

Master

EROSIVE EFFECTS OF HILLCLIMBING
ON CLAY SOILS
IN CARNEGIE STATE VEHICULAR RECREATION AREA

June 1980

By
Carol A. Whitaker
Supervising Park Interpretive Specialist

and
Theodore C. Smith
Associate Geologist

Resource Protection Division
California Department of Parks and Recreation

Open-File Report

INTRODUCTION

Carnegie State Vehicular Recreation Area (SVRA) is located on Corral Hollow and Tesla Roads at the Alameda-San Joaquin County line. Acquired by the State in 1979, Carnegie contains about two square miles of land which have been used by off-road vehicles for over ten years.

Erosion from trails, roads, and hillclimbs within other SVRAs has been observed and bemoaned by many -- park rangers and maintenance personnel, county boards of supervisors, adjacent property owners, local residents, environmental groups, concerned citizens, and even the users themselves. The outcry being heard today attests to the growing concern by many members of society for the protection of soils and other natural features from rapid destruction taking place as a result of off-highway vehicle (OHV) recreation and the desire by ORV users to perpetuate their sport. The technology exists and is readily available for undertaking corrective action to reduce the effects of accelerated erosion at Carnegie and at other OHV recreation areas.

Wilshire and others have clearly documented the effects of OHVs in California's desert environments (Wilshire, et al., 1978; Webb, et al., 1979). Yet, little data is available which discuss, quantitatively, how much soil loss can be expected from the denuded clay-textured soils formed from marine deposits in Mediterranean climates. The purpose of this study, which was conducted in conjunction with the Inventory of Features study (Whitaker, 1980), was to measure the extent of soil loss on the clay soils within Carnegie SVRA. The results of the study will hopefully aid in the development of proper mitigation measures for erosion control at Carnegie and similar SVRAs. In addition, the study provides information useful in the selection of future OHV recreation areas.

METHOD

Wischmeier (1965) demonstrated that the amount of soil loss could be approximated by using an empirical formula (the Universal Soil Loss Equation) which takes into account the following factors: rainfall "erosivity", soil erodibility, length and steepness of slope, cover density and type, and applied conservation practices (such as contour plowing). Multiplied together, these factors give a close approximation of the amount of soil loss that can be expected given the numerical values for the characteristics of any given site. Thus:

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

where:

- A = soil loss in tons/acre-year
- R = rainfall "erosivity"
- K = soil "erodibility"
- L = slope length
- S = slope angle
- C = type and density of plant cover
- P = applied conservation practices

M. J. Singer (1976) has devised a method to compare actual amounts of sediment lost with the amounts predicted by Wischmeier's equation. He directly measured the amount of soil lost from a test plot of known area, soil erodibility, slope length and angle, and using rainfall amounts and intensities obtained from a nearby weather station. The plots in Singer's study were stripped of vegetation and tilled up-and-down the slope in order to eliminate the cover and conservation practice factors (C and P, respectively) from the equation. The plots were installed on standardized slopes -- 72.6 feet long, 6 feet wide, and 9 percent slope -- in order to allow for a direct study of the relationship of the A, R, and K factors of the equation.

The design for the Carnegie study was similar to that used by Singer, with only a few modifications. The area chosen for the Carnegie study included hillclimbs located along Corral Hollow Creek approximately 0.3 km (0.2 mi) west of the main entrance to the project (see location map). The relatively uniform slopes, slope aspect, soil characteristics, denuded condition, and ease of access in wet conditions made it the ideal area to conduct the study (see Table 1 for description of the study area).

Seven plots were installed, each measuring 36.3 feet long by 6.0 feet wide. The enclosed area equaled 0.005 acre (see Figure 1). Aluminum garden edging was placed around the perimeter of each plot to prevent sediment from flowing from the outside area into the plot and to prevent the loss of sediment from the plot to the outside area. A water bar about 6 inches deep was dug above each plot to divert any water flowing downwards from the upper portions of the slope. Sediment flowing downslope within the area enclosed by the edging was trapped at the bottom of the plot in a canvas-lined frame placed in a pit such that the top of the frame was flush with the ground surface. A flume constructed of heavy-gauge plastic stapled to a wooden frame was placed at the bottom of each plot so as to allow the runoff to be funneled directly into the canvas-lined frames (see Figure 2). After each storm, the wet sediment was collected from the frames, weighed, and recorded. The approximate dry weight of the sediment collected was obtained by oven-drying a small sub-sample, determining the portion of the weight taken up by the water,

$$\%H_2O = \frac{W_w - W_d}{W_w} \times 100$$

where

W_w = Wet weight of sample
 W_d = Dry weight of sample,

and deducting the estimated weight of the water from the total weight of the sample. By multiplying the dry weight of sediment by 200 (since the total area of each plot equaled 1/200 acre), an approximate soil loss value in pounds per acre could be calculated for a storm of known duration and intensity raining on slopes with known topographic and soil characteristics.

Of the seven plots that were installed, three surface conditions were studied. The first type had a treatment consisting of straw and jute netting covering the entire surface of the plot. The second type had no treatment --

just the exposed soil surface of the hillclimb. Three replications were used for each of these two types of plots. A seventh plot was installed in an adjacent area, but with the natural vegetation (annual grasses) left intact. This plot provided a control to compare naturally occurring rates of erosion with rates of erosion of the treated and untreated plots. None of the study plots were otherwise modified.

The study period extended from December 15, 1979 through March 30, 1980. Limited continued monitoring of some of the plots is being considered at this time.

One additional point merits mention. To our knowledge, and Singer's (p.c., 1979), no studies had yet been conducted in order to determine whether the Wischmeier equation is valid for fairly steep slopes. Most investigators have used experimental plots of less than 10 percent slope, to date.

RESULTS

The data gathered from this study, as shown in Tables 2 and 3, varied greatly both within and between reported R value categories. The reasons for this high degree of variability are several. Antecedent soil moisture conditions have a dramatic effect on the quantity of sediment produced for a given storm. Soils which are dry have a greater capacity to absorb moisture, and thus reduce the amount of runoff, than moist or wet soils. Dry periods lasting from two to five weeks occurred frequently during the study period. We did not attempt to measure antecedent moisture.

A second reason for the variable data rests in the increase in seedling growth during the later weeks of the study period. This plant growth provided a partial cover on the untreated plots, which reduced the impact of raindrop energy and resultant splash erosion.

The most plausible reason for the variation among plots having similar treatments during any given storm probably is due to minor differences in slope angle and microtopography. Although the study area was chosen with the intent of minimizing topographical variation, gradient differences of 2 to 4 percent could not be avoided. Soil losses from the steepest plots were consistently greater than those obtained for gentler plots for each storm event. Also, vertisols are noted for their characteristic gilgai microrelief, and the Altamont soil, on which this study was carried out, is no exception. Mounds approximately 1 meter in diameter and 1/2 meter high were observed both in disturbed and undisturbed areas in the project.

By far, the most limiting factor which would otherwise allow for more conclusive results was the lack of a larger sample size. One season is simply not enough time to generate consistently reliable data from a field study such as this. Fortunately, the storms produced during the study period proved to be somewhat "normal" for that area, allowing the collection of some information. Had a drought year occurred, no data at all would have resulted. One should not make the assumption, however, that the storms occurring within the study period are representative of all winter storms. Long-range climatic data for the area show rainfall amounts varying anywhere from 5 inches annually to 19 inches annually. The annual R value for the area

is estimated to be 12 (Soil Conservation Service, 1975). Most of the rainfall seems to come during one or two intense storm events during the months of January and February. It is during these months that the greatest amount of soil loss can be expected to occur and, indeed, the data collected at Carnegie tend to support this assertion.

A very obvious trend that can be noted from the data is the dramatic reduction of soil loss observed on the treated plots compared to the untreated plots.* This attests to the overall effectiveness of protective mulch and cover treatments in preventing accelerated soil erosion from splash and subsequent sheet wash. An additional benefit of the treatment was the earlier germination and resulting denser growth of grass seedlings during the spring on the treated plots. This was probably due to the increased insulation from temperature extremes and increased moisture retention provided by the straw and netting.

DISCUSSION AND RECOMMENDATIONS FOR FURTHER STUDY

The results from this study seem to support assertions that soil losses in the form of sheet and rill wash from clay soils can be as severe as soil losses from coarser-textured granitic soils, such as those found at Hollister Hills SVRA**, given sufficient slope length, gradient, and rainfall intensity. To illustrate, during one particularly intense storm period which lasted five days and dropped 4.04 inches of rain (a storm calculated as having a once in five-year probability of occurrence based on the scant data available), soil losses from the steepest of the untreated plots totalled 55 pounds (5.5 tons/acre). Comparing this figure to the established soil loss tolerance (T value) of 2 tons/acre-year, a much more severe problem can be seen to exist, especially since the average slope length of hillclimbs is closer to 250 feet (much longer than the test plots) and gradients average around 40 percent (steeper than the test plots). Using the Universal Soil Loss Equation, calculated soil losses for a single hillclimb trail with soil properties similar to those of the study plots could easily approach 50 tons/acre-year. Obviously, in order to protect these and "more erodible" soils within the project and to ensure the long-term productivity of the site, a concerted effort to manage hillclimbs is in order, either by actually closing trails or by intensively managing the more popular hillclimb areas.

The results of this study, as stated earlier, should in no way be construed as being complete. An extended study period lasting from seven to 10 years is needed to produce statistically reliable results which could be used to predict sediment yield from areas having similar topographic and soil characteristics.

* Losses on the treated plots seem to be less than losses reported for the control plot. The rate of natural erosion in undisturbed areas elsewhere on and near the site is probably much less than that reported here, since significant disturbance took place during the installation of the control plot causing increased production of sediment. We made no attempt to mitigate this disturbance, only to minimize it.

** At the time this study was being conducted, a larger, similar study was in progress at Hollister Hills SVRA in San Benito County.

If further studies are to continue on these plots, measurements of soil moisture conditions prior to each storm event would be useful. Temporarily installed tensiometers or an electrical conductivity device would achieve this purpose fairly well since measurements could be taken quickly and easily by operations staff. Such data may also be useful in the day to day management of the SVRA.

The study should be expanded to include an area at least intermittently open to hillclimbing. Freshly dislodged soil is constantly being generated by the riders. This material is, no doubt, more susceptible to entrainment by flowing water, probably significantly increasing the rate of erosion. Hence, an erosion scenario more closely approaching the reality of erosional processes existing at Carnegie, as well as in other OHV recreation areas, would be monitored.

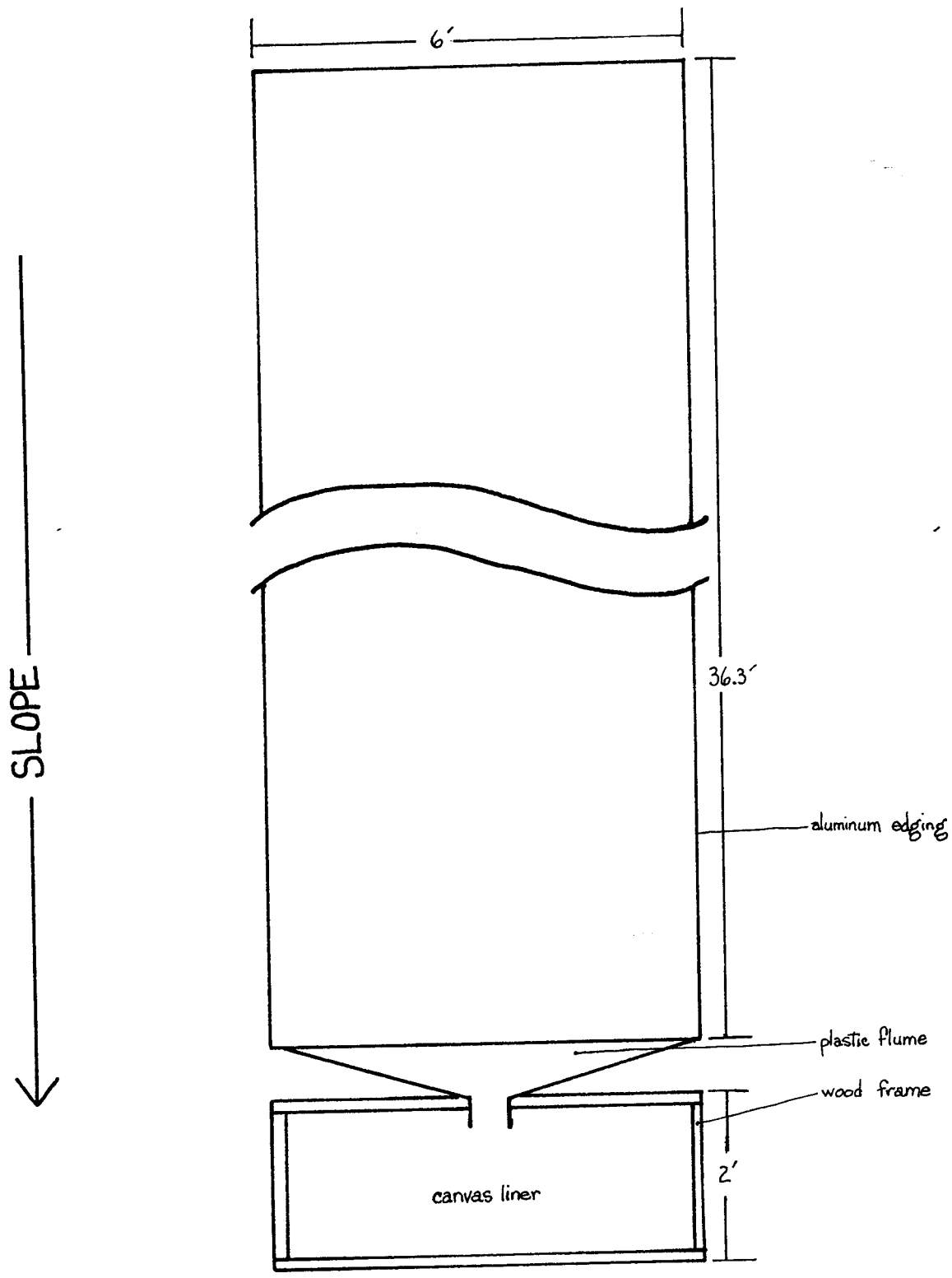
Finally, similar plots should be established in areas reclaimed by one or more methods. Such data would be useful in determining the most effective method at known cost.

ACKNOWLEDGMENTS

We would like to thank Dr. M. J. Singer for allowing us to use a modification of his design, and Lorraine Van Kekerix who did much of the initial legwork for the Hollister Hills study after which this study was patterned. Also, we would like to thank Mark Reedy, Peter Vonich, Deena Stanley, Arthur Fong, and Michael Whitaker for their assistance in installing the study plots and weather station. The staff at Carnegie also played a significant role by helping to protect the plots from vandalism. And, we couldn't have completed the study without the help of Roxanne Christner who helped process the mound of equipment and orders and "routine" paperwork. Thanks, too, to the staff of the Word Processing Center -- you made our jobs much easier.

Table 1

(insert)



Erosion Plots (Plan View)

Figure 1

Table 2

Mean Soil Loss for Treated and Untreated Plots
by Storm Event (in pounds per plot)

	<u>R Value</u>					
	<u>0.11</u>	<u>0.76</u>	<u>0.96</u>	<u>1.45 *</u>	<u>1.50</u>	<u>4.76</u>
Treated	0.05	0	0.07	0.05	0	0.25
Untreated	0.13	3.15	3.25	0	0.07	18.9
Control	0.64	0.16	0.01	-	0	0.40

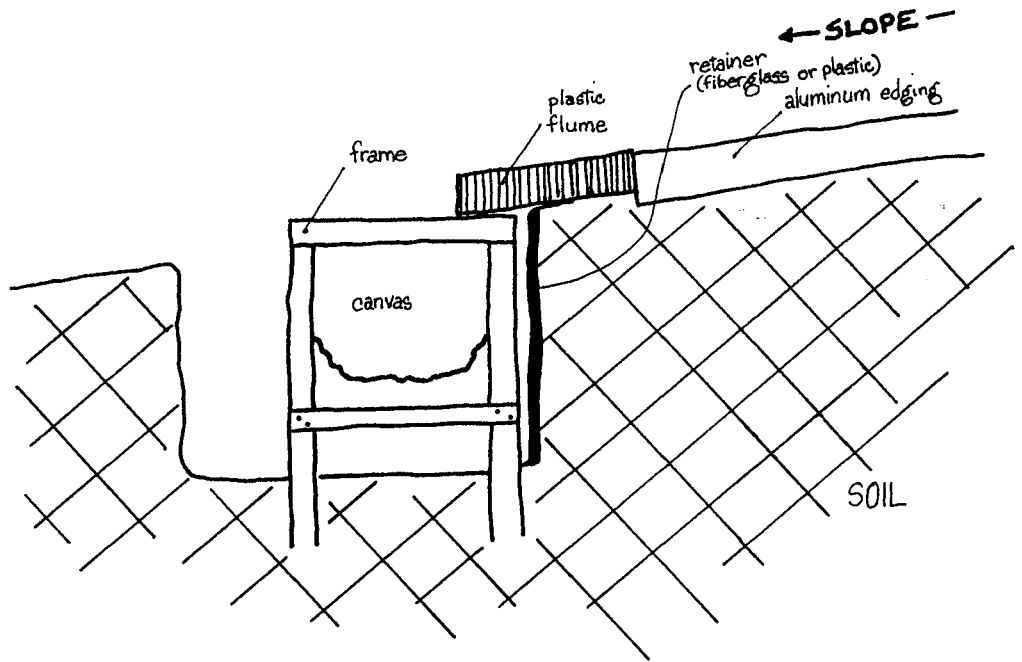
* Samples taken from one treated and one untreated plot only.

Table 3

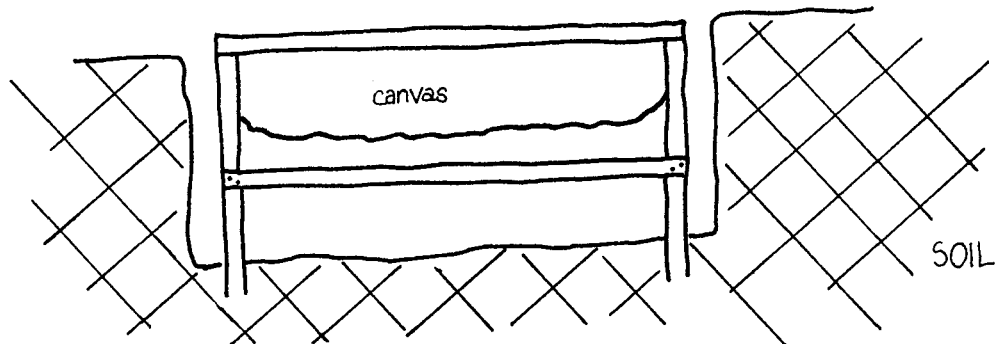
Mean Total Soil Loss Over Entire Study Period (R = 9.53)

	<u>Pounds/Plot</u>	<u>Tons/Acre</u>
Treated	0.38	0.04
Untreated	23.60	2.25
Control	1.11	0.11

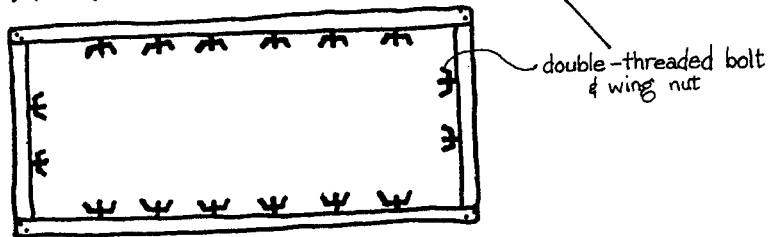
SIDE VIEW



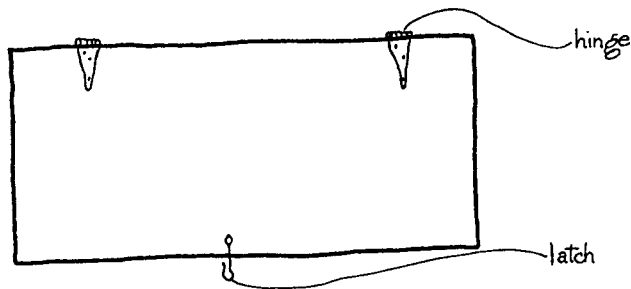
FRONT VIEW



TOP VIEW
(without cover)



TOP VIEW
(with cover)



Erosion Plots (Detail)

Figure 2