for erosion control, and (2) the values range from virtually 0 to slightly greater than 1, strongly influencing the estimated soil-loss rate. A value greater than 1 can occur where there is no vegetation, root biomass, or other surface cover to resist erosive forces on a finely pulverized, smooth soil surface because these conditions are more erodible than the unit-plot conditions under which the C-factor was developed. Considerable attention was

devoted to the determination of C values during the development of RUSLE 1.04 and again in RUSLE 1.06.

RUSLE computes a site-specific C value using a sub-factor approach for all land uses based on vegetation canopy, raindrop fall height, soil surface cover and roughness, root biomass, and prior land use. For the Northwest Wheat and Range Region (NWRR), a soil-moisture sub-factor is included. This sub-factor approach greatly enhances the versatility of RUSLE, permitting application in a wide variety of environmental settings, including those of mining, construction, and reclamation lands.

Canopy covers intercept raindrop energy, but the droplets falling from the canopy acquire new energy as the fall height increases. Surface covers also intercept raindrop energy and reduce runoff

texture, hillslope gradient, percent surface cover, and land use. RUSLE 1.06 also retains the flexibility for direct user input of b-values from an expanded menu, based upon site-specific information or experience. The equations in RUSLE 1.06 reduce the effectiveness of surface cover on steep hillslopes as supported by experimental data (Meyer et al., 1972).

Manufactured erosion-control products are used to provide temporary surface cover on mining, construction, and reclamation sites. RUSLE 1.06 also adjusts the effectiveness of these products in reducing soil-loss rates for the extent of contact between the material and the soil surface and whether the material is placed over topsoil or subsoil. Sometimes long-fiber materials may "bridge" above the surface reducing the contact with the soil. RUSLE 1.06 assumes that manufactured

tour furrows and graded terraces redirect runoff from a flow-path directly downslope to a flow-path that includes a lateral component across the hillslope and generally at lower flow velocities with lower sediment-transport capacities. Barriers to runoff, made of vegetation or manufactured materials, reduce runoff velocities, pond water and encourage deposition on or at the base of the hillslope. Considerable attention was devoted to the determination of P values in the development of RUSLE 1.04 and in RUSLE 1.06. It is assumed that the support practices are properly installed and maintained according to specifications. Improperly installed and maintained support practices may concentrate and accelerate runoff, resulting in an acceleration of soil-loss rates.

New data were used to formulate the equations in RUSLE that reflect the effect

practice in the reclamation of mining and construction lands. The effectiveness of contouring is a function of climate conditions, hillslope length and gradient, soil type, surface cover, and ridge height. For example, the P sub-factor value for contouring approaches 1 (no reduction in soil-loss) when rainfall/runoff erosivity (R) is high, the infiltration capacity of the soil is low, the hillslope gradient is steep, and the ridge height is low. Conversely, the P sub-factor value for contouring is low (significant reduction in soil loss) when the opposite is true.

Terraces divide the hillslope length into a series of short segments, reducing the accumulation and velocity of runoff. Depending on the design, terraces pond water or divert runoff across the hillslope to areas prepared for the non-erosive disposal of the water. The reduction in runoff velocity and ponding encourage deposition in terrace channels and on the "tread" of the terrace. The effectiveness of terracing is a function of climate, hillslope length and gradient between the terraces (inter-terrace interval), soil type, cover and management, soil loss from the inter-terrace interval, and the grade along the terrace. For example, the P sub-factor value for terracing approaches 1 (no reduction in soil-loss) when rainfall/runoff erosivity (R) is high, the infiltration capacity of the soil is low, and the terrace grade is greater than 2 percent. Conversely, the P sub-factor value for terracing is low (significant reduction in soil loss) when rainfall/runoff erosivity is low, the infiltration capacity is high, and the terrace grade is very flat.

An important new feature was added to the terracing sub-factor in RUSLE 1.06. A sediment-delivery ratio is computed based on the sediment load, the size and density of particles reaching the terrace channel, and the transport capacity of the flow in the channel. When the sediment production (soil loss) in the inter-terrace interval exceeds the transport capacity of the flow in the terrace channel, deposition occurs and the sediment-delivery ratio is less than 1. When the transport capacity equals or exceeds the soil loss, the sediment-delivery ratio equals 1, indicating that all of the sediment is removed from the hillslope by the channel flow. The transport capacity of the terrace channel is a function of the volume and velocity of the channel flow. If the sediment load exceeds the transport capacity, the rate of deposition depends upon the size and density of the particles in transport. The size and density of the sediment particles is estimated from the

soil texture in the inter-terrace interval. If the sediment is very small, then deposition will be less than if the sediment is large. The soil loss estimated by RUSLE version 1.06 can be multiplied by the sediment-delivery ratio to estimate the amount of sediment leaving the hillslope. The same principles are used to estimate the sediment-delivery ratio for concave hillslope profiles.

The sediment-delivery ratio for concave hillslopes is usually less than 1 due to deposition of sediment in the lower, basal portion of the hillslope (Meyer and Romkens, 1976). The sediment-delivery ratio is computed as a function of the degree of concavity, gradient at the base of the hillslope, the surface cover, and sediment-particle size and density. Deposition does not occur at the base of all hillslopes but often occurs on distinctly concave hillslopes with relatively flat basal segments. The concavity of the hillslope must be very accurately defined by the length and gradient inputs because the degree of concavity strongly influences the rate of deposition and, hence, the sediment-delivery ratio.

Various sediment-control barriers or structures are installed on mining, construction, and reclamation lands, such as permanent strips of close-growing vegetation (buffer or filter strips), straw-bale barriers, gravel- or sand-filter bag barriers, and silt fences. These practices reduce the velocity of runoff and cause ponding, resulting in sediment deposition. The effectiveness of these practices is a function of the length and volume of ponded water, which decrease rapidly as hillslope gradient increases. Therefore, RUSLE 1.06 will not compute a sediment-delivery ratio for hillslope gradients steeper than 15% because the performance of runoff barriers on steeper hillslopes has not been firmly established. Again, it is assumed that the support practices are properly installed and maintained according to specification. The effectiveness of sediment-control practices varies considerably from practice to practice and with site conditions. Examples of the proper use of RUSLE 1.06 for estimating sediment yield are provided in Toy and Foster (eds., 1998).

Mining operations and construction projects are usually required by law and regulation to retain sediment on-site to prevent downstream environmental impacts. Sediment ponds or basins are often used to collect and store sediment. Soil loss from hillslopes can be multiplied by the sediment-delivery ratio to estimate the sediment discharged into a sediment

pond. The sediment-delivery ratio for a pond or basin represents the proportion of the suspended sediment that escapes the basin and is transported downstream. In this context, the sediment-delivery ratio for the basin is the inverse of the trap efficiency, or the proportion of the sediment that is retained within the pond or basin. The sediment-delivery ratio is significantly affected by the sediment-particle size and density distributions that enter the pond or basin. As the sediment size and density decrease, the sediment-delivery ratio increases because the very fine-size particles remain suspended longer than the large-size particles.

The RUSLE 1.06 computations for sediment basins do not take into account changes in sediment-particle size resulting from deposition in the basal concave segment of a hillslope or behind sediment-control barriers. Deposition tends to remove the large-size fraction from the sediment load. As a result, the sediment reaching the pond or basin is enriched in fine-size particles. The removal of the large-size particles reduces the rate at which the pond or basin fills, therefore, reducing the frequency of necessary pond or basin maintenance. On the other hand, the enrichment of fine-size particles reduces the trap efficiency of the pond or basin and increases the sediment-delivery ratio.

RUSLE 1.06 computations also do not account for changes in sediment-particle size resulting from deposition in a series of sediment ponds or basins. Each pond or basin in the series removes a greater proportion of the large-size particles remaining in suspension than the very fine-size particles, hence, enriching the proportion of fine-size particles and increasing the sediment-delivery ratio. A general method for accounting for the change in sediment-particle size, external to the RUSLE program, is provided in Toy and Foster, eds., 1998, table 6-16.

Project planners can compare the effectiveness of various support practices in reducing soil loss and sediment yield under specific site conditions to evaluate the cost-effectiveness of the support-practice options. The users of RUSLE 1.06 again are strongly encouraged to explore the new "help screens" provided for the P factor. *It is essential that users also compute P values through the program, rather than inputting table values, due to the highly interactive nature of RUSLE.*

Table 1. Applicability and limitations of RUSLE.[1]

Equation Factor	Applicability	Limitations
Rainfall/Runoff Erosivity (R)	Perhaps the most exactly computed of the RUSLE inputs. Most accurate where rainfall occurs regularly and totals more than 20 inches per year.	R values may be inaccurate in mountainous regions with variable snow accumulation on windward and leeward hillslopes. The same unit-energy relation is used for all storm types.
Soil Erodibility (K)	Soil-loss estimates are most accurate for medium-textured soils, moderately accurate for fine-textured soils, acceptable for coarse-textured soils.	Soil-loss estimates are inaccurate for organic soils. Very coarse rock fragments in soil profile may increase permeability. Seasonal variability of K needs specification for the western U.S. Soil consolidation rates need specification, especially for the western U.S.
Topography (LS)	Soil loss estimates are moderately sensitive to gradient (S) and least sensitive to length (L). Soil-loss estimates are most accurate for hillslopes of 50-300 ft in length and 3-20 % in gradient. Estimates are moderately accurate for lengths from 20-50 ft and 300-600 ft and for gradients from 1-3 and 20-35%.	Soil-loss estimates are probably poorest for hillslopes of 600-1,000 ft. in length due to extrapolation of data. The accuracy of estimates is less for gradients exceeding 35%. Gravitational soil movements may be significant soil-loss processes at gradients above 50% and these are not addressed by RUSLE.
Cover-management (C)	Soil-loss estimates are greatly influenced by this factor. Wide variety of covers have been tested and included in the RUSLE data files.	Rock-fragment covers affecting soil loss may have a minimum size of 5 mm. Erosion-control and decomposition rates for manufactured surface-cover materials need specification for site-specific conditions. Variable quality of material application.
Support Practices (P)	Wide variety of support practices have been tested and included in the RUSLE data files.	Least reliable factor due to field variabilities and quality of implementation and maintenance. Effect of artificial barriers on sediment-delivery ratios needs specification for the steep hillslopes of disturbed lands.
Soil Loss Estimates (A)	Soil-loss estimation due to sheet and rill erosion. Average annual and seasonal soil loss. Estimated accuracy of A values:[1] 4<A<30 tons/ac/yr = ± 25% 1<A<4 tons/ac/yr = ± 50% 30<A<50 tons/ac/yr = ± 50%	Should not be used to estimate gully or stream channel erosion or soil loss due to mass-wasting. Should not be used to estimate soil loss from individual rainfall events. Should not be used to estimate soil loss from undisturbed forest lands. Least accurate where A is less than 1 or where A is greater than 50. Here, soil loss is simply regarded as low or high respectively.

[1] Based on Rapp, 1994; Risse et al., 1993, and the judgment of the RUSLE development team.

The errors in RUSLE 1.04 and 1.06 soil-loss estimates

There are no models of earth processes that provide rate estimates without error, and RUSLE is no exception. These errors are the result of model conception, parameterization, calibration, measurement of variables, and model application. It is the user's responsibility to select the model that best fits an intended application, to minimize the avoidable errors with accurate variable inputs, and to understand the errors and limitations associated with the resulting process-rate estimates.

The validity of a model should be judged according to its intended purpose. RUSLE was designed to estimate average annual soil loss. Significant errors may occur in soil-loss estimates for a specific year or from a particular precipitation event. Nevertheless, when properly employed, RUSLE offers a systematic and repeatable method for estimating soil loss as a function of the main variables that govern rill and interrill erosion based upon extensive long-term research.

To facilitate the use of RUSLE 1.06 for soil-loss estimation on mining, construction, and reclamation land, a summary of the applicability and limitations of RUSLE 1.04 and 1.06 is presented in Table 1. The information in this table is largely self-explanatory and represents the experience and judgment of the RUSLE development team (see Renard et al.,

1997 for the members of this team), the Office of Surface Mining, Reclamation, and Enforcement Working Group (see the Acknowledgments for the members of this group), and the research of Risse et al., (1993) and Rapp, (1994). The information in Table 1 also suggests numerous research opportunities. Resources have not been available to completely calibrate and evaluate RUSLE versions 1.04 or 1.06. The results of this research will further strengthen the RUSLE technology.

Conclusions

RUSLE is a powerful tool for soil-loss estimation. New data were used to refine and validate many of the component

equations within the RUSLE program. The development of new procedures, such as the sub-factor method of computing the C and P values, enhances the versatility of RUSLE. For example, there was no way to utilize the USLE with confidence in the absence of experimental data upon which to base soil-loss ratios for the C factor. As stated by the Soil and Water Conservation Society (1993, p. 8), "a strength of RUSLE is that it was developed by a group of experienced and nationally-recognized erosion scientists and soil conservationists." Like its predecessor the USLE, RUSLE often is the most practical choice for soil-loss estimation.

The comparison of the USLE, RUSLE 1.04 and 1.06 demonstrates that RUSLE is a greatly improved technology. Although the USLE may have become as comfortable as old shoes, it no longer should be used for soil-loss estimation. Much improved science is now available.

RUSLE 1.06 has been developed to accommodate the special conditions of mining, construction, and reclamation lands. This version should be used in the preparation of environmental impact assessments and reclamation plans, as well as post-reclamation site evaluations. The project planner now has the capability to test various "best management practices" and practice-combinations under site-specific conditions. RUSLE users are strongly encouraged to peruse Agriculture Handbook 703 (Renard et al., 1997) and the Office of Surface Mining, Reclamation, and Enforcement Guidebook (Toy and Foster, eds., 1998), explore the new "help screens" within the program, and always compute factor values by means of the program, rather than inputting values from tables.

Although RUSLE version 1.06 includes the capability to compute sediment-delivery ratios and sediment yields, it should be noted that there are two types of conservation planning and practice. The first type is intended to protect and retain the soil resource on the hillslopes. Here, soil-loss rates should be low (comparable to the rates of pedogenesis) in order to preserve the hydrologic, geomorphic, and agronomic functions of the soil over the long term and thereby sustain the post-reclamation land use. Toward this end, RUSLE 1.06 can be used to estimate soil loss from each distinct hillslope segment and from the hillslope as a whole. It may be necessary to alter the hillslope shape, or implement particular cover-management or support practices for parts or all of the hillslope in order to protect the soil resource.

The second type of conservation planning and practice is intended to protect off-site lands and channels from degradation resulting from land-disturbing activities. Here, the principal concern is sediment discharge from the disturbed area to the adjacent undisturbed lands and channels. Sediment-control structures and sediment ponds or basins are used to manage sediment discharges to off-site areas but these do little to protect the soil resource. In relation to soil resources, sediment control is akin to closing the barn door after the livestock have departed.

REFERENCES CITED
Farmer, E.E. and J.E. Fletcher. 1977. Highway erosion control systems: An evaluation based on the universal soil loss equation. Soil Erosion: Prediction and Control. In Foster, G.R. (ed.), Proceedings of a National Conference on Soil Erosion. Soil Conservation Society of America, Ankeny, IA, 12-21.

Foster, G.R. 1982. Modeling the erosion process: In Hydrologic Modeling of Small Watersheds. Haan, C.T., H.P. Johnson, and D.L. Brakensiek (eds.), American Society of Agricultural Engineers Monograph 5, St. Joseph, MI, pp. 297-380.

Israelsen, C.E., C.G. Clyde, J.E. Fletcher, E.K. Israelsen, F.W. Haws, P.E. Packer, and E.G. Farmer. 1980. Erosion control during highway construction: Research report and manual on principles and practices. Transportation Research Board. National Cooperative Highway Research Program Report, Nos. 220 and 221, 30 and 23 pp.

Lane, L.J. and Nearing, M.A. (eds.). 1989. USDA - Water erosion prediction project: hillslope profile version. NSERL Report No. 2, USDA-ARS National Soil Erosion Research Laboratory, West Lafayette, Indiana, 272 pp.

Meyer, L.D., C.B. Johnson, and G.R. Foster. 1972. Stone and woodchip mulches for erosion control on construction sites. Journal of Soil and Water Conservation. 27: 264-269.

Meyer, L.D., and M.J. M. Romkens. 1976. Erosion and sediment control on reshaped lands.

Proceedings of the Third Interagency Sedimentation Conference, Water Resources Council, PB-245-100, Washington, D.C. 2-65 to 2-76.

Mitchell, J.K., W.C. Moldenhauer, and D.D. Gustavson. 1983. Erodibility of selected reclaimed surface mined soils. American Society of Agricultural Engineering, Transactions. 26:1413-1417, 1421.

Rapp, J.F., 1994. Error assessment of the Revised Universal Soil Loss Equation using natural runoff plot data. Master of Science thesis, School of Renewable Natural Resources, University of Arizona, Tucson, Arizona, 90 pp.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool. and D.C. Yoder. Coordinators. 1997. Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE), U.S. Department of Agriculture, Agriculture Handbook No. 703, 404 pp.

Renard, K.G., G.R. Foster, G.A. Weesies, and J.P. Porter. 1991. RUSLE: Revised universal soil loss equation. Journal of Soil and Water Conservation. 46(1): 30-33.

Renard, K.G., and J.R. Freimund. 1994. Using monthly precipitation data to estimate the R-factor in the revised USLE. Journal of Hydrology 157:287-306.

Risse, L.M., M.A. Nearing, A.D. Nicks, and J.M. Laflen. 1993. Error assessment in the Universal Soil loss Equation. Journal of the Soil Science Society of America, 57(3): 825-833.

Shown, L.M., D.G. Frickel, R.F. Miller, and F.A. Branson. 1982. Methodology for hydrologic evaluation of a potential surface mine, Loblolly Branch Basin, Tuscaloosa County, Alabama. U.S. Geological Survey, Water Resources Investigation. Open File Report, 82-50. 93 pp.

Soil and Water Conservation Society. 1993. RUSLE user's guide. Soil and Water Conservation Society, Ankeny, IA. 164 pp.

Stein, O.R., C.B. Roth, W.C. Moldenhauer, and D.T. Hahn. 1983. Erodibility of selected Indiana reclaimed surface mined soils. In Graves, D.H. (ed.), Proceedings of the 1983 Symposium on Surface Mining Hydrology, Sedimentology and Reclamation, Lexington, Kentucky, Office of Engineering Services, University of Kentucky, 101-106.

Toy, T.J., and G.R. Foster (eds). 1998. Guidelines for the use of the Revised Universal Soil Loss Equation on mined lands, construction sites, and reclaimed lands. Office of Surface Mining, Reclamation, and Enforcement, 149pp. + software.

U.S. Congress. 1972. Clean Water Act of 1972. Public law 95-217.

U.S. Congress. 1977. Surface Mining Control and Reclamation Act of 1977. Public law 95-87.

Wischmeier, W.H. 1975. Estimating the soil loss equation's cover and management factor for undisturbed areas. Proceedings of the Sediment-Yield Workshop, 1972, USDA Sedimentation Laboratory, Oxford, MS, ARS-S-40, 118-124.

Wischmeier, W.H. 1976. Use and misuse of the universal soil loss equation. Journal of Soil and Water Conservation 31(1): 5-9.

Wischmeier, W.H., and D.D. Smith. 1965. Predicting rainfall-erosion losses from cropland east of the Rocky Mountains: guide for the selection of practices for soil and water conservation. Agricultural Handbook 282. U.S. Department of Agriculture, Washington, D.C., 47 pp.

Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall-erosion losses: a guide for conservation planning. Agricultural Handbook 537. U.S. Department of Agriculture, Washington, D.C., 58 pp.