DETERMINING COVER MANAGEMENT VALUES (C FACTORS) FOR SURFACE COVER BEST MANAGEMENT PRACTICES (BMPs)

Kurt Kelsey

Research Scientist
American Excelsior Company
831 Pioneer Ave
Rice Lake, WI 54868

Tony Johnson

National Research Director
American Excelsior Company
831 Pioneer Ave
Rice Lake, WI 54868

BIOGRAPHICAL SKETCHES

Kurt Kelsey

Mr. Kurt Kelsey is employed by American Excelsior Company—Earth Science Division—Arlington, Texas, as a research scientist. Mr. Kelsey has a Bachelor of Science degree in Water Resources with an emphasis in Watershed Science and a minor in Soil Science from the University of Wisconsin—Stevens Point, and a Masters of Science in Natural Resources with an emphasis in Soil and Water Science from the University of Wisconsin—Stevens Point. Mr. Kelsey was an intern at American Excelsior Company's ErosionLab for three years, while working on his thesis project—a soil erosion study. He has worked on streambank stabilization projects, ground water—surface water quality and interaction studies, and has published papers on erosion control. He is an active member of the American Water Resources Association (AWRA), the American Society of Testing and Materials (ATSM), and the International Erosion Control Association (IECA).

Tony Johnson

Mr. Tony Johnson is employed by American Excelsior Company—Earth Science Division—Arlington, Texas, as the National Research Director. Mr. Johnson has a Bachelor of Science degree in Reclamation and Environmental Management from the University of Wisconsin—Platteville. Mr. Johnson has work experience with the Wisconsin Department of Natural Resources, and the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) on erosion control, streambank stabilization, and soil survey projects. Mr. Johnson was responsible for the construction, start up, and operation of the ErosionLab—the company's erosion research facility. Mr. Johnson is an active member of the American Society of Testing and Materials (ASTM), the Erosion Control Technology Council (ECTC), and the International Erosion Control Association (IECA).

DETERMINING COVER MANAGEMENT VALUES (C FACTORS) FOR SURFACE COVER BEST MANAGEMENT PRACTICES (BMPs)

Kurt Kelsey

Research Scientist
American Excelsior Company
831 Pioneer Ave
Rice Lake, WI 54868

Tony Johnson

National Research Director
American Excelsior Company
831 Pioneer Ave
Rice Lake, WI 54868

ABSTRACT

Many people in the erosion control industry use the Revised Universal Soil Loss Equation (RUSLE) to estimate soil loss caused by rainfall erosion. The equation combines the interrelated physical and management parameters of climate, soils, topography, and land use. These parameters, all of which influence the rate of erosion, are represented in RUSLE's five factors whose site-specific values can be expressed mathematically. RUSLE was developed to estimate average annual soil loss. Site disturbances commonly do not last an entire year, so a method of predicting soil loss from periods of less than one year is necessary.

RUSLE has been shown to accurately predict event soil loss from sandy loam to loam soils (Kelsey, 2002). Successful erosion control plans can be developed based on accurate estimations from RUSLE. Linear regression can be utilized to help determine cover management values (RUSLE C factor) for surface cover best management practices (BMPs) when accurate event soil loss amounts are estimated by RUSLE. Properly estimated RUSLE C factors (and the associated surface cover) can be assigned to bare soil conditions that the product will successfully protect.

This paper summarizes four years of data collected at American Excelsior Company's ErosionLab. RUSLE was utilized to estimate event-based cover management values for the BMPs studied over the course of the study.

After all factors were analyzed, RUSLE was found to be a reliable tool for predicting soil loss for a single design event, and for determining RUSLE C factor values for selected surface BMPs.

Key Words: cover factor; slope protection; RUSLE; BMPs

INTRODUCTION

The Revised Universal Soil Loss Equation (RUSLE) (formerly the Universal Soil Loss Equation (USLE)) has been used in the soil erosion industry for many years. The full equation is:

$$A = R*K*LS*C*P$$

where:

A = Average annual soil loss

and

R = Rainfall runoff erosivity factor
K = Soil erodibility factor
LS = Slope length and steepness factor
C = Cover management factor
P = Support practice factor

RUSLE was originally developed to estimate soil loss from agricultural fields. The equation predicts average annual soil loss when used in its "conventional" context. The equation has proven to help reduce agricultural erosion over the years. Average soil erosion from modern farming practices is estimated to be 0.8 mm/yr (0.03 in/yr), while construction activities are estimated to have an average soil loss of 3–30 mm/yr (0.12–1.18 in/yr) (Ivarson, 2002).

The need for predicting and controlling event soil loss from construction activities is becoming more important. Updated National Pollutant Discharge Elimination System (NPDES) permits are coming in March 2003. The updated NPDES permits will require erosion and sediment control plans to be designed and implemented for disturbed sites as small as 0.405 ha (1 acre). In addition, our land is being developed at unprecedented rates. The average annual land development rate from 1992–1997 was 1.3 million hectares (3.2 million acres), which was more than double the average rate occurring over the previous 10 years (Benson, 1999). Construction sites are major sources of sediment, which is considered the number one pollutant of water bodies on a volume basis by the U.S. Environmental Protection Agency (EPA).

Wischmeier and Smith (1978) explain that USLE/RUSLE may be applied to periods of less than one year, such as construction activities. The fraction of the average annual rainfall runoff erosivity factor occurring over the construction activity replaces the average annual rainfall runoff erosivity factor that is traditionally used in the equation. A study by Kelsey (2002), that supports the use of RUSLE to predict event soil loss from disturbed sites, explains the method of calculating the rainfall runoff factor for any unique storm. The method calculates the rainfall energy based on the amount of rainfall received over a particular length of time.

Because RUSLE can be utilized to predict event soil loss, a method of back calculating the cover management value (RUSLE C factor) can be accomplished. Project planners and designers can then apply the event based cover management values when they design erosion control plans. This paper discusses the method of determining event-based RUSLE C factors for surface cover best management practices (BMPs).

BACKGROUND

RUSLE has been used in the past to determine cover management values for various erosion control products. These values are good estimates, but these estimates are based on average annual conditions. Those responsible for erosion control plans under the upcoming NPDES Permits will be held accountable for the success of the plans. Erosion control plans based on average conditions may fail if "above average" rainfall events occur during the life of the project. The ability to estimate cover management values based on *any* sized rainfall event is critical to the success of erosion control plans.

RUSLE

RUSLE has five factors that estimate average annual soil loss when multiplied together.

Rainfall Runoff Erosivity (R)

The R factor represents the climatic erosivity of a location. The R factor includes the two most important storm characteristics. These characteristics are the amount of rainfall and the peak intensity of the storm.

RUSLE R factors can be calculated for a specific rainfall event based on rain gauge readings and storm duration (Renard et al., 1997; Kelsey, 2002). The product of the total kinetic energy (E) times the 30-minute maximum intensity (I_{30}) for a particular storm equals the R factor for that event.

Average annual RUSLE R factor values are also presented in isoerodent maps. R factors from the isoerodent maps represent average EI_{30} values over many years. R factor values vary greatly from location to location. In the state of Michigan, for example, R ranges from 75 to 135 (US customary units) annually (Michigan State University, 2001). Rainfall erosivity factors have dimensions of LFL/L^2T and units of MJ*mm/ha*h*y (hundreds of foot*tonf *inch/ acre*h*yr).

Soil Erodibility Factor (K)

K is defined as the rate of soil loss per unit of rainfall erosion index for a soil cultivated in continuous fallow on a plot having a slope length of 22.1 m (72.6 ft) and a gradient of 9% (Wischmeier and Smith, 1978). The K factor represents both susceptibility of soil to erosion and the rate of runoff.

Linear regression of bare soil data sets can be used to determine event K factors (Clopper, 2001; Kelsey, 2002). The procedure is similar to determining event cover management values of surface cover BMPs, which is described in detail in the *Calculating Event C Factors* section of this paper.

An annual average soil erodibility factor can be extrapolated from the soil erodibility nomograph when soil organic matter content is 4% or less (Wischmeier and Smith, 1978). K factors can also be determined from equations found in Agriculture Handbook No. 703 (Renard et al., 1997). The nomograph considers texture, structure, and permeability in addition to organic matter. A K factor may need to be adjusted by a qualified soil scientist in situations where the subsoil is exposed, the soil's organic matter content has been depleted, soil structure has been altered, or where soil compaction has decreased permeability (Michigan State University, 2001). Soil erodibility factors have dimensions of ML^2T/L^2LFL and units of t*ha*h/ha*MJ*mm (ton*acre*hr/hundreds of acre*foot*tonf*inch).

Slope Length and Steepness (LS)

Slope and length are combined into the LS factor in RUSLE. L is the slope length factor, which is the ratio of soil loss from the slope length measured in the field to that from a 22.1 m (72.6 ft) length on the same soil type and gradient. Slope length is the distance from the start of overland flow to the point where concentrated flow or deposition occurs. The most accurate method of determining slope length is to measure the distance on the ground (Michigan State University, 2001). Slope lengths greater than 305 m (1000 ft) should not be used in RUSLE because concentration usually occurs before the end of segments of this distance (Michigan State University, 2001; Renard et al., 1997).

The S portion of the LS factor incorporates the gradient of the landscape into RUSLE. S is the ratio of soil loss from the slope found in the field to that from a 9% slope believed to be under the same conditions. Soil particle size and vegetation density along the slope influence the ratio of soil loss to slope steepness.

L and S = 1 under the unit plot conditions of 22.1 m (72.6 ft) long and 9% slope. LS factors for field plots represent how erodible the plot is relative to the standard plot conditions (Michigan State University, 2001; Renard et al., 1997). The LS factor is unitless.

Cover Management (C)

Cover management is considered by RUSLE through the C factor. The C factor represents the effect of surface cover and roughness on soil erosion. The cover factor is the most common factor used to assess the impact of BMPs on reducing erosion because the C factor represents the effect of land use on soil erosion (Renard et al., 1997). Erosion control blankets and surface applied BMPs such as blown straw are represented as C factors within RUSLE. By definition, C = 1 under standard fallow conditions. As surface cover is added to the soil, the C factor value approaches zero. For example, a C factor of 0.20 signifies that 20% of the amount of erosion will occur compared to continuous fallow conditions. C factors vary from region to region because they are strongly influenced by different R factors (Wischmeier and Smith, 1978).

The unitless cover management factor can be determined in two ways. The first method, which is discussed in the *Calculating Event C Factors* section of this paper, involves determining event specific values, which can be derived from the linear regression of soil loss data. The second method involves estimating a C value from five subfactors (Renard et al., 1997). The five subfactors are:

1) Prior Land Use (PLU)
2) Canopy Cover (CC)
3) Surface Cover (SC)
4) Surface Roughness (SR)
5) Soil Moisture (SM)

Support Practice (P)

P is the support practice factor in RUSLE. The P factor reflects the impact of support practices on the average annual erosion rate. P is the ratio of soil loss with a support factor to that with straight row farming up and down slope. Stripcropping, contouring, and terracing are all activities that are considered support practices by RUSLE (Michigan State University, 2001). The support factor is unitless.

OBJECTIVE

The objective of this study is to devise a method that accurately calculates event-specific cover management values (RUSLE C) for surface cover BMPs.

METHODS

Study Site

Fieldwork for this study was completed at American Excelsior Company's ErosionLab in Rice Lake, Wisc. The Rainfall Erosion Facility (REF) portion of the lab is equipped to test surface cover BMPs on hillslopes under simulated rainfall. REF testing follows procedures outlined in American Society for Testing and Materials (ASTM) ASTM D—6459, "Standard Test Method for Determination of Erosion Control Blanket (ECB) Performance in Protecting Hillslopes from Rainfall-Induced Erosion" (ASTM, 2001). REF contains 12 erosion plots that are 12.2 m (40 ft) long by 2.4 m (8 ft) wide and are separated from one another by a 4.9 m wide buffer of vegetated soil (see Figure 1). All 12 plots were constructed at an approximate 33 percent grade. There are four plots each of sandy loam, gravelly loam, and silty clay loam materials. All contents exiting the plots are directed into buried collection tanks by v-shaped metal flashing at the end of each plot.

Figure 1. Onsite water source in foreground with rainfall erosion plots in background.

Simulated Rainfall

Water is pumped through the rainfall simulator from an onsite 2 ha (5 acre) pond. Raindrop size, distribution, and quantity are measured during system calibrations. Eleven rainfall risers surround a plot during simulated rainfall testing. Each riser is 3 m (10 ft) tall, which gives the raindrops an approximate 4.9 m (16 ft) fall height when projected by the sprinkler system. This fall height allows the raindrops to experience terminal velocities very similar to natural rainfall.

One simulated rainfall test includes three sequential target intensities of 5.1, 10.2, and 15.2 cm/hr (2, 4, and 6 in/hr) each lasting 20 minutes. The target intensity of 5.1 cm/hr (2 in/hr) is achieved when one sprinkler head on each of the 11 rainfall risers is turned on and the system is maintained at an operating pressure determined through the calibration process. The target intensities of 10.2 and 15.2 cm/hr (4 and 6 in/hr) are achieved when two and three sprinkler heads, respectively, are turned on each of the 11 risers and predetermined operating pressures are maintained. Figure 2 shows the rainfall simulator system operating during a 15.2 cm/hr (6 in/hr) event.

Erosion Plot Preparation

Plots were tilled up and down slope using a walk-behind roto-tiller to a depth of 10.2–15.2 cm (4–6 in). Plots were hand-raked to a uniform smooth surface following tillage. A 31.8 kg (70 lb) rolling pin was then used to lightly compact the smooth plot. If a surface

Figure 2. Erosion test plot during the 20.3 cm/hr (6 in/hr) portion of the test series.

cover BMP was to be tested, the BMP was installed according to manufacturer's recommendations at that time. The simulated rainfall series was started directly following compaction when bare soil controls were tested.

Soil Types Tested

Three soils types were tested during the course of this study. Chetek sandy loam is the native soil on site and contains a grain size distribution of 82.3 percent sand, 2.8 percent silt, and 14 percent clay. An imported topsoil material with a grain size distribution of 43.6 percent sand, 30.4 percent silt, and 10.5 percent clay was also tested. The topsoil material is categorized as a gravelly loam according to the United States Department of Agriculture (USDA) textural triangle. The third soil type tested was an imported "clayey" material with a grain size distribution of 1 percent sand, 61.6 percent silt, and 37.4 percent clay, which is classified as a silty clay loam according to the USDA textural triangle. The two imported materials are maintained in the test plots as 45.7 cm (18 in) veneers. Material was added to the erosion plots from on-site stockpiles when needed.

Surface Cover BMPs Tested

Five different surface conditions were tested and cover management factors were calculated for each except for the bare soil controls. Bare soil conditions, blown oat straw applied at approximately 459 kg/m^2 (2500 lb/acre), a wood fiber blanket weighing approximately 0.40 kg/m^2 (0.73 lb/yd^2) with netting on top, a straw fiber blanket weighing approximately 0.27 kg/m^2 (0.50 lb/yd^2) with netting on top, and a straw fiber blanket weighing approximately 0.27 kg/m^2 (0.50 lb/yd^2) with netting on top and bottom were the five surface conditions tested. Each surface condition was tested three times on each of the three soil types. The blown straw was only tested at the 5.1 and 10.2 cm/hr (2 and 4 in/hr) intensities lasting 20 minutes each. The other three BMPs were subjected to the previously stated sequential intensities of 5.1, 10.2, and 15.2 cm/hr (2, 4, and 6 in/hr) lasting 20 minutes each.

Laboratory Procedures

Homogeneous samples of the collected soil slurry were taken following each 20-minute storm increment to determine the moisture content of the soil lost from the plots. The Microwave Method, ASTM #4643, was followed (ASTM, 2000). The Microwave Method is equivalent to oven drying the soils at 105° C for 24 hours. After the moisture content of the sample was known, the ratio of dry to wet soil was used to calculate the equivalent amount of dry soil that was collected during the test. This was necessary because RUSLE computes soil loss on a dry basis.

Data Analysis

Ayres Associates performed the data analysis for this project.

The bare soil dataset provided a control by which event-based soil erodibility factors (RUSLE K) could be determined (Clopper et. al., 2001). Linear regression of soil loss vs rainfall runoff erosivity was used to calculate the event-specific soil erodibility values.

The cover management factor was the only remaining unknown *event-specific* RUSLE variable once it was understood how the soils were eroding on an event basis:

$$A = RKLSCP$$

- A = Soil loss which is collected and measured during simulated rainfall testing.
- R = Rainfall runoff erosivity values are calculated based on the amount and duration of simulated rainfall.
- K = Soil erodibility determined from the baseline bare soil dataset.
- LS = Slope length and steepness of the test plots are fixed.
- C = Event specific cover management value is not known.
- P = No support practice measures were used during the testing of the BMPs so P equaled one for every test performed.

Calculating Event C Factors

Once RUSLE A and RUSLE R were known for a series of tests on a surface cover BMP, it was possible to plot A as the dependent variable and R as the independent variable. The resulting slope m of the least squares regression line fitted through the origin is equal to:

$$m = K*LS*C*P$$

solving the equation for C,

$$C = m/K*LS*P$$

and no support practices were used so P = 1 and LS is fixed for all the erosion plots = 2.78

substituting the values for P and LS,

$$C = m/2.78K$$

Figure 3 illustrates the regression of test data used to calculate event cover management factors using single net wood fiber erosion control blanket data from the loam soil type.

RESULTS

Cover management factors are dependent of soil type because the erodibility rates (RUSLE K) of different soils vary. Cover management factors are also dependent on the rainfall runoff erosivity of a particular event. Event cover management values were calculated separately on each of the three soil types for the four surface cover BMPs tested. Table 1 lists the average event based cover management values by surface cover BMP and soil type.

DISCUSSION

All four of the products performed very well on the sand soil. The sand soil has an inherently high infiltration rate, which resulted in very little erosion when a surface BMP was applied.

The wood fiber erosion control blanket performed the best on the loam soil. The unique properties of the

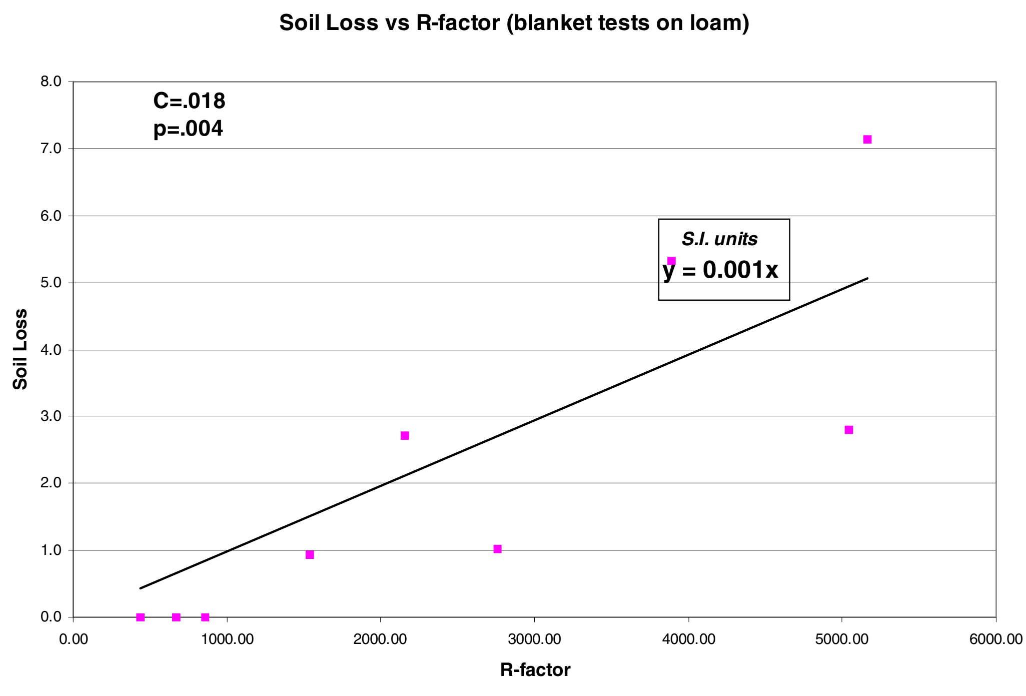

Figure 3. Regression of soil loss vs. RUSLE R factor using single net wood fiber erosion control blanket simulated rainfall test data from loam plots. The slope of the regression line was used to calculate the cover management factor (C) of the single net wood fiber erosion control blanket.

Table 1. Event Based Cover Management Values by Surface Cover Bmp and Soil Type.*

Surface Cover	Soil Type		
	Sand	*Loam*	*Clay*
Wood Fiber Blanket	0.010	0.018	0.220
Blown Straw**	0.003	0.810	***
Straw Blanket—Single Net	0.002	0.046	0.600
Straw Blanket—Double Net	0.002	0.041	0.245

* Data taken from A Quantitative Assessment of Erosion and Sediment Control Best Management Practices, Rainfall–Runoff Erosion on Hillslopes: 1. Curlex 0.73 Erosion Control Blanket Testing (2000). 2. Pneumatically applied straw testing (2000). 3. Premier Straw Erosion Control Blanket Testing (2002). 4. Premier Straw Double Net Erosion Control Testing (2002). All documents were prepared for American Excelsior Company by Ayres Associates.

** The blown straw surface was only tested at the 5.1 and 10.2 cm/hr (2 and 4 in/hr) intensities. The blown straw was the only surface cover tested that was not subjected to the third sequential intensity of 15.2 cm/hr (6 in/hr).

*** The cover management value for the blown straw on the clay soil was greater than 1, which exceeds the definition of the cover management factor for bare soil conditions. More soil loss was measured during the blown straw tests on clay than the bare soil tests on clay.

curled fibers allowed the product to adhere to the soil surface and to maintain intimate contact with the surface. Both straw erosion control blankets performed about the same on the loam soil, but not as well as the wood fiber blanket. The blown straw did not perform very well on the loam soil. The non-anchored blown straw was unable to adhere to the loam soil surface and washed downslope during simulated rainfall testing.

This is a scenario where determining cover management values on an event basis becomes important. Agriculture Handbook 537 (1978) provides a cover management value for non-anchored blown straw of 0.17 for soils with erodibility rates less than 0.30. All three soil types tested have K factors of less than 0.30, so blown straw would accordingly have a C factor of 0.17. The results of an erosion control plan that used the "generic" C factor of 0.17 for blown straw may be costly. Table 1 suggests that 81% of the soil loss at bare fallow conditions would be experienced when applying blown straw to loam soils as opposed to 17%. The difference between the two cover management values is drastic.

The wood fiber erosion control blanket also performed the best on the clay soil. The double net straw erosion control blanket performed well too. The single net straw erosion control blanket did not perform well. The results of this study suggest that applying blown straw to clay soils is worse than leaving the soils bare. Blown straw is free to easily migrate downslope as opposed to the materials contained within the erosion control blankets. The blown straw was seen to form small dam-like structures on the erosion plots, which increased infiltration and caused the soil to approach saturation. When the critical moisture level of the soil was achieved, large slugs of the material slid downslope. This phenomenon is similar to the landslides common to the west coast of the United States.

CONCLUSION

With the updated NPDES permits looming in the near future and their potential fines involved with unsuccessful erosion control plans, the ability to determine site and event specific cover management values for surface cover BMPs is priceless. Properly calculated event C factors allow designers and engineers to develop erosion control plans that have a better chance of surviving the "gully washer" in their particular area. Cover management factors can be calculated for any sized rainfall event. The main limitation to this method of determining event-based cover management factors is that there must by an established baseline bare soil dataset before C factor calculations can be performed.

REFERENCES

American Society of Testing and Materials (ASTM). 2001. "ASTM Annual Book of ASTM Standards—2001: Section Four." Construction, Vol. 04.09. ASTM, West Conshohocken, Penn.

American Society of Testing and Materials (ASTM). 2000. "ASTM Annual Book of ASTM Standards—2000: Section Four." Construction, Vol. 04.08. ASTM, West Conshohocken, Penn.

Ayres Associates. 2000. *A Quantitative Assessment of Erosion and Sediment Control Best Management Practices, Rainfall–Runoff Erosion on Hillslopes: Curlex 0.73 Erosion Control Blanket Testing*. Fort Collins, Colo.

Ayres Associates. 2000. *A Quantitative Assessment of Erosion and Sediment Control Best Management Practices, Rainfall–Runoff Erosion on Hillslopes: Pneumatically Applied Straw Testing*. Fort Collins, Colo.

Ayres Associates. 2002. *A Quantitative Assessment of Erosion and Sediment Control Best Management Practices, Rainfall–Runoff Erosion on Hillslopes: Premier Straw Erosion Control Blanket Testing*. Fort Collins, Colo.

Ayres Associates. 2002. *A Quantitative Assessment of Erosion and Sediment Control Best Management Practices, Rainfall–Runoff Erosion on Hillslopes: Premier Straw Double Net Erosion Control Blanket Testing*. Fort Collins, Colo.

Benson, J. 1999. The State of the Land. *Conservation Voices*. Soil and Water Conservation Society. April–May.

Clopper, Paul, M. Vielleux, and A. Johnson. 2001. "Quantifying the Performance of Hillslope Erosion Control Best Management Practices." World Water and Environmental Resources Congress Professional Paper.

Ivarson, R. E. 2002. "Performance Based Design of Erosion and Sediment Controls For Construction." *In* Proceedings of the International Erosion Control Association's Conference 33, p 379–392.

Kelsey, K. L. 2002. "Use of the Revised Universal Soil Loss Equation on an Event-By-Event Basis." *In* Proceedings of the International Erosion Control Association's Conference 33, p 61–69.

Michigan State University. 2001. *RUSLE—An Online Soil Erosion Assessment Tool*. Website: www.iwr.msu.edu/~ouyandga/rusle/.

Renard, K. G., G. R. Foster, G. A. Weesies, D. K. McCool, and D. C. Yoder. 1997. *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation—USDA Agric. Handb. 703*. U.S. Gov. Print. Office, Washington, D.C.

Wischmeier, W. H., and D. D. Smith. 1978. *Predicting Rainfall Erosion Losses: A Guide For Conservation Planning—USDA Agric. Handb. 537*. U.S. Gov. Print. Office, Washington, D.C.