HYDROLOGIC PARAMETERS OF SURFACE MINE SPOILS IN THE SOUTHWEST[1]

Earl F. Aldon[2]

Abstract.--Increased surface mining of coal in the Four Corners area of the U.S. has caused concern as to whether cast overburden (spoil) contributes significant sediment due to runoff to the already high levels in area streams. This paper reports some of the first measured values of these parameters from a Southwestern coal field.

INTRODUCTION

Increased surface mining of coal in the Four Corners area of the United States, generated concern as to whether cast overburden (spoil) areas would contribute significant sediment, due to runoff, to the already high levels of sediment in the ephemeral and perennial streams of the area (Natl. Academy, 1974).

The major drainages of the area contribute vital runoff to the Upper Colorado River Basin, and any decrease in runoff quality due to additional sediment loads would create adverse public reaction and biological degradation. State and federal laws enacted to address this problem by setting strict sediment standards have undergone review.

To better understand runoff potential, research personnel, in cooperation with Utah International Inc., Navajo Mine Reclamation personnel, set up a series of runoff plots in 1973 on graded but untreated and unreclaimed spoil to measure runoff and sediment production. This paper presents some of the first measured values of these parameters from a Southwestern coal field. Additionally, it suggests reclamation treatment possibilities to reduce runoff and erosion from these spoils, and analyzes existing study plot correlations to determine the time needed to detect significant effects from such treatments.

Estimates of sediment production from spoil plot data by means of the Universal Soil Loss Equation were not accurate enough to be useful.

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[2]Project Leader for the Rocky Mountain Forest and Range Experiment Station, 2205 Columbia SE, Albuquerque, N. Mex. 87106.

STUDY SITE

The Navajo Mine is located in the northwest corner of New Mexico. The strippable coal reserves occur here in the San Juan Basin. This mining area is characterized by broad, gently locally prominent outcrops of sandstone and shale, mesas, buttes, and hogback ridges. Elevation ranges from 1500 to 2200 meters. The climate is distinctly arid; annual precipitation sloping to rolling plains and valleys with averages only 15 to 20 cm. Summer is wetter than winter; spring and fall are the drier seasons. High intensity, short duration, summer and early fall thundershowers produce most of the precipitation on the area. Temperatures may reach extremes of -32° to 43° C.

The largest coal deposits are in the Fruitland formation, on which the mine is located. Of late Cretaceous age, this formation is a sequence of irregular gray, brown, and black shales; tan, yellowish-brown, and white sandstones; and coal. The sandstones are generally fine grained and crossbedded, and tend to grade laterally to shale in short distances. The major coals occur near the base of the formation, just above the underlying Pictured Cliffs Sandstone. This coal is of subbituminous rank. Sulfur content averages somewhat less than 0.8 percent.

The sandy surface unmined soils, which comprise more than half the area, support an open grassland with a scattering of shrubs. The shaley, saline soils and the thin breaks and badlands support mainly low-growing shrubs. Principal grasses of the area include galleta (*Hilaria jamesii*), alkali sacaton (*Sporobolus airoides*), and Indian ricegrass (*Oryzopsis hymenoides*). Shadscale (*Atriplex confertifolia*) and Nuttall saltbush (*Atriplex nuttallii*) are the most important shrub species. At higher elevations, pinyons (*Pinus edulis*) and junipers (*Juniperus* spp.) are found scattered on mesa tops.

RUNOFF PLOTS

Four runoff plots were installed on graded untreated spoil material from the Watson Pit area

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of the Navajo Mine. Grading resulted in an undulating topography, and plots were installed on a slope 60 m long by 21 m wide, with a generally north facing aspect.

Plot slopes range from 11 to 18 percent. Plot construction has been described previously (Garcia et al., 1963). Each 4.7 m by 18 m plot consists of buried sheet-metal borders protuding 15 cm above the spoil surface and a sheet-metal collection trough at an angle across the bottom. Runoff flows by gravity from the collection trough into a sheet metal lined plywood collection tank (1.5 x .9 x .9 m) below each plot. Runoff is measured in the tank after each storm and values are converted to depth area centimeters. The contents of the tank are then stirred and two 1-liter aliquot samples are taken for sediment determination. Tanks are then drained and cleared of sediment. The samples are settled, drained, and air dried and sediment is weighed. Sediment weight in grams is converted to kg/ha.

The spoil material on which the plots lie have the following average characteristics:

Sand, percent	33
Silt, percent	23
Clay, percent	44
Textural class	clay
Sodium absorption ratio (SAR)	35
Electrical conductivity x 10^3 (dSm^{-1})	10
pH 1:5	8.5
Na (sol.) (meq/l)	122

Precipitation is measured after each storm in a standard raingage located near the plots.

No revegetation was attempted on the plots, and they have remained bare of perennial vegetation for the entire calibration period. Several paired plot analyses were made to determine how well the plots were correlated with each other for determining differences in runoff and sediment after future treatments have been applied. Precipitation data were introduced into the analysis, also, to see whether this variable would improve the paired-plot correlations. An attempt was made to fit the data to the Universal Soil Loss Equation for there is interest in using this equation for prediction purposes.

RUNOFF AND SEDIMENT YIELDS

Rainfall on the area averaged 15 cm, and runoff averaged 5 percent of precipitation over the 8 years of study. Runoff events averaged two per year from an average storm of 2.24 cm (Table 1). Sediment yield averaged 2456 kg/ ha/storm from runoff that averaged 0.77 cm/storm (Table 1). This compares with a 1725 kg/ha/yr rate of sediment produced from a badly overgrazed but unmined watershed measured in another study on the Rio Puerco watershed near San Isidro, New Mexico. The area, about 190 km southeast of the present study site, normally receives about 24.1 cm of annual precipitation (Aldon et al., 1973).

TREATMENT POSSIBILITIES

Leaving raw untreated spoil material to weather and erode is at present illegal. Mining companies, State and Federal regulators of mining are reclaiming such lands now, but are continuously looking for better, lower cost methods of reclamation. Because answers come slowly under natural conditions in this semi-arid country, tests of new reclamation techniques must begin years before results will be available to effectively change regulations, cut costs, or reduce runoff and sediment. Some possible treatments are:

1. The first treatment to test, logically, would be the method of reclamation used for the past 8 years at the Navajo Mine--spreading stockpiled surface material, seeding, mulching, and irrigation.

2. The costs of grading, picking up, storing, and respreading top surface material (topsoil) represents over half of the reclamation costs. An alternative would be to provide a growth medium in raw spoil by adding nutrients (sludge), organics (straw mulch), bottom ash for texture changes, inoculum for micro-organisms, and irrigation.

3. Since irrigation adds another quarter of the reclamation costs, ways should be tested to establish vegetation without irrigation. It should be possible to shape topography to better collect winter precipitation to increase soil moisture for spring planting of cool season native grasses and shrubs. If an additional 6.5 cm can be stored in the soil over winter, a previous study has shown that March seedings of fourwing saltbush can be made without irrigation and still get reasonable survival after 8 years (Aldon 1981).

PLOT CORRELATIONS

If one or more of the above treatments were tested today it would be important to know how well the plots correlated with each other, and how long would it take to detect differences between treatments? Comparing these relationships for runoff the data shows:

Plot Comparison	r Value	Std. Error	n
1 vs 2	0.86	0.33(.23)[1/]	14
1 vs 3	0.92	0.25(.19)	13
1 vs 4	0.90	0.28(.23)	14
3 vs 4	0.94	0.18(.18)	14
2 vs 3	0.73	0.33(.35)	14
2 vs 4	0.74	0.33(.34)	15

[1/] Value in parenthesis is standard error when second number of the pair of plots is considered the dependent variable.

An extension of the technique of Kovner and Evans (1954) incorporating Type II error allows us to estimate how many additional storm events would be needed, after treating the plots for vegetation establishment, to detect a 50% change in mean values. If we set Type I error (a) = .05 and Type II error (b) = .10, then:

Plot Comparison	Additional Runoff Events	
1 vs 2	12[2/]	3[3/]
1 vs 3	6	7
1 vs 4	7	11
3 vs 4	6	6
2 vs 3	7	117
2 vs 4	7	51

[2/] Assumes first member of pair is treated.
[3/] Assumes second number of pair is treated.

Precipitation did not improve these relationships when introduced into the analysis.

Detecting changes in sediment after the plots are treated will require a longer period of post-treatment measurements, for these relationships were significant but more variable:

Plot Comparisons	r Value	Std. Error	n
1 vs 2	0.89	1134(1249)[1/]	14
1 vs 3	0.62	1590(2179)	13
1 vs 4	0.92	972(711)	14
3 vs 4	0.67	2016(1000)	14
2 vs 3	0.44	1742(2435)	14
2 vs 4	0.82	1567(1044)	15

[1/] Value in parenthesis is standard error when second number of the pair of plots is considered the dependent variable.

Using the same techniques as above, more additional events would be needed for detecting a 2000 kg/ha sediment difference:

Plot Comparison	Additional Events
1 vs 2	10(13)
1 vs 3	10(32)
1 vs 4	42(12)
2 vs 3	25(100+)
2 vs 4	28(54)

With these values it is now possible to apply different treatments to each of three plots, use the fourth as an untreated control, and evaluate the treatment effects on runoff within 6 years and sediment within 8-10 years.

UNIVERSAL SOIL LOSS EQUATION (USLE)

The USLE has provided a useful tool for estimating sheet and rill erosion on cultivated lands. It was developed for crop and pasture lands, but has been extended to many other erosion situations.

Sediment production was measured in this study along with total storm precipitation and runoff. Since slope length and slope percent were easily obtained, we held some of the other variables in the equation constant--runoff factor (20.0), soil erodability (0.15), cover (1.0), and cultivation practices (1.0)--to test whether it was possible to reliably estimate sediment production. Soil erodability and the runoff factor were taken from New Mexico estimates (Soil Conservation Service 1981). When these data were used in the USLE, the correlation between the estimated sediment and actual sediment measured was r = 0.2.

An additional analysis was run comparing measured annual sediment production on each plot with estimates from the USLE. In all four plots, the USLE over-estimated mean sediment values by a factor of 2 or more. The USLE estimates fell outside of computed .95 confidence intervals for each plot mean, indicating poor agreement on an annual basis.

Rainfall intensity data, not taken in this study, would have improved these estimates somewhat. This conclusion is based on an analysis using measured sediment values, the same constants as above and solving for the rainfall factor. Comparison of the estimated rainfall factor with measured runoff showed correlation r = 0.5. For the USLE to be useable, these correlations should be higher to insure better estimates of sediment production.

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Table 1--Runoff, sediment, and precipitation for four plots on the Navajo Mine, 1974-1981.

Date	Runoff				Sediment				Precipitation		
	1	2	3	4	1	2	3	4	Storm	Annual	
	cm.				kg/ha				cm.	yr.	cm.
11/12/74	1.613	1.549	1.270	1.524	1528.8	3192.0	1985.8	2215.4	6.91	74	15.22
09/15/75	1.270	1.016	0.762	0.660	2590.6	2900.8	9168.3	1957.8	1.75	75	11.97
08/09/76	1.549	1.524	1.346	1.219	6428.2	6583.6	6032.3	3553.8	1.65		
08/20/76	1.549	1.499	*	1.321	7946.0	10229.5	*	6329.2	1.57	76	11.10
07/28/77	0.160	0.579	0.414	0.401	815.4	1440.3	1127.8	838.9	0.48		
08/16/77	1.600	1.410	1.473	0.960	2897.4	2627.5	2419.2	2544.6	1.65		
09/13/77	0.864	1.036	0.673	0.808	4332.2	2018.2	4072.3	3850.6	0.71	77	9.35
09/26/78	1.207	1.765	0.724	0.610	3880.5	5689.9	1072.6	1340.1	3.15		
11/07/78	0.851	1.473	0.330	0.305	1511.1	2307.3	582.7	831.3	3.76	78	22.28
10/25/79	0.025	0.732	0.008	0.013	42.8	927.8	6.3	9.5	2.95		
11/14/79	**	0.330	**	**	*	1092.0	*	*	1.93	79	18.85
08/25/80	0.102	0.711	0.051	0.102	5.4	728.6	2.7	5.4	2.16	80	*
07/08/81	0.051	0.457	0.140	0.051	2.7	1472.7	339.4	2.7	1.75		
07/28/81	*	0.279	0.102	0.114	*	1047.5	316.5	338.0	1.57		
09/09/81	0.211	0.762	0.368	0.318	1035.3	2253.3	2100.3	1391.5	1.83		
10/06/81	0.770	1.372	0.673	0.622	3007.3	5432.0	2594.6	2628.9	1.93	81	14.78
$\bar{x}$	0.84	1.04	0.58	0.61	2572.6	3121.4	2272.5	1855.8	2.24		15.0
Std. Dev. (S)	0.64	0.48	0.48	0.48	2419.2	2606.2	2610.7	1757.3			
Overall Mean				0.77				2455.6			

*--No record
**--Trace