QUANTITATIVE EROSION CONTROL ON HIGHLY ERODIBLE LANDS: A SELECTION OF TOOLS BASED ON THE REVISED UNIVERSAL SOIL LOSS EQUATION

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Abstract
The Revised Universal Soil Loss Equation has been used extensively as a tool in assessing soil erosion issues for many years, especially in rural environments. This paper takes the Equation and applies it to non-rural sites, such as urban construction sites, highways, waste disposal sites and open-cut mining sites. It shows how the equation can be used as a soil conservation management tool to achieve a degree of objectivity not evident previously. It is particularly useful in quantifying erosion hazards.

Additional Keywords: soil, conservation, erosion hazard, stabilisation

Introduction
Since the 1970s, the issue of environmental protection has come to the fore. This has prompted both new legislation in many Australian States and rapid technological change in best soil conservation practice. Regulators are tending to set goals while allowing proponents the freedom to address them in a manner appropriate to their development proposal. This places an onus on developers and operators to show diligence in planning and care in the execution of erosion and sediment controls. It improves the opportunity for positive cost-benefit outcomes for good operators.

Unfortunately, many suggested management practices to control soil erosion and sediment pollution on disturbed lands still do not adequately take into account extreme situations that might occur, for example, during rainfall events on highly erodible soils on very steep slopes. Handbooks on management practices have tended to contain guidelines that apply anywhere and everywhere so that “one size fits all”. Mostly, they are qualitative and subjective in nature.

Initial Classification of Erosion Hazard
A procedure is provided here to help identify those sites of high erosion hazard where the normal suite of erosion control measures is considered not adequate and more complex systems need to be derived. Suggestions are offered on these more complex systems using the Revised Universal Soil Loss Equation (RUSLE) as a tool.

The RUSLE is designed to predict the long term, average, annual soil loss from sheet and rill flow at nominated sites under specified management conditions. The predicted losses are empirically derived. The original application is described by Wischmeier and Smith (1978) and revised by Renard *et al*. (1991) and Renard *et al*. (1997). It has been adapted for urban sites by Goldman *et al.* (1986).

The potential erosion hazard associated with a specific site can be simply determined from figure 1. The traditional “one size fits all” soil conservation guidelines can be applied to sites classified as having low erosion hazards. Special guidelines should be considered on high erosion hazard sites, additional to those that apply to low erosion hazard sites. Figure 1 is based on the R-factor (rainfall erosivity) that relates to a site’s location and the typical upper slope gradient (measured as percent) of the landform.

Additional Measures for Use on Lands with High Erosion Hazards
A suite of suggestions follows based on the RUSLE that can be used on high erosion hazard sites. The listing is not intended to be exhaustive, be all encompassing or to apply to all situations worldwide. It is intended to encourage readers to look beyond the normal suite of soil conservation measures on high erosion hazard sites, to “think outside the square”, both objectively and quantitatively.

The data assume that sufficient rainfall information is available for a site to determine the rainfall erosivity (R-factor), the percentage of average annual erosion index (EI) that normally occurs in the first and second half of each month, and annual exceedence probabilities for rainfall erosivity.

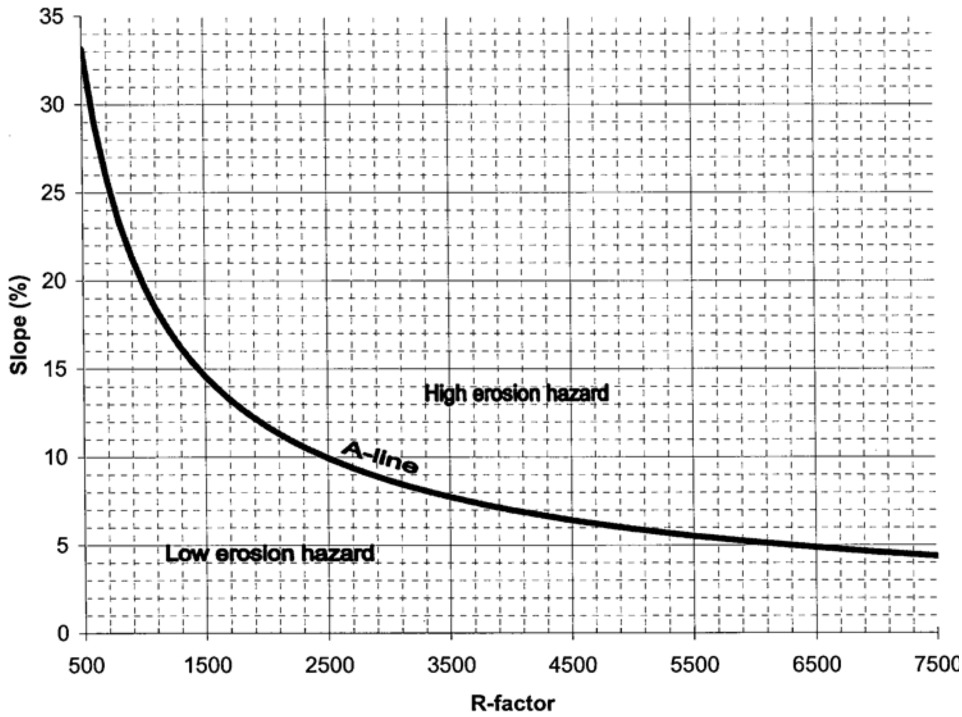

Figure 1. Assessment of potential erosion hazard

Control slope length-gradient relationships

On constructed slopes, ensure that LS-factors do not exceed 750/1.3(R×K) (Figure 2), where 750 is the calculated average annual soil loss using the RUSLE assuming no soil conservation controls, 1.3 is the P-factor for hard compact surfaces typical of construction sites, R is the R-factor for the site and K is a typical upper K-factor for the local soil materials. The equation is not condoning the failure to apply soil conservation measures. It is taking a worst-case soil loss scenario likely for a short period after formation until soil conservation measures are applied. Note that rehabilitating steep slopes (>2.5(H):1(V)) by vegetative means can be difficult in warmer climates, especially where the soils are highly permeable, irrigation is not available and on sites with aspects facing the midday and afternoon sun. The problem is greatest in areas prone to extended periods where evaporation exceeds rainfall.

Schedule land disturbance activities to periods when rainfall erosivity is low

Schedule all land disturbance activities to periods when the rainfall erosivity is low, allowing for the local soil erosion hazard. Many ways are available to assess the erosion hazard, one of which the Soil Loss Class (Table 1). These classes assume local R, K and LS-factors with 80 metre slopes for consistency. Typical of most construction areas, they also assume P-factors of 1.3 (i.e. the soils are hard and compact) and C-factors of 1.0 (i.e. no vegetative cover, probably being removed with a scraper). Of course, planners can apply different slope lengths, P or C-factors if these are properly justified. Application of shorter slope lengths, for example, can put a site into a lower Soil Loss Class. However, the management of these variations should be clearly explained in any plans for erosion control.

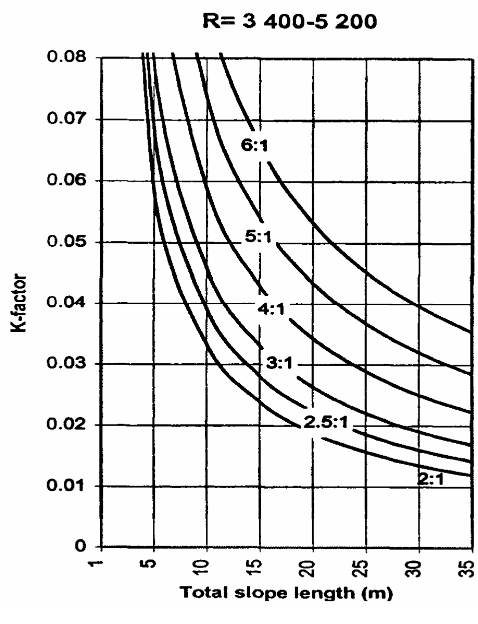

Figure 2. Maximum batter gradients (H:V) where the R-factor is 3,400 to 5.200 (adapted from Morse and Rosewell, 1993)

Having identified the applicable soil loss class, schedule activities on highly sensitive lands to periods when rainfall erosivity is low. This is illustrated in Table 2 for Sydney NSW, where the calculated average annual soil loss is less than 50 tonnes per hectare in any half month, i.e. the product of percentage average annual Erosion Index (EI) for any particular half month (Rosewell and Turner, 1992) and the calculated average annual soil loss is less than 50 tonnes assuming no soil conservation controls. For example, activities should be scheduled when more than 6 percent of the average annual EI occurs in any half month on Soil Loss Class 5 lands (i.e. $50<750 \times 0.06$). In Table 2, "Yes" means that special measures are required as well as the regular suite of soil conservation works.

Table 1. The soil loss classes (adapted from Morse and Rosewell, 1996)

Soil Loss Class	Calculated soil loss (tonnes/ha/yr)	Erosion hazard
1	0 to 150	very low
2	151 to 225	Low
3	226 to 350	low-moderate
4	351 to 500	moderate
5	501 to 750	High
6	751 to 1,500	Very high
7	>1,500	Extremely high

Table 2. Lands where scheduling of activities is required.

Soil Loss Class	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
1-4	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
5	No	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
6	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes	Yes
7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

In the example shown, highly sensitive lands occur:

- always on Soil Loss Class 7 lands
- at certain times of the year on Soil Loss Classes 5 or 6 lands
- never on Soil Loss Class 1, 2, 3 or 4 lands.

If it is not possible or practical to schedule activities on highly sensitive lands to periods when rainfall erosivity is low, ensure that any disturbed lands have C-factors higher than 0.1 only when the 3-day forecast suggests that rain is unlikely. Further, establish management regimes that facilitate stabilisation within 24 hours should the forecast prove incorrect.

Minimise the time of exposure to erosive forces

Where practicable, schedule the land disturbance program so that the time from starting activities to completion of the final rehabilitation program is less than six months. Special erosion and sediment control measures should be considered where such staging of land disturbance activities is not possible. Here, rehabilitation is defined two ways, depending on the local rainfall erosivity:

(i) In periods of expected low rainfall erosivity during the rehabilitation period, achieve a C-factor of less than 0.15 and keep it there by vegetation, paving, armouring, etc. Low rainfall erosivity is a month with an erosivity of less than 100. The erosivity for a month at a location is calculated by R-factor × percentage of annual EI occurring in that month.

(ii) In periods of moderate to high rainfall erosivity during the rehabilitation period, achieve a C-factor of less than 0.1 and set in motion a program that should ensure it will drop permanently, by vegetation, paving, armouring, etc. to less than 0.05 within a further 60 days. Of course, local water restrictions might affect this in drought times.

Stabilisation can be achieved with vegetation, paving, armouring or any other cover that protects the ground surface from erosive forces, i.e. reduces the C-factor to an acceptable level. It is essential on all disturbed lands where works are complete or in temporary abeyance to mitigate sediment pollution to downslope lands and waterways. This is because potential soil loss can often be reduced to about 1 percent or less of the prestabilisation level through the application of a suitable protective cover. In addition, stabilisation can improve the operational efficiency of the complete soil and water management program, and enhance the aesthetic values of the site. Nevertheless, sediment control works are necessary on all sites until stabilisation is complete.

However, where works are within the 2-year ARI flood level, ensure that the *C*-factors are higher than 0.1 only when the 3-day forecast suggests that rain is unlikely. In this case, management regimes should be established that facilitate rehabilitation within 24 hours should the forecast prove incorrect.

Controls for use where the receiving waters are highly sensitive

Use the 20 and 5 percent annual exceedence probabilities (AEPs) of rainfall erosivity instead of the R-factor in the derivation of the Soil Loss Class where the receiving waters are highly or extremely sensitive, respectively. The AEP is the probability of exceedence of a given R-factor in any one year. Figure 3 illustrates the effect of AEP at a site at Richmond, New South Wales. It shows:

- the 5 percent AEP rainfall erosivity is higher than data based on the *R*-factor by 1.99 on all slopes to 40 percent
- the 20 percent AEP is higher by 1.27
- the 50 percent AEP is lower by 0.79.

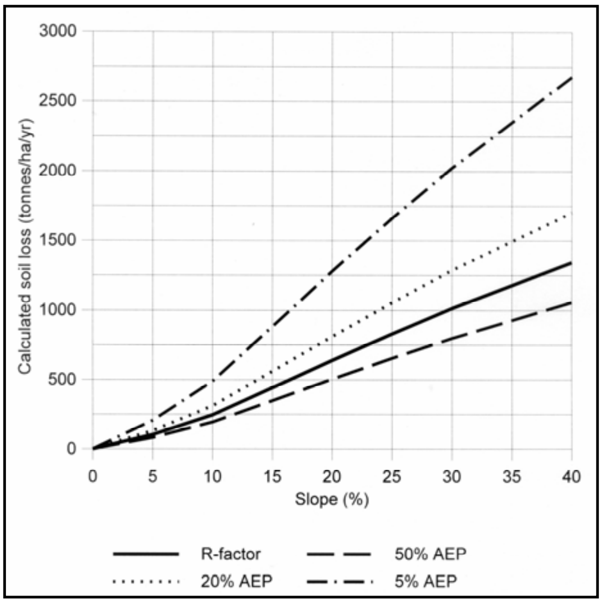

Figure 3. Average annual soil losses calculated for a site near Richmond NSW showing the R-factor and the 50, 20 and 5 percent AEP

Remember that the Soil Loss Class system is based on the R-factor, the average annual product of EI. Two sites, then, might have similar R-factors, but one with highly variable rainfall and the other not so. So, the variations illustrated in Figure 3 are not constant from one location to another. For example, a similar analysis at Port Kembla, NSW, shows the 5 percent AEP higher by 3.28, the 20 percent AEP higher by 1.52 and the 50 percent AEP lower by 0.68. Also, note that at Richmond, Rosewell and Turner (1992) show that there is a 20 percent probability that a single storm can yield an EI of 1,021 compared with the R-factor of 1,772. Likewise, there is a 10 percent and 5 percent probability that it can yield rainfall erosivities of 1,453 and 2,258 respectively.

Conclusions

This paper describes four management practices underpinned by the RUSLE for management of soil erosion on disturbed lands. The practices remove much of the objectivity of previously approved practices. They have particular application to lands with high erosion hazards.

Acknowledgements

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