# Use of Soil Properties to Estimate Soil Loss by Water Erosion on Surface-Mined Lands of Western North Dakota

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**Reclamation of surface-mined lands normally requires reestablishment of a vegetative cover. Maximum erosion potential occurs prior to and during the period of vegetation establishment when the ground cover is sparse or non-existent. Erosion losses can be predicted only if soil physical and chemical properties are known. Soil losses may be minimized by shaping land to gentle slopes and revegetating as rapidly as possible.**

## Introduction

Wischmeier and associates (1965) have published extensively on the Universal Soil Loss Equation and methods for predicting soil loss by water erosion. The Soil Conservation Service (SCS) currently uses Wischmeier's soil erodibility nomograph (1971) to assign values of erodibility, K, (see Appendix) to virtually all soil series in the United States east of the Rocky Mountains. Twelve classes are presently used ranging from 0.02 to 0.69; 0.02 represents a nonerodible soil, while 0.69 represents a highly erosive soil. Erodibility classes for reshaped mined land have not been determined. It is the purpose of this paper to discuss the implications of using the Universal Soil Loss Equation and estimating soil erodibility factors for predicting water erosion from surface-mined lands in western North Dakota.

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## Methods

Soil physical properties together with the Wischmeier soil erodibility nomograph (1971) were used to estimate K values for both mined and non-mined land at four strippable coal mines near Beulah, Center, Stanton and Zap, North Dakota. Seven sites were selected for the study. Soils were identified and described by SCS personnel. Mechanical analysis by hydrometer and sieving (Day, 1965) was used to determine clay, silt and sand percentages in soil or spoil materials taken from the surface 4 inches. Organic matter was determined by the Walkley-Black method (1947). Soil structure and permeability classes were estimated from field observations of structure and texture. In some cases, laboratory determination of saturated permeability was used to confirm the field estimates.

## Results and Discussion

Data in Table 1 show some physical characteristics of the surface materials used in the analysis. Soil types typical of the area are Flaxton sandy loam, Williams loam, Temvik silt loam and Daglum loam. Soil erodibility factors (K) for these soils were calculated and compared with those listed for these soil types by SCS. Agreement was good for the sandy loam soil. The Flaxton soil was tested further by using stockpiled material from a

**Table 1. Selected properties of soil and spoil materials used to determine soil erodibility, K, values for several western North Dakota soils.**

| Soil | Texture | New silt[1] | New sand[2] | Organic matter | Soil structure[3] | Permeability class[4] | K Calculated[5] | K S.C.S.[6] |
|---|---|---|---|---|---|---|---|---|
| | | per cent by weight | | | | | | |
| Daglum | loam | 64 | 11 | 2 | 3 | 4 | 0.40 | 0.32 |
| Flaxton | sandy loam | 28 | 68 | 1 | 3 | 3 | 0.18 | 0.20 |
| Flaxton-mined | sandy loam | 29 | 51 | 2 | 3 | 3 | 0.17 | 0.20 |
| Temvik | silt loam | 86 | 7 | 2 | 3 | 4 | 0.51 | 0.32 |
| Williams | loam | 50 | 15 | 2 | 3 | 4 | 0.25 | 0.32 |
| Spoil | sandy clay loam | 30 | 30 | 0 | 4 | 6 | 0.34 | — |
| Spoil | clay loam | 60 | 10 | 0 | 4 | 6 | 0.52 | — |

[1]*New silt = Silt plus very fine sand; particle size range, 0.002 - 0.1 mm.*
[2]*New sand = Sand minus very fine sand; particle size range, 0.1-2.0 mm.*
[3]*Soil structure classes ranked 1-4. Rank 3 = medium or coarse granular, 4 = blocky, platy or massive.*
[4]*Soil permeability classes ranked 1-6. Rank 3 = moderate, 4 = slow to moderate, 6 = very slow.*
[5]*Calculated K — From Wischmeier nomograph (1971).*
[6]*Soil Conservation Service (S.C.S.) K — Values on file at SCS State Office, Bismarck, ND. These values assigned from typical soil profile descriptions for various soils.*

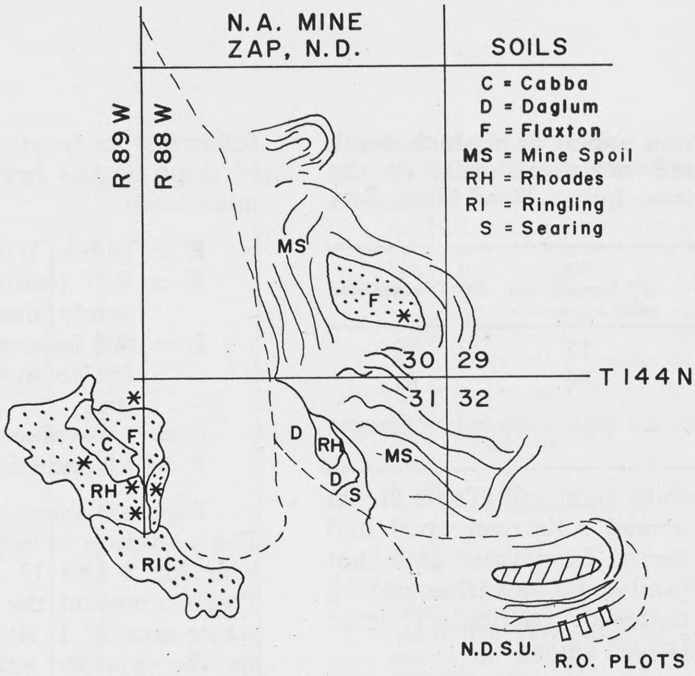


**Figure 1. Schematic soils map at North American Mine, Zap, ND, showing location of Flaxton and other soils. Dashed line indicates access road. Dotted areas represent soils mapped prior to mining. Asterisks show location of several stockpiled surface materials. Location in lower right hand corner is the area where NDSU runoff and erosion (R.O.) plots were established. Flaxton soil from section 30 was respread on several runoff plots and K values were measured on these plots (see text).**

uniform area previously classified as Flaxton fine sandy loam (see Figure 1). The stockpiled material was tested in a similar manner as the nonmined surface soil. Data presented in Table 1 show there is virtually no difference between the computed K values of the nonmined and mined Flaxton soil materials. The stockpiled material came almost entirely from the 0- to 16-inch depth of the Flaxton profile. There is some indication that small inclusions of the underlying B horizon of this soil were mixed throughout the stockpiled material. The stockpiled Flaxton had slightly more clay than the nonmined soil (Table 1), but the silt plus very fine sand percentage was virtually the same, hence the good but perhaps fortuitous agreement between the two computed K values.

Gilley and others (1976), using a rainfall simulator, measured K values for the Flaxton soil after it had been spread on runoff plots (Figure 1). They report K values as high as 0.34. A possible explanation for the difference between measured and computed values is the breakdown of the soil aggregates as a result of the disturbance due to stockpiling and subsequent spreading on the runoff plots. The spread Flaxton soil would be considered moderately erosive.

The Williams soil had a calculated K value that was less than the SCS value. The Temvik and Daglum soils both had higher computed K values than SCS values. These differences, although relatively large, may represent natural field variability in soil types. It is also possible that the assigned structure and permeability class values were slightly in error. Nevertheless, it is suggested from these observations that replaced surface soils in the area of the mines have K values ranging from 0.17 to 0.5. Further field testing will be required to substantiate this range.

The bare spoil material tested was highly dispersed (extensive surface crusting) and calculated K values are listed only for comparison. No values for this material are given by SCS. However, measurements by Gilley and others (1976) indicate that surface crusting reduces the K values of the spoil material well below those calculated (0.06 and 0.09 for the sandy clay loam and clay loam spoils, respectively).

Wischmeier and others (1971) discussed the effect of subsurface textural discontinuities on erodibility. They indicated that a fragipan or claypan below the surface of a loam soil may not contribute to erodibility until prolonged wetting occurs; then the erodibility of the soil may be increased significantly due to the poor drainage.

A similar situation appears to exist on mined land where a clayey and often dispersed subsoil (mine spoil) is covered by coarser surface materials. We compared water movement at three sites to observe the influence of the subsoil on impeded drainage. Two "reclaimed" mine spoil sites were compared to an adjacent well-drained grassland site. All three sites were wetted excessively with 10 inches of water and allowed to drain. Evaporation was prevented. After 30 days, the drainage at the grassland site had proceeded until the soil water suction approached the normal field capaci-

**Table 2. Water retention values at six-inch depth on mined and nonmined soils at the North American, Indian Head Mine, Zap, ND.**

| Time days | Grassland | Site 8" Topsoil/Spoil millibars suction[1] | 24" Topsoil/Spoil |
|---|---|---|---|
| 3 | 66 | 27 | 19 |
| 30 | 150 | 90 | 41 |

[1]*The smaller the number, the higher the water content.*

ty of a well-drained sandy loam soil (Table 2). On the other hand, the spread soils over spoil had drained little. It is inferred from these data that erosion of replaced topsoil could be influenced by the underlying spoil materials, particularly after snowmelt or after prolonged rains.

There are also implications of topsoil thickness effects on the soil loss tolerance factor, T, for reclaimed mine spoil. For thickness of spread topsoil materials less than 24 inches, there appears to be clear justification to require a T value of 2 or less because of the inherent instability of the spread topsoil and also the textural discontinuity between topsoil and spoil materials.

**Erosion loss estimates.** Erosion losses from rainfall can be predicted using the Universal Soil Loss Equation by assigning values to each of the factors affecting the erosion process. This equation can be written:

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

where A = soil loss in tons/acre
R = rainfall factor
K = soil erodibility factor
L = slope-length factor
S = slope-gradient factor
C = cropping management factor
P = the erosion control practice factor.

For a more detailed description of these erosion factors, see Appendix.

Numerical values for these factors have been determined by research on agricultural lands and are well documented by Wischmeier and Smith (1965). The applicability of the equation for mine spoil areas appears sound, but the coefficients K, C and S are not known with confidence at mine sites, since virtually no work has been done as yet to evaluate these factors on drastically disturbed lands. However, by using the established procedure for agricultural land, we can give a first approximation of the annual soil losses. By making several assumptions about the average rainfall patterns and topography, we can estimate the first year soil losses after the spoil banks have been reshaped and covered with "topsoil." Based on the following assumptions, we can predict the effect of slope on the first year erosion from reshaped mine land:

R = 50 (see Wischmeier and Smith, 1965, p. 6)
K = 0.37 (estimated upper limit for spread sandy loam soil)
L = 500 (assumes a slope length of 500 feet for an average shaped slope after mining)
C = 1.0 (value considers fallow condition)
P = 1.0 (assumes no erosion control practices)

Figure 2 shows the effect of slope on erosion. The variation is from 22 to 118 tons per acre per year for 5 and 17 per cent slopes, respectively. These represent the maximum expected losses by water erosion. It should be emphasized that these are the expected extremes under conditions of no vegetative cover.

When a plant cover is established (assuming grasses), the estimated soil losses would be greatly reduced. For a 40 per cent cover (C = 0.07), the loss from a 17 per cent slope is reduced to 8.4 tons per acre (Figure 3). A complete cover would be expected to reduce the erosion losses to well below the tolerance level of 2 tons per acre per year, the tolerance (T) value for a Flaxton soil as recommended by SCS. The question remains, however, is it acceptable to allow potentially large amounts of erosion to take place in the initial year of establishment? While erosion will occur when vegetation cover is lacking, reduction of slopes would reduce the potential hazard. It would seem that the future of these lands would be enhanced and potential erosion losses minimized by shaping the areas with reduced slopes.

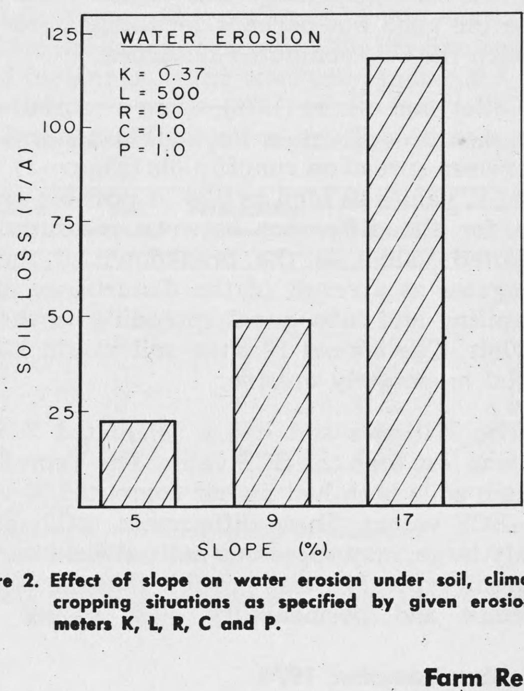


**Figure 2. Effect of slope on water erosion under soil, climatic and cropping situations as specified by given erosion parameters K, L, R, C and P.**

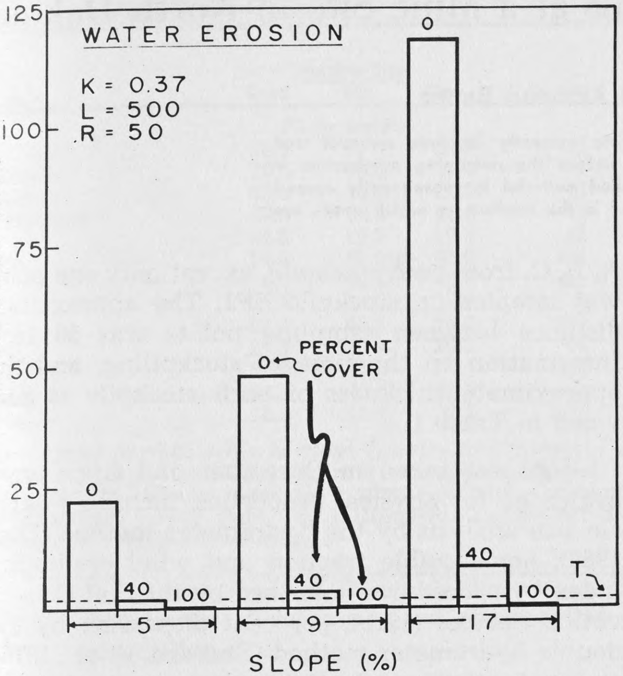


**Figure 3. Effect of cover on erosion losses on sloping land. Conditions as specified by given erosion parameters K, L, and R.**

## Summary

Soil losses up to 118 tons per acre from a sandy loam topsoil are predicted for first-year conditions on steep slopes (17 per cent) on reshaped mine land. Cultural practices can reduce this value. Seeding the area into permanent pasture is advisable, but soil losses would still be high during the initial year of establishment. Reducing the slope optimizes the land use and minimizes the soil losses occurring during the initial establishment and subsequent stabilization of the mined land.

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## Appendix

**Definition of Terms:**

The Universal Soil Loss Equation, A = RKLSCP, is used to estimate sheet and rill erosion.

A = the predicted average annual soil loss expressed in tons per acre per year.

R = the rainfall factor. It is the number of erosion-index units in a normal year's rain. The erosion-index is a measure of the erosion force of specific rainfall. When other factors are constant, storm losses from rainfall are directly proportional to the product of the total kinetic energy of the storm times its maximum 30-minute intensity.

K = the soil-erodibility factor. It is the erosion rate per unit of erosion-index for a specific soil in cultivated continuous fallow on a 9 per cent slope 72.6 feet long. Soil properties that influence erodibility by water are (1) those that affect the infiltration rate, permeability and total water capacity; and (2) those that resist the dispersion, splashing, abrasion and transporting forces of the rainfall and runoff.

L = the slope length factor. It is the ratio of soil loss from the field slope length to that from a 72.6-foot length on the same soil type and gradient. Slope length is the distance from the point of origin of overland flow to (1) the point where the the slope decreases to the extent that deposition begins, or (2) the point where runoff enters a defined channel.

S = the slope-gradient factor. It is the ratio of soil loss from the field gradient to that from a 9 per cent slope. The relation of soil loss to gradient is influenced by density of vegetal cover and by soil particle size.

C = the cropping-management factor on cropland and other land uses. It is the ratio of soil loss from a field with a specified cropping and management or plant cover to that from the fallow condition on which the factor K is evaluated. This factor measures the combined effect of all the interrelated cover and management variables plus the growth stage and vegetal cover at the time of the rain.

P = the erosion control practice factor. It is the ratio of soil loss with contouring, stripcropping or terracing to that with straight-row farming up-and-down slope.

T = the soil loss tolerance expressed in tons per acre per year. This is the maximum allowable soil loss for a given soil based on its erodibility and its overall profile characteristics (thickness of topsoil, etc.). All North Dakota soils have T values of 5 or less.

For additional details, see Wischmeier and Smith (1965) or SCS (1975).

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