SURFACE EROSION MONITORING PROJECT

ON A CLEARCUT IN THE WILLAMETTE NATIONAL FOREST

USDA Forest Service

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1 EXECUTIVE SUMMARY

Surface erosion after clear cutting on steep forest land can decrease site productivity, and increase the difficulty in meeting watershed goals set by federal legislation.

The objectives of this study were to develop a method and the measuring devices to determine rates of erosion on a typical steep forest land site; to determine effects of slope and duff cover on amount of erosion; and to determine the effect of various climatic factors on erosion.

A site was selected in the Willamette National Forest in the Blue River Ranger District. Erosion boxes were designed, built, and installed on the site on different slopes. Solid and suspended sediment were measured during the water year 1980 to get base-line erosion. The duff cover was then removed to different degrees by burning, and erosion measurements were made for two further years.

Measured erosion from plots with the same treatment varied widely. This was due to varying characteristics of the soil surface on different plots; amount of bare soil was one of the main variables. Erosion increased each year, especially for the moderately steep slopes.

The average rates of movement for inorganic material for the three years (water years, WY) at each slope class were as follows:

Slope Class	WY 1980	WY 1981	WY 1982
	tonnes/ha		
Moderately steep	0.002	0.180	0.21
Steep	0.023	0.20	0.47
Very steep	0.94	1.05	1.30

Maximum erosion rates of inorganic material measured on individual plots were 3 tonnes/ha for 1980, 2.5 tonnes/ha for 1981, and 3.5 tonnes/ha for 1982. Organic material also eroded from the plots, the amount averaged about half the weight of inorganic material. The effects of slope and duff cover were not statistically significant because of the large site variability and the small number of plots.

Measurements for water year 1983, further analysis of the results, and application of the Universal Soil Loss Equation will be contained in an M.S. thesis to be written by D. George-Claes by September 1983.

2 INTRODUCTION

Erosion can occur on steep forest land after timber harvesting and slash treatment. Management systems must be designed to prevent erosion, and hence to maintain site productivity and water quality. The purpose of this study was to develop appropriate methods for determining surface erosion.

The development of a standardized system for monitoring surface erosion rates and the quantification of rates of surface erosion will enable the U.S. Forest Service to meet watershed goals set by:

1. The Soil and Water Conservation Act of 1977, PL-95-192.
2. The National Forest Management Act of 1976, PL-94-588.
3. The Forest and Rangeland Renewable Resources Planning Act of 1974, PL-93-378.
4. The Federal Water Pollution Act of 1972, PL-95-500.
5. Title 2500 Watershed Management Guidelines R-6.
6. Multiple Use Sustained Yield Act of 1960, PL-86-517.
7. National Environment Policy Act of 1970, PL-91-190.

The duff and amount of forest litter may be one of the most important parameters determining rates of surface erosion on forest soils. The percent O.M. is a variable determining the K factor in the USLE (Wren Documents, 1980).

Lowdermilk (1930) discussed the significance of the forest litter layer in determining the macro-structure of a soil. The

surface litter of a forest soil can often absorb more rainfall than the soil mantle. The water holding capacity of a soil profile affects site productivity and therefore Site Index. Accelerated surface erosion due to a reduction of the amount of duff could decrease soil profile depth, thereby decreasing a site's water holding capacity.

The duff and humus layers of a soil absorb the kinetic energy from raindrop impact (Dohrenwend, 1977). If a forest canopy can amplify the kinetic energy of intercepted rainfall, then the residual duff layer after timber harvesting may be important in decreasing surface erosion potential in a regenerating stand of timber.

The destruction of the duff layer by wildfire and prescribed burning has been found to accelerate surface erosion (Amaranthus and Hanson, personal communication, 1979; Austin and Baisinger, 1955; Dyrness, 1976; Dyrness and Youngberg, 1957; Dyrness et al., 1957; DeByle, 1976; Megahan and Molitar, 1975; Mersereau and Dyrness, 1972; Sartz, 1953; Wells, 1979; and Vogl and Rider, 1969). The effects of surface erosion and subsequent deposition can be detrimental to Douglas fir seedling survival and establishment (Franklin and Rothacher, 1962). The loss of nutrient-rich surface soil can decrease site productivity (Sidle, 1980). The reduction in site productivity can result in a reduction in timber revenues.

The benefit of reducing erosion losses can be estimated from the potential change in site index (SI). If SI was 210 prior to harvest and decreased to 190 for the new stand, at prices of $170 MBD for Douglas fir, then the reduction in harvest revenue would be $25,800/acre.

The processes and events that accelerate surface erosion will be better understood if we know the rates of surface erosion during summer dry, winter rainy, and freeze-thaw events (Harr, 1979; Krammes, 1965). Rates of surface erosion measured in confined plots on different slopes, with varying amounts of duff cover, can be used to examine the applicability of the USLE on steep forested and timber harvested ground (Dissemyer and Foster, 1981; Wells et al., 1979).

The study had three main objectives:

1. Develop a method to determine rates of surface erosion on steep forest land. This required the design of an erosion catchment box and a suspended sediment collector as well as a sampling method.

2. Determine the effects of slope and percent duff cover on surface erosion rates.

3. Evaluate the relative importance of surface erosion during winter rainfall events, summer dry events, and freeze-thaw events.

3 SITE AND PLOT SELECTION

3.1 Site Selection

Site selection was made in 1979 by Danella George-Claes, with the participation of personnel from the Willamette National Forest. The geomorphic criteria for a desirable study area included a convex, steep to very steep, hillslope to provide the desired slope classes. It was agreed that the study site should have a south to southwest aspect since these aspects have been observed to have the greatest rates of surface erosion (Mersereau and Dyrness, 1972). The soil was to be as nearly uniform as possible. The desired logging method was to be full to partial suspension, so as to minimize site disturbance due to logging.

An inventory of current or immediately pending timber sales was conducted in the late spring of 1979 to find a site that would satisfy the above criteria. The Rosey #4 Sale Unit in the Blue River Ranger District, Willamette National Forest, was found to be acceptable. The Unit is located in T. 17 S.; R. 5 E.; Sec. 20 (Fig. 1).

The effects of slope and percent duff cover on surface erosion were assessed with duplicate plots of nine treatments, established as follows:

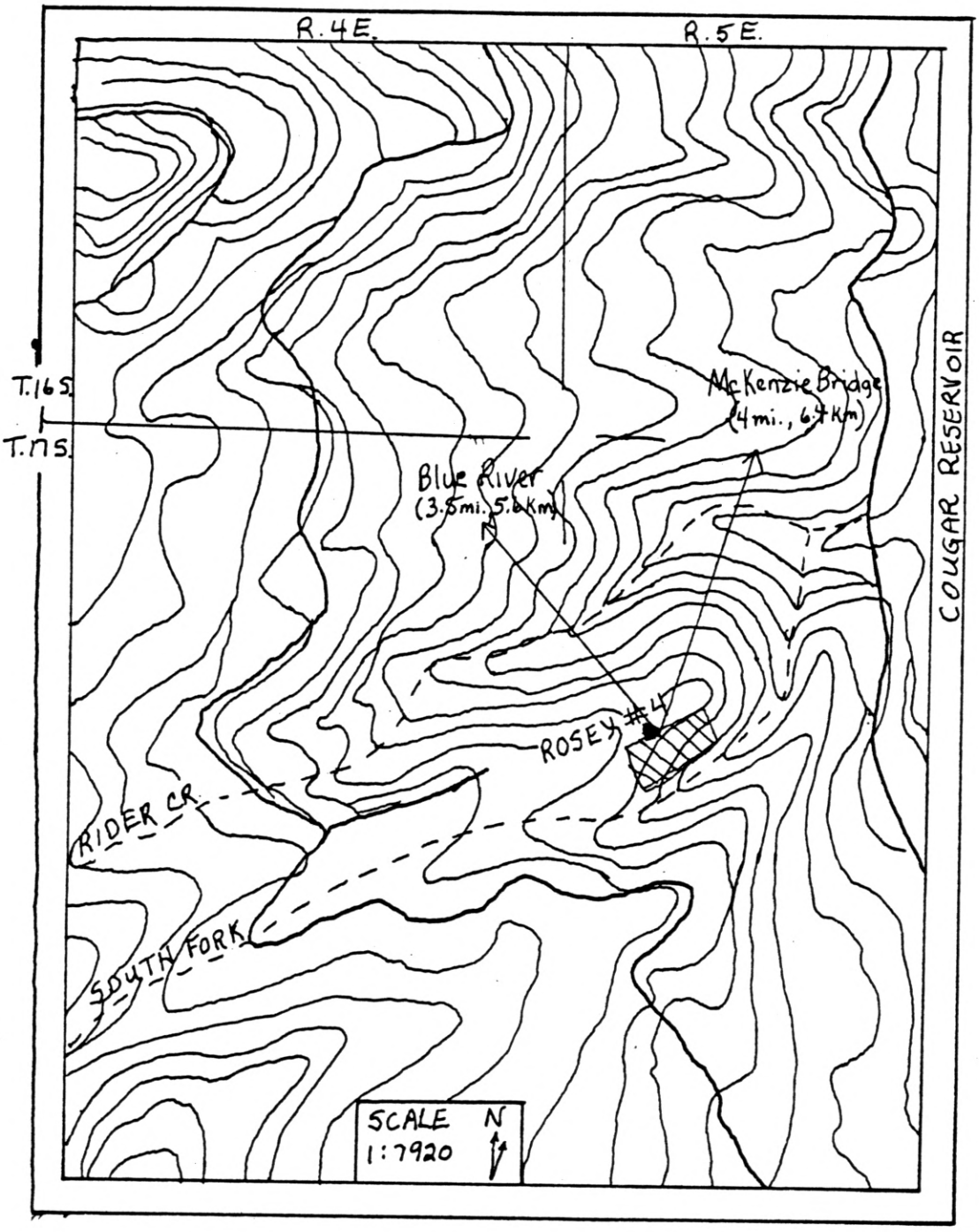


FIGURE 1 LOCATION OF EXPERIMENTAL AREA

Slope	% Duff Cover Remaining
moderately steep 28%	0, 50, 100
steep 41%	0, 50, 100
very steep 58%	0, 50, 100

Each plot was 1.52 meters square, encompassing an area of 0.00023 ha.

Two control plots were established on very steep slopes with 100% duff cover, but they were left unbordered to determine the effects, if any, of horizontal movement of material. Four forest control plots were established outside of the clearcut area.

Due to the small size of the clearcut, 9 acres (3.6 ha), and the difficulty in finding appropriate plots with the correct slope, randomization was done for percent duff cover after all plots were selected for slope (Fig. 2).

3.2 Plot Selection

The individual plots were sited in late August of 1979. They were established on the west side of the unit because of a large amount of ground disturbance on the east portion of the unit.

The criteria for plot selection were slope angle and minimal amount of large logging slash. Slopes were initially selected by laying down a two-by-four and taking a slope reading with an inclinometer. Another set of slope readings was taken at each plot using an Abney level, shooting downslope.

The potential plot areas were flagged and manually cleaned of large logging slash. Extreme care was taken to avoid any

disturbance to the site. A fire trail was established around the plot perimeters to protect the plots in the event of the unit slash burn getting out of control.

The plots are described in Table 1.

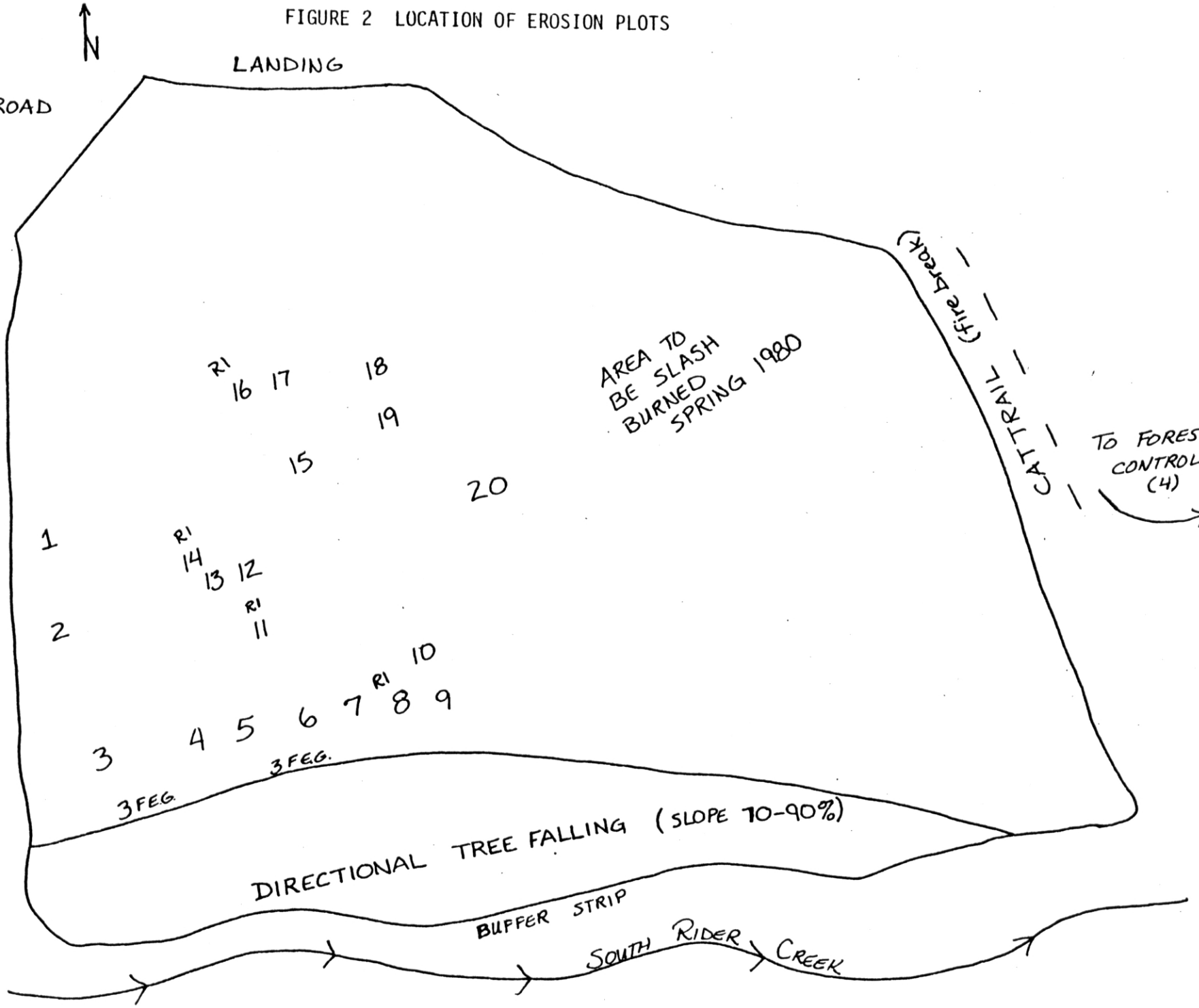
Table 1. Plot description.

Plot #	Percent duff	Border position**	*Slope class/degree	Slope at plot
1	0	b & s	st/38	35%
2	0	b & s	st/47	52%
3	0	b & s	vst/59	58%
4	100	bb	vst/65	61%
5	100	bb	vst/53	59%
6	50	bb	vst/47	61%
7	100	bb	vst/50	59%
8	100	bb	vst/60	54%
9	50	bb	vst/60	57%
10	0	b & s	vst/52	61%
11	0	bb	ms/49	19%
12	100	bb	st/45	44%
13	50	bb	st/49	42%
14	50	bb	st/42	35%
15	0	b & s	mst/32	44%
16	50	bb	mst/33	26%
17	100	bb	mst/38	26%
18	50	bb	mst/30	23%
19	100	b & s	st/26	38%
20	100	bb	mst/31	30%
21	F.C.	b & s	vst/58	38%
22	F.C.	b & s	vst/57	49%
23	F.C.	b & s	vst/	59%
24	F.C.	b & s	vst/61	45%

*Slope taken for area.
mst = moderately steep; st = steep; vst = very steep.

**b = borders at back; s = borders at sides.

FIGURE 2 LOCATION OF EROSION PLOTS



4. EXPERIMENTAL DESIGN

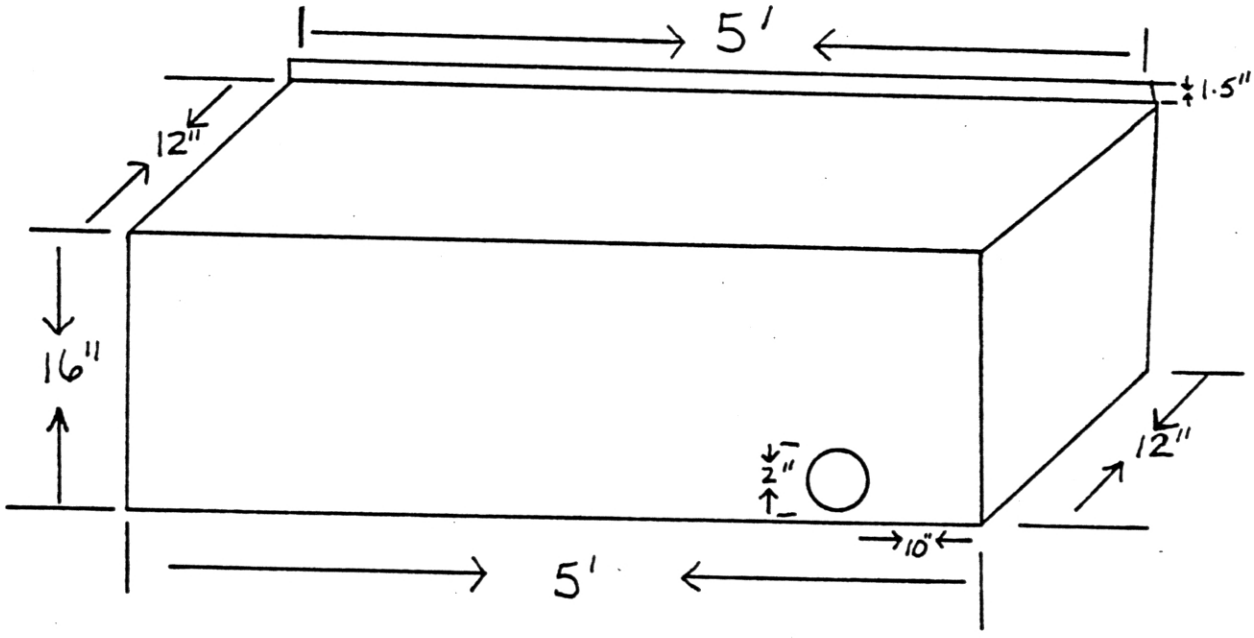
4.1 Review of Catchment Boxes

Previous studies designed to monitor surface erosion rates have relied on a variety of measurements (Ellison, 1944; Garcia et al., 1963; Gerlach, 1979; Hudson, 1964; Megahan and Molitar, 1975; and Ranger and Frank, 1978). The different techniques can be categorized as (a) catchments, (b) elevational differences, (c) samplers, and (d) tracers. These studies have shown the catchment method to be the most valid due to consistency of the results and the ability to differentiate between deposition and detachment in surface erosion processes.

A variety of catchments has been used: polyethylene traps, sheet metal traps, and troughs with or without suspended sediment collectors. Erosion plots have been bordered and unbordered.

A variety of catchment boxes has been used on steep forested ground (Bennett, 1982; Conger, 1979; Gerlach, 1979; Lowdermilk, 1930; Megahan and Molitar, 1975). D. George-Claes reviewed the literature, communicated with many box designers, and visited box sites at the H.J. Andrews and the Siskiyou National Forest. Where rates of surface erosion are high or where coarse debris is present, large collectors need to be used (Dunne, 1977). Where there is the possibility of rock slides or rock falls, the boxes need to have strong reinforcing. In areas of high elevation, boxes need to be large enough to hold material in case monitoring schedules cannot be met due to inclement weather.

FIGURE 3a DESIGN OF EROSION BOXES (BACK VIEW)



The collector boxes should have lids to keep out rainfall, to keep raindrop impact from splashing material out of the boxes, and to minimize solar radiation effects.

The construction material needs to be durable to prevent damage by large mammals and large rocks and to withstand the elements over time.

The most critical part of a catchment box is the soil-apron contact, which must be maintained so material will move into the box. The design of the apron and the box installation can all affect this function (Conger, 1979; Amaranthus and Hanson, personal communication, 1979; Dunne, 1977; McCorrison, personal communication, 1979).

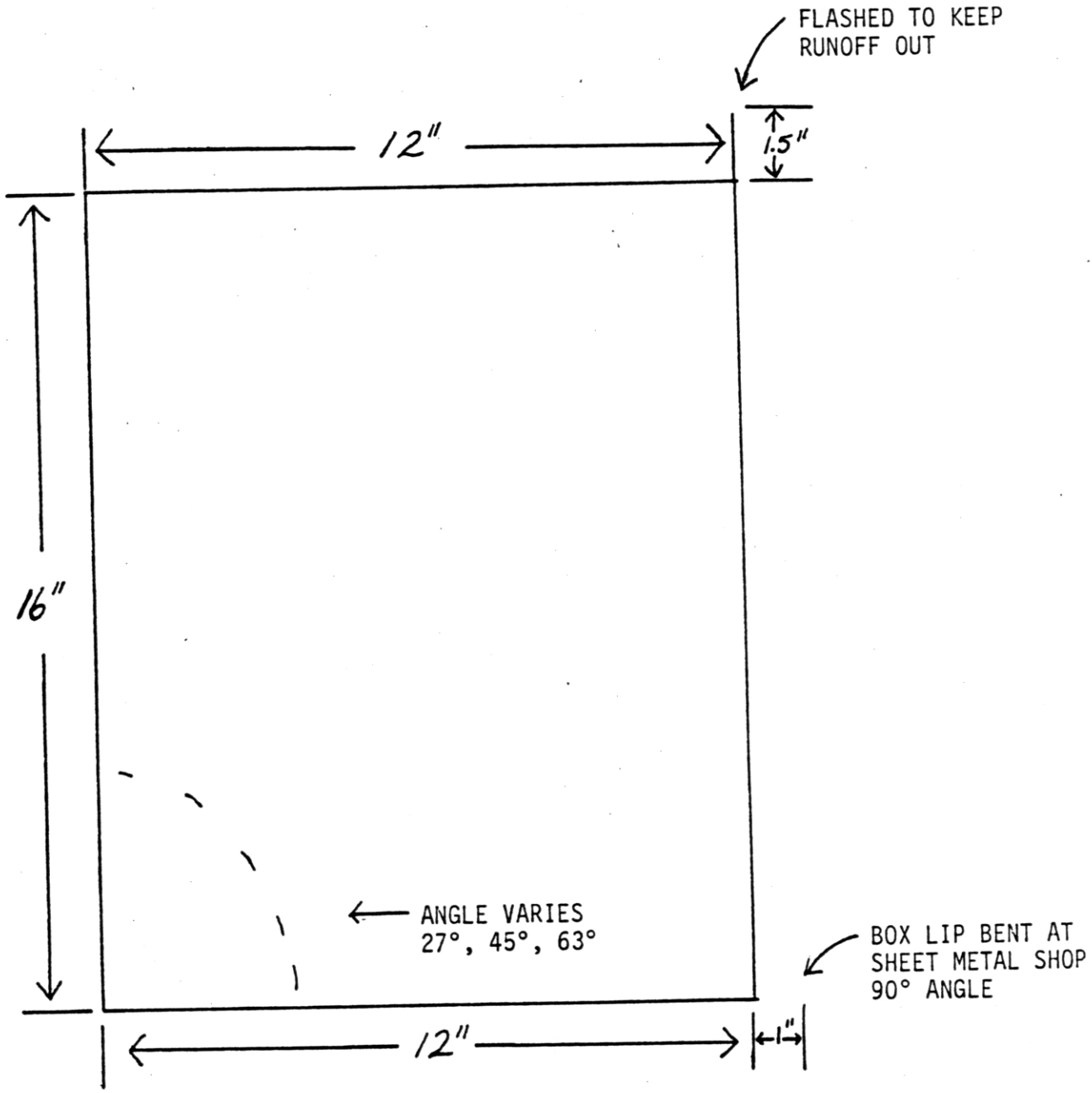
Most catchment boxes have fixed-90° angle or semi-round troughs requiring excavation for installation. The catchment box for this study had floor angles appropriate to the slope of the plot; this minimized site disturbance during installation.

4.2 Catchment Box Design

The boxes were constructed by Brainard Sheet Metal in Springfield, Oregon, out of 12-gauge galvanized metal. The box dimensions are 12" (0.30m) wide by 16" (0.41m) high by 60" (1.52m) long (Figs. 3a and 3b). The box lid is attached by hinges. The box lid has an upper lip 1.5" (0.04m) high to restrict water from dripping into the box and onto the plots.

A 2" diameter hole was punched out of the back wall of each box, 12" from one end and ½" from the box floor (Fig. 3a).

FIGURE 3b DESIGN OF EROSION BOXES (SIDE VIEW)



Polyflex tubing leads from this hole to the suspended sediment collector.

The metal apron in front of the box extends 1 inch. The angles on the box floor are 27°, 45°, 63°.

Rebar sections, cut into 2.5 ft. (0.76m) lengths and driven into the ground, were used to secure the boxes. Holes were drilled in the boxes so that metal twine could be slipped through and tied to the rebar.

4.3 Suspended Sediment Collector System

The suspended sediment collectors are 50-gallon metal trash cans with lids. They were donated by the Blue River and McKenzie Bridge Ranger Stations. Two-inch holes were drilled in the side of each can. Polyflex tubing was attached flush against the back of the catchment box and caulked; the tubing was then extended into the collectors, where a plastic 2-gallon (7.6 l) bucket was kept to catch runoff (Plate 1). Calgon was added to the buckets to minimize freezing and to keep colloidal material in suspension.

4.4 Plot Borders

The side borders for the erosion plots were made from two-by-four's; the back borders were made from two-by-eight's. One inch flashing was attached to the borders to prevent water from dripping onto the plots. The side borders had a 4" extension at the downslope end for attaching to the box (Fig. 4). The back borders were cut into 5'3¼" sections for attaching to the side borders. "Jahn" border bags (36"x4" canvas bags) were filled with

FIGURE 4 DESIGN OF PLOT BORDERS

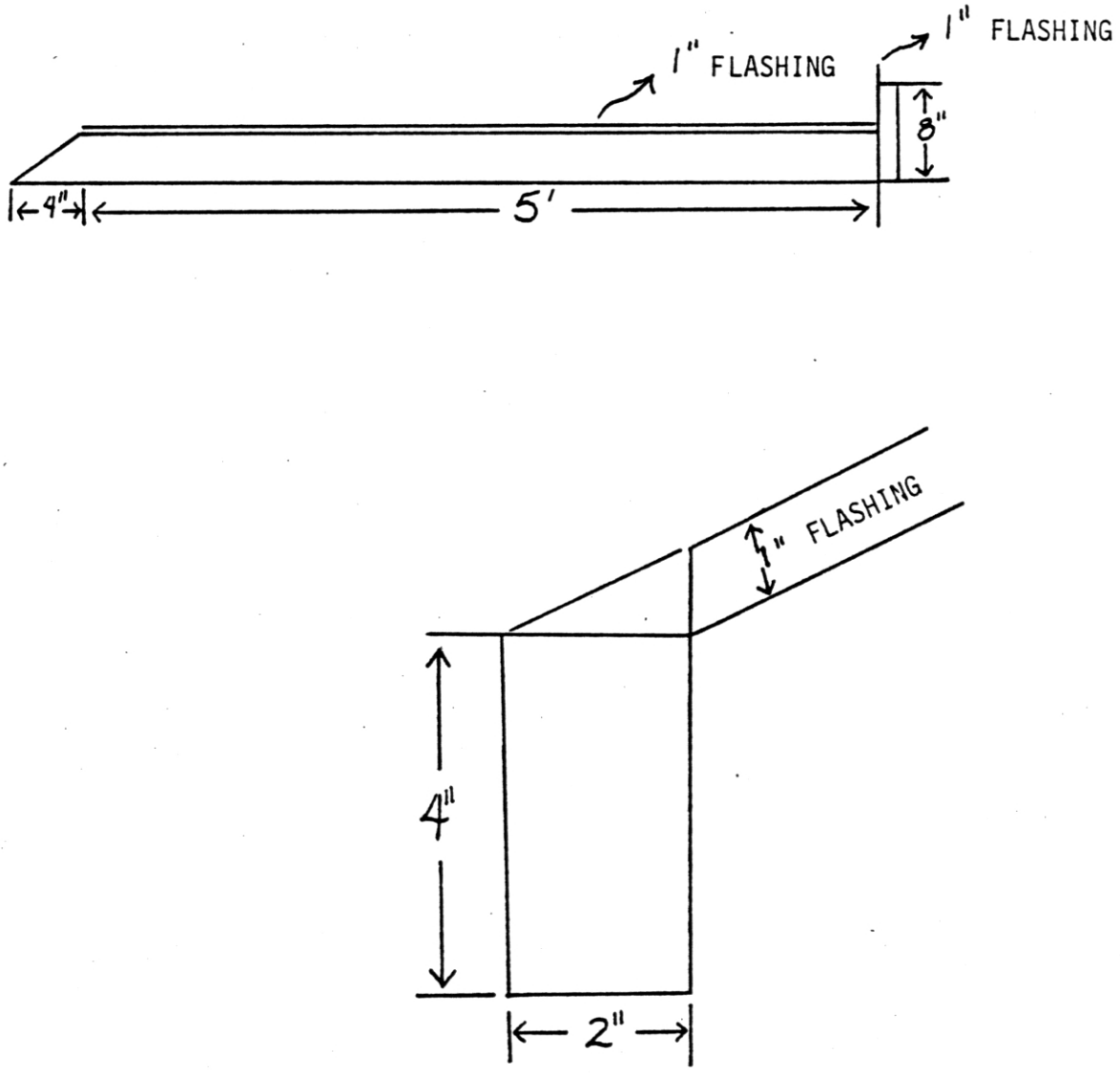
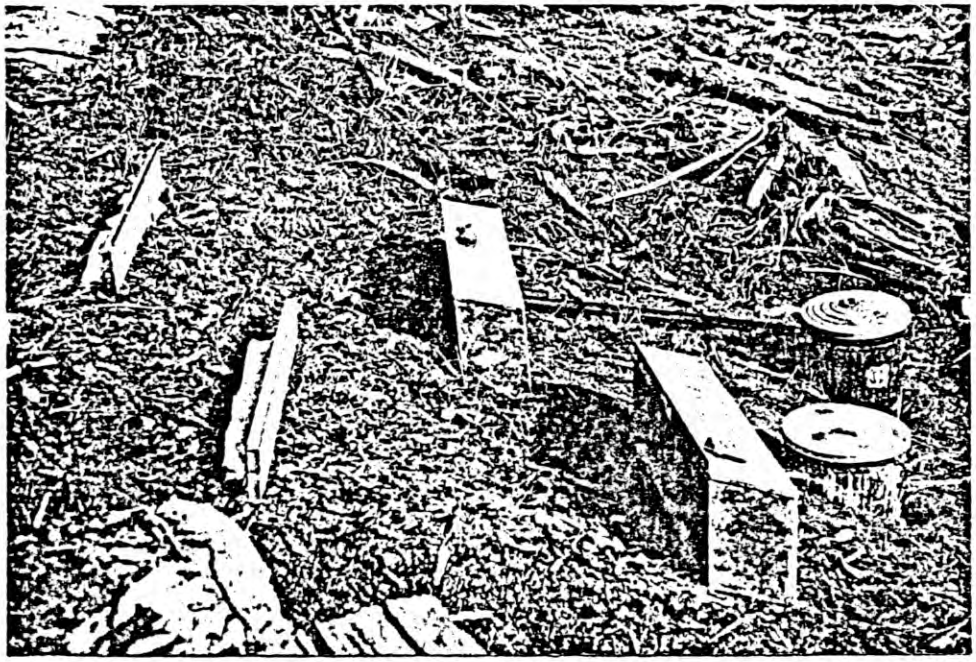
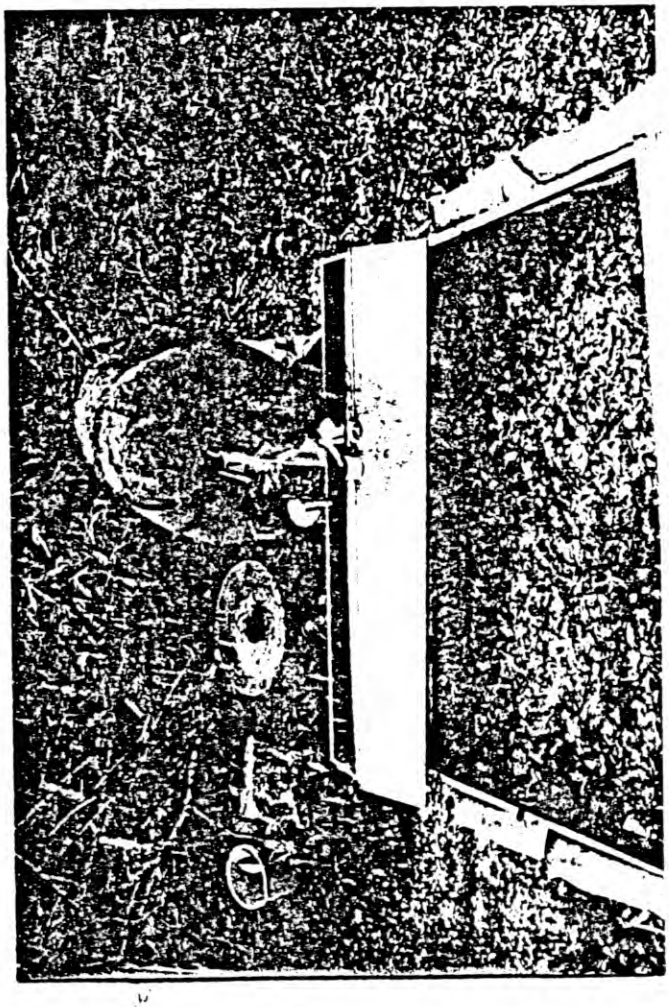


Plate 1. Erosion boxes with suspended sediment collectors.





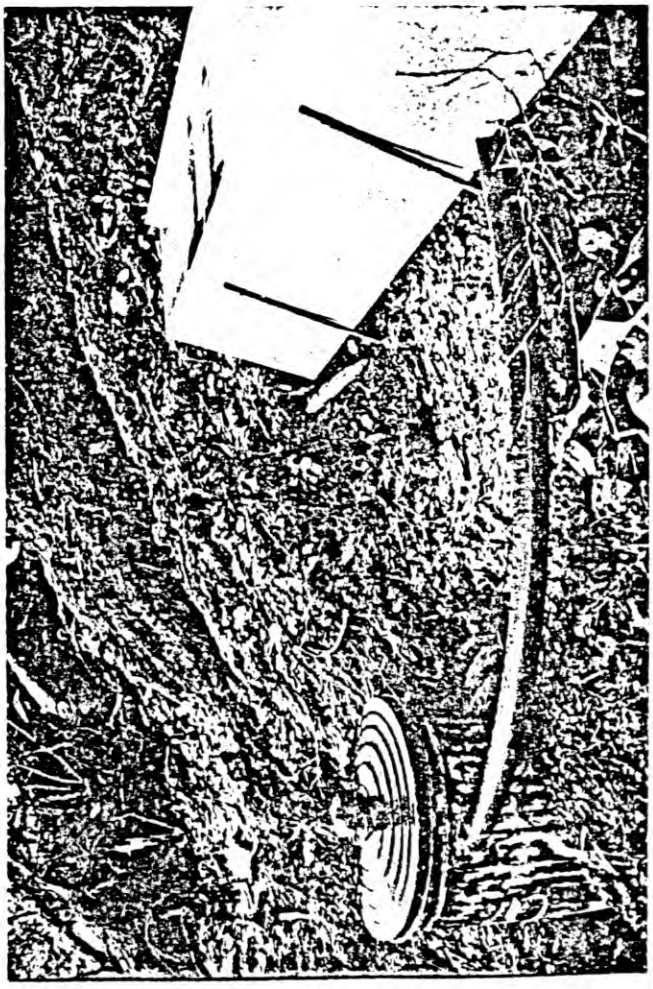
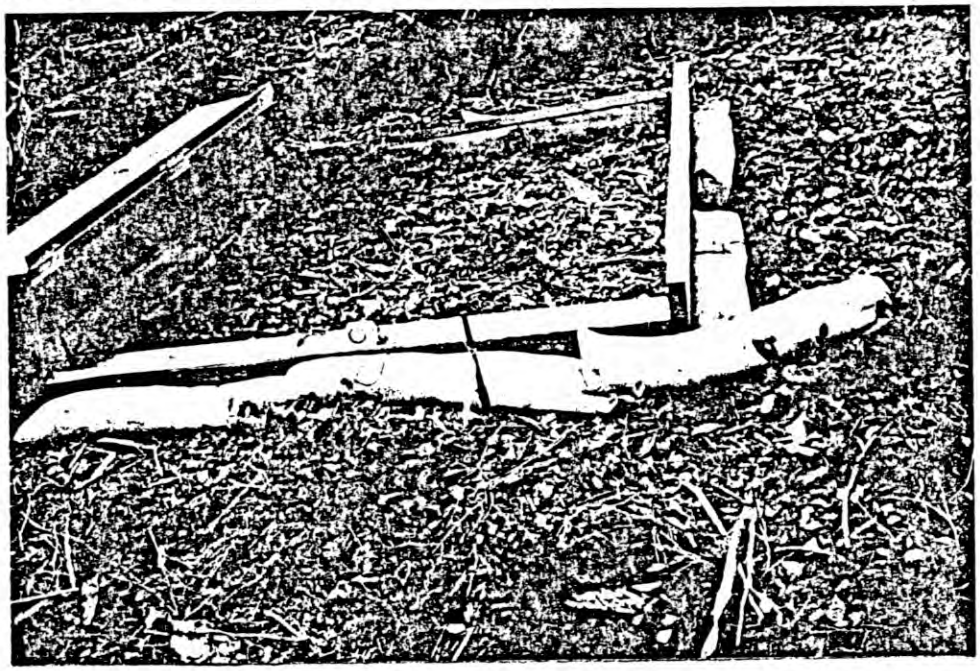
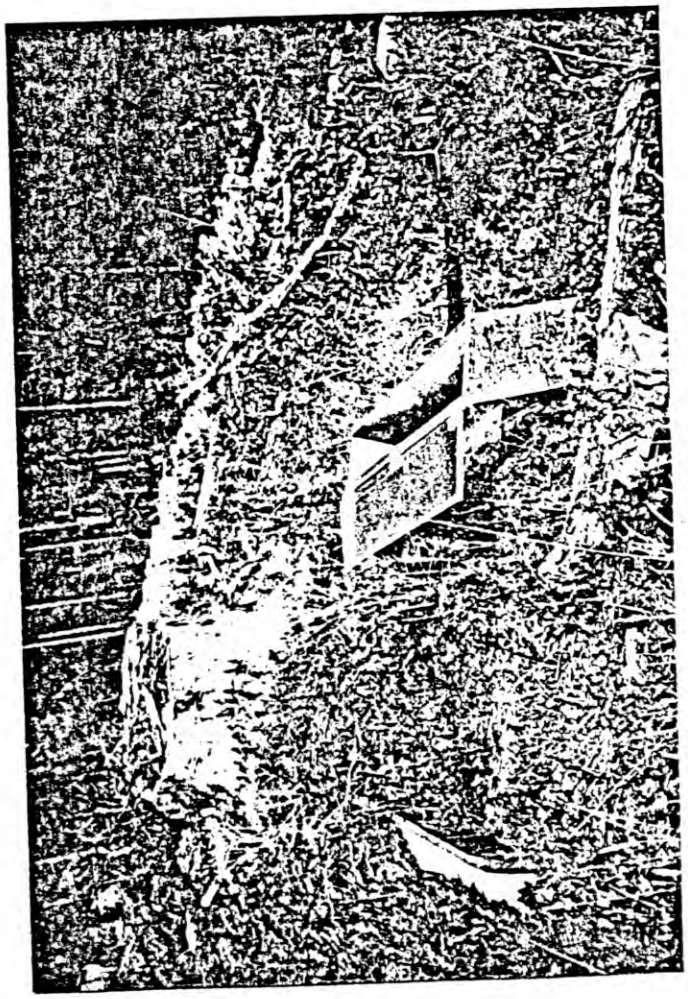


Plate 2. Erosion plots with different borders.





dry "Sacrete," tied and laid around the wooden borders. The border bags were used to plug any gaps along the wooden borders due to microtopography (Plate 2). The wooden borders were reinforced with rebar driven into the ground. We first attempted to use wooden two-by-four stakes, but due to rocks, large woody debris and slash, rebar was found to work better.

All of the borders were cut into lengths and the flashing attached at the Blue River Ranger District warehouse. Personnel at the Blue River Ranger District contributed the time for this work. Figure 5 is a plan of the completed erosion plot.

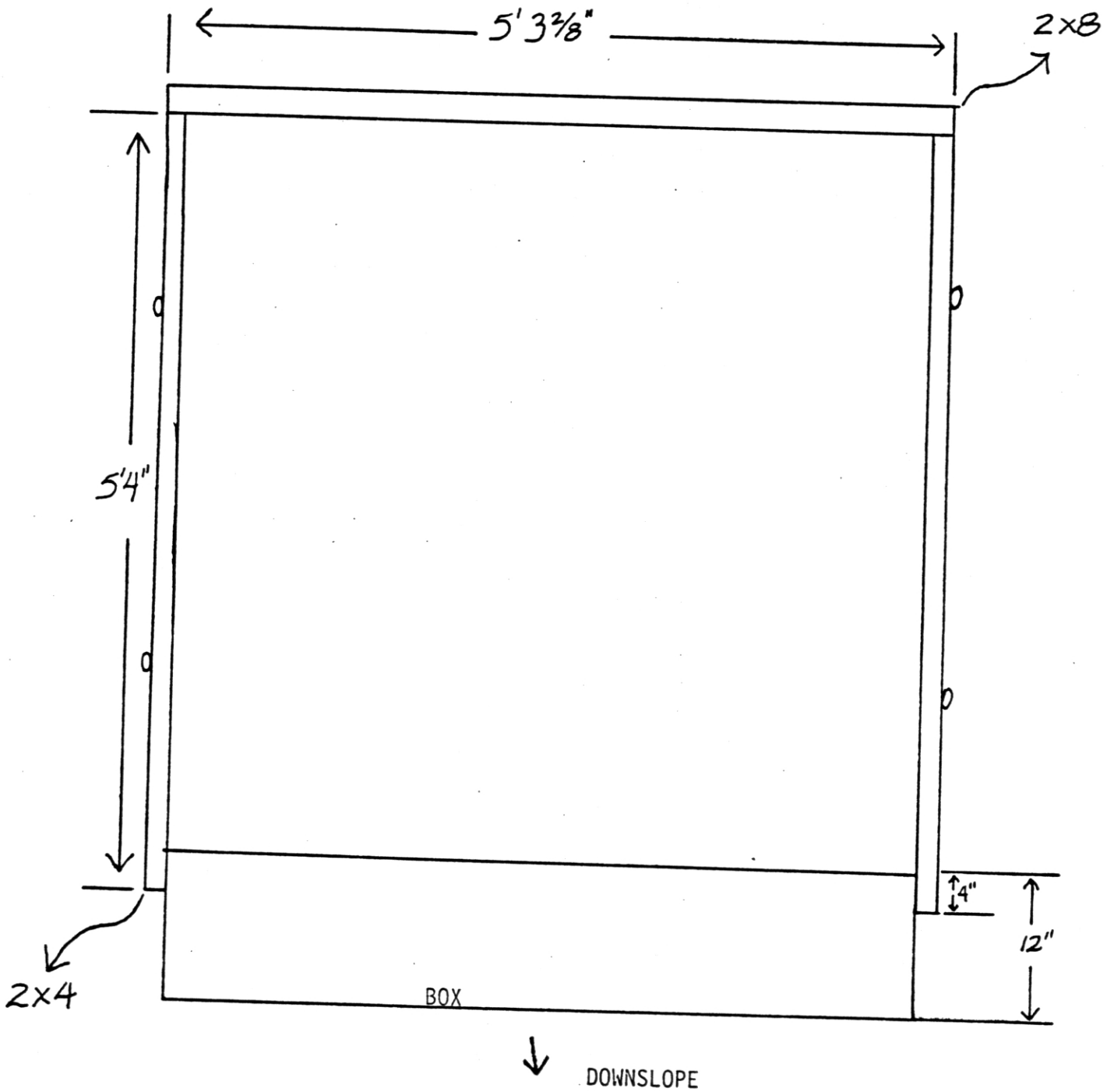
The cost for a bordered plot (including trash can) in 1979 was $104. The cost for an unbordered plot was $76. An analysis of the cost per plot is given in Table 2.

4.5 Box Installation

The erosion catchment boxes were installed from October to November, 1979. An inclinometer was placed on the box lid to insure level installation. The boxes were laid in place from downslope to protect the plot area.

One problem encountered with box installation was springiness of the duff and the mat of fine roots which prevented good contact of the box lip with the mineral soil. This problem was eliminated by stripping off any duff where the box floor was to lie. Garden shears were used to remove any roots. The box was placed with a sawing movement of the lip into and across the soil.

FIGURE 5 EROSION PLOT DIMENSIONS



The box was then stabilized on the slope with rebar. Each piece of rebar was hammered into the ground with a maul and then tied to the box with metal twine.

The border bags were filled with "Sacrete" and pressed against the outer wooden borders to conform to the border sites and microtopography; rebar was then driven into the ground along the side of the border bags. Bags were installed prior to a rainfall event so they would set up overnight.

The final step was to mortar the apron to achieve good contact for the box. The mortar was poured along the soil-box contact zone and a clean sloping angle was made with a brick layer's trowel. This should be done during warm weather for rapid set up of the mortar. After the mortar had set, any loose mortar was removed. Any cracks that appeared in the mortar were filled.

The equipment required for plot installation is listed in Table 3. The completed plots are shown in Plate 3.

4.6 Other Erosion Measurements.

Two types of #F Erosion Bridges used by the California Division of Forestry (Ranger and Frank, 1978) were installed at the lower southern boundary of the area on 70% slope and 100% duff cover. The bridge consists of a 48" (1.22m) aluminum masonry level machined with 10 vertical measuring holes; two 3/8" chambered steel support pins at either end and a 5/16" 2 ft (0.61m) chambered steel pin fitting through the holes to make the measurements.

Table 2. Cost per plot in 1979 prices.

(a) System utilized in this study

1.	Erosion box + mortar lip	$47.00
2.	Collector system, includes PVC pipe	26.00
3.	Wooden borders; nailed and flashed	6.50
4.	Border bags; filled with sacrete	20.00
5.	Twine and rebar per plot	4.60
	Total cost:	$104.00

(b) Cost per erosion plot bordered with only border bags and no suspended sediment system $74.00

(c) Cost per erosion plot bordered without suspended sediment collector system $78.00

(d) Cost per unbordered erosion plot $76.00

The amount of erosion measured in this study was below the precision of these erosion gages, so the measurements were abandoned.

Table 3. Field equipment required to install plots.

1.	Inclinometer	site selection; exact slope level box
2.	Flags	site selection
3.	Chain saw	remove large debris
4.	Pulaski	fire trail
5.	Soil spade	box installation
6.	Pocket knife	box installation
7.	Garden clippers	box installation
8.	Hammer	borders
9.	Tape	plot dimensions
10.	Maul	rebar installation
11.	Coffee cans, water	mix mortar
12.	Brick layer's trowel	box apron
13.	Caulk & caulking gun	seal PVC into box and suspended sediment collector
14.	T square	border edges
15.	Shovel	collector installation
16.	Hand saw	polyflex pipe

5 EXPERIMENTAL METHODS

5.1 Erosion Measurements

The first year of monitoring (9/79 to 5/80, referred to as water year WY 80) was done with the duff intact to establish baseline data. The method for duff removal will be discussed in another section.

The catchment boxes and suspended sediment collectors were cleaned approximately every month during the first season's monitoring, WY 1980. During water years 1981 and 1982 the average collection period was every two months.

The material found in the boxes was placed in soil cans or bags. The samples were separated in the laboratory into coarse and fine, organic and inorganic factions. An aliquot was taken of material in the suspended sediment collectors. A complete description of laboratory methods is given in the Appendix.

5.2 Plot Treatments

Timber management requires removal of fuels left after harvesting, for a variety of silvicultural reasons and to decrease fuel hazard potential. The question of the amount of duff remaining has concerned many soil scientists, foresters, and land managers. Objective #2 of this study attempted to look at the rate of erosion with respect to percent of duff cover.

The duff treatments were performed in September, 1980, by J. Martinez of the Blue River Ranger District, Willamette National Forest. The duff was burned off to different degrees with a butane torch.

After treatment, the depth of duff was determined for each erosion plot. Nine equidistant points were selected on each plot and the depth of duff was measured (Table 4).

5.3 Soil Properties

Soil samples were taken by J. McKee in May 1980 to determine cation exchange capacity, organic matter, and soil pH at the 0-8 cm depth and the 22-28 cm depth. There were eight sample sites (Fig. 6).

Previous erosion studies have shown that the size and amount of water stable aggregates can be related to the erodibility of surface soil (Dyrness, 1966; Wooldridge, 1965). Samples were taken at the 0-8 cm depth for measurement of water stable aggregates.

Soil bulk density determinations were made in the field on August 3, 1980. The method used was the bead cone device (Flint and Childs, 1983).

Infiltration capacity rates were determined at the study site in September and October 1979 by the ring infiltrometer method.

5.4 Rainfall and Temperature

A nontilting, weighing rain gauge was provided for the study by the Soils and Watershed Staff of the Willamette National Forest. The gauge was installed approximately in the middle of the study area prior to WY 1980 (Fig. 2).

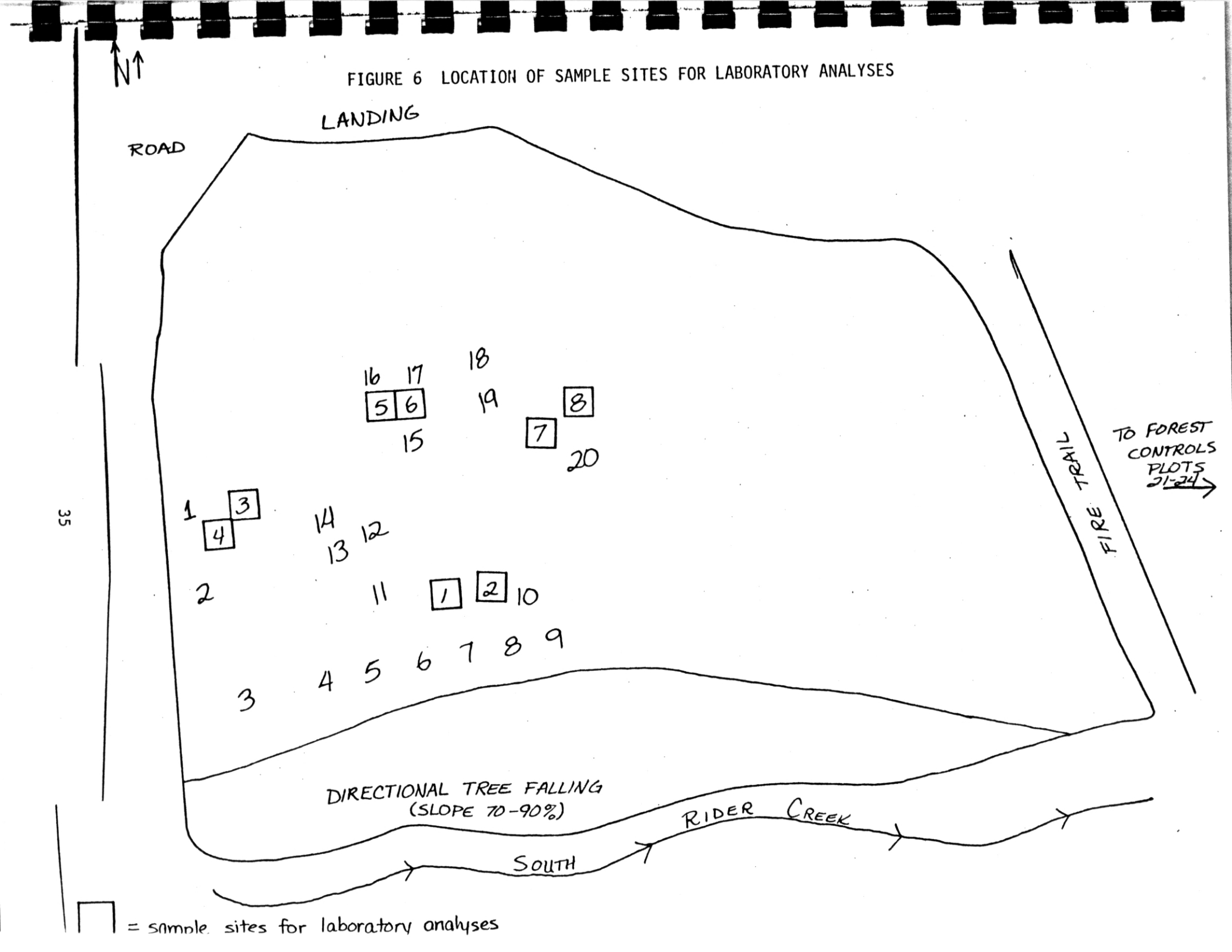
A recording thermograph was installed adjacent to the rain gauge but was removed because of improper functioning. Daily average, maximum, and minimum temperatures at Rosey were estimated

Table 4. Depth of duff measured on erosion plots, 11-3-80.

Plot no.	Average depth	Range of depth	Burning treatment	Measured values*
	------inches-----			
1	1.01	0-3.5	100%	1/8, 1 1/2, 1/2, 3 1/2, 1/2, 2 1/2, 1/16, 0, 3/16
2	.76	0-2.6	100%	2 5/8, 0, 3/4, 1 5/8, 1, 1/16, 1/4, 3/16, 0
3	.31	0-1.1	100%	0, 0, 3/16, 0, 1 1/8, 1/2, 3/4, 1/4, 0
4	.97	0-3.2	0%	3 1/4, 1, 0, 0, 0, 0, 1/2, 3 1/4, 3/4
5	2.62	0.2-5.2	0%	3 1/2, 4 1/4, 3 1/4, 1 3/4, 5 1/4, 2 3/4, 1 1/8, 3/8, 1/4
6	.86	0-3.5	50%	1/2, 3 1/2, 0, 0, 1 1/2, 3/8, 3/4, 3/4, 3/8
7	.80	0-2.0	0%	3/4, 1 1/2, 0, --, 1/2, 2, 1/2, 1, 1/8
8	2.98	0-6.5	0%	2 3/8, --, 6 1/2, 3/4, --, 5, 1 1/4, 1, 4
9	.79	0-2.0	50%	1/4, 1, 1 1/8, 2, 0, 0, 1 1/8, 3/8, 0
10	1.02	0-3.2	100%	0, 2, 3/4, 0, 3 1/4, 3/4, 1 1/8, 1, 3/8
11	.29	0-1.2	100%	0, 0, 0, 1/2, 0, 0, 5/8, 1/4, 1 1/4
12	1.51	0-3.2	0%	0, 1 1/2, 2, 1, 1 1/8, 1 1/2, 1 1/2, 3 1/2, 1 1/2
13	.29	0-1.0	50%	0, 0, 0, 0, 0, 3/4, 3/8, 1/2, 1
14	.28	0-0.7	50%	--, 1/4, 3/4, 0, --, 0, 0, 1/2, 1/2
15	.03	0-0.2	100%	0, 0, 1/4, 0, 0, 0, 0, 0, 0
16	1.56	0.5-2.2	50%	2 1/4, 1 3/8, 1, 1/2, 2, 1 3/4, 2, 1 1/2, 1 5/8
17	1.00	0.2-2.1	0%	1/2, 2 1/8, 1/4, 1/4, 1 5/8, 1 3/4, 1 1/2, 1/4, 3/4
18	1.15	0-4.0	50%	0, 5/8, --, 1 1/2, 1 1/2, 1/2, 1/4, 7/8, 4
19	1.02	0.2-1.6	0%	5/8, 3/4, 1 5/8, 3, 5/8, 1/4, 1, 7/8, 3/8
20	2.14	0.4-4.5	0%	2 3/4, 3/8, 2 1/8, 4 1/2, 1 5/8, 1 3/8, 3 3/4, 2 1/4, 1/2

*No value is recorded (--) where a stone or large piece of wood was found at the measuring spot.

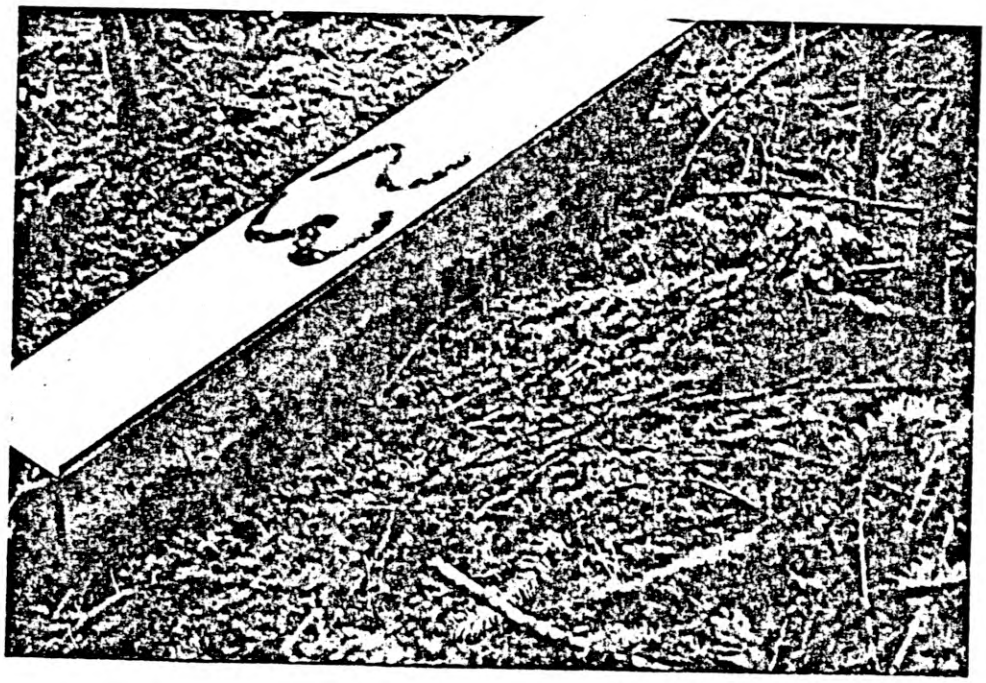
FIGURE 6 LOCATION OF SAMPLE SITES FOR LABORATORY ANALYSES

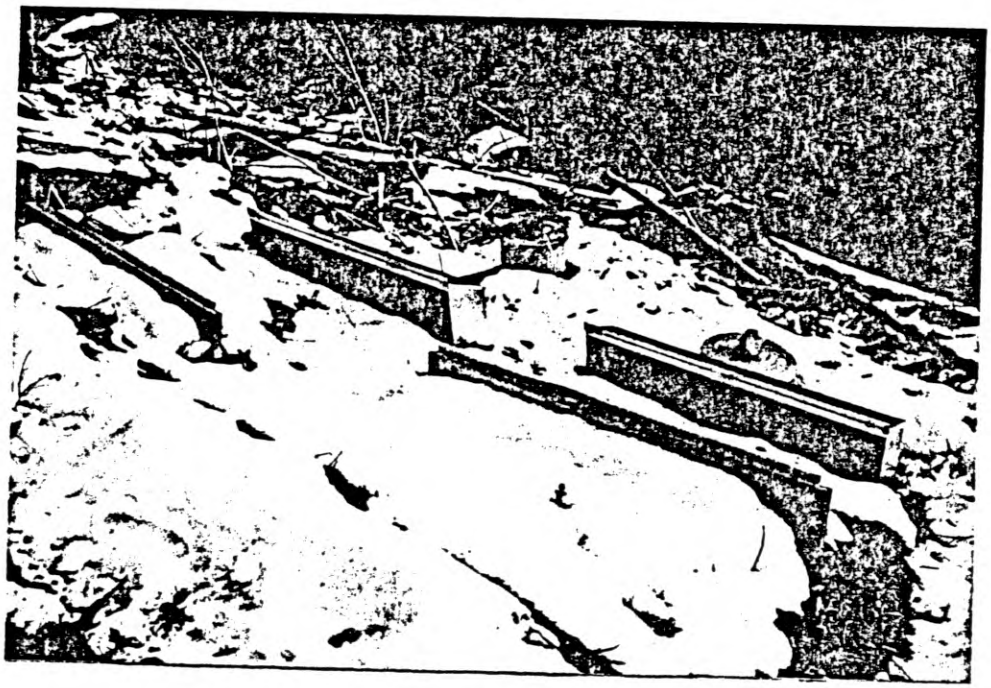


from data collected at two nearby U.S. Weather Stations, McKenzie Bridge Ranger Station (elevation 1,478 ft), which lies 9.5 miles (15 km) north 45° east of Rosey unit #4, and the H.J. Andrews Experimental Forest, reference stand #38 (elevation 3200 ft), which lies 14 miles (22 km) due north of Rosey (Waring et al., 1978; Rothacher et al., 1967).

The data were analyzed to determine freeze-thaw events, which could lift and loosen material, enabling it to be moved downslope under the force of gravity. Needle ice or surface freezing was assumed to have occurred if the night low air temperature was below -3°C (27°F) and thawing if the low air temperature was above -3°C. The number of events per collection period is listed in Table 5.

Plate 3. Completed erosion plots for the forest controls.





6 SITE CHARACTERISTICS

6.1 General

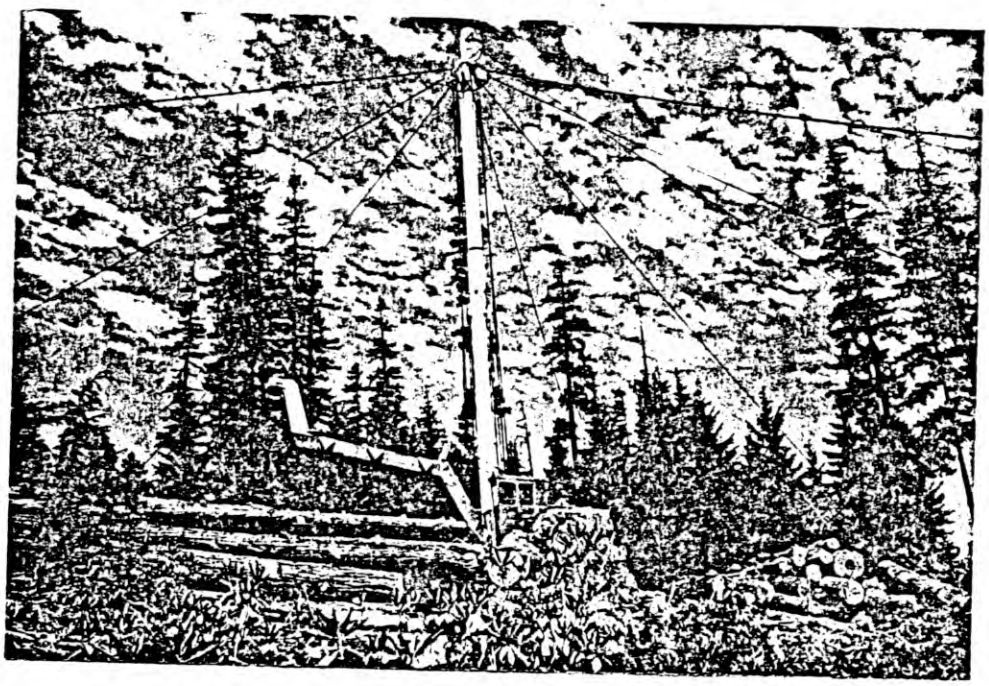
The Rosey #4 Sale Unit, selected as the study site, is located in the Old Cascade Range. The site is near Indian Ridge, within the Rider Creek drainage, a Class IV drainage and a first order stream that drains into Cougar Reservoir, a Class I body of water. The bedrock is Andesite with some inclusions of glacial till. It is part of the Sardine Formation. The clearcut unit is 9.0 acres (3.6 ha) in size.

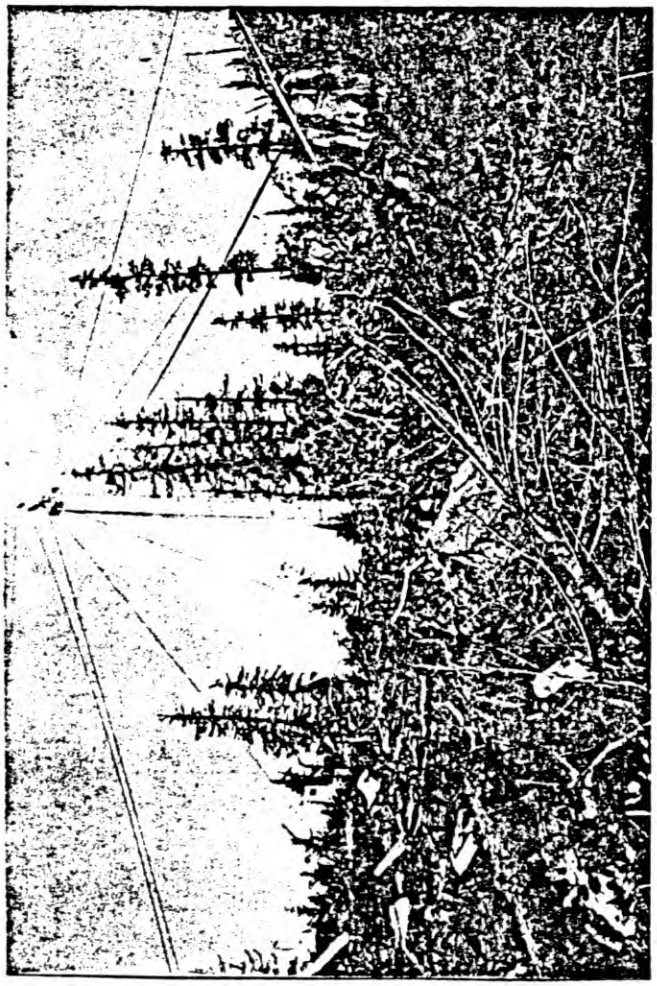
The sale unit has a south to southwest aspect and an elevation range from 2,220 ft (670.56m) to 2,440 ft (743.72m). The soil was mapped as SRI 64 and 61.

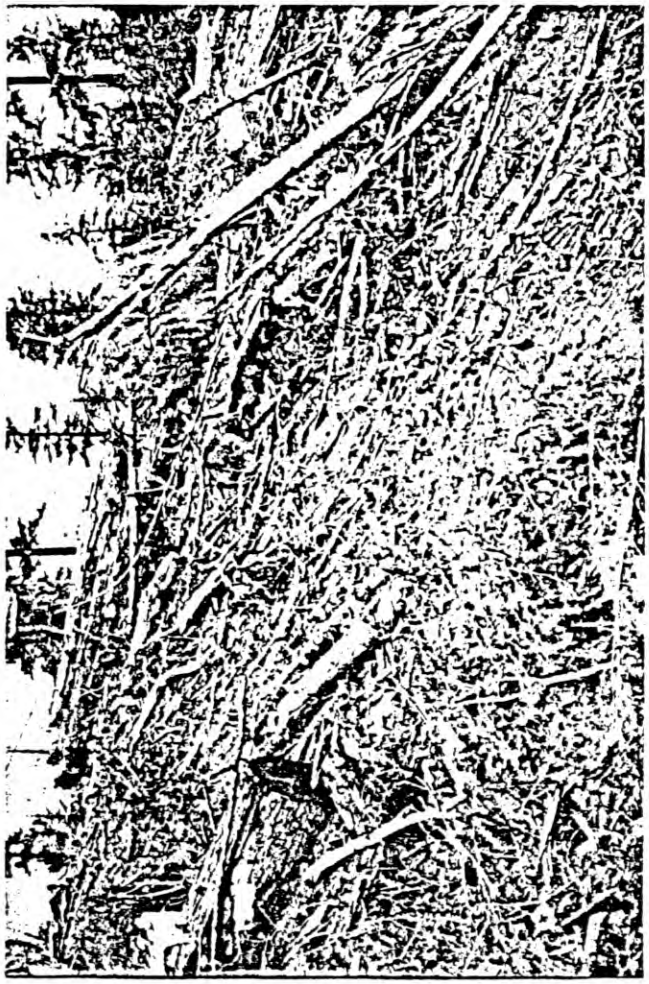
The slope varies from 26% to 60%, the steepness increasing downslope. The landform is a convex hillslope. Small bench-like steps on the lower reaches of the slope break the convex configuration of the shoulder and sideslope.

The predominate timber type was old growth Douglas fir (Pseudotsuga menziesii) with a small proportion of western hemlock (Tsuga heterophylla) with an estimated harvest volume of 660MBDF. Harvesting was completed in late summer, 1979. The Roseburg Lumber Company performed the logging, using a tower with partial and full suspension (Plate 4).

Plate 4. Logging operations at the site.







6.2 Vegetation

In September 1979, G. Terrazas, botanist on the Willamette National Forest, listed the vegetation in the clearcut area and in the forest controls (Tables 6, 7, and 8). In July 1982 T. Miglioretto estimated vegetative cover, duff cover, other cover, and bare ground, using a point sampling frame as described by (Muller-Dombois and Ellenberg (1974). Results are in Table 9.

6.3 Climate

The study area is characterized by a moderate climate; the winters are mild and wet, the summers dry and warm.

The annual precipitation recorded at the H.J. Andrews Experimental Forest, which is approximately 14 miles from the study area, is 92"/yr (234 cm), with 80 to 90% of the total rainfall falling during the autumn and winter (Harr, 1979). Rainfall intensities at the H.J. Andrews have averaged 0.12"/hr (0.30cm/hr) during the fall and may reach 0.24"/hr (0.61cm/hr) to 0.51"hr (1.30cm/hr) (Rothacher et al., 1967).

An estimate of rainfall at the study site for all collection periods was made by interpolating data from the McKenzie Bridge Ranger Station and the H.J. Andrews Experimental Forest watershed #2 and comparing this with the limited rainfall data collected at the study site. A multiple regression was performed with Rosey Unit #4 as the dependent variable and the other two sites as the independent variables. The equation is: Rosey predicted = 8.14×10^{-3} + (HJA)(.701) + (MBRS)(.123), with an R^2 value of 0.91.

Table 5. Characterization of precipitation at the site.

Collection Periods	Total Rosey precipitation Meas.	Calc.	HJA* pptn. Total	No. of days >1.5"	MBRS** pptn. Total	No. of days >1.5"	No. of freeze-thaw MBRS	HJA	% of days with snowcover
	-------inches-------				inches				
1) 11/6/79-12/17/79		5.9	13.6	2	10.8	2	1		7
2) 12/18/79-1/1/80		5.0	4.3	-	2.3	-	0		-
3) 1/2/80-1/30/80	14.2	12.4	15.3	3	12.5	3	14		17
4) 1/31/80-2/27/80	6.3	6.8	8.5	1	5.0	-	1		-
5) 2/28/80-4/21/80	12.4	13.1	16.0	1	12.6	-	-		7
6) 4/22/80-10/1/80		8.2	6.2	-	9.4	-	1		-
7) 10/2/80-11/3/80		3.5	4.5	-	2.4	-	5		-
8) 11/4/80-1/7/81		26.7	33.7	10	23.5	7	23		11
9) 1/8/81-1/28/81		2.8	3.5	-	1.9	-	6	-	-
10) 1/29/81-4/1/81		17.4	21.5	3	15.0	2	8	2	-
11) 4/2/81-5/11/81	4.1	5.6	6.7	1	4.7	-	-	1	-
12) 5/12/81-6/11/81	3.9	5.6	7.7	1	4.7	-	-	1	-
13) 6/12/81-7/15/81		2.5	3.0	-	2.2	-	-	-	-
14) 7/16/81-10/14/81		8.5	10.2	1	9.2	1	-	-	-
15) 10/15/81-12/9/81		21.0	27.0	4	19.5	1	-	-	-
16) 12/10/81-3/22/82		42.6	54.3	12	30.8	7	24	31	49
17) 3/23/82-5/81/82			12.1	-			2	9	5
18) 6/1/82-6/24/82	2.0		2.2	-			-	-	-

*HJA - H.J. Andrews Forest.
**MBRS - MacKenzie Bridge Ranger Station.

Table 6. Vegetation in forest controls.

Tree Species

1.	Pseudotsuga menziesii	Douglas fir
2.	Thuga plicata	western red cedar
3.	Tsuga heterophylla	western hemlock
4.	Castanopsis chrysophylla	golden chinquapin

Shrub Species

1.	Acer cercinatum	vine maple
2.	Berberis nervosa	Oregon grape
3.	Chimaphila menziesii	little prince's pine
4.	Gaultheria shallon	salal
5.	Rhododendron macrophylla	rhododendron
6.	Rubus ursinus	trailing blackberry
7.	Whipplea modesta	whipplea

Herbaceous Species

1.	Linnaea borealis	twinflower
2.	Pyrola picta	white vein pyrola
3.	Polystichum munitum	swordfern
4.	Viola glabella	pioneer violet
5.	Adenocaulon bicolor	pathfinder
6.	--	various mosses

Table 7. Vegetation in clear cut prior to fuels treatment.

Tree Species

1.	Pseudotsuga menziesii	Douglas fir
2.	Tsuga heterophylla	western hemlock
3.	Castanopsis chrysophylla	golden chinquapin

Shrub Species

1.	Acer circinatum	vine maple
2.	Acer macrophylla	bigleaf maple
3.	Berberis nervosa	Oregon grape
4.	Chimaphila menziesii	little prince's pine
5.	Gaultheria shallon	salal
6.	Holodiscus discolor	ocean spray
7.	Rhododendron macrophylla	rhododendron
8.	Rosa gymnocarpa	rose
9.	Rubus parviflorus	thimbleberry
10.	Rubus ursinus	trailing blackberry
11.	Whipplea modesta	whipplea

Herbaceous Species

1.	Achlys triphylla	vanillaleaf
2.	Adinocaulon bicolor	pathfinder
3.	Epilobium augustifolium	fireweed
4.	Galium triflorum	sweet scented bedstraw
5.	Hieracium albiflorum	white hawkweed
6.	Linnaea borealis	twinflower
7.	Conyza canadensis	Canadian thistle
8.	Polystichum munitum	swordfern
9.	Antennaria neglecta	pussytoes
10.	Cirsium vulgare	common thistle

Table 8. Vegetation within plot borders, 6-25-82.

Unburned Plots

Hieracium albiflorum	white hawkweed
Gaultheria shallon	salal
Berberis nervosa	Oregon grape
Cirsium vulgare	common thistle
Lolium perenne	perennial ryegrass
Epilobium augustifolium	fireweed
Whipplea modesta	whipple vine
Epilobium minutum	small-flowered willowweed
Rubus ursinus	trailing blackberry

Burned Plots

Adinocaulon bicolor		pathfinder
Corylus cornuta	(?)	hazelnut
Hieracium albiflorum		white hawkweed
Epilobium minutum		small-flowered willowweed
Cirsium (little)		common thistle

Table 9. Condition of plot surfaces measured 6-24-82.

Plot no.	Cover			
	% Plant cover	% Duff	% Other*	% Bare soil
1	54	20	3	23
2	50	3	5	42
3	54	29	5	12
4	49	12	21	18
5	21	43	27	9
6	31	20	20	29
7	55	5	13	27
8	32	44	17	7
9	44	14	5	37
10	55	13	8	24
11	39	41	4	16
12	57	30	8	5
13	36	14	8	42
14	46	21	8	25
15	31	5	4	60
16	58	21	10	11
17	44	32	19	5
18	27	48	8	17
19	49	46	4	1
20	34	40	23	3

*Other: rocks, large pieces of bark & wood, etc.

Table 10 shows the amount of rainfall recorded at each site per collection period. The highest intensity recorded at Rosey was 0.8"/hr during a storm event on January 11, 1980. The average annual precipitation at the site during the study period was 75"/yr (190cm/yr).

Snow cover was also estimated from interpolation of data from the McKenzie Bridge Ranger Station and the Cougar Reservoir Dam recording station (elev. 1,260ft), which lies 3.5 mi (6km) north of the site (S. Howick, National Weather Information Center). Percent days with snow cover during each collection period was calculated (Table 5).

6.4 Measured Plant Cover

Vegetation found on the site is listed in Tables 4, 5, and 6. Fewer species were found in the burned plots than on the unburned plots, but all the species described had been present prior to any treatments. There was no significant difference in percent plant cover related to the amount of duff remaining.

6.5 Duff

There was a significant difference in the percent of duff remaining at the various treatment levels as well as a large difference in the percent of bare ground for different duff treatments. Table 8 shows values of percent plant cover, duff cover, other cover, and percent bare soil. The means for percent duff cover and percent bare ground for the different duff treatments on July 1982 were as follows:

Table 10. Total rainfall.

	WY 1	WY 2	WY 3, through March	WY 3, through June
	inches			
Rosey	51.4	72.6	63.6	
HJA*	63.9	90.8		95.6
MBRS**	52.6	65.1	50.3	

*H.J. Andrews
**McKenzie Bridge Ranger Station

Treatment cover remaining	Measured duff cover	Measured bare soil	Average depth	
	-%		-cm-	-in-
100	32	9	4.14	1.63
50	23	27	2.08	0.82
0	18	30	1.45	0.57

6.6 Soil Profile Descriptions

A detailed field soil description was made by J. McKee and G. H. Simonson in May 1980. Ten sites were chosen for detailed soil descriptions (Fig. 7). The profile descriptions and a generalized profile description for the area are in Tables 11 and 12.

Soil within the Rosey Unit is relatively uniform. The variation is in depth and in content of coarse fragments. The major soil present is the Klickitat series, a member of the loamy skeletal, mixed, mesic Typic Haplumbrept family. The shallow inclusion is in the Kilchis series, a loamy, skeletal, mixed mesic Lithic Haplumbrept. The inherent erodibility of the two soils based on the USLE K value is 0.1 for the Klickitat and 0.15 for the Kilchis series.

The soil texture in the A_1 and B_1 horizons varies from very gravelly loam to fine gravelly loam. The textures of the B_2 and C include very to extremely gravelly or cobbly loams and clay loams. Cobbles and a few stones are abundant in the mineral horizons, ranging from 5 to 10% in the A horizon and from 15 to 35% in the B horizons. Cobbles and stones increase with depth to between 50 and 80% in the C horizon.

FIGURE 7 LOCATION OF SITES FOR SOIL PROFILE DESCRIPTIONS

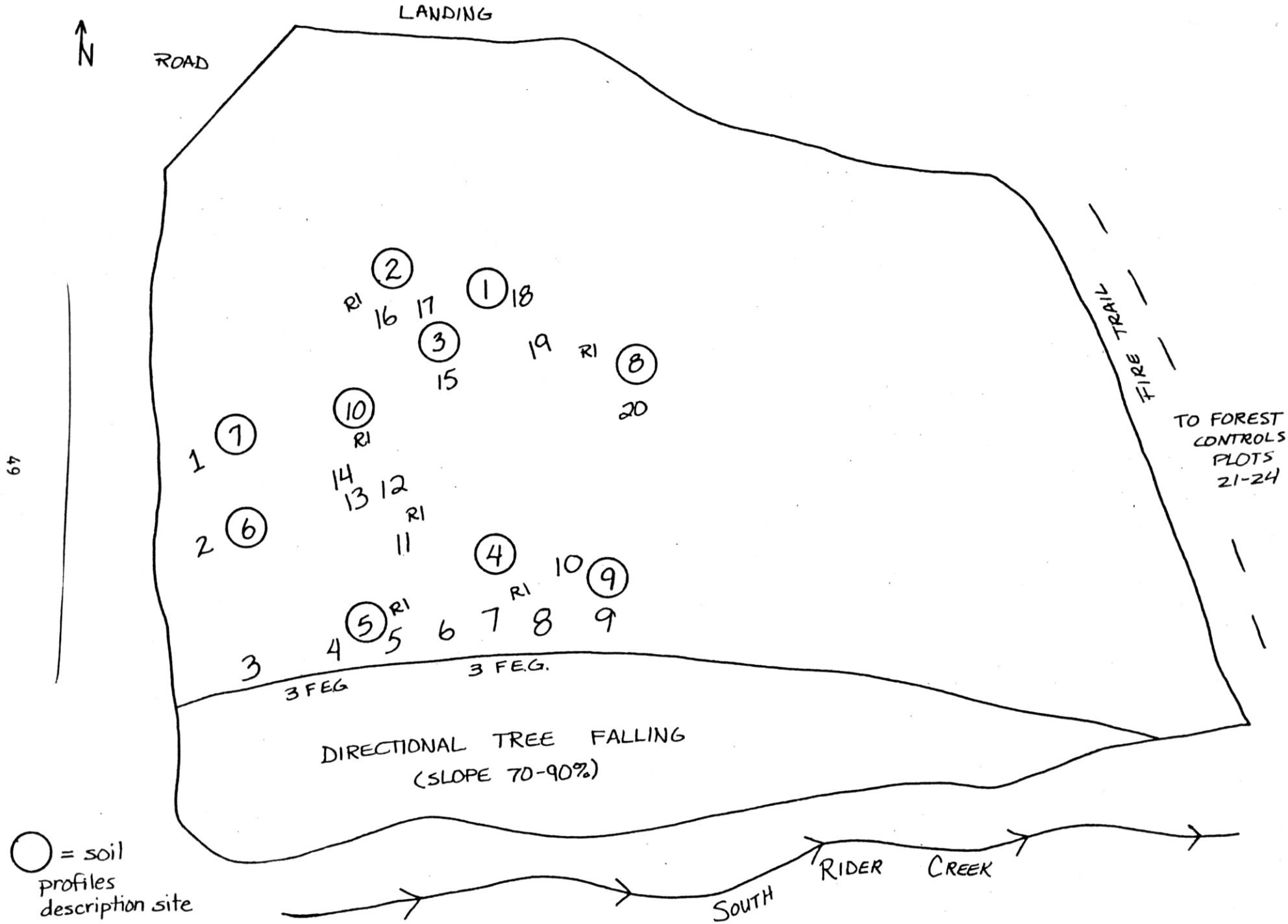


Table 11. Detailed soil description.

Approx. slope	Site	Depth	Description
UPPER SLOPE (EROSION BOXES 15-19)			
30%	1.	24" total	
		A 0-17"	Disturbed surface, coarse gravelly loam 5% stones and cobbles, 5YR3/3.
33%	2.	4 ft total	Increase in coarse fragments after 3 ft.
		O_1 1½"	Needles and twigs.
		O_2 1½"	Decayed
		A_1 3-14"	Fine gravelly loam (shot-like), 5YR3/3.
		B_1 14-24"	Fine gravelly loam, 5 YR3/4.
		B_2 24-36"	Gravelly loam, 7.5 YR4/4, angular gravel 1-2".
		C_1 36-48"	Extremely gravelly loam, 10 YR4/3, angular gravel >2"
32%	3.	30" total	
		O_1 1"	
		O_2 1-2"	
		A_1 2-12"	Fine very gravelly loam, 5 YR3/3.
		B_1 12-20"	Very gravelly loam, 7.5 YR3/4, angular cobbles 3-5".
		C 20-30"	Extremely gravelly loam, 10 YR4/4.
		R >30"	Fractured rock.

continued...

Table 11, cont.

Approx. slope	Site	Depth	Description
MIDDLE SLOPE (EROSION BOXES 1, 2, 12-14, 20)			
35%	10.	30" total	
		O_1	
		O_2	
		A^2	Very gravelly loam, 7.5 YR3/3, 10% cobbles.
		B_1	Very gravelly loam, 7.5 YR3/4, 20% cobbles.
		B_2^1	Very gravelly clay loam, 10 YR4/4.
31%	8.	40" total	
		O_1 0-2"	Very gravelly loam.
		A^1 2-9"	Very gravelly loam.
		B_1 9-19"	Very gravelly loam (shotty), 7.5 YR3/4, 15% cobbles 3-5".
		B_2 19-26"	Very gravellly loam, 10 YR4/4, roots found up to 26".
		C 26-40"	Extremely gravelly loam, 10 YR4/4, 80% gravel (angular rock fragments).
38%	7.	>40" total	
			Shotty gravelly loam (coarse), many rock fragments, no clay loam, good root distribution.
47%	6.	48" total	
		O_1 0-2"	Sawdust accumulation.
		O_2^1 2-2½"	Decayed.
		A^2 2½-12"	Gravelly, shotty loam, 5% cobbles >" wide.
		B_1 12-23"	Gravelly shotty loam.
		B_2^1 23-36"	Light clay loam.
		C^2 36"	Weathered bedrock.

continued...

Table 11, cont.

Approx. slope	Site	Depth	Description
LOWER SLOPE (SHALLOW SOILS, MORE CLAY IN LOWER HORIZONS, EROSION BOXES 3-11)			
55%	5.	22" total	
		A 0-2"	Gravelly shotty loam.
		B_1 2-10"	Gravelly loam.
		B_2^1 10-20"	Loam, 10 YR4/4 cobbley.
		C^2 20-22"	Fractured bedrock.
50%	4.	36" total	
		O_1 0-1"	
		O_2^1 1-3"	10% angular cobbles (3-6").
		A^2 3-9"	20% angular cobbles (3-6").
		B_1	Gravelly loam.
		B_2^1	Gravelly loam.
		C^2 24"	Loam, 10 YR4/4 cobbles (3-6").
		R 24-36"	
55%	9.	26" total	
		O_1 0-2¼"	Gravelly loam (shotty).
		A^1 2¼-8"	Very gravelly fine loam, 7.5 YR3/3, many fine roots.
		B_1 8-16"	Gravelly loam, 7.5 YR3/4 fine roots.
		B_2^1 16-26"	Very gravelly loam, 7.5 YR4/4 35% cobbles.
		C^2 26"	Very gravelly light clay loam, 7.5 YR4/4, 75% cobbles and gravel.

Table 12. General soil profile description.

O_1 8-5cm; needles, twig, leaves, and grass.

O_2 5-0cm; decayed organic matter.

A 0-15cm; dark brown (7.5 YR3/3) fine gravelly loam, strong fine granular structure; slightly hard; friable; slightly sticky; nonplastic; many fine and medium roots; many fine irregular pores; many 2-5mm shot-like fragments; 5-10% angular coarse pebbles and 8-20cm size cobbles; medium acid; clear smooth boundary.

B_1 15-36cm; dark reddish brown (5 YR3/3) very gravelly loam; moderate medium granular structure; slightly hard; friable; slightly sticky; nonplastic; many fine and medium roots; many fine irregular pores; many 2-5mm shot-like fragments; 15% angular coarse pebbles and 8-15cm size cobbles; medium acid; gradual smooth boundary.

B_2 36-61cm; reddish brown (5 YR4/4) very gravelly loam; moderate medium subangular blocky structure; slightly hard; friable; slightly sticky; slightly plastic; medium roots; many fine irregular pores; few 2-5mm shot-like fragments; 35% angular coarse pebbles and 8-15cm size cobbles; strongly acid; gradual smooth boundary.

C_1 61-123cm; dark yellowish brown (10 YR4/4) very cobbly clay loam; weak coarse subangular blocky structure; friable; slightly sticky and slightly plastic; few roots, common very fine irregular pores; 50-60% angular coarse pebbles and 8-15cm size cobbles.

R 123 cm; hard fractured andesite bedrock.

Range in Characteristics

The soil textures of the Blue River Forest District, Rosey number four timber sale site vary from very gravelly loam to fine gravelly loam in the A_1 and B_1. Textures of the B_2 and C include very to extremely gravelly or cobbly loams and clay loams.

The color of the A horizon ranges from 5 YR3/3 to 7.5 YR 3/3. The B_1 horizon varies in hue from 7.5 YR to 5 YR and from 3 to 4 in value. The B_2 horizon is either 7.5 YR4/4 or 10 YR4/4. This change in hue occurs either between the B_1 and B_2, or the B_2 and C horizon.

Cobbles and a few stones are abundant in the mineral horizons, ranging form 5 to 10 percent in the A horizon, from 15 to 35 percent in the B horizon and increasing with depth to between 50 and 80 percent in the C horizon.

Soil color ranges from 5 YR3/3 to 7.5 YR3/3 in the A horizon. The B_1 horizon varies in hue from 7.5 YR to 5 YR and from 3 to 4 in value. The hue of the B_2 horizon is either 7.5 YR 4/4 or 10 YR 4/4. The changes in hue occur between the B_1 and B_2 or B_2 and C horizon.

Soil profile thickness ranges from 70 cm to 125 cm, most of the area being less than 100 cm to fractured bedrock. Soil depth is extremely limited near a rock outcrop in the southwest corner. Within 10 to 20 ft (3.3 to 6.6m) of the outcrop, the soil depth is 30 cm of very gravelly loam. Upslope from the outcrop the soil is still a very gravelly loam, but the soil depth ranges from 41 to 46 cm. This inclusion is located near erosion plot #3.

There is some variation in the depth of the duff layer at the different profile sites. Disturbance from logging has left surface irregularities of 1 to 3 feet due to yarding of merchantable and unmerchantable logs.

6.7 Measured Soil Characteristics

The cation exchange capacity (CEC) was high for both the surface soil (0-8cm depth) and the subsoil (22-28cm depth). The mean value for the 0 to 8 cm depth was 24 meq/100 gm and the mean at the 22 to 28 cm depth was 26 meq/100 gm (Table 13).

The organic matter content was relatively high; the mean value for the 0 to 8 cm was 6.1%. The soil pH ranged from strongly acid to slightly acid (Table 13).

The bulk density at the 0 to 8 cm depth ranged from 0.72 g/cm^3 to 1.05 g/cm^3, with a mean value of 0.89 g/cm^3 (Table 14). The

Table 13. Characterization of soils.

Site	Depth	Cation Exchange Capacity	Organic matter	pH
	--cm--	me/100g	-%-	
1	0-8	28	5.4	5.8
	22-28	24	2.1	5.4
2	0-8	23	5.4	6.1
3	0-8	24	6.8	5.5
	23-25	23	2.6	5.5
4	0-8	22	7.6	5.7
5	0-8	24	4.1	5.4
	25-28	29	3.0	5.3
6	0-8	22	5.4	5.8
7	0-6	28	5.8	6.1
	25-29	26	5.4	5.7
8	0-8	23	8.6	5.8

bulk density determination also involved measurement of the percent coarse fraction and the percent fine fraction. The mean value for the coarse fraction was 51% and for the fine fraction 49% (Table 14).

The water stable aggregate analysis showed highly stable aggregates, with the greatest percentage being in the greater than 1.0 mm size fraction. Table 15 shows the analysis for the eight sample sites and three size fractions.

The infiltration rates, measured with a ring infiltrometer in September and October, 1979, were very high. Values ranged from 100 to 200 inches per hour. The actual values may not be reliable, but indicate a very high infiltration rate.

Forest control	Clear cut M. steep	Clear cut steep	Clear cut V. steep
212 in/hr	100 in/hr	167 in/hr	116 in/hr
(0.15cm/sec)	0.071 cm/sec)	(0.11 cm/sec)	0.082 cm/sec)

Table 14. Soil bulk density and coarse fragment content.

Site	Total soil bulk density	Fine fraction bulk density	Coarse fragments	Fine fragments
	g/cm^3		----percent----	
1	0.94	.44	64	36
2	0.81	.50	46	54
3	0.72	.36	58	42
4	1.01	.57	56	44
5	0.92	.69	34	66
6	0.85	.53	46	54
7	0.81	.50	48	52
8	1.05	.58	57	43
		Mean	51	49

Table 15. Size of water stable aggregates in surface soil samples.

Site	% Stable aggregates		
	>1mm	1-0.5mm	0.5-0.25mm
1	63	9	6
2	61	11	7
3	56	15	10
4	50	16	8
5	51	13	11
6	52	15	10
7	62	9	6
8	60	9	6

Table 16. Total sediment in boxes, WY 1980.
(Nov. 1979 - Oct. 2, 1980)

Box #	Organic		Mineral	
	>2mm	<2mm	>2mm	<2mm
	grams			
1	31	1	1	1
2	15	1	2	1
3	40	0	0	0
4	143	85	483	176
5	116	61	249	102
6	66	13	170	7
7	42	3	17	5
8	29	0	18	0
9	58	3	491	3
10	20	0	0	0
11	7	0	0	0
12	13	0	0	0
13	12	0	0	0
14	16	0	27	0
15	45	0	0	0
16	12	0	0	0
17	8	0	1	1
18	12	0	1	0
19	3	0	0	0
20	21	1	0	0
21	8	0	0	0
22	14	0	0	0
23	10	0	0	0
24	10	0	0	0

7 MEASUREMENTS OF SURFACE EROSION

7.1 Base Line Year Measurements

The amounts of sediment collected in the boxes during the base line year of monitoring (WY 1980) are given in Table 16. The conversion factor is 100g per box equals 0.43 tonnes per hectare.

Minimal surface soil movement was observed in most plots. No inorganic material was collected at the four forest control plots, 21 to 24, and in about the half the other plots. The mean value for the total movement of inorganic material in the clearcut was 0.3 tonne/ha. Most of this was stones moving in a few plots. The greatest volume of material in the boxes was coarse organic material such as twigs, bark and needles. The amount of organic material was generally less than 0.2 tonne/ha for the entire winter season.

The mean values for the surface movement of inorganic material for the different slope classes in the clear cut are:

Slope Class	Inorganic
1. Moderately steep	0.002 tonnes/ha
2. Steep	0.023 tonnes/ha
3. Very steep	0.94 tonnes/ha

Plots #4 and #5, located in the very steep class, consistently had both coarse and fine inorganic and organic. The coarse inorganic material consisted of stones. The amount of inorganic material was 2.8 tonnes/ha at plot #4 and 1.5 tonnes/ha at plot #5 during WY 1980. Both plots had patches with no duff cover, the greatest being on plot #4 (Table 9). In December micro-debris avalanches were observed on plot #4. Repair work on the soil

Table 17. Total sediment in boxes, WY 1981.
(Oct. 2, 1980 - Oct. 15, 1981)

Box #	Organic		Mineral	
	>2mm	<2mm	>2mm	<2mm
	grams			
1	21	25	20	16
2	41	35	75	40
3	19	18	4	43
4	129	37	452	102
5	205	42	194	55
6	581	110	339	72
7	102	41	264	94
8	76	6	54	3
9	32	11	73	13
10	61	11	165	13
11	39	6	13	3
12	10	3	104	2
13	37	3	1	5
14	17	3	5	2
15	25	35	39	72
16	46	20	48	50
17	121	6	6	6
18	18	8	6	6
19	7	0	0	0
20	17	2	0	0
21	15	2	72	19
22	9	8	7	2
23	22	3	0	10
24	19	55	8	29

mortar apron on plots 4 and 5 during November and December may have created some disturbance.

The greatest amount of material was collected between January 2 and January 31, 1980. This erosion may have been caused by needle-ice transport. During January and February 1980, needle ice up to 1 cm in height was observed in the morning hours. Needle-ice can lift material which is then subject to movement by gravity upon thawing.

No suspended sediment was found during the base line year.

7.2 Measured Erosion After Burning Treatments

Measured values for WY 1981 and 1982 are given in Tables 17 and 18.

Moderately steep plots. Several plots became relatively high yielders of inorganic material after burning the duff. Total erosion, however, was less than 0.4 tonnes/ha. Plots #11 and #15 yielded much more material than during the base line year. Plot #15 was observed to have very actively eroding areas with erosion pavement observed in September 1982. Plot #15 had 60% bare soil.

Plots #16 and #18, with 50% duff removed, also began to yield material into the catchment box; this trend continued into WY 1982. Plot #16 has a very actively eroding surface. Field observations on September 7, 1982, showed that the soil at the mortar apron contact was lower than the apron; thus, some material is missing the box. Plot #18 was also observed to have a very actively eroding surface.

Table 18. Total sediment in boxes, WY 1982.
(Oct. 16, 1981 - Sept. 7, 1982)

Box #	Organic		Mineral	
	>2mm	<2mm	>2mm	<2mm
	grams			
1	51	62	159	71
2	31	70	147	163
3	38	21	60	42
4	217	53	176	107
5	238	208	550	231
6	242	87	202	45
7	75	58	158	66
8	85	60	157	57
9	23	35	464	42
10	19	17	34	13
11	51	34	87	17
12	13	8	5	4
13	26	23	12	17
14	80	32	36	28
15	53	25	68	29
16	30	18	56	20
17	18	5	1	2
18	8	4	2	3
19	1	2	0	3
20	42	6	1	1
21	23	13	6	--
22	26	19	13	--
23	56	16	6	1
24	27	10	6	5

Steep slope class. Plots #1 and #2 treated to 0% duff remaining became significantly greater contributers, with the rates increasing with time. Erosion was about 1 tonne/ha in WY 1982. Both plots have actively eroding surfaces. During WY 1981 box #12 contributed a greater amount of material in the larger than 2.0mm size class; the cause is believed to be disturbance by mammals.

Very steep slope class. At the very steep slope class, surface erosion of inorganic material increased with time for all duff treatments. Plots #3 and #10, treated to 0% duff remaining, contributed no inorganic material during the base line year, but the amount has increased each winter after treatment. Both plots have actively eroding surfaces. Box #3 is within the shallow Klichis series. Plots #6 and #9, at the 50% duff treatment, have increasing erosion rates.

Plots #4 and #5 continued to be large contributers of material. Again, small debris avalanches could be the major source of transport. There is a large boulder within plot #4, but the remainder of the surface is actively eroding; there is also an animal trail across the plot. At plot #5 the open areas are actively eroding, with the slash left on the plot acting as a check dam.

Average values. The average rates of movement (Tables 19 and 20) for inorganic material for the study area for the three years are as follows:

Year	Tonnes/ha/year
WY 80	0.32
WY 81	0.47
WY 82	0.66

Table 19. Total sediment collections for three erosion seasons. (Nov. 1979 to Sept. 1982)

Box #	Organic		Mineral		Total
	>2mm	<2mm	>2mm	<2mm	
	grams				
1	103	88	180	88	459
2	87	106	224	204	621
3	96	36	64	83	279
4	439	162	1050	355	2006
5	559	311	993	388	2251
6	779	190	651	116	1736
7	210	96	419	157	882
8	142	54	193	56	445
9	109	44	996	55	1204
10	96	24	190	24	334
11	92	36	96	19	243
12	31	7	106	4	148
13	66	23	11	120	220
14	113	35	68	30	246
15	119	54	94	95	362
16	83	35	101	66	285
17	135	9	8	8	160
18	38	12	9	9	68
19	11	2	0	3	16
20	80	9	1	1	91

The average rates of movement for inorganic material at each slope class are as follows:

Slope Class	WY 1980	WY 1981	WY 1982
	tonnes/ha		
Moderately steep	0.002	0.180	0.21
Steep	0.023	0.20	0.47
Very steep	0.94	1.05	1.30

7.3 Suspended Sediment

The water in the suspended sediment collectors was examined each time a collection was made. No visible turbidity was present. A trace of turbidity was present in some samples on January 29, 1981, so water samples were collected and analyzed for suspended sediment by drying an aliquot of suspension. The greatest amount was found on plot #4, which had also yielded the greatest amount of inorganic material in the collection box. The samples yielding the greatest amounts tended to be in the steep slope class, and with some duff removal. The average for all plots was 86 ppm (Table 21). Since the amounts were so small in comparison to the sediment collected in the catchment boxes, no further suspended sediment samples were taken.

Table 20. Mean amounts of erosion by slope class.

Year	Slope class	Total	Fine mineral	Coarse mineral	Fine organic	Coarse organic
		----------g per box----------				
WY 1	Low	18	.2	.3	.2	18
	Medium	21	.3	5	.3	15
	High	300	37	179	21	64
WY 2	Low	99	23	19	13	44
	Medium	79	11	34	12	22
	High	428	49	193	35	151
WY 3	Low	97	12	36	15	34
	Medium	174	48	60	33	34
	High	485	75	225	67	117
Sum 1-3	Low	202	33	52	26	91
	Medium	285	75	98	44	69
	High	1142	154	570	115	304

Table 21. Suspended sediment measured on samples taken Jan. 29, 1981.

Plot	ppm
1	104
2	85
4	254
5	27
8	90
9	61
10	150
13	56
14	<143
15	62
17	<28
18	<27
19	<33
Ave.	86

Table 22. Movement of fine material in tonnes/ha.

Box no.	WY 1 11/79 - 10/2/80 Total	FOM	F Min	WY 2 10/2/80 - 10/15/81 Total	FOM	F Min	WY 3 10/16/81 - 9/7/82 Total	FOM	F Min
1	.15	--	--	.36	.11	.07	1.49	.27	.31
2	.09	--	--	.83	.15	.17	1.78	.30	.71
3	.17	--	--	.36	.08	.19	.70	.09	.18
4	3.84	.37	.76	3.12	.16	.44	2.40	.23	.46
5	2.29	.26	.44	2.15	.18	.24	5.31	.90	1.00
6	1.11	.06	.03	4.78	.48	.31	2.46	.38	.20
7	.29	.01	.02	2.17	.18	.41	1.55	.25	.29
8	.20	--	--	.60	.03	.01	1.55	.26	.25
9	2.40	.01	.01	.59	.05	.06	2.44	.15	.18
10	.09	--	--	1.08	.05	.06	.36	.07	.06
11	.03	--	--	.26	.03	.01	.82	.15	.07
12	.06	--	--	.52	.01	.01	.13	.04	.02
13	.05	--	--	.20	.01	.02	.34	.01	.07
14	.19	--	--	.12	.01	.01	.76	.14	.12
15	.20	--	--	.74	.15	.31	.76	.11	.13
16	.05	--	--	.71	.09	.22	.54	.08	.08
17	.04	--	--	.60	.03	.03	.11	.02	.01
18	.06	--	--	.17	.04	.03	.07	.02	.01
19	.01	--	--	.03	--	--	.03	.01	.01
20	.10	--	--	.08	.01	--	.22	.03	--
21	.04	--	--	.47	.01	.08	.18	.06	--
22	.06	--	--	.11	.04	.01	.25	.08	--
23	.04	--	--	.15	.01	.04	.34	.07	.02
24	.05	--	--	.48	.24	.13	.21	.04	--

*FOM = fine organic material.
**F Min = fine mineral material.

7.4 Movement of Organic Materials

The largest mass of organic material was collected during WY 1981 at box #6, where 3 tonnes/ha of organic material moved into the collection box. Box #6 was located at a very steep site and was treated to the 50% duff level. Only four other plots, 4, 5, 7, and 17, yielded more than 0.5 tonnes/ha/year. Most of the material was coarse organic particles such as cones and twigs (Tables 16-20).

7.5 Movement of Fine Materials

Most of the water quality concerns would come from movement of fine material, rather than from stones and twigs. Table 22 summarizes the amount of fine material collected during the three years.

8 STATISTICAL ANALYSIS

The relationship of slope and duff cover to total erosion was analyzed statistically. An analysis of variance was performed for the data from Water Years 1, 2, and 3 and the sum of the three years. The independent variables were duff cover (high, medium, low) and slope (high, medium, low); the dependent variable was total erosion. The trend in all of the water years was for more total material to be collected from plots with high slopes and or low duff cover. Neither slope nor duff cover effects were significant at the 5% level, as shown below.

Analysis of Variance
Probability of exceeding F values by chance.

	WY 1	WY 2	WY 3	WY 1-3
Duff effect	0.52	0.24	0.63	0.34
Slope effect	0.15	0.27	0.12	0.09

Slope had a larger effect than duff cover, as shown by the lower probabilities.

Large variation is expected in measurements of erosion. The amount of material eroded depended more upon surface conditions on individual erosion plots than upon the major factors of slope and duff cover.

A correlation matrix was also calculated for the different variables (Table 23). There was a high correlation between total eroded material and the different fractions (0.84 to 0.94). Slope was more highly correlated than duff cover with eroded material.

Table 23. Correlation matrix.

Variables	Coarse organic matter	Fine organic matter	Coarse mineral	Fine mineral	Total
Duff class	0.20	0.16	0.28	0.16	0.25
Slope class	0.49	0.50	0.64	0.48	0.62
Coarse OM		0.86	0.70	0.64	0.87
Fine OM			0.76	0.87	0.91
Coarse mineral				0.73	0.94
Fine mineral					0.84

9 CONCLUSIONS

9.1 Evaluation of Erosion Catchment Plots

The catchment boxes performed reasonably well, but there were problems that could be avoided by improvements in the boxes in future studies.

The two main problems were drainage from the boxes and soil/apron contact. The drainage problem could be solved by bending the box floor into a V-groove in the middle of the box. Another possible solution would be to step-angle the box floor. Placement of the drain hole at the middle of the box floor could be another solution.

The soil/apron contact has been a problem with most catchment box surface erosion studies. A piece of flat, heavy gauge sheet metal was laid upslope from the mortar lip allowing material to move into the box at sites where lip/apron contacts were poor. Field checks over time have shown this "patch up" to be successful. Another problem has been pieces of the mortar moving into the box. A solution would be to stain the mortar material with a dye so that the mortar material could be removed from samples with tweezers. This could be very time consuming.

Plots 3, 5 to 9, 11 to 14, and 16 to 19 had no side borders. The amounts of material collected at these plots was not significantly different from plots that had side borders. Future studies on similar terrain need not use side borders.

The study used both wooden side borders and "Jahn" border bags. Future studies can rely on the border bag for a back border.

The "Jahn" border bag is easy to take to the field, requires minimal storage area and takes less time to install in the field than wooden borders. The "Jahn" border bags mold themselves to the land surface and are less apt to be knocked over by large mammals.

Since this study showed no appreciable amounts of suspended sediment, the suspended sediment collectors need not be installed. A microweb nylon net filter could be attached to the drain holes from the boxes. The filter cloth could be weighed before and after collection. Deletion of the suspended sediment collector would save money, time, and site disturbance. For surface erosion studies on severely compacted skid trails or on logging roads, a suspended sediment collector would be necessary for measuring sediment and overland flow.

9.2 Amounts of Erosion

The amounts of eroded material varied considerably among plots. A factor of 100 or more was found between plots with the same treatments. Surface erosion on steep forested ground varies due to inherent variability in land form, timber harvest process, and the degree of soil variability found at the site. In addition, lip and soil separation, small sample size, variation in treatments, amount of plant cover, human error, and presence of rocks, animal trails, and slash also affect results. The plot area is small ; therefore sampling points represent only a small percentage of the area. These factors made it difficult to obtain statistically significant effects of slope and percent duff cover on erosion.

surface erosion rates three to five years after the fuels treatment.

10 FUTURE SURFACE EROSION STUDIES

Recording thermographs and recording rain gauges should be an integral part of any erosion study. A thorough analysis of climatic events and surface erosion rates could then be attempted. This requires personnel at the site every week, with daily visits necessary at times to keep equipment functioning.

Measurements would have to be carried out for five to eight years to answer questions about changes of erosion with time after clear cutting.

Splash collectors should be installed on various treatments. This would allow a study of whether surface aggregates and particles were moved by rainfall impact.

More direct observations are required of erosion after freeze/thaw events to establish whether this is a major mechanism for soil detachment.

Models including various site parameters, perhaps a modified USLE, should be tested at several sites to obtain information by which measurements at a few sites can be used to predict erosion at other sites. Some measurements at a range of sites should be used to check the models.

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12 CONVERSION FACTORS

1 hectare = $10{,}000m^2$ = 2.471 acres.

1 ton (short) = .907 tonne = 2000 pounds

1 tonne = 1000 kg = 1,000,000 grams

1 pound = 453.6 grams

1. Area of plot: $1.52m \times 1.52m = 2.31m^2$

   (a) in hectares:

$$\frac{1 \text{ ha}}{10{,}000m^2} \times \frac{2.31m^2}{\text{plot}} = 0.000231 \frac{\text{ha}}{\text{plot}}$$

   (b) in acres:

$$\frac{0.000231 \text{ ha}}{1 \text{ plot}} \times \frac{2.471 \text{ acres}}{\text{ha}} = 0.0005708 \frac{\text{acres}}{\text{plot}}$$

2. grams/plot to tonne/ha

$$\frac{\text{grams}}{\text{plot}} \times \frac{0.000001 \text{ tonne}}{\text{gram}} \times \frac{1 \text{ plot}}{0.000231 \text{ ha}} = \frac{\text{tons}}{\text{ha}}$$

3. grams/plot to ton/acre

$$\frac{\text{grams}}{\text{plot}} \times \frac{0.0000011 \text{ tons}}{\text{gram}} \times \frac{1 \text{ plot}}{0.0005708 \text{ acre}} \quad \frac{\text{tons}}{\text{acre}}$$

13 LABORATORY METHODS

13.1 Separation of Coarse and Fine Inorganic and Organic Fractions From the Catchment Boxes

A. The samples collected from the boxes were dried for 2 days in an oven at 60°C, and weighed.

B. Each sample was then sieved through a 2.0mm screen to separate coarse and fine fractions.

C. The material on the 2.0mm sieve was lowered into a basin of water. The organic material which floated to the surface was screened off, collected, and recorded as coarse organic. The material remaining on the sieve was recorded as coarse inorganic.

D. Both organic and inorganic coarse fractions were then oven dried for 2 days at 60°C, and weighed.

E. The material passing through the 2.0mm sieve was weighed. A subsample of approximately 4.0g was placed in a crucible, weighed, and then placed in the muffler furnace at 550°C for 6 hours. The sample was cooled and reweighed.

F. The weight of inorganic material less than 2.0mm was calculated as follows:

$$\frac{\text{Weight of material remaining in the crucible}}{\text{Weight of subsample}} = \frac{X}{\text{O.D. weight of material } <2.0\text{mm}}$$

G. The weight of organic material less than 2.0mm was calculated by difference as the weight loss on heating at 550°C.

13.2 Suspended Sediment Analysis

A. A measured volume of suspension (500 ml) was poured into a preweighed beaker.

B. The sample was oven dried and reweighed. The weight of dry matter left as residue was the suspended sediment.

C. Calculation of percent dry matter:

$$\frac{\text{Weight of dry matter}}{\text{Volume of suspension}} \times 100 = \text{Percent dry matter.}$$

Percent dry matter x 10,000 = ppm.

13.3 Measurement of Plant Cover

A point sampling frame was used. The frame is 100cm in length, stands about 50cm off the ground, and has holes approximately 10cm apart. Ten pointed aluminum pins are lowered vertically through the holes on the frame. The kind of cover which the pin touches is recorded.

Ten sets of 10 points were taken on each plot to give a 100 point sampling for each plot. The first set of points was taken 5cm from the side border and every 15cm thereafter.