AN ABSTRACT OF THE THESIS OF

Michael Gordon Johnson for the degree of Master of Science

in Forest Engineering presented on June 9, 1978

Title: INFILTRATION CAPACITIES AND SURFACE ERODIBILITY ASSOCIATED WITH FOREST HARVESTING ACTIVITIES IN THE OREGON CASCADES

Abstract approved: ______________________________

Robert L. Beschta

An infiltration capacity and surface erodibility study was conducted six years after forest harvesting in the Oregon Cascades. A portable rainfall simulator was utilized to obtain field measurements on the Coyote Creek and Hi-15 Watersheds during summer and fall, 1977.

Seasonal variations were found to occur in infiltration capacities and surface erodibility. Infiltration capacities increased by 1.4 times from summer to fall, while surface erodibility characteristics, suspended sediment concentration and sediment yield, decreased from summer to fall. Surface limiting conditions during the summer and soil profile controlled conditions in the fall were hypothesized to explain this seasonal variation.

Nearly all timber harvesting treatments for each study area had statistically equal summer infiltration capacities in comparison with adjacent unlogged areas. In addition, summer surface

erodibility characteristics on treated areas were typically less than those found on undisturbed areas. Only certain skid trails, cable log paths and severely disturbed sites such as tractor windrowed and burned areas had substantially reduced infiltration capacities and increased surface erodibility. However, all areas, including the most severely disturbed, had fall infiltration capacities that exceeded usual and maximum fall precipitation intensities.

Many skid trails and other highly disturbed and compacted areas at Coyote Creek appeared to have greatly recovered since logging six years ago. Freezing/thawing, biological activity, and shrinking and swelling of soils may account for this recovery in infiltration capacities, surface erodibility and soil properties. Skid trails and severely disturbed areas may partially account for peak flow increases and minor sedimentation the first few years after logging. However, data from this study collected six years following timber harvesting do not support the premise that continued increases in peak flows are caused by changes in infiltration capacities, except perhaps for a tractor windrowed and burned area.

Predictive models for infiltration capacity (normally distributed) and surface erodibility characteristics (requiring normalizing transformations) were not found using regression techniques because of large amounts of variance. Variation in estimates of infiltration capacities and surface erodibility for individual plots and between study areas was identified.

Infiltration Capacities and Surface Erodibility Associated with Forest Harvesting Activities in the Oregon Cascades

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed June 1978

Commencement June 1979

ACKNOWLEDGEMENTS

This study was made possible by a grant from the U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon.

I wish to express my appreciation to Dr. Robert Beschta for providing guidance and encouragement during all phases of this project. I also appreciate the interest shown and the help obtained from Dr. Henry Froehlich, Dr. Larry Boersma, Dr. Richard Fredriksen, Michael McCorison and Dr. R. Dennis Harr. Particular thanks to Richard Fredriksen and friends on sharing their delightful, gourmet cooking with me when visiting Coyote Creek.

Special thanks to my loving wife, Susan, for putting up with me throughout this escapade.

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INTRODUCTION

Infiltration represents an important and fundamental hydrologic process on wildland watersheds. Infiltration capacities on most forested watersheds are typically high and exceed precipitation rates, and thus rainfall usually reaches the stream system via subsurface flow (Whipkey, 1965; Hewlett and Hibbert, 1967; Hewlett and Troendle, 1975). As a result, overland flow rarely occurs on undisturbed forested watersheds. This is especially true for the western Cascades of Oregon (Rothacher, Dyrness and Fredriksen, 1967; Dyrness, 1969; Harr, 1976a; 1976b; 1977).

Land use activities associated with forest harvesting often alter the physical condition of the soil surface and may cause a reduction in infiltration capacities. Infiltration capacities can be reduced in several ways. These include compaction, the formation of non-wettable layers as a result of burning and the blocking or plugging of macropores of exposed soils by raindrop impact. Compaction, in particular, can greatly affect macroporosities and infiltration characteristics of soils (Froehlich, 1976).

Forest harvesting activities that sufficiently reduce infiltration capacities can cause overland flow. As a consequence, this water may subsurface flows and may contribute to higher peak flows. Increased peak flows have been noted on several U. S. Forest Service experimental watersheds in southern Oregon (the Coyote Creek Watersheds) following forest harvesting (Fredriksen and Rothacher, 1973; Harr, Fredriksen and Rothacher, 1978). Changes in infiltration capacities on the harvested areas as a result of compaction and/or other soil disturbance may represent a mechanism for these peak flow increases.

Another important by-product of overland flow on harvested watersheds is that onsite erosion rates may be accelerated particularly during high intensity rainfall events (Dunford, 1954; Bethlahmy, 1967). Such soil movements may affect both onsite productivity and sedimentation in streams. Again, the U. S. Forest Service has noted increased sedimentation in streams following forest harvesting on the Coyote Creek Watersheds (Fredriksen and Rothacher, 1973; Harr et al., 1978).

The primary objective of this study was to evaluate the changes in infiltration capacities and surface erodibility associated with forest harvesting practices on the Coyote Creek Watersheds with adjacent unlogged areas being used for control. An additional area, the Hi-15 Experimental Watersheds, was used for comparison. The secondary objective was to relate infiltration capacities and surface erodibility to measurable physical characteristics of the soil.

LITERATURE REVIEW

Infiltration Capacity

Infiltration is the process by which water passes through the soil surface. Infiltration should be distinguished from percolation, which is the movement of water through the soil profile, and should not be confused with hydraulic conductivity, which is the ability of the soil to transmit water. However, in certain instances, infiltration may equal the hydraulic conductivity. Comprehensive reviews of the infiltration process can be found in Parr and Bertrand (1960), Philip (1969), Gray (1970), Hillel (1971), and Satterlund (1972).

Infiltration of water into an unsaturated soil is in response to capillary and gravitational forces (Gray, 1970; Hillel, 1971; Satterlund, 1972). Both forces act in a downward direction. In addition, the capillary force also acts laterally. The capillary force exerted is a function of the shape of its meniscus determined primarily by the capillary radius and the degree of attraction (contact angle) between the water and the soil pore surfaces. Initially, the capillary force controls infiltration but as water penetrates deeper into the soil profile and the soil water content increases, the capillary force becomes progressively less important. When the upper soil profile approaches saturation, gravitational forces which act on individual water molecules predominate and infiltration is practically equal to the saturated hydraulic conductivity, given that the soil profile is homogeneous and structurally stable.

The rate at which water is actually entering the soil at any given time is the infiltration rate. The infiltration capacity is the maximum rate of water entry attained by a soil at a given time (Horton, 1940; Parr and Bertrand, 1960). In general, the infiltration capacity for a given soil is high in the early stages of infiltration but tends to decrease and eventually approach asymptotically a constant rate when the soil is thoroughly wetted which is the final infiltration capacity (Hillel, 1971). For the purpose of this study, infiltration capacity and final infiltration capacity are synonymous.

Numerous empirical equations have been proposed to describe the infiltration process over time. The most well-known equations are by Kostiakov (1932), Horton (1940) and Philip (1957). More recently, some authors have modified older equations and approaches, particularly the Green-Ampt approach, to simulate infiltration (Hillel, 1971; Morel-Seytoux, 1976). Since all empirical equations are not entirely based upon basic physical relationships, they cannot be expected to apply universally with satisfactory results (Gifford, 1976).

Numerous factors have been found to affect the infiltration capacity of a soil (Lewis and Powers, 1938; Dortignac, 1951; Packer, 1951; Parr and Bertrand, 1960; Dortignac and Love, 1961; Johnson, 1963;

1969; Wischmeier and Mannering, 1969; Hatchell, Ralston and Foil, 1970; Meeuwig, 1970a; 1971; DeBano and Rice, 1973; Blackburn, 1975; Dixon, 1975; Dyrness, 1976; Dohrenwend, 1977). Soil factors include texture, structure, total porosity, capillary and non-capillary porosity, antecedent soil moisture content, bulk density, organic matter content, biological activity, soil permeability, thickness of individual soil horizons and any restricting layer, the amount and kind of shrinking and swelling clays, the depth to a restricting layer, the total soil depth and the parent material. Vegetation-related factors include vegetation, humus and litter mass, density and percent cover composition, vegetation height and vigor, vegetation types present, litter thickness, and the degree and depth of rooting. Surface factors include the percent protective cover composition of rock, the size and percent areal extent of bare openings, soil surface roughness, slope shape, percent slope, the degree of surface disturbance, the degree and affected depths of compaction, and the degree, depth, and continuity of non-wettable soils. Water-related and other factors are rainfall intensity and duration, raindrop size, water temperature and viscosity, quality of infiltrating water, amount of entrapped and displaced soil air, soil frost and aspect.

Surface Erodibility

The principal causes of surface erosion are surface runoff and overland flow that occur when the infiltration capacity of a given site has been exceeded by precipitation rates. Although the same factors determining infiltration also affect surface erodibility, exposure of bare soil, soil surface compaction and severe fire are primary mechanisms influencing erosion.

When soil surfaces are unprotected from raindrop impact, soil particles are detached and soil structure is broken down and compacted by raindrop slash (Lowdermilk, 1930; Ekern, 1950; McIntyre, 1958; Dohrenwend, 1977). Splashed soil particles move into the surface water, clog large soil pores and act to seal the soil surface. Thus, infiltration capacities are reduced, runoff created and substantial soil erosion may result.

Soil surface compaction, whether by machine or animals, can reduce infiltration capacities via decreased total and non-capillary pore space, produce runoff and result in surface erosion (Froehlich, 1974, 1976). Surface erodibility can be extremely high especially when compaction is combined with litter and vegetation removal.

Fire can consume organic components of the forest floor and leave the soil surface exposed to raindrop impact. Furthermore, infiltration can be reduced by ash plugging large soil pores (Zwoliniski, 1971). Severe fire in particular may induce a water-repellent condition in the soil surface or immediate subsurface. Although hydrophobic substances may be released by vegetation and the decomposition of cause litter and soil organic matter to release unknown hydrophobic compounds and have resulting vapors move into the soil in response to temperature gradients (DeBano, Mann and Hamilton, 1970; Debano and Rice, 1973). Infiltration capacities are then decreased and substantial runoff and erosion may occur.

Non-Logging Related Investigations

Hundreds of infiltration studies have been reported for non-timber harvesting situations associated with rangeland and forest environments, especially in the Great Basin regions of the U. S. These studies have evaluated infiltration capacities and surface erodibility in relation to environmental characteristics and land use activities. Some of the more important studies are discussed below. Of these studies, nearly all were conducted with rainfall simulators.

In comparison with undisturbed infiltration capacities (5.4 cm/hr) of the Missouri Ozark region, Arend (1941) discovered infiltration capacities were reduced by 38% following annual woods burning (3.4 cm/hr) and by 59% following grazing (2.2 cm/hr). The mechanical removal of the litter layers reduced infiltration by 18% (4.9 cm/hr) relative to undisturbed areas (6.0 cm/hr). In the same region, Auten (1934) earlier found that the undisturbed forest soils had an infiltration capacity six to nine times greater than that for burned forest soils.

On grass rangeland having a loose granitic soil and 30 to 60% slopes in southwestern Idaho, infiltrometer tests have shown that a ground cover of 70% is required for controlling runoff and surface erosion under simulated storm intensities of 9.1 cm/hr (Packer, 1951). Ground cover density and size of bare openings were the most influential site characteristics affecting overland flow and soil erosion, respectively.

Dortignac and Love (1961) studied infiltration capacities of rangelands and open ponderosa pine areas on soils derived from granitic alluvium in Colorado. They discovered infiltration capacities of 6.4, 4.5 and 2.9 cm/hr for pine, pine-grass and grassland areas, respectively. These areas did not deviate significantly in bulk densities but the pine area had the greatest percentage of macropore space (33%) in comparison with the other two areas (27%).

In open forest/range conditions in central Utah, Meeuwig (1965; 1970a; 1970b) found that infiltration was normally distributed and was influenced primarily by soil bulk density and non-capillary porosity, and secondarily by the amount of protective cover via vegetation, litter and stones. Surface erodibility, with and without a log normal transformation, was influenced primarily by the proportion of soil surface protected from direct raindrop impact and secondarily by soil bulk density. Meeuwig noted that the influence of cover is greatest at high bulk density and least at low bulk density. If protective cover exceeded

85%, surface erosion was small, irrespective of bulk density. Litter weight, slope and soil organic matter helped account for some of the variance in the logarithm of surface erosion.

Meeuwig (1969) also studied infiltration and erosion on a granitic subalpine ridge in northcentral Idaho during summer conditions and again found soil erosion closely correlated with the amount of exposed soil. Infiltration capacity was not highly correlated with any single factor, but organic matter content, clay content and macroporosity at 20 cm tension together were good predictors of infiltration ($R^2 = .73$).

In southern Utah, infiltration and erodibility data from small plot studies utilizing high intensity simulated rainfall indicated that areas cleared of pinyon-juniper vegetation and seeded to grass showed no consistent increase or decrease in sediment yields or infiltration capacities (Williams, Gifford and Cotharp, 1969). Therefore, infiltration and erosion were not particularly affected by the treatment. Infiltration capacities were found to range from about 3.6 to 6.6 cm/hr for both treated and untreated areas.

Meeuwig (1971) determined infiltration capacities for granitic soils with varying degrees of water repellency in western Nevada under open Jeffrey pine forests. He characterized different soil profile wetting patterns with infiltration. Eight general wetting patterns were discovered and infiltration capacities ranged from 12.0 to 0.0 cm/hr with

Gifford (1972), in southern Idaho on gently rolling topography with basalt derived soils, reported a trend toward lower infiltration capacities following the plowing and seeding of a big sagebrush site. He noted especially during the second year following treatment that infiltration capacities decreased from 4.4 cm/hr in the spring to 3.5 cm/hr in the summer to 2.6 cm/hr in the fall. These changes probably represented normal seasonal fluctuations and the influence of land management. Gifford (1972) further found that the ability to predict infiltration using cover characteristics in multiple regression equations varied with time, both within a given rainfall event and on a seasonal basis.

Blackburn (1975) studied infiltration capacities and sediment production of 28 plant communities and associated soils in central and eastern Nevada. Infiltration capacities and erosion rates varied considerably both within and between communities. He found that infiltration was directly related to organic matter, sand sized particles, surface horizon thickness, plant and litter cover, slope and surface roughness. Furthermore, infiltration was inversely related to bulk density, silt and clay sized particles, moisture content, bare ground and sediment production. A vesicular surface horizon near field capacity was found produce more sediment than initially dry surface soils.

Campbell, Baker, Ffolliott, Larson and Avery (1977) investiponderosa pine forest in northcentral Arizona. They obtained infiltration data using Meeuwig's (1971) infiltrometer. They discovered infiltration capacities of 6.9, 3.7 and 2.6 cm/hr for unburned, moderately burned and severely burned areas, respectively. The reduced infiltration capacities caused soils to erode and increase water yields. Runoff was eight times greater on severely burned than on unburned areas during heavy autumn rains. The following year after the wildfire, water yields from the burned watersheds were 3.1 to 3.8 times greater than the unburned. These differences decreased substantially in subsequent years.

Balci (1968) studied soils sampled under Douglas-fir stands located on similar parent materials in eastern and western Washington. Laboratory simulated rainfall showed that eastern forest soils were 45% more erodible than western Washington soils. The differences in soil properties were attributed to climatic influences on litter production and litter decomposition and incorporation into the soil.

Soil wettability characteristics were investigated for six years following a wildfire in the High Cascades of Oregon on volcanic ash-cinder-pumice derived soils (Dyrness, 1976). Infiltration capacities for unburned areas were three times greater than that for soils in burned areas caused by water repellency in burned soils. The recovery of infiltration capacities was not pronounced five to six years after the

Mattison (1978) studied the sediment potentials of various ecological land units in central Oregon during two summers. In non-forest areas a high natural variability in sediment production tended to override any differences caused by management treatment. However, significant differences were associated with soil or ecological condition differences.

Logging Related Investigations

Very few studies have examined infiltration capacities and subsequent surface erodibility related to timber harvesting activities. This is particularly true for the Pacific Northwest conditions. Here, slopes of 20 to 80% and portability of equipment are major drawbacks for infiltration studies.

From the Southeast and under loblolly pine forests, Hatchell, Ralston and Foil (1970) indicated that infiltration capacities were reduced by 78, 89 and 90% for secondary skid trails, primary skid trails and log decks, respectively, when compared to undisturbed areas. Although bulk densities ranged from .92 to 1.14 gm/cm^3 for the surface compaction treatments, they found compacted forest soils slow to recover from severe disturbance.

In the pine region of California, Munns (1947) recognized that logging can damage infiltration through soil compaction. Here, tractor rails covered 25 to 40% of the logged areas and reduced infiltration capacities by 75%.

In southwestern Washington, Steinbrenner (1955) collected soil samples from skid trails occupying 26% of a tractor logged area for a laboratory investigation of infiltration. He found that under dry, summer soil conditions, four trips with a tractor over the same site reduced the infiltration capacity of that site by 80% and reduced the macroporosity by half. One trip with a tractor over a site under moist soil conditions could be equated with four trips when the soil was dry.

In a similar study in Washington, certain physical properties of an undisturbed area, a tractor cutover unit and skid trails were compared (Steinbrenner and Gessel, 1955). The tractor yarded cutover area had a 35% decrease in permeability, a 2.4% increase in bulk density and a 10% decrease in macroporosity in comparison with the control. The skid trails showed a 93% loss in permeability, a 15% increase in bulk density and a 53% loss in macropore space.

In the western Cascades of Oregon, Tarrant (1956) studied the effect of slash burning on permeability, macroporosity at 60 cm tension and bulk density of soils from undisturbed, lightly burned and severely burned areas. Severe burning was found to reduce permeability markedly, while light burning did not seriously alter the soil. He also found bulk densities unchanged for all treatments, while macropore

Tackle (1962) examined infiltration capacities on undisturbed, scarified, broadcast burned and tractor skid trail areas in northern Montana on soils derived from shale. His five years of record indicated that immediate and variable reductions in infiltration capacities occurred on scarified, broadcast burned and skid trail surfaces. He noted that improvement in infiltration can be expected within a few years except on soil surfaces that have been excessively compacted.

A high intensity simulated rainfall was applied to logged and unlogged plots with 47 to 74% slope in central Idaho on granitic soils and two different exposures (Bethlahmy, 1967). Infiltration capacities of 4.8 and 8.4 cm/hr were found for logged and unlogged areas on the southwest exposure, respectively. For the northeast exposure, infiltration capacities of 11.2 and 10.2 cm/hr were determined for logged and unlogged sites, respectively. After performing a log normal transformation on the erodibility data, Bethlahmy (1967) found surface erosion on the southwestern exposure 18 and 14 times greater than on the northeastern exposure for logged and unlogged areas, respectively.

In western Montana on 20 to 35% slopes with soils formed on sedimentary parent material under western larch and Douglas-fir, Packer and Williams (1976) found that soil erosion of logged and burned areas was related more to the amount of total protective cover and the magnitude of climatic events than to other measured site factors. Prescribed burning was

... effects on hydrologic and soil stability

This impairment of watershed conditions and increases of runoff and erosion were noted to be temporary with recovery occurring within a few years.

Mattison (1978), in central Oregon's ponderosa pine and Douglas-fir covered topography, discovered tractor logging to cause significant increases in sediment loss. Surface erosion from undisturbed sites ranged from 0 to 73 kg/ha, while erosion from a tractor yarded area ranged from 218 to 2995 kg/ha and erosion from a burned slash pile ranged from 85 to 19000 kg/ha.

Based on the literature reviewed, some conclusions can be made. Infiltration capacities are highly variable and affected by a large number of factors. In particular, compaction and severe burning can greatly decrease infiltration capacities. Surface erodibility data are also highly variable, and as measured by rainfall simulators, are often characterized by skewed distributions. The amount of exposed mineral soil is the primary factor influencing surface erosion.

DESCRIPTION OF THE STUDY AREAS

Location

Two study areas, the Coyote Creek Watersheds and the Hi-15 Watersheds, were utilized for field measurements. The Coyote Creek Watersheds are located in the South Umpqua Experimental Forest approximately 65 km southeast of Roseburg, Oregon, at the head of Coyote Creek, a tributary of the South Umpqua River (Figure 1). Four contiguous, experimental watersheds, ranging in size from 48.6 to 69.2 ha, encompass this study area. The watersheds have well-defined boundaries except in several small areas and have an east northeasterly aspect ranging from east southeast for Watershed 1 to north for Watershed 4. Elevation varies from 730 to 1065 m above mean sea level.

The Hi-15 Watersheds include three experimental watersheds located in the H. J. Andrews Experimental Forest about 72 km east of Eugene, Oregon (Figure 2). The watersheds range in size from 12.8 to 22.0 ha and have a east southeasterly aspect. Elevation of the watersheds ranges from 855 to 1050 m above mean sea level.

Climate

The climate of the two study areas is influenced primarily by the

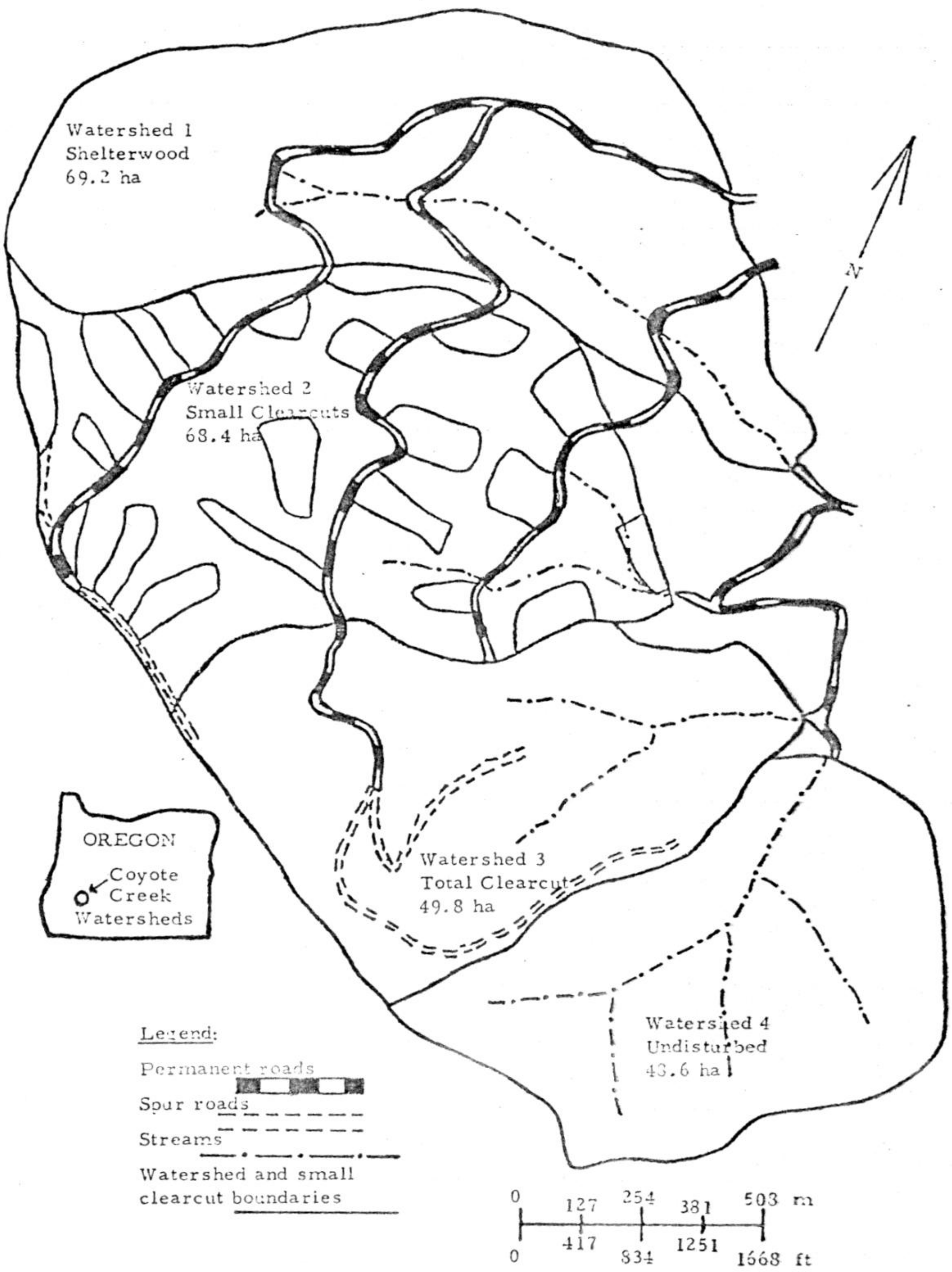

Figure 1. Coyote Creek Watersheds, South Umpqua Experimental Forest, Oregon.

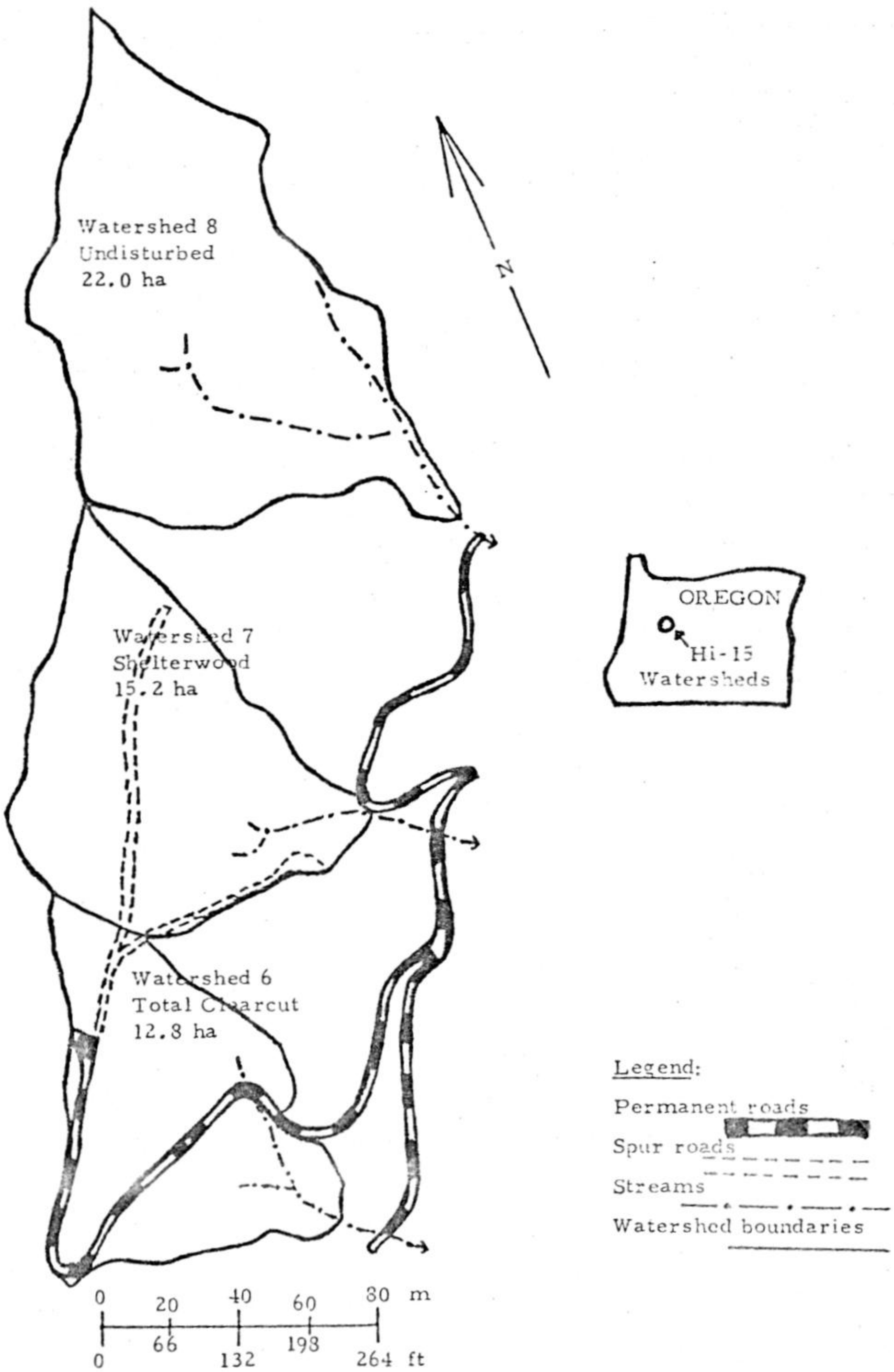

Figure 2. Hi-15 Watersheds, H.J. Andrews Experimental Forest, Oregon.

relatively mild winters and dry, warm summers. Occasionally, the temperature reaches extreme lows of -18°C in the winter and highs of 38°C for the summer. The mean January and July temperatures for the Coyote Creek and Hi-15 Watersheds are approximately 1.1°C and 17.3°C, respectively (Rothacher, Dyrness and Fredriksen, 1967; Fredriksen and Rothacher, 1973).

The mean annual precipitation for the Coyote Creek and Hi-15 Watersheds is 123 cm and 234 cm, respectively. Approximately 80 to 87% of the annual precipitation falls in the October to March/April period for both study areas (Rothacher et al., 1967; Harr, Fredriksen and Rothacher, 1978). Most winter storms are of long duration, low to moderate intensity rainfall and are associated with low pressure areas originating over the ocean. Typical winter storms consist of two to three days of low intensity rainfall and several additional days of intermittent rainy periods. Winter precipitation intensities average about 0.3 cm/hr and may reach intensities of 0.6 to 1.3 cm/hr (Rothacher et al., 1967).[1]

Although most precipitation occurs as rain, light to moderate accumulations of snow, particularly at higher elevations, are common to both areas. At Coyote Creek, an occasional snowpack may remain for a month, but in most years snow usually melts within one to two

[1]Personal communication, R. Fredriksen, 1978, Pacific Northwest Experiment Station, Corvallis, Oregon.

weeks and melting is associated with prolonged rainfall (Harr et al., 1978). For the Hi-15 Watersheds, snowpacks commonly remain one to three months.

Summer precipitation is low for both study areas but irregular, high intensity, short duration storms do occur on the Coyote Creek Watersheds. Richlen (1963) calculated that rainfall intensities of 4.1 cm/hr can be expected on the South Umpqua Forest for periods of 15 minutes with a 25 year recurrence interval. From precipitation data on Watershed 2 and during the late spring of 1977, a storm lasting five o ten minutes had an intensity of 8.0 cm/hr.[2]

Geology and Soils

The Coyote Creek Watersheds are underlain by the Little Butte Formation laid down during the upper Oligocene to lower Miocene Epochs (Kays, 1970). The deeply weathered volcaniclastic materials consist of rhyodacitic pyroclastic rocks of welded and nonwelded ash-flow tuffs with basalt common on ridges (Kays, 1970). Although many smooth and uneven side slopes are present, the latter includes benches and poorly developed external drainage patterns that provide evidence of past and present mass erosion processes (Swanston and Swanson, 976; Swanson and Swanston, 1977). Slopes range from 20 to 80% for Coyote Creek.

R. Fredriksen, 1978, Pacific Northwest

The four Coyote Creek experimental watersheds contain a mix-ıre of soils derived from basalt and red and green breccias, agglo-ıerates and tuffs with scattered rhyolitic breccia and agglomerate ·oils (Appendix A). Basalt soils, Freezener and Coyota, dominate 'atershed 1 with scattered Vena soil, rhyolite derived, also occurring. he Freezener soil is a moderately permeable, well-drained loam with clay loam subsoil. The Coyota soil is similar to Freezener, but is hallower and gravelly. Vena is a shallow, moderately rapid perme-ble, well-drained gravelly loam.

Watershed 2 is comprised of mostly red breccias and agglomer-te(rived soils, Dumont and Straight, with some Freezener and oyota. The Dumont soil is a moderately permeable, moderate well-rained silt loam with a clay loam/clay subsoil. Straight is a shallow, ell-drained gravelly loam with moderately rapid permeability.

Green breccia, agglomerate and tuff derived soils, Deatman, ives and Fives variant, occupy most of Watershed 3 with areas of reezener and Dumont. The Deatman soil is a shallow, moderate to apidly permeable, well-drained gravelly loam with a gravelly clay am subsoil. Fives is a moderately permeable, well-drained loam ith a clay loam subsoil. The Fives variant soil is a poorly-drained ay loam with slow permeability and a clay subsoil.

Vatershed 4 is dominated by Dumont and Straight soils with some een breccia soils also present.

The Sardine Formation from the middle to upper Miocene Epoch consists of andesitic and basaltic lava flows (Cascade Andesites) and underlies the Hi-15 Watersheds (Peck, Griggs, Schlicker, Wells and Dole, 1964; Swanson and James, 1975). During the late Pleistocene Epoch, mountain glaciation sculptured portions of this area and left glacial deposits of basic igneous materials (Stephens, 1964). Mostly smooth and uneven mountain side slopes are present on the Hi-15 area with some benchy areas indicative of past mass movements (Swanson and James, 1975). Slope gradients of 20 to 70% are typical of this area.

Two andesite derived soil series cover most of the Hi-15 Watersheds (Appendix A). The Carpenter soil is a moderately permeable, well-drained gravelly sandy loam with a gravelly loam subsoil. Blue River is a moderately permeable, well-drained gravelly loam.

Vegetation

The Coyote Creek study area lies within the mixed conifer zone (Minore, 1972; Franklin and Dyrness, 1973; Minore, Carkin and Fredriksen, 1977). Here, Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) of the more mesic regions to the north and west is the dominant species and is intermingled with ponderosa pine (Pinus ponderosa Laws.), sugar pine (Pinus lambertiana Dougl.) and incense cedar (Libocedrus decurreus Torr.) characteristic of warmer, drier sites. Within the Coyote Creek Watersheds, other habitats contain western hemlock (Tsuga heterophylla (Raf.) Sarg.), grand fir (Abies grandis (Dougl.) Lindl.), big leaf maple (Acer macrophyllum Pursh) and Pacific madrone (Arbutus menziesii Pursh). Prior to timber harvesting, both age class and density of the overstory varied considerably between and within watersheds (Fredriksen and Rothacher, 1973).

Understory vegetation consist primarily of salal (Gaultheria shallon Pursh.), sword fern (Polystichum munitum (Kaulf.) Presl.), bear grass (Xerophyllum tenax (Pursh) Nutt.), long-leaved Oregon grape (Berberis nervosa Pursh.), kinnikinnick (Arctostaphylos uva-ursi (L.) Spreng.), snowberry (Symphoricarpos albus (L.) Blake), chiquapin (Castanopsis chrysophylla (Dougl.) A. DC.), Hooker's fairy-bells (Disporum hookeri (Torr.) Nicholson), Oregon bedstraw (Galium oreganum Britt.), false Solomon's seal (Smilacina racemosa (Bak.) Nutt.) and white-veined wintergreen (Pyrola picta J. E. Sm.). Vine maple (Acer circinatum Pursh.) is commonly found along the streams and rhododendron (Rhododendron macrophyllum G. Don.) is scattered sparcely throughout the area. Cutover, thinned or bordering undisturbed areas contain Oregon grape (Berberis aquifolium Pursh.), snow-brush (Ceanothus velutinus Dougl. ex Hook.), evergreen blackberry (Rubus laciniatus Wild.), little wild rose (Rosa gymnocarpa Nutt. in T. & G.) and grasses (Graminae family).

The Hi-15 area is in the western hemlock habitat zone (Rothacher, et al. 1967; Franklin and Dyrness, 1973). Overstory tree species are old-growth Douglas-fir, approximately 150 years old, intermixed with western hemlock and western red cedar (Thuja plicata Donn.). Noble fir (Abies procera Rchd.), silver fir (Abies amabilis (Dougl.) Forbes) and Pacific yew (Taxus brevifolia Nutt.) also occur in this area. Understory vegetation consist predominantly of rhododendron, long-leaved Oregon grape, bear grass, red huckleberry (Vaccinium parvifolium Smith), vine maple, Pacific dogwood (Cornus nuttallii Audubon), chinquapin and vanilla leaf (Achlys triphylla (Smith) DC.). Oregon grape, evergreen blackberry, snowbrush, grasses, kinnikinnick and pine-mat manzanita (Arctostaphylos nevadensis Gray) occupy cutover, thinned and bordering undisturbed areas.

Watershed Treatments

On Coyote Creek, a permanent road system was constructed to provide access for logging during the summer of 1970. By October 1, 1970, road cutbanks and fillslopes were seeded, mulched, and fertilized and all road construction operations completed.

Several timber harvesting treatments were tested on the Coyote Creek Watersheds. Timber harvesting began in May, 1971, and all logging was completed by late September of the same year.

In Watershed 1, approximately 1.8 million board feet of timber or 50% of the total basal area were removed through light shelterwood tered throughout the watershed, were constructed to tractor land- and were scarified and water-barred after use. Cull logs and tops e left where they fell. Percentages of soil disturbance for Water- d 1 are given in Table 1.

Watershed 2 contains 20 small clearcut patches ranging from 0.7 1.4 ha in size and comprising 30% of the total area. Slightly over e million board feet of timber were harvested from this watershed. lf of the clearcut patches were logged by a D7 tractor, while the er half, those on steeper slopes, were logged by a mobile, high- ad cable system. In the tractor logged units, all slash was piled by actors with a brush blade and later burned. Cull logs and slash were o burned in the high-lead logged units. Table 1 provides soil dis- bance percentages for both tractor and cable logged portions of tershed 2. The leave-strips between the patch-cuts, 70% of Water- d 2, were unlogged and undisturbed.

Watershed 3 was clearcut, with 5.4 million board feet of timber ving been removed. After spur roads were constructed, 77% of the tershed was clean-logged with a high-lead cable system. To be an-logged, all material over 20 cm in diameter or 2.4 m in length s yarded to a high-lead landing. In the remaining area (23%), most- he lower portions of Watershed 3, D6 and D7 tractors were used to d logs and then pile slash in windows. Both windrowed slash piles ... areas were burned, along with slash piles on able 1 Percent soil disturbance on the Coyote Creek Watersheds following several methods of logging and slash treatment (after Harr, Fredriksen and Rothacher, 1978).

isturbance Category	Watershed 1 (Shelterwood)[a]	Watershed 2 (Small patch-cuts)[a]			Watershed 3 (Clearcut)[a]		
	Tractor	Tractor	Cable	Total[b]	Tractor	Cable	Total[b]
ndisturbed	52.3	5.4	42.3	22.0	10.8	44.1	34.4
lightly Disturbed	17.1	24.9	39.4	28.2	25.7	29.1	28.2
eeply Disturbed	9.0	30.0	8.6	20.3	25.2	8.2	13.2
ompacted	12.7	26.4	5.6	17.1	27.3	6.8	12.9
Non-soil Areas	9.0	13.3	4.1	9.2	10.9	11.8	11.3
Bare Soil	10.6	35.1	14.8	26.6	33.8	9.4	16.6
Totals[c]	110.7	135.1	114.8	123.4	133.7	109.4	116.6

[a] "Tractor" and "Cable" refer to methods of yarding and slash disposal.
[b] Total figures were obtained by weighting tractor and cable percentages by the percent of area logged by each method.
[c] Columns do not total 100% because disturbed areas may also be compacted or bare.

tershed 2, two years after harvesting had been completed. For the ctor windrowed slash and cable logged areas of Watershed 3, per- at soil disturbance is in Table 1.

No cutting or other activities have taken place on Watershed 4 aving it an undisturbed control watershed.

In March, 1970, before road construction or logging, Watershed was fertilized with 224 kg of urea per ha applied aerially to deter- ine the amounts and forms of nitrogen entering streams (Moore, 1970; redriksen and Rothacher, 1973; Fredriksen, 1977). Also, Water- hed 3, many of the patch clearcuts of Watershed 2 and certain areas f Watershed 1 were stocked with two-year old Douglas-fir during the pring of 1972 with varying degrees of establishment and survival suc- ess (Fredriksen and Rothacher, 1973). During a 1976 seedling sur- ey, stocking was considered adequate on all logged watersheds Minore, Carkin and Fredriksen, 1977).

On the Hi-15 experimental watersheds, a system of permanent oads was constructed during the spring of 1974 to provide logging ac- ess. Several timber harvesting treatments were utilized with logging ccurring during the summer of 1974 and completed by early Septem- er.

Watershed 6, containing a basal area of 400 square feet, was to- ally clearcut.[3] Approximately 90% of the area was logged by a

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nication. R. Fredriksen, 1978, Pacific Northwest portable, high-lead cable system. The remaining ridge-top area was tractor logged with D4 and D7 tractors. Spur roads were constructed to facilitate tractor and cable yarding. In the tractor yarded area, slash was piled and then burned, spring, 1975. Cull logs and slash found throughout the cable clearcut area were also burned. The relative amounts of soil disturbance and compaction are shown in Table 2.

In Watershed 7, timber was removed through shelterwood harvesting. The lower one-third of the total area was high-lead cable logged with the remainder being tractor logged with D4 and D6 tractors. All cull logs and tops were left where they fell with one exception. Near the bottom of the cable unit a slash pile was established and later burned. Spur roads and skid trails were scattered throughout the tractor area, while one spur road was constructed along a ridge to the cable landing area. Table 2 provides soil disturbance and compaction percentages for the tractor and cable treatments of Watershed 7.

Watershed 8 was unlogged and is the undisturbed control watershed. Small areas between and adjacent to Watershed 6 and 7 have had no activity and are undisturbed.

able 2. Percent soil disturbance and compaction on the Hi-15 Watersheds following several methods of timber harvesting.[a]

Disturbance Category[b]	Watershed 6 (Clearcut)[c]			Watershed 7 (Shelterwood)[c]		
	Tractor	Cable	Total[d]	Tractor	Cable	Total[d]
Undisturbed	47	64	62	38	69	48
Disturbed						
Light	11	6	7	4	3	4
Medium	15	11	12	24	16	21
Heavy	28	9	12	30	3	21
Compacted						
Light	4	4	4	6	6	6
Medium	21	12	13	27	14	23
Heavy	29	10	13	25	2	17
Totals[e]	155	116	123	154	113	140

[a] Personal communication, M. McCorison, 1978, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon.

[b] The terminology used is a modified adaptation of the Dyrness (1965) surface classification system.

[c] "Tractor" and "Cable" refer to yarding methods.

[d] Total values were obtained by weighting tractor and cable percentages by the percent of area logged by each method.

[e] Columns do not total 100% because disturbed areas may also be compacted.

METHODS AND MATERIALS

Field Methods

ımpling Procedure

Similar field procedures were followed at both the Coyote Creek nd Hi-15 Watersheds. On Coyote Creek, field investigation began in :arly July, 1977, and was finished by early September. Field work on :he Hi-15 area was accomplished within early to late September. Because of the documented increased peak flows, sedimentation and mass movement on the Coyote Creek Watersheds (Fredriksen and Rothacher, 1973; Swanston and Swanson, 1976; Harr et al., 1978), they were more intensely sampled than the Hi-15 Watersheds. The Hi-15 Watershed treatments were used for comparison and as replication in the final statistical analysis.

Sampling was stratified by treatments--shelterwood harvested, cable logged, tractor logged or windrowed slash and undisturbed. Within each treatment, sampling locations were randomly located within the constraints of accessibility as determined by time and the magnitude of the study.

After sampling locations were randomly located on aerial photographs, the sampling sites were found on the ground with a detailed topographic map. If a site fell upon adverse terrain (stumps, rock outcrops, down timber, etc.), it was moved to the first favorable terrain site closer to the road. Site location distances from the road varied from about 15 to 240 m as a result of the variable terrain and slope conditions.

At each sampling location, two infiltration plots were established. Infiltration capacities and soil erodibility were measured on each plot. Detailed site information was obtained for only one of the plots, leaving the paired plot relatively undisturbed except for the infiltration and erodibility determination. The paired plot location is described later.

This paired plot approach has the advantages of remeasurement of infiltration and other site data during the fall months when soil moisture levels are high and of providing an estimate of variance for a given site. For Coyote Creek, fall remeasurement of infiltration capacities, soil erodibility and other data took place during mid-November, while fall data collection on the Hi-15 Watersheds occurred in early December.

To adequately define treatment effects at Coyote Creek, 16 sampling locations, each with a pair of infiltration plots, were randomly established within each treatment, with all treatments having an equal number of samples (Figure 3). The number of sampling locations is based upon preliminary infiltration data collected in late June, 1977, on the study watersheds and statistical advisement.[4]

[4]Personal communication, Dr. Roger Peterson, June, 1977, Statistics [illegible] University, Corvallis, Oregon.

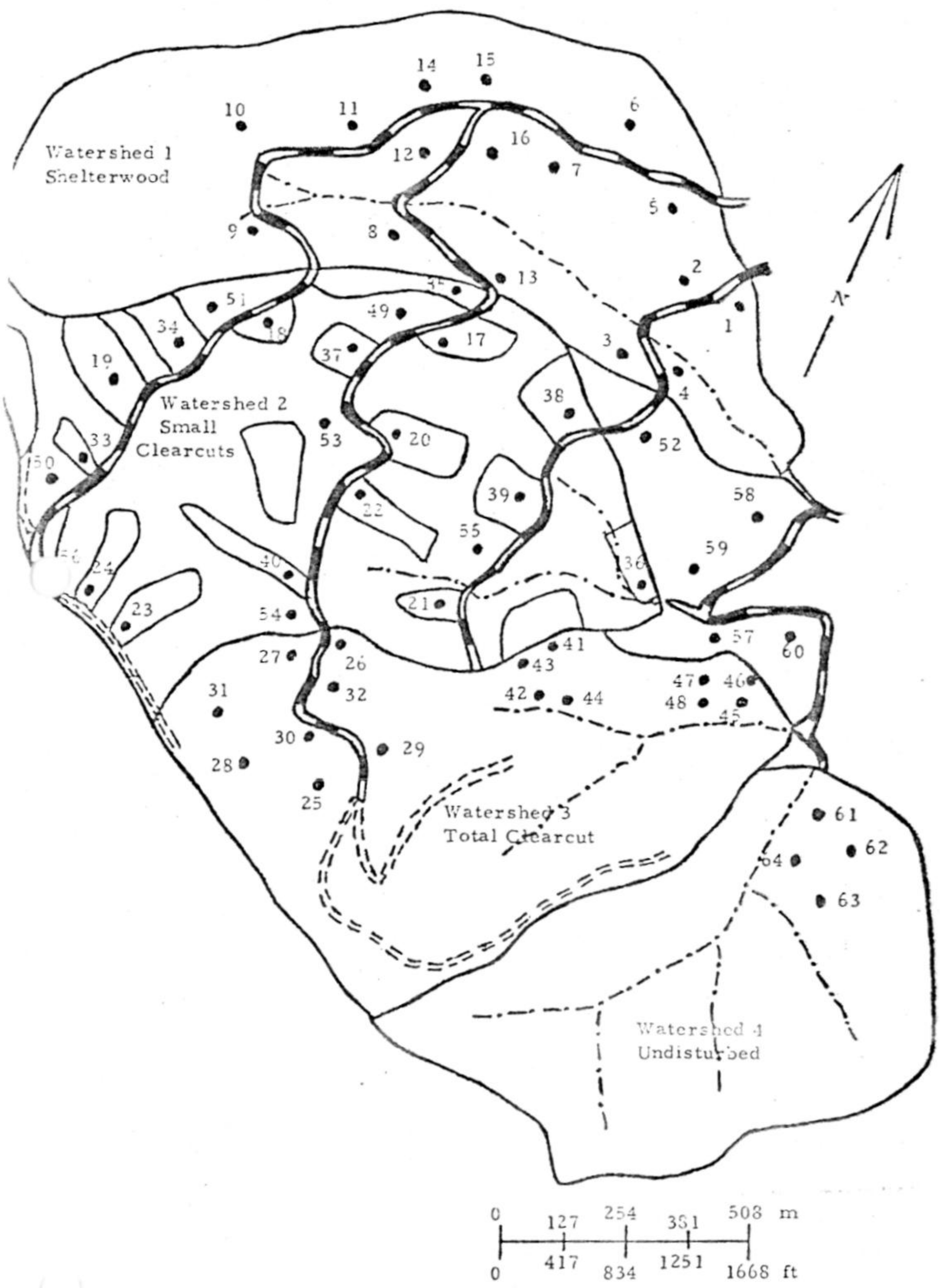

Figure 3. Sampling locations on the Coyote Creek Watersheds, South Umpqua Experimental Forest, Oregon.

On Coyote Creek, all shelterwood samples were taken within Watershed 1. From Watershed 2, 50% of all cable logged, tractor logged or windrowed slash and undisturbed samples were collected. The remaining 50% of all cable harvested and tractor windrowed slash samples were collected from Watershed 3. On Watershed 4 and outside the lower perimeters of Watersheds 2 and 3, the remaining undisturbed samples were taken.

Nearly all treatments on the Hi-15 Watersheds had an equal number of samples, three pairs, except for the tractor logged area on Watershed 6 which provided confounding and inconsistent results (Figure 4). The undisturbed samples were taken from outside the lower perimeters of all three experimental watersheds because of inaccessibility to Watershed 8. The total number of sampling locations was 13 for the Hi-15 Watersheds.

Site Information

At each sampling site, percent slope, aspect, landform position and datewere recorded. Percent slope was determined by using a clinometer, while aspect was located using a hand compass. Landform positions were identified, consistent with the terminology used in the U.S. Forest Service Pilot Soil Survey (Richlen, Arnold and Stephens, 1976).

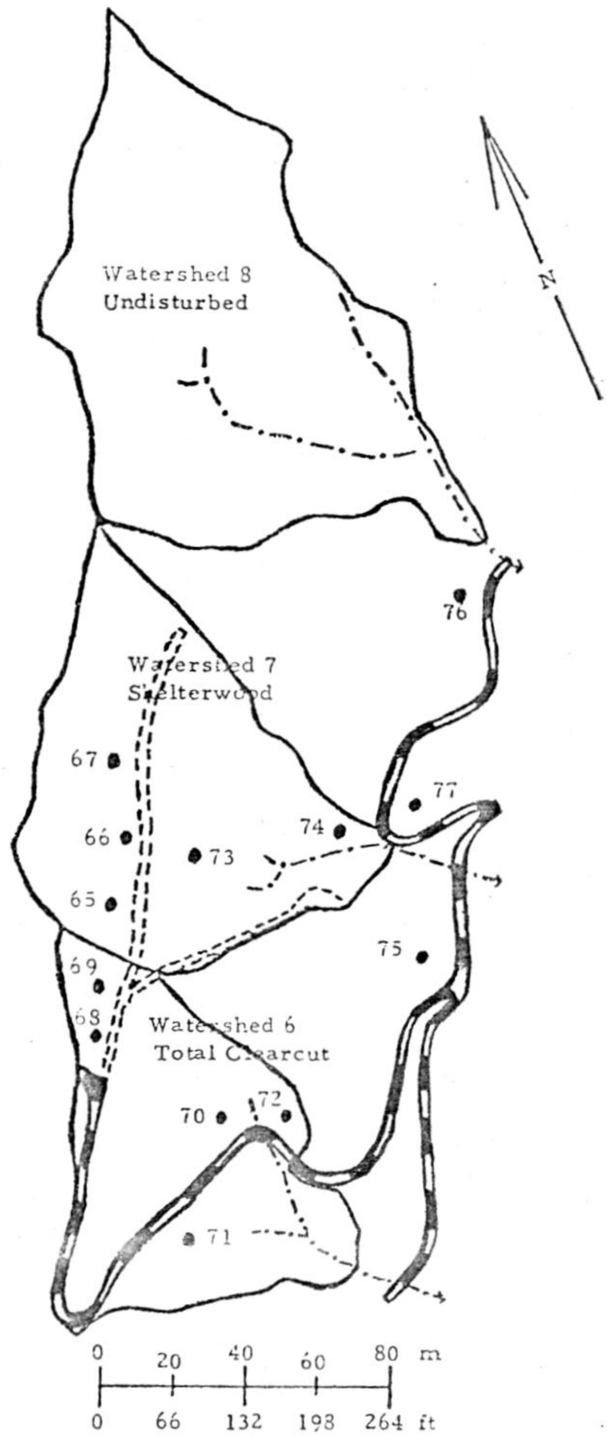

Figure 4. Sampling locations on the Hi-15 Watersheds, H. J. Andrews Experimental Forest, Oregon.

experience, percent cover was estimated for the entire sample site without the use of the frame.

Plant species were identified, if possible, or categorized--grass, shrub, seedling, etc. The average depth and the constituents of the litter layer were recorded. The square frame was then removed prior to the commencement of the infiltration determination.

Infiltration and Erodibility Investigation

Infiltration capacities and erodibility were determined with an infiltrometer developed by the school of Forestry, Oregon State University (Froehlich and Hess, 1976). This infiltrometer is similar to that used by Meeuwig (1971) which in turn had been based on a raindrop producing unit developed by Chow and Harbaugh (1965). The O. S. U. infiltrometer differs from Meeuwig's design in the leg construction, the added water filter, and the suspended water container (Figure 5). Munn and Huntington (1976) provided estimates for raindrop velocity and kinetic energy per drop and rainfall volume for the infiltrometer.

The O. S. U. infiltrometer is a rainfall simulator which applies water uniformly to an area of 3122. 6 cm^2 at a controlled rate (Figure 5). Runoff from the plot is caught by a collector at the downhill edge of the application area. Infiltration capacities are determined from measured rates of application and volume of runoff (Appendix B).

The treatment and class (undisturbed vs. disturbed--scarified, compacted, disturbed, fire affected or a combination of these factors) were identified at each sampling location. Since scarification of spur roads and skid trails took place six years ago, no evidence of any scarification was found when sample plot locations fell on skid trails.

The degree of compaction was subjectively identified as light, moderate or heavy. Light compaction indicated possibly one or two passes of logging equipment or logs over a soil surface. About three to five passages by tractors or logs were evidence of moderate compaction. Heavy compaction was defined as possibly more than five passes by equipment or logs.

Disturbance classes were similar to those used by Wooldridge (1960). Light disturbance indicated disturbance to litter cover whereby some litter was removed but the soil surface was not damaged or entirely exposed. Removing of nearly all litter cover and soil to a depth of 3 cm and exposing the mineral soil identified moderate disturbance. Soil removed and exposed below 3 cm depths indicated heavy disturbance.

Next, a rigid, square frame of 1000 cm^2 was placed over a representative portion of the sampling site. Percent cover by live vegetation, litter, rock and bare soil was recorded. As the author gained

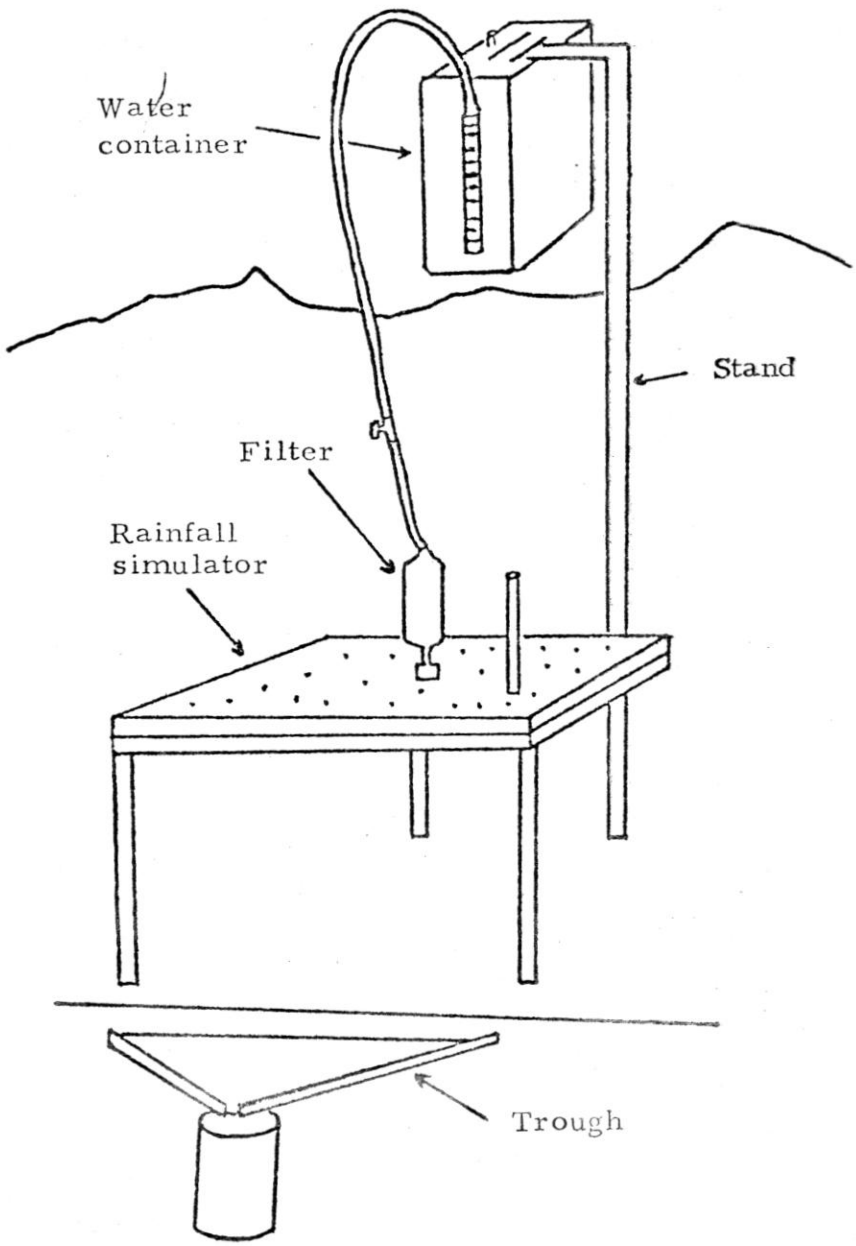

Figure 5. O.S.U. infiltrometer.

Prior to field use, the infiltrometer was calibrated and tested for uniformity of rainfall application. Also infiltrometer needles were cleaned, replaced and repaired as needed as were other infiltrometer associated parts.

After placing the infiltrometer on the randomly located site and leveling the device, the infiltration plot was pre-wet with 7.6 l of water via sprinkler cans and allowed to soak for ten minutes prior to the start of the infiltration run. During this ten minute period, a shallow soil pit was dug with a nearly even soil face approximately 5 to 7 cm downhill from the infiltrometer in order to collect runoff. A trowel was used to make a slit approximately 3 to 5 cm below the soil surface for the insertion of a trough. The trough routed runoff into collection cans. After trough insertion and prior to the start of the infiltration determination, a wash bottle and brush were used to remove any loose soil that could be detached by initial runoff. Finally, overhanging vegetation and litter that would facilitate runoff and/or tall vegetation that would hinder the infiltrometer operation were trimmed with grass shears.

The infiltration measurement began with an initial simulated rainfall intensity of approximately 7.7 cm/hr (3 in/hr). Although 7.7 cm/hr exceeds the usual intensities for this region, it was used so that infiltration capacities could be determined for porous forest soils in a assumed that the relative comparisons of the infiltration process being made between treatments with this procedure would be valid, even though natural rainfall rates were not duplicated.

After the rainfall start, the time of beginning runoff collection was recorded. Runoff was collected in a 250 ml graduated cylinder and volumes measured in three minute intervals until a constant, final infiltration capacity had been attained. Constant, final infiltration capacity was reached when runoff was nearly constant over a sufficient time interval (Figure 6). Although this interval was subjectively ged, five to ten minutes were usually sufficient to determine constant runoff. In many instances, the runoff measurement interval was decreased because of a large runoff volume being collected over a three minute period. Appendix B provides conversions for runoff and infiltration measurements in ml/min to cm/hr and in/hr.

Six to ten minutes after the initial application of rainfall and on those plots where runoff rates were less than 2% of the precipitation rate, a higher rate of rainfall was applied to a plot (10.5 cm/hr). If the higher rainfall rate did not produce runoff rates in excess of 2% of the 10.5 cm/hr and after a sufficient time period, the precipitation rate was increased to 14.5 cm/hr. If the situation warranted it his higher rainfall rate was again increased to the maximum for the infiltrometer (17.8 cm/hr or 7.0 in/hr). After gaining experi-

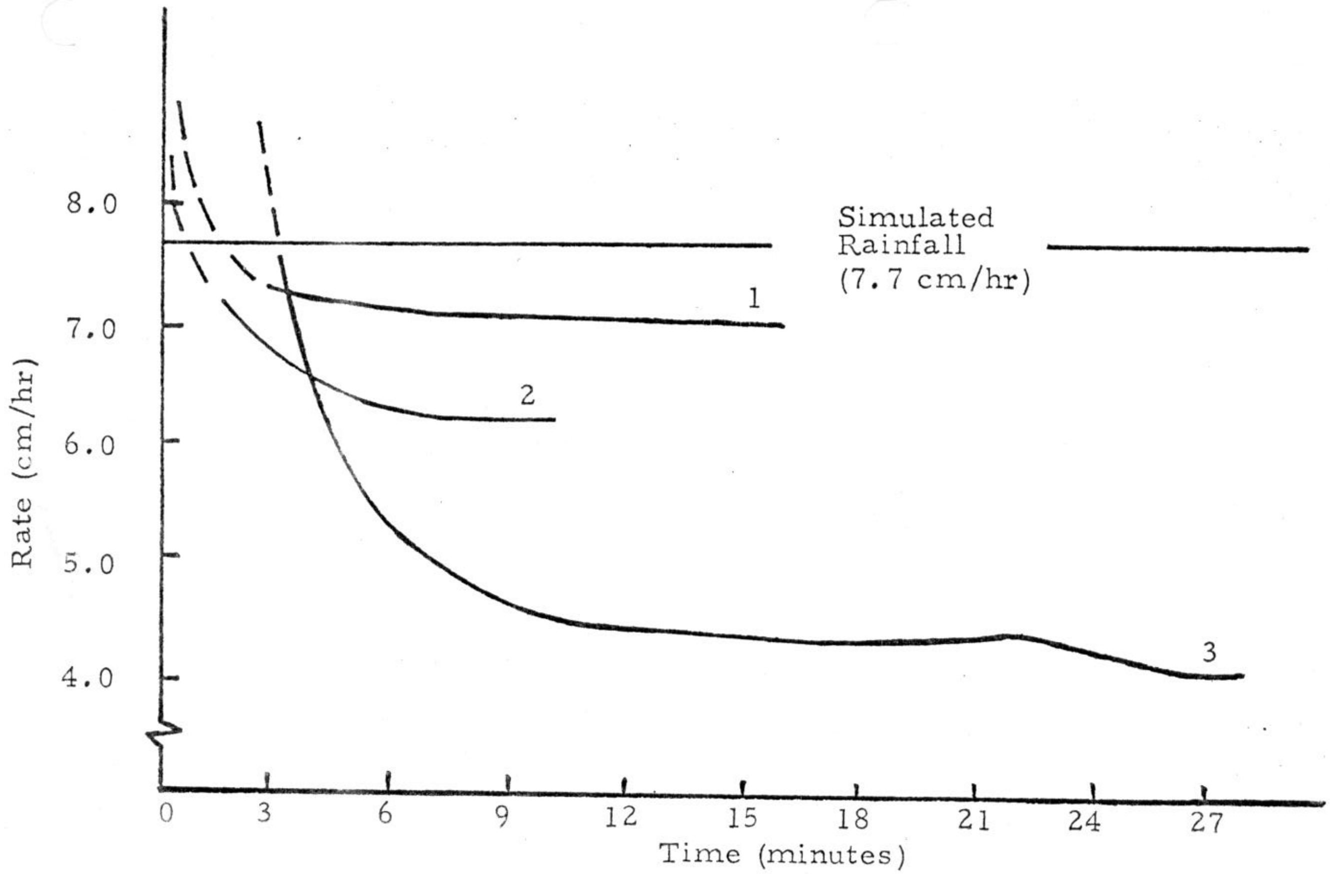

Figure 6. Infiltration curves for three different plots on the tractor windrowed area of Watershed 3. Infiltration curves 1 and 2 had been determined following two days of light rain and a pre-wet treatment. Infiltration curve 3 was obtained with no pre-wet treatment early in the summer.

examination, the author was able to estimate with what precipitation rate to begin the infiltration determination.

If constant, final infiltration capacities were not attained even at high rates of moisture application ringed infiltrometers were used to identify the infiltration capacity with three rings used per plot. Ringed infiltrometers were used in only two instances. The time necessary to reach constant, final infiltration capacity with the infiltrometer ranged from 9 to 20 minutes for most sites (Figure 6).

The relative surface erodibility of each site was assessed by determining the sediment concentration and yield in the runoff water from infiltration runs. Although plot erosion may exceed that which occurs during natural rainfall events, the relative rates of erodibility for each site can be indexed by this procedure (Bethlahmy, 1967; Meeuwig, 1969; 1970a; 1970b; Blackburn, 1975). Following each runoff collection and volumetric measurement, the runoff was composited in a bottle for later analysis.

During the infiltration determination, the paired plot location was randomly chosen. It was selected by designating one end of a piece of woody debris as a pointer. Then the debris was tossed into the air with a spinning motion. After the debris had fallen and was resting on the ground, the pointer indicated a certain direction. The paired plot was located approximately 2 m in the direction indicated away from the original site location. If the plot location landed on adverse terrain (stumps, down timber, large logging debris, rock outcrop), it was moved accordingly.

After the infiltration capacity had been determined and the erodibility sample collected, the infiltrometer was moved to the paired plot and leveled. The remaining measurements at the original site location were now completed before starting investigation of the paired plot.

Surface and Subsurface Measurements

The square frame was now replaced on the representative portion of the plot. Surface litter, now wet from the previous infiltration run, was collected, placed in labeled, plastic bags and the bag number recorded. Live vegetation and pieces of dead organic matter larger than 1 cm in diameter or 10 cm long were not collected.

A soil pit was dug approximately in the middle of the sampling plot and was as deep as the wetting front, typically 30 to 46 cm deep. A soil profile description was made using guidelines in the Soil Survey Manual and in Soil Taxonomy (Soil Conservation Service, 1967; 1975), and identified by soil series (Stephens, 1964; Richlen, Arnold and Stephens, 1976). After the author was able to recognize all needed soil series and sufficient representative soil profiles had been recorded, profile description and characterization were discontinued except for occassional note taking. Using existing soil profile descriptions for each study area (Stephens, 1964; Richlen, 1973; Richlen, Arnold and ephens, 1976) and field information, representative soil profiles ere developed for each soil series. Soil profile descriptions for each oil series found on the Coyote Creek and Hi-15 Watersheds are in- luded in Appendix A.

Characterization of surface and subsurface macropore space was nade for each soil pit by a portable air permeameter, similar to the ne used by Steinbrenner (1959). Prior to insertion into the soil, the ir permeameter soil tube was held against an object having no macro- ore space and the backpressure gauge was adjusted by the regulator to ead full scale. The full scale backpressure reading was 15 lbs/in^2 103,400 Pa) as dictated by the gauge being used.

The soil tube was now inserted into the soil and the pressure alve was depressed which shot a pressurized gas into the test soil sec- ion. Depending on the amount of non-capillary pore space and mois- ure content, a backpressure reading was obtained. When calibrated ith different soil samples of varying moisture contents and macropore pace, this backpressure reading should index the percent of macro- ore space (Steinbrenner, 1959).

Using this procedure, the soil surface and subsurface to the bottom of the soil pit were characterized by air permeameter readings. The depth at which the maximum reading was located was recorded as was the backpressure reading, and this was considered the most impermeable soil layer.

For each soil horizon, the unconfined compressive strength was measured with a pocket penetrometer. After the preliminary data collection period at Coyote Creek, the pocket penetrometer usage was discontinued because of the extreme variability of readings associated with forest soils.

Relatively undisturbed soil samples were now taken. Moist, soil surface and impermeable soil layer samples were obtained for determinations of bulk density, moisture content and particle size distribution. If the impermeable soil layer occurred at the soil surface, a subsurface soil sample was taken for substitution of the impermeable layer sample. Another impermeable soil layer sample was obtained for use in soil moisture-tension tests, and for a total porosity and bulk density calculation.

The soil samples were obtained by using an impact type bulk density sampler. The sampling instrument employed a brass retainer ring, 6 cm x 5.4 cm in diameter, fitted inside a stainless steel cutting cylinder. Brass spacer rings were fitted both above and below the soil tainer ring. Both Ranken (1974) and Yee (1975) found this type of npact sampler to give satisfactory results.

To obtain an individual sample, the sampling tool was hammered o the soil. The soil sample, held in the brass retaining ring, was eed from the soil by inserting a trowel underneath the cutting edge d removing the sampler. This procedure insured that none of the il fell or was pulled from the retainer ring. Certain soils, being y, rocky or extremely hard, were difficult to sample using this thod.

After the sampler was extracted from the soil, the retaining ring th the soil was removed from the sampler. Excess soil was immed from the ends of the sample with a pocket knife. If large ones or roots were observed in the sample, the sample was discard- and another taken.

For soil samples to be used in bulk density, moisture content d particle size distribution determinations, the soil was pushed from retainer ring into a labeled soil can, the soil can covered and taped prevent evaporation and the can number recorded. For the samples be tested for soil moisture-tension characteristics, a double layer of eesecloth was placed over one end of the retainer ring and secured th rubber band. A piece of plastic was placed over the other end d also secured with a rubber band. The retainer ring was now placed into a small, labeled, plastic bag to reduce evaporation and transferred into a soil can for transport.

Paired Plot Investigation

After completing data collection on the original site location, equipment and gear were moved to the paired plot. From initial site information to infiltration capacity determination and erodibility collection, the same procedures were followed on the paired plots as were followed on the original site locations. The soil was briefly described or identified given the shallow soil pit used for runoff collection. Miscellaneous observations and comments were recorded. Before moving to the next sampling location, stakes were installed to facilitate plot location in the fall for remeasurement of infiltration capacities and other data.

Approximately 2.5 to 3 hours were required to complete data collection at each sampling location. Therefore, only three to five sites were completed per day.

Laboratory Analysis Methods

Oven Dry Litter Weight

When brought from the field, litter samples were removed from the plastic bags and allowed to air dry. After air drying, any rocks,

e vegetation or large organic debris were removed. The litter
nples were then oven dried at 105°C for 24 hours and weighed imme-
tely upon removal from the oven. Litter mass per 1000 cm^2 was
mputed and converted into kg/ha (Appendix B).

ırbidity

Erodibility samples were analyzed for turbidity before determin-
g suspended sediment concentrations. To resuspend colloidal materi-
, each bottle was stirred and shaken thoroughly 24 hours before test-
g. Prior to testing, the samples were gently stirred to insure ade-
uate mixing, with care being taken not to create air bubbles that
ould influence readings.

Two representative samples, 25 ml/sample, were extracted from
ach erodibility bottle and analyzed on a Hach Model 2100A Turbidime-
r using the 0 to 100 ntu (nephelometric turbidity units) scale and a
rmazin standard. Appropriate dilutions were made and an average
rbidity calculated from the duplicate samples.

ıspended Sediment Concentration

Erodibility samples were now analyzed for suspended sediments
sing a filtration technique. Each bottle was reagitated and approxi-
ately 150 ml of sample filtered. After filtering, the sediment-con-

and weighed immediately upon removal from the oven. This procedure was employed for the entire volume of each erodibility bottle, with the final filtering process containing the distilled water rinse of each bottle. Oven dry tare weights of the filter paper had been obtained prior to filtering.

Suspended sediment concentrations (mg/l) were obtained for each portion of the erodibility bottle filtered. After all sediment concentrations had been computed for an individual bottle, a weighted average was calculated. Using the weighted average sediment concentration, total runoff collected and total runoff time, sediment yield (kg/ha/hr) was determined for each erodibility sample (Appendix B).

Oven Dry Soil Weight

Soil cans, containing surface and impermeable layer or subsurface soil samples, were weighed when brought from the field. Next, they were uncovered and oven dried at 105°C for 48 to 72 hours. Upon removal from the oven, the cans were covered, allowed to cool to room temperature and weighed. Prior to the field study, soil can tare weights had been determined. Bulk density (gm/cm^3) and soil moisture content by volume (%) were then computed (Appendix B). Each soil sample was placed into a small paper bag and retained for particle size analysis.

il Porosity Measurements

The impermeable layer soil samples, in plastic bags, were aced in cold storage (4^oC) immediately upon returning from the field ıd kept moist until ready for laboratory use. The cold storage re- rded biological activity which might have altered the hydrologic char- teristics of the samples.

Prior to laboratory analysis all samples were removed from cold orage and allowed 24 hours to equilibrate with room temperature. groups of 24, the soil sample retainer rings were removed from the astic bags and submerged approximately 8 cm in containers filled th deaerated distilled water for saturation. The samples were then owed to stand for 24 hours to ensure complete saturation and mini- ize entrapped air.

The saturated weight of each sample was now determined using nken's (1974) C-clamp apparatus (Figure 7) in order to calculate to- l porosity (Appendix B). Following saturation, each sample retainer ng was placed in the C-clamp underwater and sealed by clamping the vice. The clamp and sample were then removed and dried. The urated weight of the sample was recorded as the weight of the sam- and clamp. Later, tare weights of the retainer ring, cheesecloth, bber band and clamp were subtracted from the total weight to give

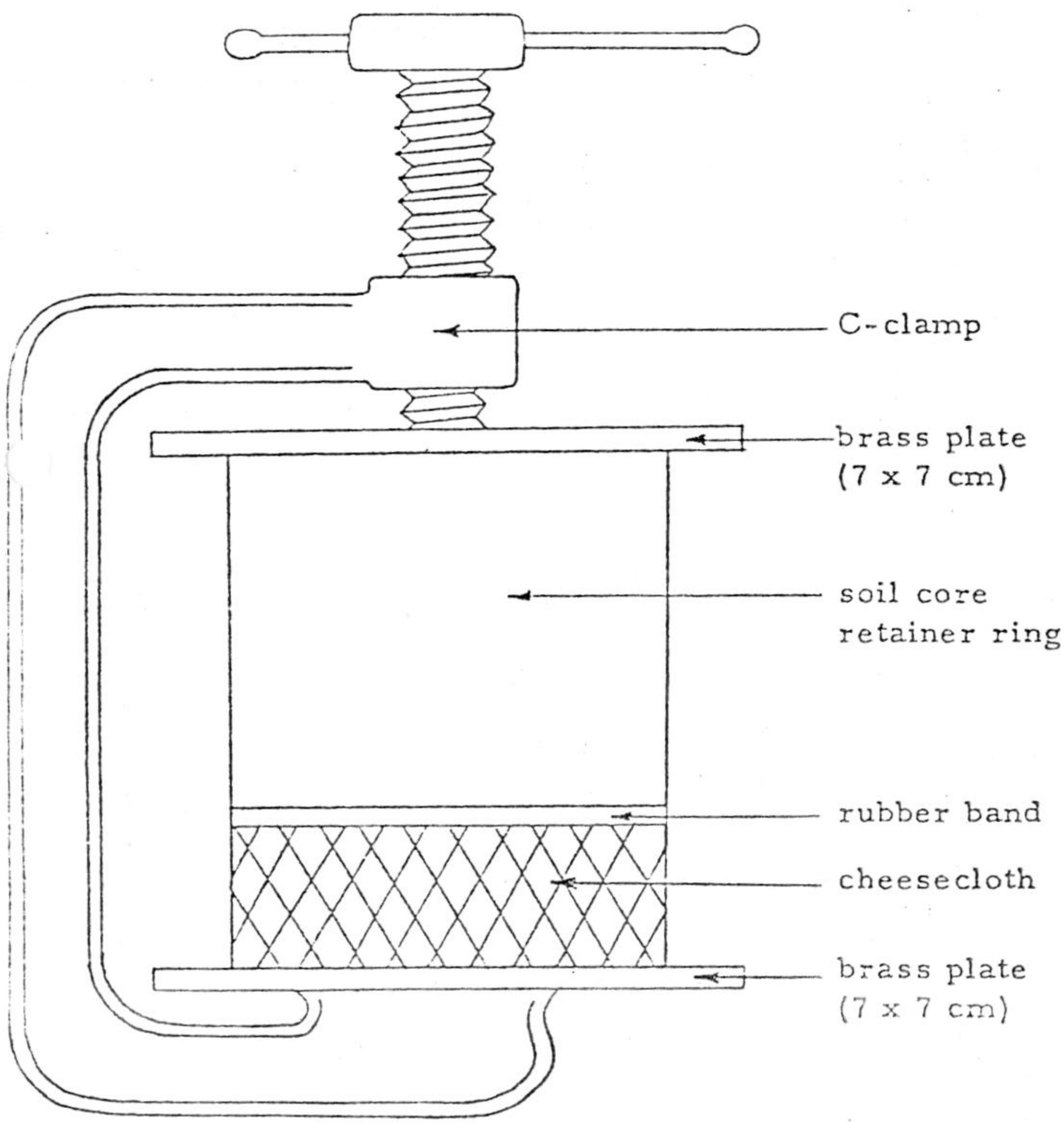

Figure 7. C-clamp apparatus (after Ranken, 1974).

the saturated weight of the soil samples. After every weighing, each sample was replaced back into the water-filled container to maintain saturation.

Ranken's (1974) tension tables (Figure 8) were used to determine the soil moisture characteristics of each soil sample in order to calculate non-capillary pore space (Appendix B). After deaerated distilled water was added to each tension table to cover the screen, a 36 cm x 51 cm sheet of white blotter paper was lowered into the water. After the blotter paper was in place, the outlet tubing clamp was released a . excess water on the table allowed to drain. Next a hard rubber roller was used to smooth out the wrinkles in the blotter paper. This procedure was necessary to ensure a tight seal between the paper and table, and to keep air from entering the system.

With the tension tables prepared and having a capacity of 24 retainer rings, saturated soil samples from the water containers were quickly transferred to the blotter paper. When all samples had been placed on the blotter paper, the top of the tension table was sealed with tape to reduce evaporation. The tension applied to the surface of the blotter paper was controlled by an overflow reservoir of water connected to the table with tygon tubing. The outflow of the reservoir was first ced at 10 cm below the midpoint of the samples and the outlet tubing clamp released. The samples were then allowed to equilibrate with the

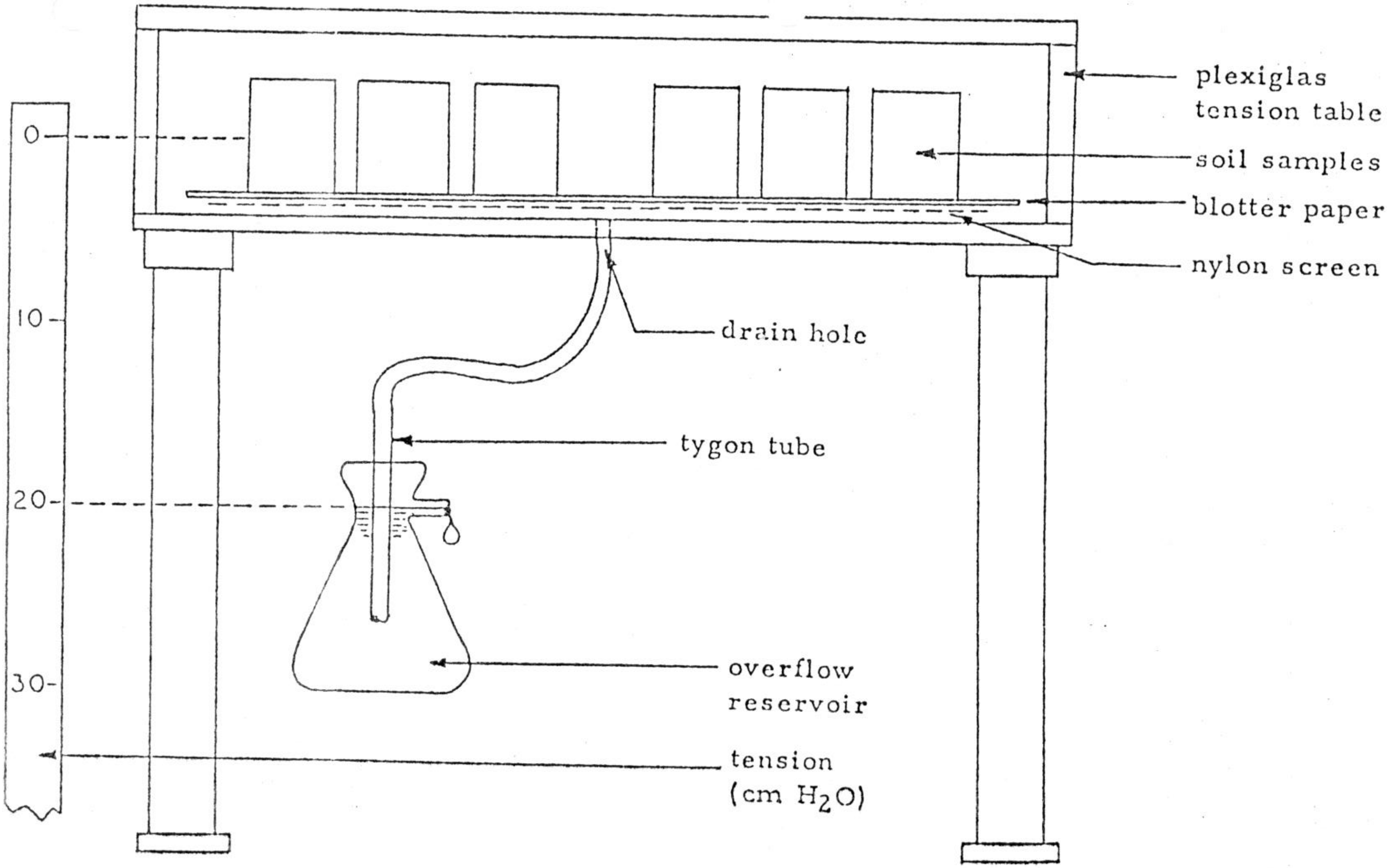

Figure 8. Tension table (after Ranken, 1974).

red 48 hours to equilibrate with 72 hours allowed for equilibration gher tensions.

When apparent equilibrium had been reached, the outlet tubing clamped. Each retainer ring was removed, any condensation ed off and the 10 cm weight of the sample was determined. The nples were temporarily stored on moist paper towels while the other nples were being weighed and the table was prepared for the next sion, as previously stated. The retainer rings were then replaced, table top sealed and the reservoir lowered to the 30 cm level. e c le of increasing tensions and weighing of soil samples was re-ated for tensions of 60 cm and 80 cm.

When the retainer rings had been weighed after 80 cm tension uilibrium, the soil was removed from the retainer rings and placed soil cans. Loose soil from the cheesecloth was also added to the il cans. The cans were then oven dried at 105°C for 48 hours and ighed. The retainer ring, cheesecloth and rubber band for each mple was oven dried for two hours and weighed to determine the tare ight. Total porosity, macroporosity and bulk density were now cal-lated for these samples (Appendix B).

Data Analysis

One-way analysis of variance for completely randomized design luate treatment effects on infiltration capacity and rface erodibility for the two study areas. T-tests were also utilized evaluate differences between treatments. One-way analysis of variance for a nested design was used to determine differences between the vo study areas and their combined effects on infiltration and surface rodibility.

A completely randomized block design for blocking treatments and soil series or parent materials was not used in the data analysis because not all soil series or parent materials appeared on each treatment. Blocking of those soil series or parent materials that did occur on every treatment would have resulted in small sample sizes, problems in deciding which sites to include in the analysis and possibly erroneous results. Furthermore, the variation of infiltration capacities and surface erodibility within soil series or parent materials may also be great and create large amounts of unwanted variance.

Paired t-tests were used to compare original and paired plot infiltration capacities and surface erodibility. Summer to fall comparisons of various parameters for only those sites sampled in the fall and taken collectively, were evaluated with paired t-tests. The statistical significance of relationships between the dependent variables, infiltration capacity and surface erodibility, and the independent variables were determined by the least squares method of regression analysis. All hypothesis testing was accomplished at the 90% level of confidence. If a hypothesis test was also significant at the 99% confidence level, it

RESULTS AND DISCUSSION

Treatment Characteristics

Data obtained during the summer and fall of 1977 for this study re shown in Appendix C.

Sampling locations in Watershed 1, tractor shelterwood harvest-d, on the Coyote Creek Watersheds had slopes ranging from 13 to 52% ith a mean slope of 32%. Nearly 56% of the infiltration plots were lo-ated on smooth to uneven mountain side slopes. The remaining 44% ver found on landforms associated with ridges. About 63, 19 and 18% f the sampling sites were located on basalt, red breccia and rhyolite erived soils, respectively. Approximately 53% of the infiltration plots ell on or adjacent to skid trails with moderate to heavy compaction and isturbance. Skid trail means for bulk densities, the total porosity and acroporosities defined at 30 and 60 cm tension are nearly equal to the verages provided in Table 3 for shelterwood harvesting. The other 7% of the plots were found on areas of light compaction and light to oderate disturbance. Of the 32 infiltration plots, 29 plots had a total ercent cover, which is the summation of cover percentages for rock, itter and live vegetation, of greater than or equal to 95%. The other hre plots had 70 to 85% total cover. Table 3 provides the averages or litter thickness and mass on Watershed 1. The mean soil moisture le 3. Average soil and litter characteristics for the Coyote Creek Watersheds, summer 1977.[a]

aracteristic	Treatment			
	Tractor Shelterwood	Cable	Tractor	Undisturbed
rface bulk density (gm/cm^3)	0.930 (.13)	0.991 (.23)	0.903 (.16)	0.927 (.09)
bsurface bulk density (gm/cm^3)	1.041 (.12)	1.105 (.17)	1.046 (.14)	1.064 (.12)
otal porosity (%)	56.8 (4.6)	55.0 (6.4)	59.0 (5.1)	55.5 (4.9)
a[illegible]porosity at 30 cm tension (%)	17.1 (7.3)	15.5 (7.1)	12.6 (5.3)	19.2 (5.8)
acroporosity at 60 cm tension (%)	20.1 (7.4)	18.6 (7.2)	16.6 (6.1)	22.4 (5.6)
itter thickness (cm)	4.4	5.1	3.4	6.6
itter mass (kg/ha)	11509	5775	6279	15991
ample size	16	16	16	16

Values in parentheses are standard deviations.

.racteristic curve for each treatment on Coyote Creek is illustrated Figure 9.

On Watershed 2, high-lead, cable logged sampling sites had an erage slope of 35%, ranging from 21 to 54%. Three-fourths of all :es were found on smooth or uneven mountain side slopes. The other ıe-fourth were located on a saddle or in a slump basin. One-half of .e infiltration plots were located on soils formed from red breccia. he other plots were equally found on green breccia and basalt derived oils. All cable logged sites were fire affected with four infiltration lots having severely fired surfaces. About 31% of the infiltration plots ell on or near log skid paths or landings with moderate to heavy comaction and disturbance. Surface and subsurface bulk density, total orosity and non-capillary pore space averages for the paths or landıgs are less than or equal to the total means for cable logging (Table). The remaining 69% of the plots were located on areas of light comaction and light to moderate disturbance. Nearly all sites had a subtantial rock surface cover. Approximately 86% of all infiltration plots ad greater than or equal to 95% total cover, while the other 14% had otal cover ranging from 70 to 90%. The litter thickness and mass for able logged areas of Watershed 2 averages higher than the total cable ıeans in Table 3. Ring infiltrometers were used in one instance. Alıough applicable in other cases, inadequate insertion into rocky soils [illegible] ring infiltrometer useage.

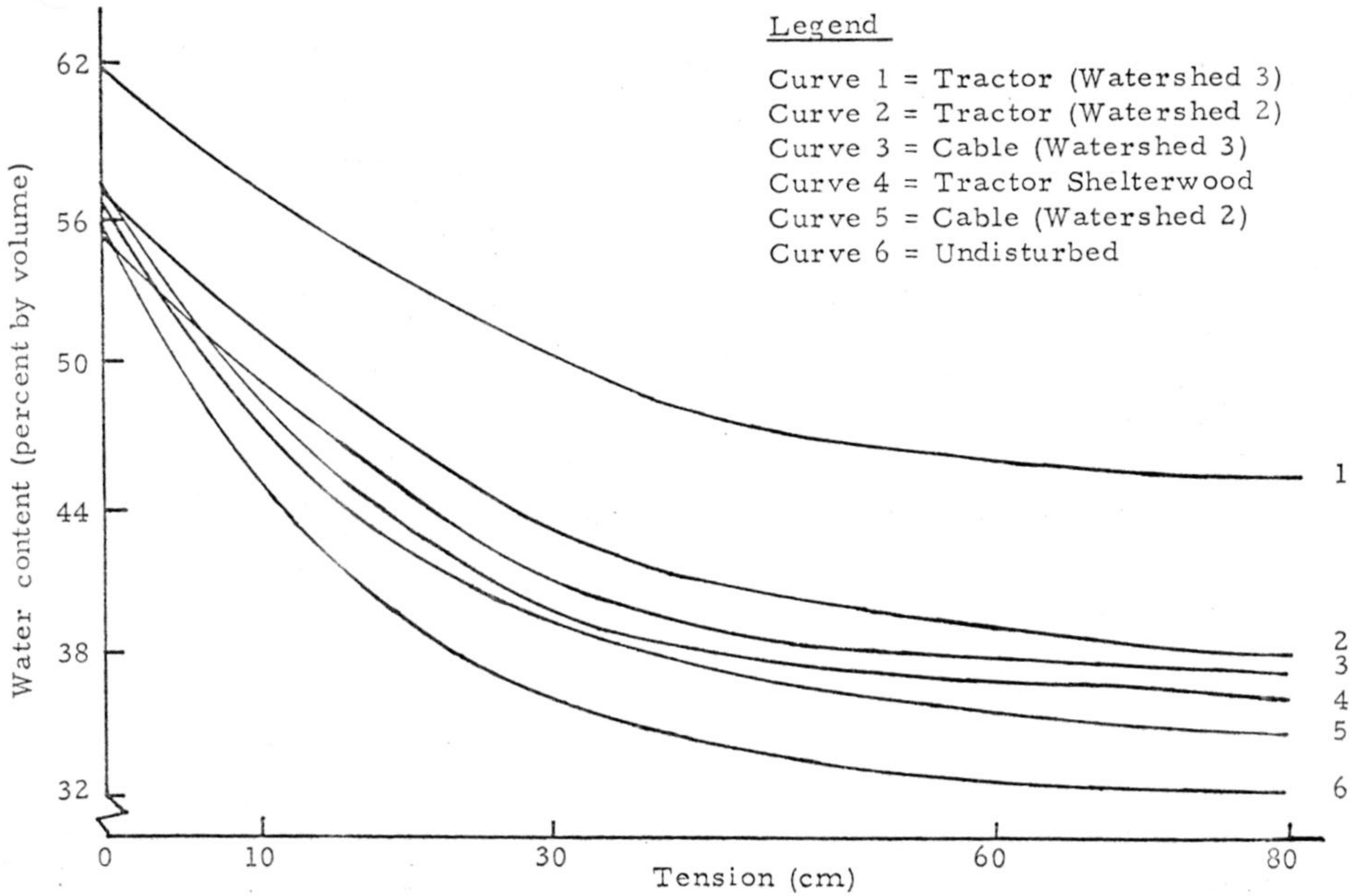

Figure 9. Mean soil moisture characteristic curves by treatments for the Coyote Creek Watersheds.

On the cable logged area of Watershed 3, percent slope for the ımpling sites ranged from 31 to 65% with 44% as average. Nearly 5% of the sites were found on smooth or uneven mountain side slopes. he remaining sites were located in slump basins. The sampling locaions were found predominantly on green breccia derived soils (63%) with some sites occurring on soils formed from red breccia and rhyolite parent materials (25 and 12%, respectively). Only two sample locations were influenced by fire but they were severely affected. Four of the 16 infiltration plots were located on log skid paths or landings. The bulk densities for the skid paths were greater than the total cable means while the porosity values were nearly equal to the means (Table 3). The other 75% of the plots were found on areas of light to moderate disturbance and light compaction. Only 38% of all infiltrometer plots had total cover greater than or equal to 95%. One-half of all plots had 65 to 94% total cover, while the remaining 12% had 47% total cover. The litter thickness and mass averages were substantially less than the total cable means (Table 3). Ring infiltrometers were used for one sampling location.

Sampling sites on the tractor logged and windrowed slash units of Watershed 2 had a mean slope of 32%. Smooth and uneven mountain side slope landforms accounted for 63% of the sampling locations. The remaining locations were found on a ridge top or in a slump basin.

...ated on soils formed from basalt

d red breccia parent material. All plots were fire affected and occrred in areas of moderate to heavy compaction and disturbance. ne-half of the infiltration plots occurred on or adjacent to skid trails, hile the other half occurred away from skid trails. Surface and suburface bulk densities and macroporosities for skid trails were slightly igher than the total tractor means (Table 3). Seven of the 16 infiltraion plots had greater than or equal to 95% total cover, eight plots had 0 to 94% total cover and one plot had 50% total cover. Litter thickess and mass averages were substantially higher than the total tractor means (Table 3).

On the tractor windrowed slash area of Watershed 3, sampling ocation slopes ranged from 13 to 51% with 28% as the mean. The mooth mountain side slope landform accounted for 75% of all sample ites. The other 25% of sites were located on a ridge top. Green brecia derived soils underlaid 75% of all infiltration plots. Of the remainng 25%, half of the plots were found on red breccia formed soil and alf were found on basalt. All sites were fire affected and had moderate to heavy compaction and disturbance. Again, 50% of the infiltration lots occurred on or adjacent to skid trails, while 50% occurred away rom skid trails. The bulk density and porosity values for the skid rails were substantially less than the total tractor means (Table 3). No plot had greater than 95% total cover. The majority of the plots ... d 50 to 70% total cover. The other 31% of the plots had 25 to

5% total cover. The litter thickness and mass averages were substantially lower than the total tractor means in Table 3.

Sampling sites in the undisturbed sections of the Coyote Creek Watersheds had slopes ranging from 21 to 60% with a mean of 36%. Smooth and uneven mountain side slope landforms dominated sites found in Watershed 2 (75%). The other 25% of those sites were located on landforms associated with ridges. On sites in Watershed 4 and along the outside perimeter of Watersheds 2 and 3, 88% occurred on smooth mountain side slopes with 12% on ridges. Of the infiltrometer plots located in Watershed 2, 50, 39 and 11% of the plots were found on soils formed from basalt, red breccia and green breccia parent materials, respectively. The other plots, chosen outside Watershed 2 and in Watershed 4, were predominately located on red breccia derived soils (88%), while the remaining sites were on basalt derived soils (12%). All sampling locations were undisturbed or nearly so. Game trails were found near many infiltration plots but no plots were located on or immediately adjacent to any trails. Over 94% of all plots had greater than or equal to 95% total cover. Two plots (6%) had 85% total cover. Table 3 provides mean bulk density, porosity, litter thickness and litter mass values found on undisturbed sampling sites.

On the Hi-15 Watersheds in the tractor shelterwood portion of Watershed 7, sampling sites had a mean slope of 30%. Two sites were located on a smooth mountain side slope landform, while the other site ound on an upland ridge. Andesite derived soils were found on all here and throughout the Hi-15 Watersheds. Only one of the three was located on a skid trail with heavy compaction and disturb- . The values for the surface and subsurface bulk densities and ›sities for the skid trail were slightly lower than those for the total tor shelterwood means (Table 4). The other two sites were found reas of light to moderate compaction and light to heavy disturbance. he six infiltration plots, three plots had greater than or equal to total cover, while three plots had 55 to 90% total cover. Table 4 s litter thickness and mass averages for this treatment. The an soil moisture characteristic curve for the tractor shelterwood tment as well as other treatments found on the Hi-15 Watersheds iven in Figure 10.

Sampling locations on the tractor logged portion of Watershed 6 a mean slope of 31% and were found on an upland ridge. Both sites e located on or near skid trails with moderate to heavy compaction disturbance. One site was also fire affected. Bulk density and osity values are identical to those in Table 4 for the tractor treat- nt. All infiltration plots had 70 to 95% total cover. Litter thickness mass averages are given in Table 4.

ampling sites on the cable logged portion of Watershed 6 had a an slope of 42%. All sites were found on a smooth mountain side

fire affected and had light to moderate

le 4. Average soil and litter characteristics for the Hi-15 Watersheds, summer 1977.[a]

aracteristic	Treatment Tractor Shelterwood	Tractor	Cable	Cable Shelterwood	Undisturbed
face bulk ensity (gm/cm^3)	0.822 (.09)	0.968 (.03)	0.929 (.11)	0.741 (.14)	0.799 (.18)
surface bulk ensity (gm/cm^3)	0.964 (.02)	1.087 (.01)	1.004 (.08)	0.941 (.03)	0.928 (.10)
al porosity)	63.6 (2.3)	60.7 (2.3)	62.3 (2.0)	61.0 (3.3)	63.1 (3.6)
croporosity 30 cm nsion (%)	18.5 (5.1)	14.8 (3.6)	17.9 (2.5)	18.1 (3.7)	24.8 (3.0)
croporosity 60 cm nsion (%)	23.0 (5.1)	18.4 (3.3)	22.8 (4.6)	22.8 (2.1)	29.3 (2.6)
er thick- ss (cm)	3.1	3.0	4.4	5.6	7.1
r mass g/ha)	5782	1819	13542	23404	20098
ple size	3	2	3	2	3

lues in parentheses are standard deviations.

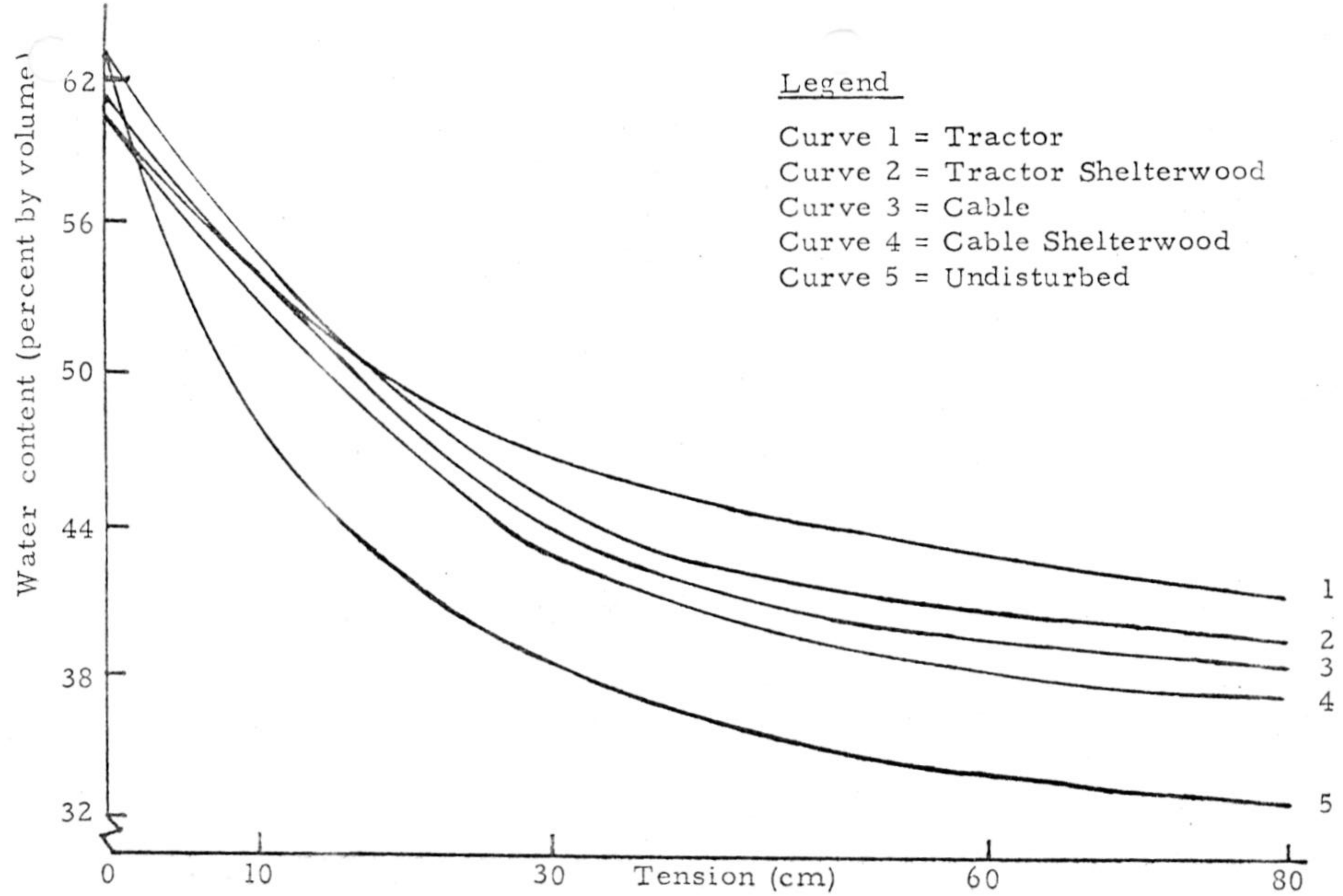

Figure 10. Mean soil moisture characteristic curves by treatments for the Hi-15 Watersheds.

Infiltrometer trough insertion problems occurred on 41 and 92% he sampling sites on the Coyote Creek and Hi-15 Watersheds, respectively. For both study areas, these problems were common to all atments but for different reasons. Infiltrometer trough insertion oblems were caused by roots, rocks and buried logging debris in immediate subsurface, heavily compacted soil, slumping of nonhesive surface soil or a combination of these factors. A good fit of trough into the soil was achieved in most instances in spite of these oblems.

Precipitation Effect

Total precipitation amounts received five days prior to each mpling period for the summer and fall of 1977 are given in Table 5. ssentially no precipitation was received on Coyote Creek during the mmer until late August. Following the precipitation event of August -26, only two shelterwood sites, all undisturbed sites for Watershed and outside the perimeters of Watersheds 2 and 3, and all tractor winowed sites on Watershed 3 remained to be sampled. On all remaing shelterwood and undisturbed sites, the sites were well protected om all rainfall influences by overstory and understory vegetation, d thus the rainfall event only dampened the extremely dry litter and p . m of soil. By the time of sampling, the litter and soil conditions

Table 5. Total five-day precipitation prior to each sampling period on the Coyote Creek and Hi-15 Watersheds, summer and fall 1977.[a]

Dates	Sampling location	Total five-day prior precipitation (cm)
June 26-29	Coyote Creek Watersheds	0
July 10 & 11	Coyote Creek Watersheds	0
July 18-22	Coyote Creek Watersheds	0
July 25-28	Coyote Creek Watersheds	0
Aug. 1-3	Coyote Creek Watersheds	0.1
Aug. 16-19	Coyote Creek Watersheds	0
Aug. 23 & 24	Coyote Creek Watersheds	0
Aug. 29 - Sept. 2	Coyote Creek Watersheds	3.5
Sept. 12-15	Hi-15 Watersheds	0
Nov. 13-15	Coyote Creek Watersheds	4.4
Dec. 3	Hi-15 Watersheds	8.1

[a] Personal communication, R. Fredriksen and A. Levno, 1978, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon.

re similar to all sites previously sampled indicating little to no fect by the precipitation.

The sites on the tractor windrowed area of Watershed 3 were un-otected from rainfall influence and the precipitation event affected arkedly the soil surface and subsurface properties. From prelimin-ry sampling early in the summer, a possible irregular and discontinu-us hydrophobic condition near the soil surface had been noted for this ea. During the early to middle phases of the rainfall event, discon-nuous overland flow had been observed for this area with rilling and d aling occurring. Also, surface runoff with high sediment loads d been observed for skid trails, log paths and permanent roads und throughout the Coyote Creek Watersheds. Upon sampling several ys later, the subsurface soil for this tractor windrowed area was a swollen, massive-looking, nonworkable clay. Surprisingly, the filtration capacities for plots on this area had increased by 50 to 75% er the values obtained during the preliminary sampling period for es located nearby on this same area (refer back to Figure 6). The ecipitation event therefore changed the soil properties, altered and rtially mitigated a possible hydrophobic surface condition and in-ased the infiltration capacity of the soil. Even so, these sites had l est values of infiltration capacity for all of Coyote Creek, except certain skid trails. The result of higher infiltration capacities for

Precipitation for the Hi-15 Watersheds was non-existent through-
the summer until late August and early September when major rain-
l events occurred. Upon sampling the Hi-15 Watersheds, all sites
re found slightly moist on the surface and in the subsurface except
r the undisturbed sites that were dry. This moist condition was
.used by the late August/early September precipitation because no new
infall had been received five days prior to sampling. As will be dis-
ssed later, fall infiltration capacities were greater than summer
apacities for the Hi-15 Watersheds. Keeping this pattern in mind and
ec[illegible] izing that some possible non-wettable soil conditions may have
ccurred, especially on the cable logged area of Watershed 6, the in-
ltration capacities obtained are again overestimates of the infiltration
apacities that probably occurred during the summer. A noteworthy
xample is the inconsistent results determined for the tractor logged
ortion of Watershed 6. Here, infiltration plots on or adjacent to skid
rails provided infiltration capacities at least twice as high as any of
e other treatments. This is possibly caused by the removal of the
rface soil layers by skidding, leaving a porous gravelly loam for the
il surface. Also, any hydrophobic surface effect may have been re-
oved by the late August/early September rainfall events.

all sampling at the Coyote Creek Watersheds found the soils on
l treatments near or at field capacity. From early October to the

ampling date in November, over 13 cm of rainfall had been received vith 4.4 cm falling within five days prior to sampling. Because of the igh clay content of nearly all soils on the Coyote Creek Watersheds and nd the summer drought conditions, soils retained much of the precipi- ation. As previously stated, infiltration capacities increased markedly ver those of the summer, despite the highly moist soils.

Fall sampling on the Hi-15 Watersheds was not attempted until arly December because of large rainfall events in late November that amaged certain bridges and because of snow on the watersheds. From nid Tovember to early December, over 40 cm of precipitation fell with . 1 cm falling within five days prior to sampling. Because these soils ave little clay and are coarser textured, they do not retain water and erefore pass it quickly via subsurface flow. It was noticed that these oils did not appear as moist when sampling as did those on Coyote reek. Also, when sampling in early December, all snow had gone and e soil surface did not appear to have been frozen by the previous cold eather.

Infiltration Capacity

Infiltration capacities as measured by the infiltrometer may be, m y cases, larger estimates of infiltration than occur naturally eeuwig, 1971). First, relatively short time periods were used to uthor was attempting to identify as quickly as possible the inflection oint on each infiltration curve, or the point where the slope becomes ero and the infiltration capacity becomes constant. Approximately ive to ten minutes were allowed on most plots to verify that the inflec-ion point had been reached but this may be insufficient. In some plots he infiltration determination lasted 20 minutes or longer after the in-ltration capacity curve became level with little change occurring in he infiltration capacity. The author does expect after a sufficiently ong time period (hours), the infiltration capacity to further decrease o a final, constant level as the soil surrounding a plot becomes totally aturated.

A second reason to explain higher than natural infiltration capa-ities is the higher lateral flow rates of soil water and trapped soil air at may be occurring for this study than naturally exists for the period f greatest precipitation and when soils are near saturation. For a iven storm of uniform areal distribution, as water infiltrates the soil urface resistance by trapped soil water and air is encountered. Yet, or western Oregon, lateral flow rates are extremely high during these onditions (Ranken, 1974; Yee, 1975; Harr, 1977). For this study, a re-wet treatment was used to simulate the saturated condition by fill-ng surface and immediate subsurface macropores with water, theoret-ally decreasing the higher summer lateral flow rates to fall rates nd thereby hastening the occurrence of the inflection point. Despite s treatment, summer lateral flow rates were thought dominant and is, infiltrating water was met by less resistance. Accordingly, the plied rainfall rate was higher than theoretically would have been nec-ssary and the infiltration capacities were greater than natural.

Final reasons are associated with the low raindrop velocities and ie high, relatively constant rainfall intensities used. Although the gh precipitation rates are considered unrealistic for any extended me period for this region, they were utilized to also speed-up deter-nination of the inflection point for each infiltration curve. Damage to he oil surface by high intensity precipitation via surface sealing by ilts and clays was reduced for most sites by a substantial rock, litter nd live vegetation cover. The total cover reduced the rainfall velocity nd decreased raindrop impact. On those sites with little cover, dam-ge was small because terminal raindrop velocity could not be attained y the infiltrometer. The fall distance for the infiltrometer is approxi-nately 0.5 m, while 7.2 and 12.8 m are required for raindrops com-only produced by the infiltrometer to attain 95 and 99% terminal velo-ity, respectively (Dohrenwend, 1977). Furthermore, surface sealing as reduced by the relatively constant rates of rainfall applied. Irregu-ar, short bursts of high intensity rainfall intermixed with low intensity rec itation are characteristic of summer thunderstorms. These ir-egular, short bursts are more damaging to soil surfaces through rain-

... rates common during fall storms

'ischmeier and Smith, 1958; Moldenhauer and Long, 1964). The in-
trometer thus applies high thunderstorm-like intensities at constant
ites. Therefore, given an unusually high, relatively constant pre-
pitation intensity, substantial total cover, reduced raindrop velocity
d impact, reduced surface sealing, generally high lateral flow rates,
d relatively short determination periods, infiltration capacities for
e infiltrometer are expected to be greater than those which occur
aturally.

An inherent factor in the infiltrometer operation, the depth of
ough insertion, may possibly offset the other infiltration effects pre-
io y discussed by increasing runoff volumes collected and thereby
creasing infiltration. The depth of infiltrometer trough insertion
s generally as close to the soil surface as possible without damaging
e surface. Depths of 3 to 5 cm were used. During any given infiltra-
on run, some subsurface flow was intercepted and collected in addi-
on to surface runoff. The amounts of subsurface flow collected var-
d from site to site depending on soil properties and site conditions,
t from field observation and for any given plot, surface runoff pre-
ominated with little subsurface flow being obtained. Therefore, the
pothesis that infiltration capacities measured are higher than those
aturally occurring remains valid.

Another operational factor, the distance from the downhill side of
e infiltrometer to the trough, may affect infiltration by increasing

easured runoff. Runoff may be increased when the distance between e downhill side of the infiltrometer and the trough is small, causing ainfall from the infiltrometer to fall directly or spash from adjacent egetation and litter indirectly onto the trough. This rarely occurred hen the infiltrometer was 5 to 7 cm uphill from the trough and adja-ent vegetation and litter was trimmed or removed. Also from field bservation, wind has little effect on the infiltrometer. Therefore, imulated precipitation fell directly on the plot and rarely onto the ough. The amounts that rarely fell onto the trough were insignifi-ant.

A final inherent factor of the infiltrometer operation, raindrop ize, may possibly promote surface sealing by its apparently large size a increased raindrop impact and decreased infiltration. The average op size produced by the infiltrometer was 2.87 mm in diameter. rom Laws and Parsons (1943) and Wischmeier and Smith (1958), this indrop size is characteristic of the average drop for intensities of out 10.2 cm/hr. However, it is well within the raindrop distribution erances for the usual storms characteristic of fall and winter precip-ation events in the Northwest. Therefore, the infiltrometer raindrop es not deviate significantly from usual raindrop sizes and will have a gligible affect on infiltration.

Mean infiltration capacities obtained for the treatments on the oyote Creek and Hi-15 Watersheds are presented in Table 6. The able 6. Mean infiltration capacities by treatments for the Coyote Creek and Hi-15 Watersheds, summer 1977.[a]

oyote Creek reatments[b]	Sample size	Mean (cm/hr)	Significance[c]	
ractor				
Shelterwood				
CC-1	32	10.27		b
ractor				
CC-2	16	11.28		b
CC-3	16	5.83	a	
able				
CC-2	16	11.68		b
CC-3	16	10.94		b
ndisturbed				
CC-2	16	11.17		b
CC-out	8	9.54		b
CC-4	8	9.60		b
Average	(128)	10.13		
Coyote Creek Treatment Averages				
Tractor				
Shelterwood	32	10.27		b
Tractor	32	8.55	a	
Cable	32	11.31		b
Undisturbed	32	10.37		b
Average	(128)	10.13		

Hi-15 Treatments[b]	Sample size	Mean (cm/hr)	Significance[c]	
Tractor				
Shelterwood				
H-7	6	8.65	a	
Tractor				
H-6	4	16.65		b
Cable				
H-6	6	6.84	a	
Cable				
Shelterwood				
H-7	4	7.12	a	
Undisturbed				
H-out	6	8.14	a	
Average	(26)	9.11		

Table 6. (continued)

[a] Infiltration data for both study areas were normally distributed.

[b] CC-1 = Watershed 1, CC-2 = Watershed 2, CC-3 = Watershed 3, CC-4 = Watershed 4, CC-out = outside the lower perimeters of Watersheds 2 and 3 (Coyote Creek Watersheds); H-6 = Watershed 6, H-7 = Watershed 7, H-out = outside the lower perimeters of Watersheds 6, 7 and 8 (Hi-15 Watersheds).

[c] Treatments with the same letters are not significantly different. Treatments not followed by the same letter are significantly different at the 90% level of confidence. T-tests were used to evaluate treatment differences following analysis of variance.

nfiltration capacity data were found normally distributed for both study areas and required no transformation prior to analysis. Also, signifi- cant differences between treatments are indicated in Table 6.

For the Coyote Creek treatment averages (sample size equals 2), infiltration capacities were higher for the cable areas than undis- urbed areas. However, these differences were not significant. On he undisturbed sites, a possible minor hydrophobic effect on the soil urface may have existed; caused by a combination of litter residue, oil organic matter, and extremely hot and dry weather. Also on the ndisturbed sites, a litter shingle effect may have been in operation imilar to that found in the Northeast (Pierce, 1967). This effect xists when the litter acts like shingles on a house, routing water down- ill and reducing the amounts that penetrate the roof (or the soil sur- ace). Two cable sites, one in Watershed 2 and the other in Watershed , had uncommonly coarse grained, very porous soils with infiltra- ion capacities so high that ring infiltrometers were used. After re- noving these cable logged sites from the analysis, mean infiltration apacities for the cable and undisturbed treatments were nearly equal.

Mean infiltration capacities for both the shelterwood and undis- urbed treatments were significantly greater than that for the tractor ogged treatment, while the difference between the cable and tractor eatments was highly significant.[5] All differences attributed to the actor treatment are due to the effect of the tractor windrowed area Watershed 3.

Possible reasons why the undisturbed mean infiltration capacity r Watershed 2 was slightly less than those for either the tractor or ble treatments also of Watershed 2 are the occurrence of a possible inor, short-lived, non-wettable condition, the litter shingle effect or combination of the two. Again one cable logged site of Watershed 2 ntains an uncommonly coarse grained, porous soil. Relative to all disturbed sampling locations, a more dense, heavier clay loam was und on most sites in Watershed 4 and outside the perimeter of Watereds 2 and 3 than was found on Watershed 2 undisturbed sites. This counts for the lower means on undisturbed sites outside of Watershed

A highly significant difference was found between the mean infilation capacity from the tractor windrowed portion of Watershed 3 and y other treatment. It is difficult to assess if the difference is due tirely to the tractor windrowing and burning or also a function of the ils found there. Nowhere else on the Coyote Creek Watersheds were ils found with such a massive-appearing subsurface clay. It is unknown compaction by tractors partially created this tight clay. The severe

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ignificant equals 90% level of confidence. Highly significant equals [illegible] level of confidence.

ace disturbance and burning of this area and the high summer tem-
ures have caused little revegetation and a possible hydrophobic ef-
discussed previously. Thus, tractor windrowing and burning has
ced the infiltration capacity of this area but the degree or severity
e reduction is unknown.

The effects of soils and parent materials on infiltration capaci-
for each treatment, especially the undisturbed treatment, were
examined. Confounding and inconsistent results were obtained
no general trends or ordering of soil series, parent materials, or
se/fine textured soils evident.

For the Hi-15 treatments with statistically equivalent infiltration
cities (Table 6), only the tractor shelterwood area of Watershed 7
slightly greater mean infiltration capacity than that for the undis-
d sites. A litter shingle effect may be the possible cause for this
rence. As observed in the field, the litter shingle effect was more
rent on the Hi-15 than the Coyote Creek Watersheds.

The tractor yarded area of Watershed 6 exhibited a highly signifi-
increase in infiltration capacity in relation to all other treatments.
ssible explanation for these differences relates to the exposure of
se textured subsoils and has been discussed previously.

Combined infiltration capacity means for the Coyote Creek and
treatments are presented in Table 7. Collectively, no difference
ound between the treatment means. Although significant to highly

ıle 7. Combined infiltration capacity, turbidity and sediment yield medians for the Coyote Creek and Hi-15 Watersheds, summer 1977.[a]

eatment	Sample size	Infiltration capacity (cm/hr)	Turbidity (ntu)	Sediment yield (kg/ha/hr)
actor Shelterwood	38	10.02	85	14.3
actor	36	9.45	242	30.6
ble	38	10.60	27	4.1
disturbed	38	10.02	60	17.3
erage	(150)	10.03	75	13.2

urbidity and sediment yield data were normalized before calculating medians. The infiltration data were normally distributed. No significant differences between treatments were found at the 90% level of confidence for all variables following analysis of variance.

ignificant differences were found between the tractor treatments and ther treatments for each individual study area, the two tractor means nded to offset one another when combined.

A highly significant difference in infiltration capacities was dis- overed between study areas. Treatments at Coyote Creek generally ad larger means than those at the Hi-15 Watersheds. Specifically, the able and undisturbed infiltration capacities for the Coyote Creek Water- heds were significantly greater than those for the cable/cable shelter- ood and undisturbed sites on the Hi-15 Watersheds, respectively. he tractor shelterwood treatments for both areas had statistically qu means. Finally, the Hi-15, tractor infiltration capacity mean as statistically greater than the Coyote Creek tractor mean (99% con- dence level).

Mean infiltration capacities for skid trails and cable log paths for th the Coyote Creek and Hi-15 Watersheds are provided in Table 8. statistical analysis was performed on this data.

On all treatments for both areas, except for the tractor and cable rded portions of Watershed 6 on the Hi-15 Watersheds, the mean in- tration capacities for skid trails and paths were substantially re- ced from those previously shown. Reasons for these reductions are sociated mainly with the blocking and plugging of surface and imme- ate ubsurface macropores with silts and clays. Because these sites nerally had the lowest total cover percentages of all treatments, a

Table 3. Infiltration capacities and surface erodibility characteristics for skid trails and cable log paths by treatments for the Coyote Creek and Hi-15 Watersheds, summer 1977.[a]

Treatment[b]	Percent in skid trails or paths[c]	Mean infiltration capacity (cm/hr)	Median surface erodibility characteristics: Turbidity (ntu)	Sediment concentration (mg/l)	Sediment yield (kg/ha/hr)
Tractor Shelterwood					
CC-1	53%	8.57	71	235.2	13.9
H-7	33%	5.55	190	573.5	80.0
Tractor					
CC-2	50%	8.83	225	539.6	19.1
CC-3	50%	4.82	474	1551.4	182.2
H-6	100%	16.65	32	202.2	3.6
Cable					
CC-2	31%	9.48	90	254.9	20.2
CC-3	25%	6.69	123	562.8	23.7
H-6	33%	6.86	24	94.8	6.5

[a] Surface erodibility data were normalized before calculating medians. The infiltration data were normally distributed.

[b] CC-1 = Watershed 1, CC-2 = Watershed 2, CC-3 = Watershed 3 (Coyote Creek Watersheds); H-6 = Watershed 6, H-7 = Watershed 7 (Hi-15 Watersheds).

[c] Indicates the percentage of infiltration/erodibility plots located on or adjacent to skid trails or cable log paths within each treatment for each watershed.

surface sealing effect was produced rapidly after the rainfall start. Also, in certain instances where burning occurred, a possible hydrophobic surface condition may partially explain the lower infiltration capacities, if the skid trail or path was more severely burned than the rest of the general area. The explanation of increased surface and subsurface bulk densities via a restricting layer as causing reduced infiltration capacities is doubtful. From previous discussions, surface and subsurface bulk densities for skid trails and paths generally did not produce any consistent trends from treatment to treatment nor did they differ greatly from entire treatment means or undisturbed treatment means. The same can be stated about non-capillary pore space except that differences were significant when compared to the undisturbed treatment. However, lower undisturbed infiltration means, when compared to certain other treatments, indicates that the amount of macropore space is not responsible for the infiltration reduction on skid trails and paths.

The log path mean for the cable yarded portion of Watershed 6 was nearly identical to the mean infiltration capacity for the same area because of a small sample size and because the general disturbance and burning of the area may have had a larger influence than the paths.

Surface Erodibility

Surface erodibility for each site was characterized by turbidity, suspended sediment concentration and sediment yield. All erodibility data were highly skewed and needed normalization before analysis. A natural logarithmic transformation was found to normalize the turbidity and sediment yield data from both study areas. On Coyote Creek, a square root transformation was required to normalize the sediment concentration data, while a natural logarithm was needed to transform the same data collected from the Hi-15 Watersheds. Because of normalization via two different numerical functions, the suspended sediment concentration data could not be combined from the two study areas for analysis. Therefore, visual comparison was used to evaluate differences in sediment concentration between the two study areas.

All surface erodibility values appearing in the appropriate tables are retransformed medians. This is because in the transformation process, original population medians transform directly, while means do not. For a normal distribution, the median, mode and mean are identical. However, in a log normal distribution for example, the median equals e^{μ}, the mode is $e^{(\mu-\sigma^2)}$, and the mean is defined as $e^{(\mu+\sigma^2/2)}$, where e is the base of the natural logarithm, and μ and σ^2 are the mean and variance of the transformed variable, respectively. This then creates difficulty in making inferences about the original pulation when the statistical analysis was conducted on the trans-rmed sample observations. Therefore, because means do not trans-rm in a straightforward manner, the antilog of those logarithmic ansformed medians equals the medians of the original populations. milarly for the square root transformed medians, a square of the edian is the median for the original population.

The surface erodibility characteristics indexed the amounts of silts nd clays being removed from each infiltration plot surface by the sim-ated rainfall via surface runoff. A serious problem with this proce-ure was that erosion from the exposed soil face into which the infil-or ter trough was inserted may have an overriding influence on soil rface erosion. Also, any slumping of soil adjacent to the soil face ay affect the true amount of material eroded from the plot surface. herefore, comparisons with undisturbed plots, a base level, are man-atory and only large differences should indicate "problem areas." lso, it is difficult to determine if the surface erodibility data obtained re realistic estimates of what might be expected during natural rain-ll events.

From field observations, it was generally noted that during an dividual infiltration run, the greatest amounts of sediment removal ccurred during the first few minutes of initial runoff. A tapering off f e sion then occurred with time. This may be analogous to the ob-rvation that the highest levels of surface erosion on a watershed asis, particularly from skid trails and other highly disturbed areas, ccur during the first few fall rains and then taper to a low base level s soils become and remain near field capacity. A result similar to his will be discussed later when comparing summer to fall erodibility haracteristics.

Turbidity

Turbidity medians for the treatments on Coyote Creek are given n Table 9. Comparing entire treatments (sample size equals 32), both helterwood and undisturbed medians were statistically greater than the ab. logged median (99% confidence level). The shelterwood and un-isturbed treatments were statistically equal. The tractor treatment urbidity was larger than that resulting from any other treatment (high- significant differences).

An explanation for the undisturbed turbidity being larger than the able treatment turbidity is due to the cable treatment having a greater nfiltration capacity and lesser amounts of surface runoff than the un-isturbed treatments. The shelterwood treatment had a larger percent f sampling sites in skid trails with lower infiltration and greater run-ff than did the cable treatment, explaining the highly significant differ-nce. The tractor turbidity was greater than all others because of the arg percentage of infiltration plots on surface damaging skid trails nd because of the soil influence and site conditions of Watershed 3.

ɔle 9. Median surface erodibility characteristics by treatments for the Coyote Creek Watersheds, summer 1977.[a]

atment[b]	Turbidity (ntu)	Sig.[c]	Sediment concentration (mg/l)	Sig.[c]	Sediment yield (kg/ha/hr)	Sig.[c]
actor						
helterwood						
CC-1	95	c	284.2	b	12.7	c
actor						
CC-2	164	d	432.8	c	10.2	bc
CC-3	594	e	1540.1	d	156.4	d
ble						
CC-2	41	b	155.5	a	4.8	ab
CC-3	20	a	152.4	a	2.3	a
disturbed						
CC-2	70	bc	241.5	ab	15.2	c
CC-out	99	c	280.0	b	17.0	c
C 4	58	b	184.9	a	13.3	c
erage	89		348.2		12.6	
eatment edians						
actor helterwood	95	b	284.2	b	12.7	b
actor	312	c	901.4	c	40.0	c
ble	29	a	154.0	a	3.3	a
disturbed	73	b	235.7	ab	15.1	b
erage	89		348.2		12.6	

urface erodibility data were normalized before calculating medians.

C-1 = Watershed 1, CC-2 = Watershed 2, CC-3 = Watershed 3, CC- = Watershed 4, CC-out = outside the lower perimeters of Watersheds 2 and 3.

reatments with the same letters are not significantly different. reatments not followed by the same letter are significantly different the 90% level of confidence. T-tests were used to evaluate treatment differences following analysis of variance.

Highly significant differences were found between the turbidities f the tractor windrowed portion of Watershed 3 and all other treat- ıents, whether tractor, cable, shelterwood or undisturbed, on any vatershed (Table 9). Reasons for the differences are primarily relat- d to the soils and the heavily disturbed surface. Since this area is nderlain by mostly green breccia derived, fine-textured soils, amor- phous colloidal clays are abundant. With tractor windrowing and burn- ng, an easily erodible surface condition exists in which long-term urbidity-causing clays can be removed quickly.

Differences associated with either Watershed 2 or 3 cable medi- ans and other treatments are caused by the higher infiltration capaci- ies, lower runoff amounts and the smaller percentages of sample sites n cable log paths on either cable treatment. The undisturbed medians vere greater than either cable medians due to the edge effect of the oil face cut into the downhill side of the infiltrometer plot. Since over 0% of the undisturbed sample sites, totally, were located on red brec- ia, colloidal-producing soils, the disturbance of cutting a soil face for ough insertion was sufficient to cause small amounts of colloidal clay o be collected.

An explanation for differences in turbidities related to the tractor ogged units of Watershed 2 and other treatments, except for the trac- or activity of Watershed 3, is attributed to the skid trails sampled. Most skid trails in the Watershed 2 tractor units were found more amaging to the soil surface and had less total cover than related trails nd paths in other treatments.

Changes in turbidity as a result of the treatments appear to have een relatively minor. Only the tractor medians for Watersheds 2 and may be of importance relative to the base level established by the ndisturbed sites. The tractor windrowing and burning treatment on Watershed 3 can be considered a "problem area" because of the magni-ude of increase.

Turbidity medians for each treatment were analyzed for effects by soil series, parent materials and coarse/fine textured soils. In-co istent trends and confounding results were obtained for each of hese categories. Also, the same confounding results and inconsisten-ies were found for suspended sediment concentration and sediment yield data.

Turbidity medians for the treatments on the Hi-15 Watersheds (Table 10) were not significantly different from the undisturbed condi-tions, in most instances. Reasons for the tractor shelterwood and tractor treatments having larger medians can be explained by some in-filtration plots being located on skid trails. Despite plots located on skid trails, all turbidities are insignificant and no "problem areas" are evident.

Examining the combination of turbidity medians for both the Coyote Creek and Hi-15 study areas, no differences were found among ıle 10. Median surface erodibility characteristics by treatments for the Hi-15 Watersheds, summer 1977.[a]

reatment[b]	Turbidity (ntu)	Sig.[c]	Sediment concentration (mg/l)	Sig.[c]	Sediment yield (kg/ha/hr)	Sig.[c]
ractor Shelterwood H-7	47	c	245.6	c	26.5	bc
ractor H-6	32	bc	202.2	bc	3.6	a
able H-6	21	ab	124.1	ab	13.1	b
able Shelterwood H-7	14	a	79.9	a	10.2	ab
ndisturbed H-out	22	ab	197.1	bc	36.1	c
verage	25		162.8		15.4	

Surface erodibility data were normalized before calculating medians.

H-6 = Watershed 6, H-7 = Watershed 7, H-out = outside the lower perimeters of Watersheds 6, 7 and 8.

Treatments with the same letters are not significantly different. Treatments not followed by the same letter are significantly different at the 90% level of confidence. T-tests were used to evaluate treatment differences following analysis of variance.

treatments (refer back to Table 7). However, a highly significant difference was found between turbidities for treatments on the Coyote Creek and Hi-15 Watersheds, taken collectively. The Coyote Creek medians were greater than those on the Hi-15 Watersheds. Specifically, corresponding cable and shelterwood treatment medians from both study areas were statistically equivalent, while undisturbed and tractor medians from Coyote Creek were greater (highly significant differences) than those from the Hi-15 Watersheds. The differences between study areas were caused by the green and red breccia and basalt derived, fine-textured, colloidal-producing soils found on the Coyote Creek area versus the andesite formed, coarser-textured, non-colloidal soils occurring on the Hi-15 area.

Median turbidities for skid trails and cable log paths on both study areas are provided in a previous table--Table 8. On Coyote Creek, turbidities for skid trails and paths located in the cable and tractor areas of Watershed 2 and the cable area of Watershed 3 are greater than those for corresponding cable and tractor treatments of Watersheds 2 and 3. The median for skid trails on the tractor shelterwood treatment and the tractor windrowed area of Watershed 3 are smaller than medians previously discussed. On the shelterwood treatment, a possible explanation of reduced turbidities on skid trails is that sufficient numbers of skid trail sites were located on soils containing lesser amounts of clay colloids. These sites then had a greater

fluence on the smaller sample size of values obtained for the compu-
tion of the skid trail median. For the tractor windrowed area of
atershed 3, the severe surface disturbance and burning of this gen-
ral area had a larger influence than skid trails on turbidity production.

All skid trails and paths on the Hi-15 Watersheds had nearly
dentical turbidities in comparison with their corresponding treatments.
The skid trail median on the tractor shelterwood treatment was greater
han the treatment median. This is explained by the skid trail sites
aving a reduced infiltration capacity and increased runoff and erosion
ates in comparison with other sites on the same treatment.

uspended Sediment Concentration

The sediment concentration medians for the various treatments
n Coyote Creek are presented in Table 9. Considering individual
reatments and entire treatment medians for suspended sediment con-
entrations, results are essentially the same as those obtained for the
urbidity medians.

The undisturbed sampling locations, via slightly lower infiltra-
ion capacities and greater runoff, had slightly higher sediment concen-
rations than those for the cable treatments on Watersheds 2 and 3.
Also, given the edge effect and its influence upon the undisturbed treat-
t medians, only the tractor treatments for Watersheds 2 and 3 may

e of concern. The outstandingly high sediment concentration for the ractor portion of Watershed 3 can be identified as a "problem."

Table 10, previously listed, contains the suspended sediment concentration medians for the treatments on the Hi-15 Watersheds. Again, the results are nearly identical to those for turbidity.

The undisturbed median concentration, although statistically equal, was greater than the median for the cable treatment, besides being significantly larger than the cable shelterwood median. An explanation for these occurrences is the edge effect. The overriding damage of digging a shallow soil pit and inserting the infiltrometer tr gh on undisturbed sites on the Hi-15 Watersheds is expressed dramatically. With lower mean infiltration capacities than those for the undisturbed treatment, both the cable and cable shelterwood sampling sites produced on the average slightly more runoff than the undisturbed sites. This emphasizes the influence of the edge effect on surface erodibility. Again, suspended sediment concentrations for all treatments, relative to the undisturbed treatment, are not significant and no "problem areas" are indicated.

A visual comparison of sediment concentrations from corresponding treatments for both study areas shows Coyote Creek treatments having larger concentrations than those for the Hi-15 Watersheds. This re ult would probably be statistically evident. The major differences between study areas for sediment concentration would probably occur with only the tractor treatments for reasons already discussed. Finally, if medians were combined for like treatments from both areas, no difference would probably be found among treatments.

Sediment concentration medians for skid trails and cable log paths on the Coyote Creek and Hi-15 Watersheds are presented in Table 8. Excluding the shelterwood treatment, medians for skid trails and paths on Coyote Creek increased over the medians for individual treatments. This increase was substantial for the cable area on Watershed 3. The slight increase in the skid trail median for the tractor windrowed area of Watershed 3 again indicates that the severe surface disturbance and burning throughout this general area had a greater influence than did skid trails on sediment concentration production. The slight decrease in the median for skid trails on the shelterwood treatment has been explained with the turbidity results.

On the Hi-15 Watersheds, only the tractor shelterwood skid trails increased in suspended sediment concentration for reasons provided in the turbidity results. The median for cable log paths on the cable area of Watershed 6 decreased over that for the entire cable treatment. This decrease was caused by the larger effect of general surface disturbance and burning on sediment concentration than paths.

Sediment Yield

In Table 9, previously listed, sediment yield medians for the treatments occurring on Coyote Creek are given. For entire treatments (sample size equals 32), highly significant differences were discovered between the tractor sediment yield and those for all other treatments. Also, both the undisturbed and shelterwood treatment yields were statistically larger (99% confidence level) than the cable yield.

Sediment yield, as calculated, is directly related to the suspended sediment concentration and the total volume of runoff and inversely related to the total runoff time. This explains the highly significant difference between the undisturbed and cable sediment yields. Since the cable treatment had a slightly higher infiltration capacity and slightly lower suspended sediment concentration than the undisturbed treatment, the cable sediment yield was expected to be lower than the undisturbed sediment yield. Furthermore, the cable sites averaged less total runoff volume and nearly the same total runoff time compared with the undisturbed sampling sites. This compounded the difference between the two sediment yields.

Even though statistically equal, the undisturbed median was slightly greater than the shelterwood median, again due to the sediment yield calculation procedure. The shelterwood sampling sites on the average had smaller runoff volumes and greater runoff time than the undisturbed treatment. This resulted in the slightly smaller sediment yield for the shelterwood treatment versus the undisturbed.

On a treatment and watershed basis, the only noteworthy result was the highly significant difference between the tractor median from Watershed 3 and all other treatment medians on any watershed.

Differences between the undisturbed sediment yields and those for treatments with lower yields can generally be explained entirely by the various components of the sediment yield formulation. The physical reasons explaining differences among treatments for infiltration capacities, turbidities and suspended sediment concentrations, previously discussed, are valid but enter, only partially, into the explanation here. Sediment yields are substantially a by-product of the measurement procedures employed except when a surface or soil condition has an overriding influence.

Considering the undisturbed treatment medians as base level, only the tractor sediment yield median for Watershed 3 is highlighted and can be identified as a "problem."

Sediment yield medians for the various treatments on the Hi-15 Watersheds are indicated in Table 10. A significant increase in sediment yields, in relation to undisturbed sites, was not found for any treatment. Therefore, no "problem areas" are evident.

Combined sediment yield medians for respective treatments from both study areas are shown in Table 7. Collectively, no difference was ound among the treatments. However, a significant variation among the two study areas was again indicated. Although undisturbed, cable and shelterwood treatments were shown statistically equivalent, the Hi-15 sediment yield medians for those treatments were greater than the corresponding medians on the Coyote Creek Watersheds. The major influence of study area variation was attributed to the highly significant differences between tractor medians.

Median sediment yields for skid trails and cable log paths for both study areas are given in Table 8. For Coyote Creek, all sediment yields for skid trails and paths except for the shelterwood treatment increased substantially over those yields for the individual treatments. The shelterwood skid trail median increased only slightly. Overall, surface conditions have influenced sediment yield medians over that expected as a function of the methodology.

On the Hi-15 Watersheds, a noteworthy effect of surface conditions on skid trails substantially increasing sediment yield occurred on the tractor shelterwood treatment. A slight decrease in the sediment yield median for a cable log path was obtained for the cable treatment. This decrease was caused by the lower suspended sediment concentration already explained.

Original and Paired Plot Comparisons

Median infiltration capacities and surface erodibility characteristics for original and paired plots on the Coyote Creek and Hi-15 Watersheds are provided in Table 11. The sample standard deviations for all variables collected on original and paired plots are also given. The combined medians for the suspended sediment concentrations from both study areas for original and paired plots could not be determined because of the two different normalizing transformations.

In order to compare infiltration capacities of original and paired plots, the reproducibility of the infiltrometer requires examination. Reproducibility is defined as obtaining nearly identical infiltration capacities from different plots with the same soils and site conditions. To test infiltrometer reproducibility, summer infiltration capacities for certain similar sites on the tractor windrowed portion of Watershed 3, infiltration data from Watershed 3 windrowed sites sampled in the fall and the summer, and infiltration results for a single plot sampled twice in the fall were compared. As a result, the infiltrometer was generally found reliable and capable of providing reproducible results under similar conditions. Therefore, any differences found between original and paired plots are a function of the variability of the site conditions created by the treatment and the soils within a treatment, and not the inconsistency of the infiltrometer.

Table 11. Original and paired plot comparisons of the infiltration capacities and surface erodibility characteristics for the Coyote Creek and Hi-15 Watersheds, summer 1977.[a]

Variable	Coyote Creek Watersheds Median	Sig.[b]	S.D.[c]	Hi-15 Watersheds Median	Sig.[b]	S.D.[c]	Combined median
Infiltration capacity (cm/hr)							
Original plot	10.59	*	4.01	9.59	*	3.72	10.42
Paired plot	9.66		3.60	8.62		4.15	9.48
Turbidity (ntu)							
Original plot	85	NS	4	25	NS	2	69
Paired plot	93		4	25		2	75
Sediment concentration (mg/l)[d]							
Original plot	(330.6)	NS	(117.8)	(140.8)	NS	(1.8)	-----
Paired plot	(366.4)		(166.6)	(188.3)		(2.4)	-----
Sediment yield (kg/ha/hr)							
Original plot	9.7	*	6.6	11.2	*	2.5	10.0
Paired plot	16.4		6.6	21.1		4.4	17.1
Sample size	64			13			77

[a] Surface erodibility data except for sediment concentration were normalized with a natural logarithm for the Coyote Creek and Hi-15 Watersheds. The infiltration capacity data were normally distributed for both study areas.

[b] Significance of differences in paired t-tests (NS = not significant, * = significant at 90% confidence level).

[c] S.D. = Standard deviation for appropriate normal and transformed sample populations.

[d] Combined medians for the original and paired plots were not possible to calculate because the Coyote Creek sediment concentration data were normalized with a square root function, while the Hi-15 data were normalized with a natural logarithm.

Table 13. Summer and fall comparisons of the infiltration capacities and surface erodibility characteristics by treatments for the Coyote Creek Watersheds, 1977.[a]

		Mean infiltration capacity (cm/hr)		Median surface erodibility characteristics					
				Turbidity (ntu)		Sediment concentration (mg/l)		Sediment yield (kg/ha/hr)	
Treatment[b]	Sample size	Summer	Fall	Summer	Fall	Summer	Fall	Summer	Fall
Tractor Shelterwood									
CC-1	(5)	7.98	12.25	90	76	223.0	96.9	23.0	7.7
Tractor									
CC-2	2	11.24	13.86	89	313	173.8	432.3	15.5	21.9
CC-3	2	4.69	5.30	950	881	2483.5	1723.2	394.1	259.2
Average	(4)	7.96	9.58	291	525	657.0	863.1	78.2	75.4
Cable									
CC-2	2	9.82	15.87	44	20	202.5	9.1	10.3	1.9
CC-3	2	6.77	7.82	59	386	359.5	1231.6	19.4	82.5
Average	(4)	8.30	11.85	51	89	269.8	106.1	14.2	12.4
Undisturbed									
CC-2	1	9.54	14.20	73	152	179.6	238.8	16.9	5.4
CC-out	2	9.59	17.23	69	20	186.8	89.4	13.1	0.4
CC-4	1	9.60	14.06	102	121	296.7	315.0	25.7	9.2
Average	(4)	9.58	15.68	77	52	207.9	156.6	16.5	1.8
Average	(17)	8.42	12.33	100	113	295.7	185.4	25.3	10.4

[a] Comparisons were made on only those sites with both summer and fall data. Surface erodibility data were normalized with a natural logarithm before calculating medians. The infiltration data were normally distributed.

[b] CC-1 = Watershed 1, CC-2 = Watershed 2, CC-3 = Watershed 3, CC-4 = Watershed 4, CC-out = outside the lower perimeters of Watersheds 2 and 3.

the high variation in point estimates of infiltration. Also, little is known concerning the seasonal variation of the infiltration process.

With respect to the small rainfall amounts received by these study areas during the summer, the lower infiltration capacities reported for the summer than for the fall may be of little importance except for surface erodibility. Excluding some tractor windrowed and burned sites and certain skid trails and cable log paths, all sites on the Coyote Creek and Hi-15 Watersheds can easily handle a high intensity summer storm. Furthermore, fall infiltration capacities on even the most severely disturbed sites far exceeds usual and maximum fall intensities. However, as discussed previously, the infiltration capacities characterized by the infiltrometer are an overestimate of actual or natural infiltration capacities.

With fall infiltration capacities increasing substantially from those in the summer and given the same summer simulated rainfall rates, it would be expected that runoff amounts and surface erodibility rates would decrease in the fall. Because of the methodology utilized, it is important to recognize that higher infiltration capacity determinations required higher simulated precipitation rates. Therefore, runoff amounts were as large in the fall as they were in the summer but erosion rates were decreased. This was especially true for suspended sediment concentrations and sediment yields. This apparent

Infiltration capacity point estimates were found highly variable r both study areas, especially on Coyote Creek. For the Coyote reek Watersheds, the original plot infiltration capacity was signifi- antly greater than that for the paired plot. This difference was caused rimarily by the original shelterwood plots having significantly larger nfiltration capacities than their corresponding paired plots. Also, riginal plot means were significantly larger than those for the paired lots for the undisturbed sites located in Watershed 2 and outside the erimeters of Watersheds 2 and 3.

The original plot infiltration capacity averages on the Hi-15 rsheds were found significantly greater than that for the paired lot. As on the Coyote Creek Watersheds, this difference between plot eans was attributed to differences obtained on the tractor shelterwood nd undisturbed treatments.

Combining averages for similar plots from the Coyote Creek and i-15 Watersheds results in a highly significant difference between ori- inal and paired plot infiltration capacities. The specific treatments ausing this difference have been enumerated.

For the Coyote Creek and Hi-15 Watersheds, the turbidity and spended sediment concentration medians were statistically equivalent r both the original and paired plots. This indicates that there is lit- riation in point estimates of turbidity and sediment concentration hen utilizing two related erodibility plots on the same treatment.

The original plot sediment yield was found smaller than the paired plot for both study areas. On Coyote Creek, the causes of this difference were on the undisturbed and shelterwood treatments. For the Hi-15 Watersheds, the undisturbed and tractor treatments were the basis for the paired plot medians being greater than the original plot sediment yield medians. Point estimates of sediment yield therefore are variable and again tied to the infiltration determination procedure.

Finally, from examination of Table 11, a general trend was found indicating that as infiltration capacity is reduced, all surface erodibility characteristics increase. In light of the discussion comparing skid trails and cable log paths to the corresponding individual treatment, this seems a logical pattern.

Summer and Fall Comparisons

All comparisons of summer and fall data were performed on only those sites sampled in the fall and taken collectively for each study area. On Coyote Creek, 17 of the total 64 sampling locations were remeasured for infiltration and surface erodibility in the fall. On half of these sites, soil samples were taken. For the Hi-15 Watersheds, seven of the total 13 sites were resampled for infiltration and erodibility in the late fall. Soil sampling occurred on less than half of those sites. A combining of similar data from both study areas was also accomplished.

Mean soil data collected from the same sites during summer and fall from the Coyote Creek and Hi-15 Watersheds are given in Table 12. All data in this table were normally distributed and required no transformations prior to analysis.

Surface bulk densities sampled in the fall on Coyote Creek were found significantly larger than those collected in the summer. The same variable was statistically equivalent for both sampling periods on the Hi-15 Watersheds. For both study areas, a highly significant difference was found between subsurface and impermeable layer bulk densities obtained in the summer and fall. Here, the fall bulk densities were larger than those from the summer. The water content of the restricting layer for the fall was statistically larger (highly significant difference) than that for the summer on Coyote Creek, while on the Hi-15 Watersheds, no difference was obtained. Total porosity means for both sampling periods and from the two study areas were statistically equal. For the Coyote Creek and Hi-15 Watersheds, a highly significant difference was found in most instances between summer and fall macroporosity averages defined at either 30 or 60 cm tension. Here, the summer averages were always greater than the fall averages. Overall, bulk densities increased, total porosity remained the same, capillary pore space increased, macroporosity decreased and soil water contents increased from summer to fall at both study areas.

Table 12. Summer and fall comparisons of the average soil characteristics for the Coyote Creek and Hi-15 Watersheds, 1977.[a]

Characteristic	Coyote Creek Watersheds			Hi-15 Watersheds			Combined average	
	Summer	Fall	Sig.[b]	Summer	Fall	Sig.[b]	Summer	Fall
Surface bulk density	0.908	1.028		0.863	0.855			
(gm/cm^3)	(.16)	(.23)	*	(.16)	(.11)	NS	0.891	0.962
Subsurface bulk density	1.068	1.194		0.970	1.033			
(gm/cm^3)	(.18)	(.12)	**	(.09)	(.08)	**	1.030	1.132
Impermeable								
layer bulk density	1.044	1.192		0.970	1.033			
(gm/cm^3)	(.20)	(.17)	**	(.09)	(.08)	**	1.015	1.131
Impermeable								
layer water content	27.5	39.4		37.5	42.6			
(%)	(9.6)	(4.9)	**	(6.4)	(3.9)	NS	31.4	40.6
Total porosity	57.2	56.2		63.2	61.3			
(%)	(8.6)	(6.9)	NS	(2.6)	(3.6)	NS	59.2	57.9
Macroporosity at 30	16.7	13.0		19.6	9.1			
cm tension (%)	(7.3)	(7.3)	*	(5.2)	(4.3)	**	17.7	11.7
Macroporosity at 60	20.2	16.0		24.1	13.0			
cm tension (%)	(7.7)	(7.4)	**	(5.7)	(5.2)	**	21.5	15.0
Sample size[c]	8			5			13	

[a] Comparisons were made on only those sites with both summer and fall data. Values in parentheses are standard deviations.

[b] Significance of differences in paired t-tests (NS = not significant, * = significant at 90% confidence level, ** = significant at 99% confidence level).

[c] The sample size for the Hi-15 Watersheds and combined average for the total porosity and macroporosity at 30 and 60 cm tension is 4 and 12, respectively. A soil sample was not collected on the Hi-15 Watersheds during the fall.

To explain portions of the above results, the sampling technique was examined. All sampling was conducted in a consistent manner and thus it was assumed that the differences were not due to operator technique. Next, the inherent variability of the sampling device being used under various soil moisture conditions was considered. This may partially explain some of the bulk density variation from summer to fall but not all of it. A shrink and swell soil condition was finally hypothesized and may account for nearly all of the summer and fall differences.

The shrink and swell properties of a soil are determined by the amounts and types of clay present. Shrinking and swelling of clays throughout the Coyote Creek Watersheds was apparent from summer to fall sampling periods. This was discovered both in the data collected and from field observation. Richlen (1963; 1973) discusses the various clay types and their dominance in soils found on Coyote Creek. On the Hi-15 Watersheds, clay shrinking and swelling was not obvious from field observation and according to results, not occurring significantly on the soil surfaces sampled. Since all fall sites sampled on the Hi-15's had impermeable layers in the subsurface, this explains why those bulk densities and macroporosities were affected.

The only inconsistency in the shrink/swell hypothesis was that total porosities remained statistically equal from summer to fall. With a highly significant increase in restricting layer bulk densities from summer to fall, total porosities should decrease accordingly. Although a slight decrease in fall total porosities was indicated, it was not significant.

It may be that the pre-wet treatment and the infiltration determination significantly affected the soil properties, particularly total porosity as obtained during the summer. A detailed investigation of clay types, depths and amounts would be required on a site by site basis to determine such significance.

Tables 13 and 14 provide the summer and fall infiltration capacity and surface erodibility medians on an individual treatment basis for the Coyote Creek and Hi-15 Watersheds, respectively. No statistical analysis was performed on individual treatment data from these tables. Summer and fall statistical comparisons were only performed on treatments taken collectively from each study area.

Median infiltration capacities and surface erodibility characteristics collected from the same sites during the summer and fall from the Coyote Creek and Hi-15 Watersheds are available in Table 15. From examination of the data upon which the table is based, infiltration capacities from both study areas were discovered normally distributed. All surface erodibility data were found highly skewed and normalized with a natural logarithmic transformation before analysis.

A highly significant difference was obtained between the summer and fall infiltration capacity means on Coyote Creek. Here, fall infiltration capacity was on the average about 1.5 times larger than the

Table 13. Summer and fall comparisons of the infiltration capacities and surface erodibility characteristics by treatments for the Coyote Creek Watersheds, 1977.[a]

Treatment[b]	Sample size	Mean infiltration capacity (cm/hr)		Median surface erodibility characteristics: Turbidity (ntu)		Sediment concentration (mg/l)		Sediment yield (kg/ha/hr)	
		Summer	Fall	Summer	Fall	Summer	Fall	Summer	Fall
Tractor									
Shelterwood									
CC-1	(5)	7.98	12.25	90	76	223.0	96.9	23.0	7.7
Tractor									
CC-2	2	11.24	13.86	89	313	173.8	432.3	15.5	21.9
CC-3	2	4.69	5.30	950	881	2483.5	1723.2	394.1	259.2
Average	(4)	7.96	9.58	291	525	657.0	863.1	78.2	75.4
Cable									
CC-2	2	9.82	15.87	44	20	202.5	9.1	10.3	1.9
CC-3	2	6.77	7.82	59	386	359.5	1231.6	19.4	82.5
Average	(4)	8.30	11.85	51	89	269.8	106.1	14.2	12.4
Undisturbed									
CC-2	1	9.54	14.20	73	152	179.6	238.8	16.9	5.4
CC-out	2	9.59	17.23	69	20	186.8	89.4	13.1	0.4
CC-4	1	9.60	14.06	102	121	296.7	315.0	25.7	9.2
Average	(4)	9.58	15.68	77	52	207.9	156.6	16.5	1.8
Average	(17)	8.42	12.33	100	113	295.7	185.4	25.3	10.4

[a] Comparisons were made on only those sites with both summer and fall data. Surface erodibility data were normalized with a natural logarithm before calculating medians. The infiltration data were normally distributed.

[b] CC-1 = Watershed 1, CC-2 = Watershed 2, CC-3 = Watershed 3, CC-4 = Watershed 4, CC-out = outside the lower perimeters of Watersheds 2 and 3.

Table 14. Summer and fall comparisons of the infiltration capacities and surface erodibility characteristics by treatments for the Hi-15 Watersheds, 1977.[a]

Treatment[b]	Sample size	Mean infiltration capacity (cm/hr)		Median surface erodibility characteristics: Turbidity (ntu)		Sediment concentration (mg/l)		Sediment yield (kg/ha/hr)	
		Summer	Fall	Summer	Fall	Summer	Fall	Summer	Fall
Tractor Shelterwood H-7	2	6.95	10.15	101	57	690.7	229.8	105.0	12.0
Tractor H-6	1	17.49	9.76	30	168	176.5	441.9	2.8	100.7
Cable H-6	1	7.08	17.80	15	1	74.3	0.1	3.8	0.1
Cable Shelterwood H-7	1	6.95	13.52	9	24	51.4	161.9	3.4	10.1
Undisturbed H-out	2	6.72	10.51	17	15	228.0	62.9	74.1	9.2
Average	(7)	8.41	11.77	28	23	207.8	54.8	21.6	7.4

[a] Comparisons were made on only those sites with both summer and fall data. The surface erodibility data were normalized with a logarithmic transformation before computing the medians. The infiltration data were normally distributed.

[b] H-6 = Watershed 6, H-7 = Watershed 7, H-out = outside the lower perimeters of Watersheds 6, 7and 8.

Table 15. Summer and fall comparisons of the infiltration capacities and surface erodibility medians for the Coyote Creek and Hi-15 Watersheds, 1977.[a]

Variable	Coyote Creek Watersheds			Hi-15 Watersheds			Combined median	
	Summer	Fall	Sig.[b]	Summer	Fall	Sig.[b]	Summer	Fall
Infiltration capacity (cm/hr)	8.42 (2.82)	12.33 (4.28)	**	8.41 (4.21)	11.77 (4.07)	*	8.42	12.17
Turbidity (ntu)	100 (3)	113 (8)	NS	28 (3)	23 (5)	NS	69	71
Sediment concentration (mg/l)	295.7 (2.6)	185.4 (19.8)	NS	207.8 (3.1)	54.8 (18.2)	NS	266.8	130.0
Sediment yield (kg/ha/hr)	25.3 (4.6)	10.4 (14.3)	*	21.6 (6.7)	7.4 (8.4)	NS	24.2	9.4
Sample size	17			7			24	

[a] Comparisons were made on only those sites with both summer and fall data. The surface erodibility data were normalized with a logarithmic transformation before calculating medians. The infiltration data were normally distributed. Values in parentheses are standard deviations.

[b] Significance of differences in paired t-tests (NS = not significant, * = significant at 90% confidence level, ** = significant at 99% confidence level).

summer. On the Hi-15 Watersheds, the fall average was greater than the average summer infiltration capacity by 1.4 times. Median summer and fall turbidities and suspended sediment concentrations from both study areas were statistically equivalent. Despite this similarity, sediment concentrations for the summer from the Coyote Creek and Hi-15 Watersheds were larger than those for the fall. Summer sediment yield medians for Coyote Creek and for the two study areas jointly were significantly greater than those for the fall. On the Hi-15 Watersheds, the two medians were statistically equal even though the summer sediment yield was larger than the fall sediment yield.

Examination of Table 13 indicates that the undisturbed treatment on the Coyote Creek Watersheds had the greatest increase in infiltration capacity from summer to fall. Also noteworthy was the extremely small, undisturbed fall sediment yield median.

On the Hi-15 Watersheds, because of the small fall sample size per treatment (refer to Table 14), caution should be exercised when comparing summer to fall results between treatments. This is illustrated by the cable treatment of Watershed 6 apparently having the largest summer to fall increase of all infiltration capacities based on a single fall sampling location. Also, the tractor yarded portion of Watershed 6 again provided inconsistent results.

A variety of conflicting reasons may be responsible for the increased fall infiltration capacities on the Coyote Creek and Hi-15

Watersheds. Initially, any litter shingle effects, surface sealing effects and non-wettable surface conditions created during the summer by litter residue, incorporated soil organic matter, severe slash burning, the hot, dry climatic conditions or any other factor may have been reduced or mitigated by the high fall moisture levels. This would then cause the immediate soil surface to be highly conducive for infiltration. However, conflicts are found after examining increased fall infiltration capacities in light of soil data. Here, the fall soil results of increased bulk densities, decreased macropore space, increased capillary pore space, increased soil moisture and the swelling of soils describe con-itions of decreased lateral flow rates and increased resistance to infiltrating water. This is the opposite of fall observations. It may be that these fall lateral flow rates in a wetted soil are higher than those in the summer, but this seems highly unlikely.

To explain this apparent conflict, a hypothesis has been developed to account for increased infiltration. During the summer, the infiltration capacity of a soil appears controlled by a short-lived condition found on the immediate soil surface. During fall rains, the controlling surface condition is mitigated and the infiltration capacity increases. As the soil becomes recharged from continued fall precipitation, the infiltration capacity is decreased and limited by the soil profile charac-ristics. The length of the transition period between summer and fall infiltration capacities is dictated by the speed of surface condition mitigation and the amount of soil swelling. The more a soil is influenced by shrink and swell clays, the less dramatic will be the initial increase in infiltration and shorter will be the transition zone because the soil profile will almost immediately limit the infiltration capacity. A visual conception of this hypothesis is provided in Figure 11.

Examples of this seasonal infiltration capacity variation on Coyote Creek can be seen in Figure 12. Curve 1 was obtained from data collected from a tractor yarded unit of Watershed 2, while curve 2 was obtained from the tractor windrowed area of Watershed 3 (refer to Figure 6). Both summer base levels were determined from preliminary infiltration data collected in early summer. This study's "summer" infiltration determination occurred within the transition zones for both areas for two different reasons. On curve 2, a two-day rainfall event removed partially the limiting surface condition but created a swollen, relatively moist, subsurface condition. For curve 1, the pre-wet treatment and infiltration determination minimized any controlling surface condition and loosened any restricting layer. Upon sampling in the fall following high rainfall amounts and with the soil near or at field capacity, both sites showed higher infiltration capacities with the total removal of any limiting surface condition and were now controlled by the properties of the soil profile, influenced primarily by swelling clays.

The inconsistencies found for the tractor logged portion of Watershed 6 on the Hi-15 Watersheds can also be explained by this hypothesis

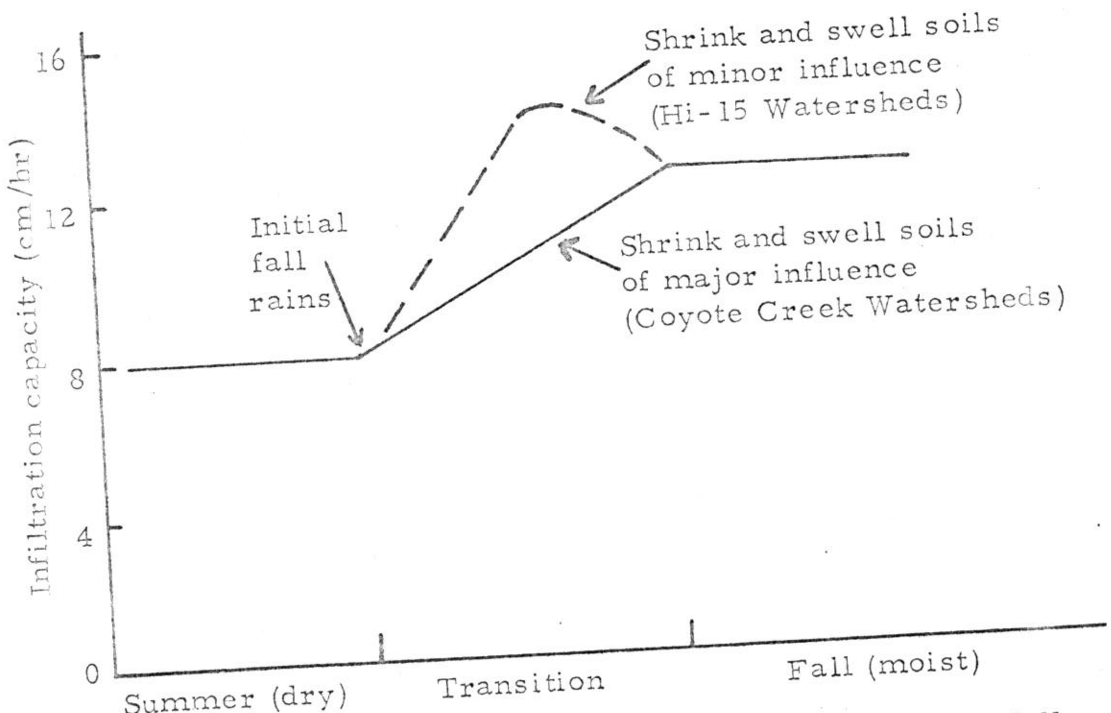

Figure 11. Infiltration capacity variation from summer to fall on the Coyote Creek and Hi-15 Watersheds, 1977.

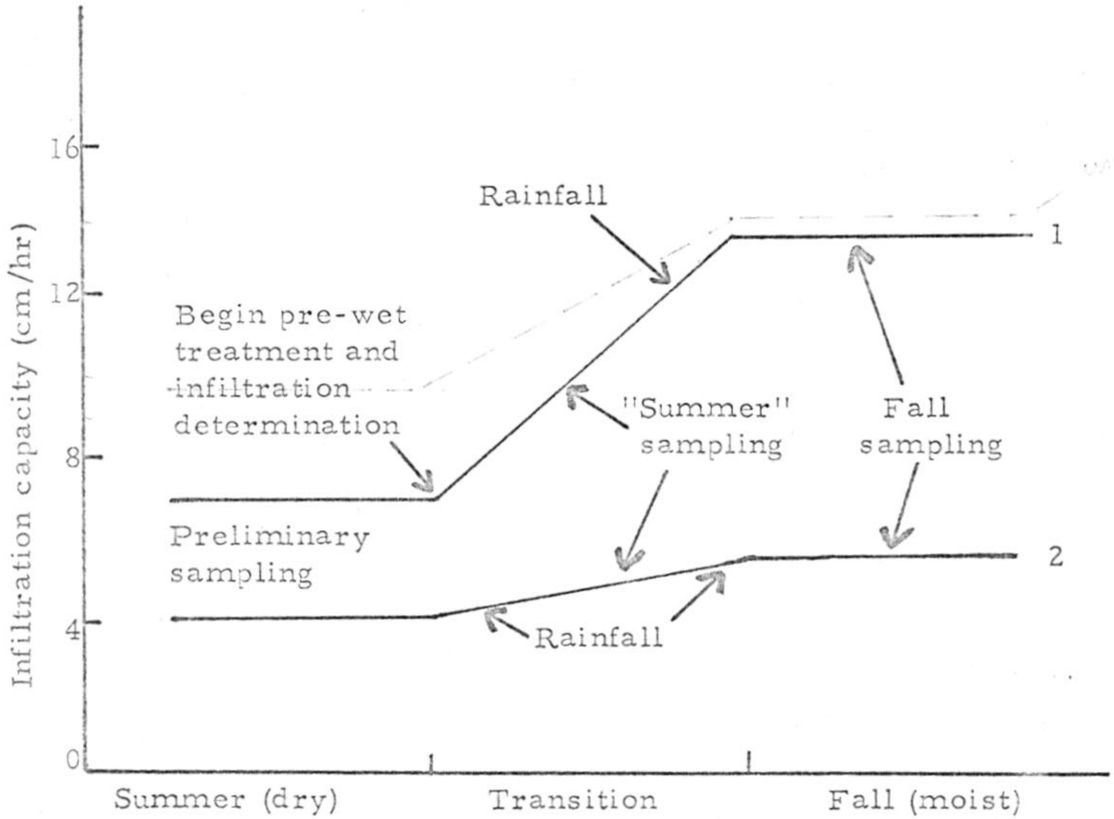

Figure 12. Infiltration capacity variation examples from the Coyote Creek Watersheds. Curve 1 is from a tractor yarded unit in Watershed 2. Curve 2 is from the tractor windrowed area of Watershed 3.

(see Figure 13). All sites, except for the undisturbed treatment, were apparently sampled during the transition period following the early September rains that removed partially any hydrophobic or limiting surface effect. This was especially true for the Watershed 6 tractor sites. For those tractor sites, the previous rains had entirely removed all controlling surface conditions. Because the soil profile was far from field capacity, shrink and swell clays were of minor influence, and because the lateral flow rates were much larger than those occurring in the fall but slightly reduced from summer rates, the soil profile exerted little resistance to infiltration and extremely high infiltration capacities were thus obtained. During fall sampling, these sites were entirely controlled by a near field capacity profile with lower lateral flow rates. Therefore, the infiltration capacity was reduced but still would be substantially higher than if surveyed during the hot summer under surface limiting conditions. The summer base level for Figure 13 was estimated from other sites on the Hi-15 Watersheds.

From the previous discussion concerning seasonal infiltration variation, the amount of rainfall required to remove and mitigate a surface limiting condition is unknown and may vary from site to site. Also, the pre-wet treatment and the infiltration determination may partially remove and influence this surface condition. This may further explain

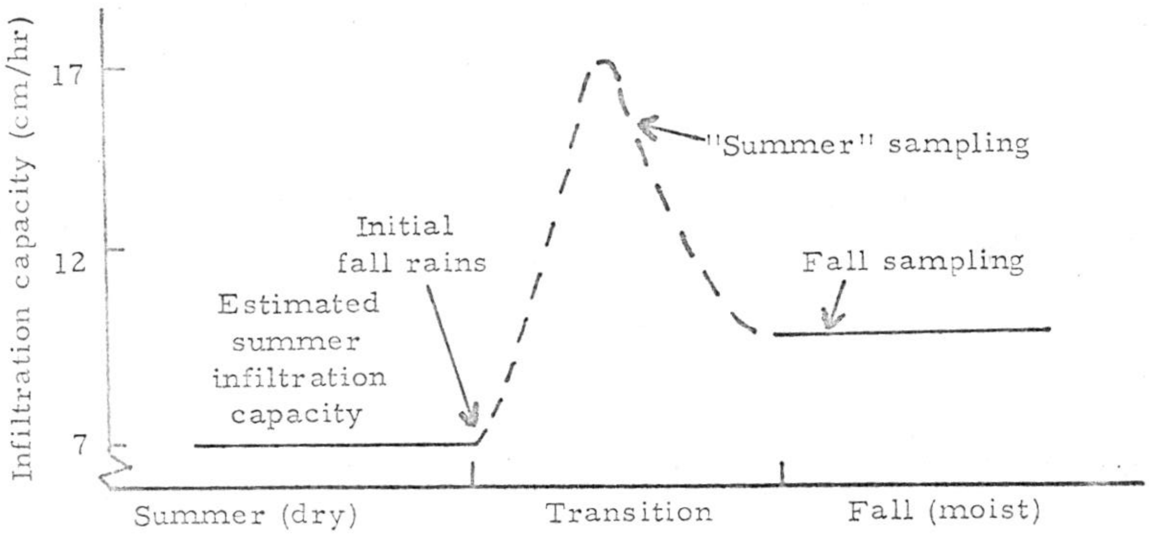

Figure 13. An example of infiltration capacity variation on the tractor logged portion of Watershed 6, Hi-15 Watersheds.

the high variation in point estimates of infiltration. Also, little is known concerning the seasonal variation of the infiltration process.

With respect to the small rainfall amounts received by these study areas during the summer, the lower infiltration capacities reported for the summer than for the fall may be of little importance except for surface erodibility. Excluding some tractor windrowed and burned sites and certain skid trails and cable log paths, all sites on the Coyote Creek and Hi-15 Watersheds can easily handle a high intensity summer storm. Furthermore, fall infiltration capacities on even the most severely disturbed sites far exceeds usual and maximum fall intensities. However, as discussed previously, the infiltration capacities characterized by the infiltrometer are an overestimate of actual or natural infiltration capacities.

With fall infiltration capacities increasing substantially from those in the summer and given the same summer simulated rainfall rates, it would be expected that runoff amounts and surface erodibility rates would decrease in the fall. Because of the methodology utilized, it is important to recognize that higher infiltration capacity determinations required higher simulated precipitation rates. Therefore, runoff amounts were as large in the fall as they were in the summer but erosion rates were decreased. This was especially true for suspended sediment concentrations and sediment yields. This apparent inconsistency with runoff amounts can be explained again by the seasonal infiltration hypothesis.

During the summer, infiltration capacities were lower on all sites than in the fall and were controlled by surface limiting conditions. Another by-product of the summer conditions were relatively unstable and erosive soil surfaces, particularly on skid trails, cable log paths, tractor windrowed areas and severely burned areas. Reduced cohesion at the soil surface may have been caused by the same surface conditions partially restricting infiltration. During storms in late summer and early fall, low infiltration capacities, especially on compacted areas, caused runoff with the additional help of the noncohesive surface via surface sealing. Thus large amounts of noncohesive surface sediment were eroded. This was visually observed by the author and measured with the infiltrometer. After sufficient fall rains, surface limiting conditions were reduced or mitigated. This resulted in higher infiltration capacities that were soil profile controlled and stable, less erosive soil surfaces. At the time of fall sampling, infiltration capacities were relatively high, while soil surfaces were in their least erosive and most stable state. Thus, the fall surface erosion rates were low despite equal summer runoff amounts.

These above results were observed on a small scale for nearly all individual infiltration plots. During an infiltration run, sediment [illegible] greatest during the first few minutes of initial runoff and then tapered to some base level with time. Similar results have been noted by Adams, Kirkham and Nielsen (1957). Therefore, the initial, high sediment runoff can be likened to that created by the first late summer/early fall storms, and the tapering of sediment to a base level synonymous to that caused by continued fall rains and the fall/winter precipitation period (Meyer, 1965).

The amount of rainfall needed to stabilize soil surfaces is unknown and may be highly variable from site to site. The rapidity of establishment of this stable, more cohesive, soil surface during any infiltration determination may again further explain the large variation in point estimates of infiltration. Also, knowledge of seasonal patterns of surface erodibility is extremely meager.

Miscellaneous Comparisons and Observations

During fall sampling, an additional area was investigated to provide some perspective on possible recovery time of reduced infiltration capacities on skid trails. This area was tractor logged during the summer of 1977 and was located nearby the Coyote Creek Watersheds, which had been logged six years ago.

Two sampling sites were established on skid trails. Both sites were on Dumont soils and had slopes of 24%. The skid trail sampling locations were heavily disturbed and compacted but had not been burned.

surface bulk density = 1.222 gm/cm^3

subsurface bulk density = 1.502 gm/cm^3

total porosity = 48.2%

macroporosity (30 cm tension) = 4.8%

macroporosity (60 cm tension) = 5.9%

total cover = 32%

litter depth = 0.3 cm

litter mass = 1150 kg/ha

Both plots had high moisture contents as a result of rains prior to sampling. Therefore, the infiltration capacities obtained were expected to be relatively high and the surface erodibility rates relatively low. All transformations performed on Coyote Creek data were likewise performed here. Finally, these sites were located on skid trails typically found throughout this region and not on extraordinarily damaged areas.

For comparison, two sampling sites from tractor yarded units on Watershed 2 which had been located on or adjacent to skid trails were utilized. These sites were on Dumont soils at about 46% slope. These two pairs of sites had been sampled in the summer but not in the fall. Therefore, their bulk densities can be expected to increase and macropore space expected to decrease from summer to fall. These sampling locations were characterized by the following summer conditions:

surface bulk density = 1.018 gm/cm^3

subsurface bulk density = 1.121 gm/cm^3

total porosity = 52.0%

macroporosity (30 cm tension) = 15.4%

macroporosity (60 cm tension) = 18.7%

total cover = 70%

litter depth = 4.4 cm

litter mass = 5299 kg/ha

Since these sites were investigated in the summer, infiltration capacities should be lower and surface erodibility should be higher than for fall values. The same transformations were performed on these data as for the entire Coyote Creek data. Finally, because these skid trails occurred on soils similar to those outside Coyote Creek, they can be compared and may provide accurate estimates of recovery.

Means of 4.34 cm/hr and 8.29 cm/hr were obtained for infiltration capacities of the skid trail sites outside Coyote Creek and on Watershed 2, respectively. For the skid trails outside Coyote Creek, surface erodibility medians of 3430 ntu, 5390 mg/l and 1280 kg/ha/hr were discovered for turbidity, suspended sediment concentration and sediment yield, respectively. The turbidity, sediment concentration and sediment yield medians for the Watershed 2 skid trails were 340 ntu, 50 mg/l and 42 kg/ha/hr, respectively.

Based on this comparison, the Watershed 2 skid trails have recovered tremendously in six years relative to the recent skid trails outside Coyote Creek. On the skid trails on Watershed 2, bulk densities have decreased, macropore space, total cover, litter thickness and mass have increased, infiltration has increased greatly, and all surface erodibility characteristics have greatly decreased. This general pattern of recovery may be representative of many skid trails and highly disturbed areas on the Coyote Creek Watersheds. The recovery of Watershed 2 skid trails may be due to a number of factors, including a loosening of surface and subsurface horizons by freezing and thawing, biological activity, and shrinking and swelling of soils.

Harr et al. (1978) found increases in peak flows following logging on the Coyote Creek Watersheds during the fall/winter precipitation seasons. Peak flow increases on Watersheds 1 and 3 were relatively large but small for Watershed 2. They attributed the peak flow increases to reductions in evapotranspiration, and surface disturbance and compaction caused by road building, logging and slash disposal. Results of this study, excluding the logged area outside of Coyote Creek, do not support the hypothesis that changes in infiltration capacities, resulting from soil disturbance and compaction, may be responsible for the increased peak flows.

The main problem in identifying a partial cause and effect in relation to increased peak flows was that insufficient fall data were obtained.

Since the pre-wet treatment used during summer sampling to simulate fall conditions near the surface and immediate subsurface did not remove the restricting surface conditions, all infiltration determinations on Coyote Creek and many on the Hi-15 Watersheds were controlled entirely or partially by certain surface limiting conditions. Therefore, infiltration capacities were not restricted by the soil profile, which can be altered markedly through skid trails and other logging disturbance and compaction and which has control over infiltration during the peak flow season. Although patterns established during the summer such as skid trails and cable log paths having lower infiltration capacities than their surrounding treatment can be expected in the fall, fall differences between trails or paths and their corresponding treatment may be substantially greater.

Another problem was that no undisturbed pretreatment data could be collected. Although adjacent unlogged areas were used as controls, the distribution of soils was variable enough in certain cases that randomly located, undisturbed sites did not appear sufficiently on all soils. This was particularly true for Watershed 3 and the green breccia derived soils. Soils in Watersheds 1 and 2 were adequately distributed throughout Coyote Creek that sufficient, undisturbed, baseline data could be accumulated.

In conjunction with the lack of pretreatment data, recovery rates on disturbed areas were unknown. Information obtained on the recently tractor yarded area outside of Coyote Creek indicates more emphasis should be placed on surface disturbance and compaction effects during the first few years after logging. At the time of this study, six years after logging, a certain amount of recovery of skid trails and severely disturbed areas had occurred. The recovery was such that many of those areas were no longer influencing infiltration, erodibility or soil properties.

With respect to Watershed 3, a good case may be presented for surface disturbance and compaction currently increasing peak flows. From comparison with the recently logged area outside of the Coyote Creek Watersheds, the lower portions of this watershed and certain upper parts have recovered very little. This is particularly true for the tractor windrowed area where overland flow has been observed in the late summer by the author. However, quantification of Watershed 3 soils in an undisturbed, highly moist, fall state is mandatory before any further emphasis can be placed on surface disturbance and compaction as the primary causes of peak flow increases.

Fredriksen and Rothacher (1973) noted that increased sedimentation of the Coyote Creek Watersheds, especially on Watershed 3, has occurred. In comparison with the recent tractor yarded area investigated outside of Coyote Creek, increased sedimentation due to surface erosion would be likely immediately following logging. Of course, this would depend upon skid trail and cable log path orientation and location with respect to the stream channel. However, surface erosion would be of lesser importance than mass erosion and streambank erosion, particularly with the mobile soils found on Coyote Creek (Swanston and Swanson, 1976; Swanson and Swanston, 1977). Six years after logging, a partial recovery of skid trails and many highly disturbed areas is evident, and thus surface erodibility may currently be of no significance, except for one area. This exception would be the tractor windrowed and burned area of Watershed 3. Here, high surface erodibility is still indicated relative to undisturbed base levels. However, mass and streambank erosion will predominate with surface erosion of minor consequence (Fredriksen, 1970).[6]

Regression Analysis

The dependent variables used in the regression analysis were infiltration capacity, suspended sediment concentration and sediment yield. The surface erodibility characteristic of turbidity was not incorporated because of its dependency on colloidal-producing soils and high correlation with suspended sediment concentration.[7] The independent variables utilized were surface, subsurface and restricting layer bulk

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[6]Personal communication, R.D. Harr, December, 1977, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon.

[7]For Coyote Creek: Sed. conc. = 52.0 + (1.80 x Turb.), r^2 = .90, n = 130; for Hi-15: Sed. conc. = 51.9 + (3.15 x Turb.), r^2 = .81, n = 26.

density, impermeable layer moisture content, total porosity (determined at 0 cm tension), soil moisture content at 30 and 60 cm of tension, air permeameter reading, percent rock, bare ground, live vegetation, litter and total cover, litter thickness and mass, percent slope, soil series and cumulative summation of site factors (via indicator variables), macroporosity at 30 and 60 cm tension, and standardized noncapillary pore space at 30 and 60 cm tension. The analysis was performed on both dependent variables with and without normalizing transformations, and on independent variables with and without various transformations and cross-multiplications.

For the Coyote Creek Watersheds, all dependent variables indicated very poor relationships with independent variables. This was true for data from individual treatments and from all treatments collectively. Scatter diagrams of all data from Coyote Creek showed "shotgun" patterns and thus little meaning and large amounts of variance. Residual plots indicated no apparent patterns. The correlation coefficient squared (r^2) for infiltration capacity ranged from 0.0 to 0.17 when correlated with independent variables. The percent bare ground correlated best with all three dependent variables. The r^2 values for suspended sediment concentration and sediment yield versus percent bare ground was 0.41 and 0.20, respectively. No useful predictive models were discovered from either stepwise or backstep regression selection [illegible] on the dependent variables. With nearly all independent variables in a stepwise selected model, those variables explained only 34, 65 and 53% of the variance in infiltration capacity, suspended sediment concentration and sediment yield, respectively. Further analysis of the dependent variables was discontinued when no statistically significant relationships were evident.

The primary reason for this lack of predictive power by the independent variables was the extreme amounts of variation with point estimates of each dependent variable, particularly infiltration capacity and sediment yield. This was noted in the original and paired plot discussion. Specific reasons for this point estimate variation have also been mentioned previously. Initially, variability exists between and within soils. Despite a hypothesized rating of soils for the regression analysis, little insight was gained here. Next, the degree of removal of the surface limiting conditions was important in causing variability. Some sampling locations at Coyote Creek were indicative of summer conditions, while others with more mitigation of the surface conditions were characteristic of the transition period. Relative to summer, transition and fall conditions, some sampling sites via the pre-wet treatment and infiltration determination were significantly affected by changing soil properties and the rapid establishment of stable soil surfaces, while others were influenced to a lesser extent. The variability created by the degree of edge effect was an important influence for sediment related dependent variables. Finally, the substantial correlation of the

Table 13. Summer and fall comparisons of the infiltration capacities and surface erodibility characteristics by treatments for the Coyote Creek Watersheds, 1977.[a]

Treatment[b]	Sample size	Mean infiltration capacity (cm/hr)		Median surface erodibility characteristics					
				Turbidity (ntu)		Sediment concentration (mg/l)		Sediment yield (kg/ha/hr)	
		Summer	Fall	Summer	Fall	Summer	Fall	Summer	Fall
Tractor Shelterwood									
CC-1	(5)	7.98	12.25	90	76	223.0	96.9	23.0	7.7
Tractor									
CC-2	2	11.24	13.86	89	313	173.8	432.3	15.5	21.9
CC-3	2	4.69	5.30	950	881	2483.5	1723.2	394.1	259.2
Average	(4)	7.96	9.58	291	525	657.0	863.1	78.2	75.4
Cable									
CC-2	2	9.82	15.87	44	20	202.5	9.1	10.3	1.9
CC-3	2	6.77	7.82	59	386	359.5	1231.6	19.4	82.5
Average	(4)	8.30	11.85	51	89	269.8	106.1	14.2	12.4
Undisturbed									
CC-2	1	9.54	14.20	73	152	179.6	238.8	16.9	5.4
CC-out	2	9.59	17.23	69	20	186.8	89.4	13.1	0.4
CC-4	1	9.60	14.06	102	121	296.7	315.0	25.7	9.2
Average	(4)	9.58	15.68	77	52	207.9	156.6	16.5	1.8
Average	(17)	8.42	12.33	100	113	295.7	185.4	25.3	10.4

[a] Comparisons were made on only those sites with both summer and fall data. Surface erodibility data were normalized with a natural logarithm before calculating medians. The infiltration data were normally distributed.

[b] CC-1 = Watershed 1, CC-2 = Watershed 2, CC-3 = Watershed 3, CC-4 = Watershed 4, CC-out = outside the lower perimeters of Watersheds 2 and 3.

Sediment Yield

In Table 9, previously listed, sediment yield medians for the treatments occurring on Coyote Creek are given. For entire treatments (sample size equals 32), highly significant differences were discovered between the tractor sediment yield and those for all other treatments. Also, both the undisturbed and shelterwood treatment yields were statistically larger (99% confidence level) than the cable yield.

Sediment yield, as calculated, is directly related to the suspended sediment concentration and the total volume of runoff and inversely related to the total runoff time. This explains the highly significant difference between the undisturbed and cable sediment yields. Since the cable treatment had a slightly higher infiltration capacity and slightly lower suspended sediment concentration than the undisturbed treatment, the cable sediment yield was expected to be lower than the undisturbed sediment yield. Furthermore, the cable sites averaged less total runoff volume and nearly the same total runoff time compared with the undisturbed sampling sites. This compounded the difference between the two sediment yields.

Even though statistically equal, the undisturbed median was slightly greater than the shelterwood median, again due to the sediment yield calculation procedure. The shelterwood sampling sites on the average had smaller runoff volumes and greater runoff time than the highly variable infiltration capacity with sediment yield created variability with the latter dependent variable.

If a satisfactory predictive model for infiltration capacity would have been developed, it would have been of limited utility. As indicated by the percent bare ground providing the highest r^2 when correlated against infiltration capacity, surface conditions were in control during the summer sampling period. However, the seasons for peak flow increases occur during the fall and winter. At that time the relatively moist soil profile is limiting infiltration. Therefore, a predictive model characteristic of fall/winter conditions is necessary and not summer/fall-transition conditions.

As for surface erodibility characteristics, summer predictive models are most important, not fall predictive models. The largest amounts of surface erosion were discovered to occur during the first few fall storms when the surface is most erosive. However, since a satisfactory model was not discovered, surface erosion as related to site factors cannot be predicted from these data.

Slightly more meaningful relationships were obtained for the Hi-15 Watersheds. Because of the small sample size per treatment, individual treatment investigation was not conducted. Scattergrams and residual plots, as for Coyote Creek, provided mostly "shotgun" patterns. The highest r^2 for infiltration capacity was obtained with the percent live vegetation cover and equalled 0.43. With a model selected through stepwise selection procedures, containing percent live vegetation cover, surface and subsurface bulk density, percent slope and air permeameter reading, and predicting infiltration capacity, a R^2 value of 0.85 was found. For sediment concentration, the highest r^2 (0.21) resulted after correlation with percent rock cover. The highest r^2 for sediment yield was 0.22 and was obtained with the percent live vegetation cover. With five dominate independent variables in a stepwise selected predictive model for sediment concentration and sediment yield, those independent variables only accounted for 49 and 56% of the variance, respectively.

The same explanations given for Coyote Creek apply here with respect to lack of predictive power and variation of point estimates of the dependent variables. Unlike Coyote Creek, data from the Hi-15 Watersheds were more controlled by the soil profile due to the late August/early September rains. This was noted by certain soil properties included within a predictive model for infiltration capacity. Yet, the sampling period occurred during the transition period between summer, surface limiting conditions and fall, soil profile controlled conditions. Therefore, any models found are not accurate for fall/winter conditions of infiltration or summer conditions of surface erodibility.

Additional regression analysis was performed on air permeameter data from both study areas separately to develop predictive equations for amounts of macropore space at 30 and 60 cm tensions. Very poor relationships were discovered. Air permeameter readings from Coyote

Creek when correlated against restricting layer bulk density, impermeable layer moisture content, macroporosity at 30 cm tension and macroporosity at 60 cm tension provided r^2 values of 0.04, 0.31, 0.22 and 0.21, respectively. For the same variables on the Hi-15 Watersheds, r^2 values were 0.06, 0.18, 0.26 and 0.28, respectively. As in covariance analysis, the air permeameter reading should be recomputed in terms of a covariable which would be the restricting layer moisture content before further regression analysis. This could possibly improve the relationships between air permeameter readings and macropore space.

CONCLUSIONS

Infiltration capacities on the Coyote Creek and Hi-15 Watersheds were discovered to vary seasonally; increasing by about 1.4 times from a summer capacity of 8.42 cm/hr to a 12.17 cm/hr fall capacity. During the summer, lower infiltration capacities are created by surface limiting conditions. These restricting conditions include a litter shingle effect, a minor, non-wettable surface condition caused by litter residue, soil organic matter, hot, dry climatic conditions or severe slash burning, and a surface sealing effect created by easily erosive surface soil and little protective cover. Following initial fall rains, the restricting surface condition is reduced and infiltration capacities increase. After surface condition effects are reduced, the infiltration capacities are controlled by the soil profile which can be severely altered through logging disturbance and compaction. The increase in infiltration, during the transition period from summer to fall conditions, can be dramatic and appears to be controlled by the speed of surface condition removal and the amount of swelling clays present. The more a soil is influenced by shrinking and swelling clays, the less dramatic will be the infiltration increase because the soil profile will almost immediately control infiltration.

Surface erodibility was also found to vary seasonally; decreasing from summer to fall for suspended sediment concentration (267 to 130 mg/l, respectively) and sediment yield (24.2 to 9.4 kg/ha/hr, respectively). In the summer, an unstable, noncohesive, highly erosive surface condition exists. During the first few fall rains, this erosive surface is easily removed in large quantities by runoff. As more rains occur, moist soil conditions are established and surface erosion is reduced as the soil surface becomes more stable and cohesive.

On the Coyote Creek and Hi-15 Watersheds and except for certain highly disturbed areas, all treatments appeared capable of handling a high intensity, summer storm. Also, for each study area, nearly all treatments had statistically equal summer infiltration capacities. The mean infiltration capacities for the Coyote Creek and Hi-15 Watersheds were 10.13 and 9.11 cm/hr, respectively. Furthermore for each study area, nearly all treatments had insignificant surface erodibility in comparison with the undisturbed treatment, except again for highly disturbed areas. Highly disturbed areas were characterized by skid trails, cable log paths and tractor windrowed and burned areas. These areas had substantially reduced infiltration capacities and increased surface erodibility. However, all areas including the most severely disturbed sites had fall infiltration capacities that exceeded the usual and maximum fall/winter precipitation intensities. Recognition that the rainfall simulator may overestimate actual infiltration capacities of a site was realized.

A significant difference in infiltration capacities and sediment yields was discovered between subplots, while no difference was found for turbidities or suspended sediment concentrations. Factors contributing to these differences include site condition and soil variability, high dependence of sediment yield on infiltration methodology, the pre-wet treatment and infiltration determination changing summer soil properties, partially removing surface limiting conditions and partially establishing stable, less erosive soil surfaces and the degree of edge effect influence.

A significant difference in infiltration capacities and surface erodibility characteristics was discovered between study areas and was caused by soil differences. The Coyote Creek Watersheds have more fine textured, shrinking and swelling, colloidal-producing soils than do the Hi-15 Watersheds. This was especially indicated by Coyote Creek turbidities being larger than those for the Hi-15 Watersheds. With greater infiltration capacities obtained for corresponding treatments from Coyote Creek than from the Hi-15 area, it may be hypothesized that surface limiting conditions are more restrictive on coarse textured soils.

Since logging of the Coyote Creek Watersheds six years ago, many skid trails and other severely disturbed and compacted areas have greatly recovered and in many cases have characteristics of undisturbed soils. Freezing/thawing, biological activity, and shrinking and swelling of soils may account for this recovery. Skid trails and other severely disturbed areas, however, may have helped cause increased peak flows and minor sedimentation the first few years after logging. Infiltration data collected six years following logging lend little support to the concept that surface disturbance and compaction have caused current peak flows by increasing overland flow, except perhaps on Watershed 3. A tractor windrowed and burned area and certain cable log paths on Watershed 3 may result in increased overland flow, and thus increased peak flows and minor sedimentation.

Infiltration capacity data and associated erodibility data are influenced by a large number of factors and interactions. All infiltration data were found normally distributed, while highly skewed, surface erodibility data required normalizing transformations. Predictive models for infiltration capacity and surface erodibility characteristics were not discovered because of the large amounts of variance in point estimates of those variables.

Management Implications

Several management implications may result from infiltration and erodibility data as collected for this study. First, rehabilitation priorities can be determined. Certain highly disturbed and/or compacted areas may have lower infiltration capacities and higher surface erodibility than those on other areas. These areas should then be given a priority in rehabilitation over other areas. An example from Coyote Creek would be the tractor windrowed and burned area in the lower portion of Watershed 3 that needs stabilization and rehabilitation quickly. Second, the infiltration capacity and surface erodibility of a site may assist in selecting suitable plant species for revegetation. On sites with low infiltration capacities and substantial erosion, replanting with grass species or other deeply rooted vegetation will help loosen those soils and add protective cover, and thus increase infiltration and reduce surface erosion. On sites with fair to high infiltration capacities and little erosion, replanting with Douglas-fir or other desired species would be best. Replanting of Douglas-fir on low infiltration capacity sites will only produce seedlings with markedly reduced growth, cause little soil loosening, particularly if a compacted layer is restricting infiltration, and add little protective cover. Third, the relative susceptibility of various soils to similar logging disturbance and compaction, and the relative rates of damage of different types of harvesting equipment may be indexed by infiltration capacities and surface erodibility. Recovery rates of damaged sites may also be estimated by infiltration and erodibility. Fourth, because of the paucity of infiltration data in the Northwest, the systematic collection of infiltration data may provide a better understanding of the infiltration processes on steep, forested slopes common to this region.

Recommendations for Future Studies

From this pilot study, Meeuwig's (1971) infiltrometer as modified by Froehlich and Hess (1976), has been found a practical and useful device for the slopes and conditions of the Northwest. Some recommendations relative to the infiltration methodology can be made. First, simulated rainfall rates should be increased when the runoff rate is less than 5 or 10% of the precipitation rate, instead of 2% of that rate as used in this study. This should make the infiltration determination less dependent upon the inherent factors in the methodology, and thus should increase the validity of the infiltration estimation. Second, since peak flow increases and soil profile control of infiltration occur during the fall/winter season, sampling should be conducted at that time of year with a pre-wet treatment being utilized. Third, if surface erodibility information is desired, conduct the infiltration determinations in the late summer because this is a period of maximum sediment production from surface soils. Fourth, do not perform infiltration determinations during a rain. Obtaining accurate infiltration measurements during a precipitation event is nearly impossible.

If another study of this type is to be conducted, a detailed survey of onsite soils may be helpful. This could minimize the variance in infiltration capacity and improve the strength of the statistical analysis if a randomized block design was being used. However, the soil properties within a soil series may be as variable as the treatment itself. Then instead of minimizing variance, a larger error term is created. If a completely randomized design is utilized, a large sample size is necessary to reduce the variance and aid in interpretations. A further suggestion relative to Coyote Creek is to better quantify in terms of infiltration and erodibility, the undisturbed, green breccia derived soils under fall conditions. By sampling the topmost, adjacent, undisturbed sections of Watershed 2 and the undisturbed area joining Watersheds 3 and 4, the green breccia formed soils will be quantified in an undisturbed state. Also at Coyote Creek, more fall sampling of nearby recent logging operations on various soils should put increased perspective on recovery rates of damaged areas.

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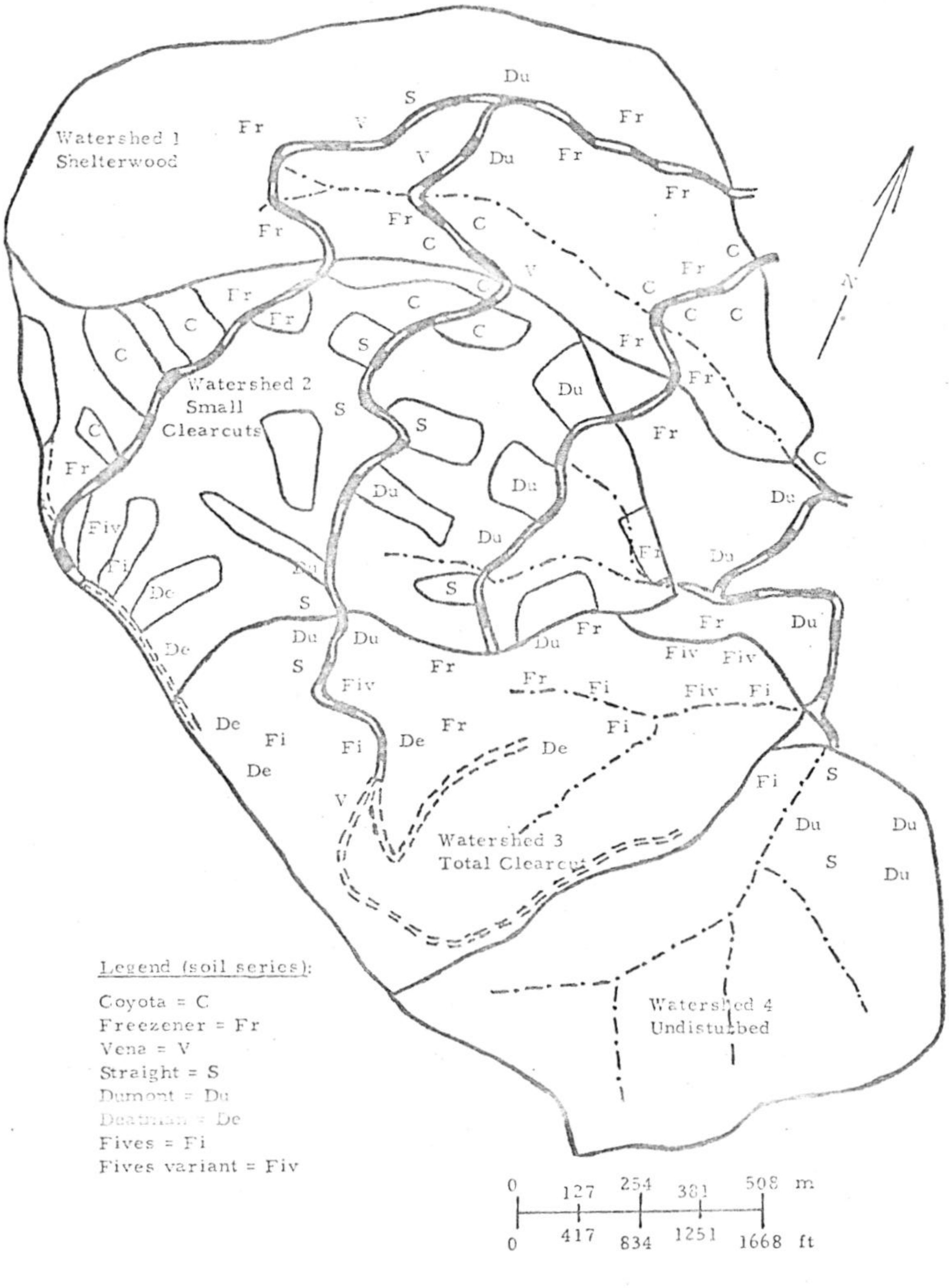
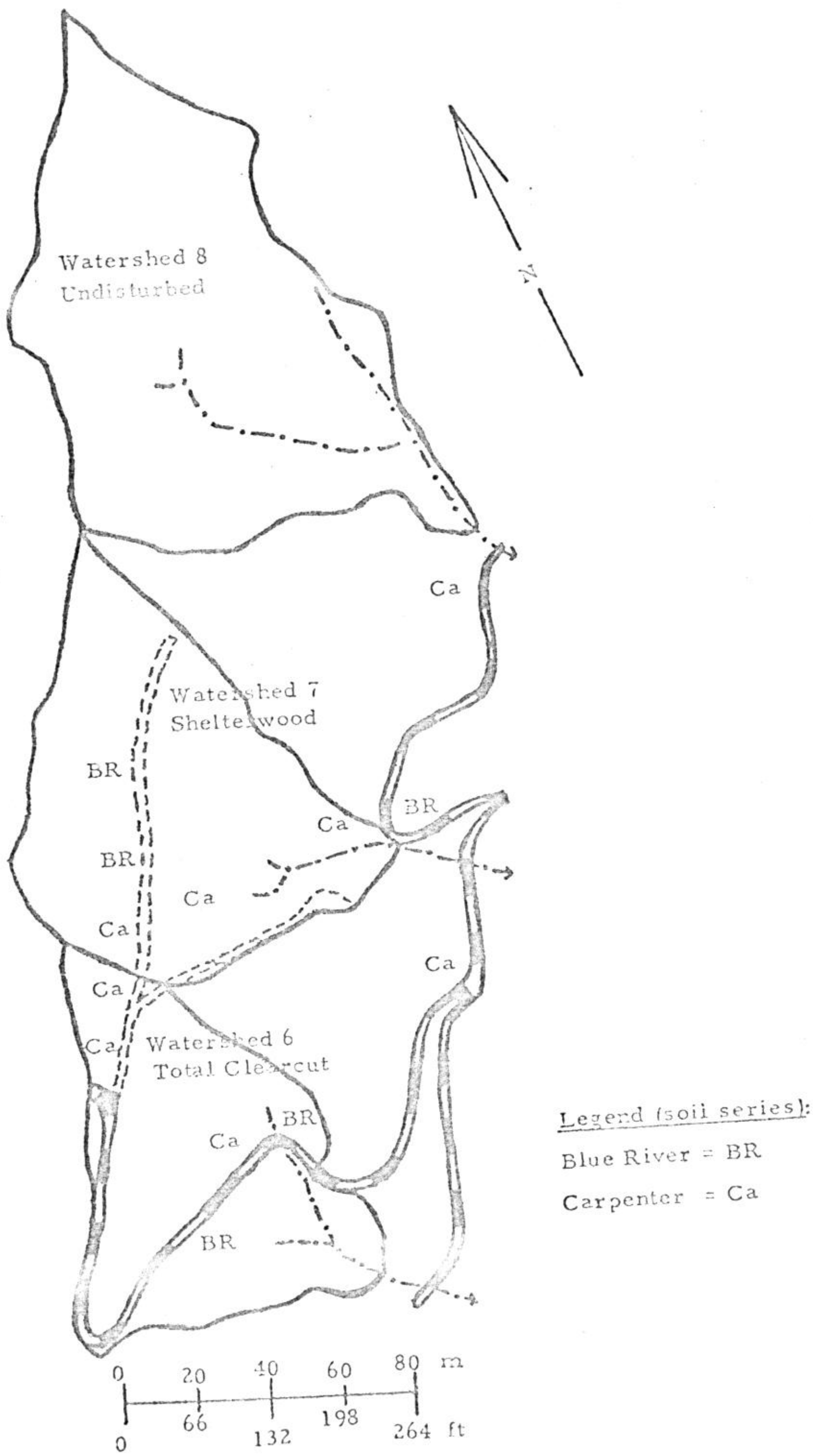


Soil series locations on the Coyote Creek Watersheds, South Umpqua Experimental Forest, Oregon.



Soil series locations on the Hi-15 Watersheds, H. J. Andrews Experimental Forest, Oregon.

Soil Series: Coyota

Parent Material: Basalt

Horizon	Depth, cm	Description
0_1	5-2	Leaves, twigs, cones, needles, and tree limbs.
0_2	2-0	Partially decomposed leaves, needles, and twigs, and charcoal bits.
A_1	0-20	Dark reddish-brown (5YR 3/3 moist) gravelly loam; moderate fine and medium granular structure; slightly hard, friable, slightly sticky, slightly plastic; many fine to medium roots; many fine interstitial pores; 25 percent pebbles; slightly acid (pH 6.2); clear smooth boundary.
AC	20-64	Dark reddish-brown (5YR 3/4 moist) gravelly clay loam; weak fine and medium subangular blocky structure; slightly hard, friable, sticky, slightly plastic; common very fine to medium roots; many very fine to medium pores; 30 percent pebbles and 15 percent cobblestones; slightly acid (pH 6.1); abrupt wavy boundary.
C	64-102+	Dark reddish-brown (5YR 3/4 moist) fractured basalt bedrock.

Soil Series: Freezener

Parent Material: Basalt

Horizon	Depth, cm	Description
0_1	5-3	Needles, leaves, twigs, tree limbs, cones, and bark.
0_2	3-0	Charcoal bits and partially decomposed needles, leaves, and twigs.
A_1	0-23	Dark reddish-brown (10YR 3/3 moist) loam; moderate fine and medium granular structure ; slightly hard, friable, slightly sticky, slightly plastic; many very fine to medium roots; many very fine to fine pores; strongly acid (pH 5.4); clear smooth boundary.
B_1	23-41	Reddish-brown (5YR 4/3 moist) clay loam; moderate fine and medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; many very fine to coarse roots; many very fine and fine pores; strongly acid (pH 5.2); clear smooth boundary.
B_{21t}	41-107	Reddish-brown (5YR 4/4 moist) clay loam; moderate medium and coarse subangular blocky structure; hard, firm, sticky, plastic; few fine and very fine roots; common very fine and fine pores; strongly acid (pH 5.2); gradual smooth boundary.
B_{22t}	107-142	Reddish-brown (5YR 4/4 moist) clay loam; weak medium subangular blocky structure; hard, firm, slightly sticky, plastic; few very fine roots; few very fine pores; strongly acid (pH 5.1); clear smooth boundary.
C	142-183+	Reddish-brown (5YR 4/4 moist) cobbly clay loam; massive; hard, firm, slightly sticky, slightly plastic; few very fine and fine pores; 25 percent cobblestones; strongly acid (pH 5.1).

Soil Series: Vena

Parent Material: Rhyolitic breccias, agglomerates and tuffs, and rhyolite

Horizon	Depth, cm	Description
0_1	3-0	Loose litter of twigs, needles, cones and tree limbs and partially decomposed twigs, needles, leaves, and bark, and charcoal bits.
A_1	0-13	Very dark grayish-brown (10YR 3/2 moist) gravelly loam; weak fine granular structure; soft, very friable, nonsticky, nonplastic; many very fine to medium roots; common medium and coarse pores; 25 percent pebbles; medium acid (pH 5.6); clear smooth boundary.
AC	13-41	Dark grayish-brown (10YR 4/2 moist) very gravelly loam; weak fine and medium granular structure; soft, very friable, nonsticky, nonplastic; many very fine to coarse roots; common fine and medium pores; 30 percent pebbles and 5 percent cobblestones; medium acid (pH 6.0); clear smooth boundary.
C_1	41-53	Grayish-brown (10YR 5/2 moist) very gravelly loam; massive; soft, very friable, nonsticky, nonplastic; many very fine to medium roots; common fine and medium pores; 40 percent pebbles and 10 percent cobblestones; strongly acid (pH 5.5); abrupt wavy boundary.
C_2	53-89+	Light gray (10YR 7/1 moist) fractured rhyolitic tuff bedrock.

Soil Series: Straight

Parent Material: Reddish breccias, agglomerates and tuffs

Horizon	Depth, cm	Description
0_1	5-3	Loose litter of tree limbs, twigs, needles, leaves, cones, and bark.
0_2	3-0	Partially decomposed twigs, needles, and leaves, and charcoal bits.
A_1	0-23	Dark reddish-brown (5YR 3/3 moist) gravelly loam; moderate fine and medium granular structure and moderate very fine subangular blocky structure; soft, friable, nonsticky, nonplastic; many very fine to medium roots; many interstitial pores; 30 percent pebbles; medium acid (pH 5.9); clear smooth boundary.
AC	23-76	Dark reddish-brown (5YR 3/4 moist) very gravelly loam; weak and moderate fine and medium granular and subangular blocky structure; soft, friable, nonsticky, nonplastic; common very fine to medium roots; common very fine and fine pores; 40 percent pebbles and 5 percent cobblestones; medium acid (pH 5.7); clear wavy boundary.
C	76-89+	Variegated colors of red, reddish-brown, and light reddish-brown weathered red breccia bedrock.

Soil Series: Dumont

Parent Material: Reddish breccias, agglomerates and tuffs

Horizon	Depth, cm	Description
0_1	5-3	Loose litter of twigs, needles, bark, cones, and leaves.
0_2	3-0	Partially decomposed twigs, needles, bark, and leaves, and charcoal bits.
A_{11}	0-10	Dark reddish-brown (5YR 3/4 moist) loam; moderate fine and medium granular structure; slightly hard, friable, slightly sticky, slightly plastic; many very fine to medium roots; common very fine and fine pores; medium acid (pH 5.8); clear wavy boundary.
A_{12}	10-23	Dark red (2.5YR 3/4 moist) silt loam; moderate fine and medium granular structure; slightly hard, friable, slightly sticky, slightly plastic; many very fine to coarse roots; common very fine and fine pores; medium acid (pH 5.8); clear wavy boundary.
B_1	23-36	Dark red (2.5YR 3/6 moist) silt clay loam; moderate coarse granular and strong fine subangular blocky structure; hard, firm, slightly sticky, slightly plastic; common very fine to coarse roots; many very fine pores; medium acid (pH 5.6); clear wavy boundary.
B_{21t}	36-56	Dark red (2.5YR 3/6 moist) clay loam; moderate very fine and fine subangular blocky structure; hard, firm, sticky, plastic; few very fine to medium roots; few fine and very fine pores; strongly acid (pH 5.4); clear smooth boundary.
B_{22t}	56-114	Dark red (2.5YR 3/6 moist) clay; moderate medium to coarse subangular blocky structure; hard, firm, sticky, plastic; few very

Horizon	Depth, cm	Description
		fine to medium roots; few fine and very fine pores; strongly acid (pH 5.4); gradual smooth boundary.
B_{23t}	114-157	Dark red (2.5YR 3/6 moist) clay; moderate medium to coarse subangular blocky structure; very hard, very firm, very sticky, very plastic; few very fine to medium roots; few fine and very fine pores; strongly acid (pH 5.3); clear wavy boundary.
C	157-183+	Yellowish-red (5YR 4/6 moist) silty clay loam; massive; hard, friable, sticky, plastic; few fine pores; very strongly acid (pH 5.0); gradual boundary.

Soil Series: Deatman

Parent Material: Intermediate green breccias and agglomerates, and greenish tuffs

Horizon	Depth, cm	Description
0_1	3-1	Litter of undecomposed needles, twigs, cones, and leaves.
0_2	1-0	Partially decomposed needles, twigs, and leaves, and charcoal bits.
A_1	0-15	Very dark grayish-brown (10YR 3/2 moist) gravelly loam; weak fine granular structure; soft, friable, nonsticky, nonplastic; many very fine and fine roots; many very fine pores; 25 percent pebbles; slightly acid (pH 6.0); clear wavy boundary.
AC	15-51	Very dark grayish-brown (10YR 3/2 moist) gravelly clay loam; weak fine and medium granular structure and weak fine and medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; few fine and medium roots; many fine pores; 25 percent pebbles; medium acid (pH 5.7); gradual wavy boundary.
C_1	51-64	Very dark grayish-brown (10YR 3/2 moist) gravelly clay loam; massive; slightly hard, firm, sticky, slightly plastic; few roots; many very fine to medium pores; 40 percent pebbles; medium acid (pH 6.2); abrupt wavy boundary.
C_2	64-89+	Variegated colors of brown, dark yellowish-brown, olive, and green semiconsolidated green breccia bedrock.

Soil Series: Fives

Parent Material: Intermediate green breccias and agglomerates, and greenish tuffs

Horizon	Depth, cm	Description
0_1	5-3	Litter of loose leaves, twigs, cones, bark, and needles.
0_2	3-0	Partially decomposed leaves, twigs, and needles, and charcoal bits.
A_1	0-10	Very dark gray (10YR 3/1 moist) gravelly loam; moderate medium granular structure; soft, friable, slightly sticky, slightly plastic; many very fine to medium roots; common very fine and fine pores; 5 percent pebbles; medium acid (pH 5.7); clear smooth boundary.
A_3	10-23	Dark grayish-brown (10YR 4/2 moist) loam; weak fine subangular blocky structure and moderate fine and medium granular structure; slightly hard, friable, slightly sticky, slightly plastic; many very fine to coarse roots; common very fine and fine pores; strongly acid (pH 5.3); clear smooth boundary.
B_{21t}	23-64	Olive-brown (2.5YR 4/4 moist) clay loam; moderate fine and medium subangular blocky structure; hard, firm, sticky, plastic; few very fine to medium roots; common very fine pores; strongly acid (pH 5.2); gradual wavy boundary.
B_{22t}	64-114	Olive (5Y 5/4 moist) clay loam; moderate medium and coarse subangular blocky structure; hard, firm, very sticky, very plastic; few very fine to coarse roots; common very fine and fine pores; very strongly acid (pH 5.0); gradual wavy boundary.
C	114-183+	Variegated colors of brown, dark yellowish-brown, reddish-brown, and bluish-green clay loam; massive; slightly hard, friable, slightly

sticky, slightly plastic; few very fine to medium roots; few very fine to medium pores; very strongly acid (pH 5.0); gradual wavy boundary.

Soil Series: Fives variant

Parent Material: Intermediate green breccias and agglomerates, and greenish tuffs

Horizon	Depth, cm	Description
O_1	5-3	Needles, leaves, twigs, cones, and tree limbs.
O_2	3-0	Charcoal bits and partially decomposed leaves, needles, and twigs.
A_1	0-10	Dark grayish-brown (10YR 4/2 moist) loam; moderate fine and medium granular structure; soft, friable, nonsticky, nonplastic; many very fine to medium roots; many very fine and fine pores; slightly acid (pH 6.0); clear wavy boundary.
A_3	10-25	Dark grayish-brown (10YR 4/2 moist) clay loam; moderate fine and medium granular and subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; many very fine to coarse roots; common very fine and fine pores; medium acid (pH 5.7); clear wavy boundary.
B_{21t}	25-46	Olive-brown (2.5Y 4/4 moist) clay; common medium faint dark yellowish-brown (10YR 4/4 moist) mottles; moderate fine and medium subangular blocky structure; hard, firm, sticky, plastic; few very fine to medium roots; common very fine pores; strongly acid (pH 5.3); gradual wavy boundary.
B_{22t}	46-114	Olive-brown (2.5Y 4/4 moist) clay; many medium faint to prominent light olive-brown (2.5Y 3/3 moist) and yellowish-red (5YR 4/6 moist) mottles; moderate medium and coarse subangular blocky structure; hard, firm, very sticky, very plastic; few very fine to medium roots; common very fine and fine pores; very strongly acid (pH 5.0); gradual wavy boundary.

Horizon	Depth, cm	Description
B_{23t}	114-142	Olive (5Y 5/4 moist) clay; common medium faint light olive-brown (2.5Y 3/3 moist) mottles; strong medium and coarse subangular blocky structure; very hard, firm, very sticky, very plastic; few very fine and fine roots; few very fine and fine pores; very strongly acid (pH 5.0); gradual wavy boundary.
C	142-183+	Variegated colors of green, bluish-green, olive, and light olive-gray clay loam; common medium faint light olive-brown (2.5Y 3/3 moist) mottles; massive; hard, firm, sticky, plastic; few very fine roots; few very fine pores; very strongly acid (pH 5.0); gradual wavy boundary.

Soil Series: Blue River

Parent Material: Andesite and basalt

Horizon	Depth, cm	Description
0_1	8-0	Loose litter of twigs, needles, leaves, cones, tree branches, and charcoal bits.
A_2	0-5	Very dark gray (10YR 3/1 moist) gravelly loam; weak very fine and fine granular structure; soft, friable, nonsticky, nonplastic; many fine to medium roots; many very fine and fine pores; 10 percent pebbles; very strongly acid (pH 4.5); abrupt wavy boundary.
B_2	5-20	Dark brown (7.5YR 3/2 moist) gravelly loam; weak very fine and fine granular structure; slightly hard, friable, nonsticky, nonplastic; many fine, medium, and coarse roots; many very fine and fine pores; 25 percent pebbles; strongly acid (pH 5.2); gradual wavy boundary.
B_{31}	20-36	Dark brown (7.5YR 3/2 moist) gravelly loam; weak very fine and fine granular structure; slightly hard, friable, nonsticky, nonplastic; common fine to coarse roots; many fine and very fine pores; 25 percent pebbles; strongly acid (pH 5.5); gradual wavy boundary.
B_{32}	36-51	Dark brown (7.5YR 3/2 moist) gravelly loam; weak very fine and fine granular and subangular blocky structure; slightly hard, friable, nonsticky, slightly plastic; common fine to coarse roots; many very fine and fine pores; 35 percent pebbles; strongly acid (pH 5.5); gradual wavy boundary.
B_{33}	51-107	Dark brown (10YR 3/3 moist) gravelly loam; weak very fine and fine granular and subangular blocky structure; slightly hard, friable, nonsticky, slightly plastic; common fine and medium roots; common very fine and fine pores; 35 percent pebbles; medium acid (pH 5.7); clear wavy boundary.

Horizon	Depth, cm	Description
C_1	107-130	Very dark grayish brown (10YR 3/2 moist) cobbly gravelly loam; massive; slightly hard, friable, slightly sticky, slightly plastic; few fine to medium roots; common very fine and fine pores; 75 percent pebbles and cobblestones; medium acid (pH 5.7); abrupt irregular boundary.
C_2	130+	Very dark grayish-brown (10YR 3/2 moist) fractured andesite bedrock.

Soil Series: Carpenter

Parent Material: Andesite

Horizon	Depth, cm	Description
0_1	8-0	Needles, leaves, twigs, cones, tree branches, and charcoal bits.
A_2	0-5	Dark gray (10YR 4/1 moist) gravelly sandy loam; weak very fine and fine granular structure; soft, friable, nonsticky, nonplastic; many fine to medium roots; many very fine and fine pores; 20 percent pebbles; strongly acid (pH 5.4); gradual wavy boundary.
B_2	5-28	Dark brown (7.5YR 3/3 moist) gravelly sandy loam; moderate very fine and fine granular structure; soft, friable, nonsticky, nonplastic; many fine to medium roots; many very fine and fine pores; 30 percent pebbles and 5 percent cobblestones; strongly acid (pH 5.4); gradual wavy boundary.
B_{31}	28-66	Dark brown (7.5YR 4/4 moist) gravelly loam; weak fine and medium subangular blocky structure; slightly hard, friable, slightly sticky, nonplastic; common fine to medium roots; many fine and very fine pores; 30 percent pebbles and 5 percent cobblestones; strongly acid (pH 5.5); gradual wavy boundary.
B_{32}	66-89	Dark brown (7.5YR 4/4 moist) gravelly loam; weak and moderate fine and medium subangular blocky structure; slightly hard, friable, slightly sticky, nonplastic; few fine and medium roots; common very fine and fine pores; 30 percent pebbles and 10 percent cobblestones; strongly acid (pH 5.5); gradual wavy boundary.
C	89-152+	Dark brown (10YR 4/3 moist) gravelly loam; massive to moderate fine and medium subangular blocky structure; slightly hard, friable,

slightly sticky, nonplastic; few fine and medium roots; common very fine and fine pores; 40 percent pebbles and cobblestones; strongly acid (pH 5.5).

APPENDIX B

CALCULATIONS AND CONVERSIONS

The following calculations were performed using values obtained in the field and laboratory. Following an equation is an example using actual figures. Applicable conversions are provided following the example.

Infiltration Capacity

Infiltration Capacity = simulated rainfall rate - constant runoff rate

Example:

Infiltration Capacity = 399.6 ml/min - 154.0 ml/min = 245.6 ml/min (tractor logged site)

$$\text{Conversion to cm/hr} = \frac{\text{X ml}}{\text{min}} \times \frac{\text{60 min}}{\text{1 hr}} \times \frac{1}{3122.6 \text{ cm}^2} \times \frac{1 \text{ cm}^3}{\text{1 ml}}$$

Example:

Infiltration Capacity = 7.68 cm/hr - 2.96 cm/hr = 4.72 cm/hr (tractor logged site)

$$\text{Conversion to in/hr} = \frac{\text{X cm}}{\text{hr}} \times \frac{\text{.3937 in}}{\text{cm}}$$

Bulk Density

$$\text{Bulk Density (gm/cm}^3) = \frac{\text{mass of oven dry soil}}{\text{volume of oven dry soil}}$$

$$\text{Bulk Density} = \frac{\text{oven dry wt - soil can tare wt}}{\text{volume of soil retainer ring}}$$

Example:

$$\text{Bulk Density} = \frac{215.24 \text{ gm} - 52.09 \text{ gm}}{137.4 \text{ cm}^3} = 1.187 \text{ gm/cm}^3$$

Soil Moisture Content by Volume

$$\text{Moisture content} = \frac{\text{volume of water}}{\text{volume of sample}}$$

$$\text{Moisture content (\%)} = \frac{\text{moist field wt - oven dry wt}}{\text{volume of soil retainer ring}} \times \text{specific}$$

volume of water x 100%

Example:

$$\text{Moisture Content} = \frac{248.57 \text{ gm} - 215.24 \text{ gm}}{137.4 \text{ cm}^3} \times \frac{1 \text{ cm}^3}{\text{gm}} \times 100\%$$

$$= 24.3\%$$

Litter Mass/Area

$$\text{Litter Mass/Area (kg/ha)} = \frac{\text{X gm oven dry litter}}{10^3 \text{ cm}^2} \times \frac{1 \text{ kg}}{10^3 \text{ gm}}$$

$$\times \frac{10^4 \text{ cm}^2}{1 \text{ m}^2} \times \frac{10^4 \text{ m}^2}{1 \text{ ha}}$$

Sediment Yield

$$\text{Sediment Yield (gm/m}^2) = \frac{\text{X mg}}{\text{liter}} \times \frac{\text{Z liter total runoff volume}}{3122.6 \text{ cm}^2}$$

$$\times \frac{10^{-3} \text{ gm}}{1 \text{ mg}} \times \frac{10^4 \text{ cm}^2}{1 \text{ m}^2}$$

$$\text{Sediment Yield (kg/ha/hr)} = \frac{X\ \text{gm}}{\text{m}^2} \times \frac{10^4\ \text{m}^2}{1\ \text{ha}} \times \frac{1\ \text{kg}}{10^3\ \text{gm}}$$

$$\times \frac{1}{Z\ \text{min total runoff time}} \times \frac{60\ \text{min}}{1\ \text{hr}}$$

$$\text{Sediment Yield (lb/acre/hr)} = \frac{X\ \text{kg}}{\text{ha/hr}} \times \frac{1\ \text{ha}}{2.471\ \text{acres}} \times \frac{2.205\ \text{lb}}{1\ \text{kg}}$$

Total Porosity

$$\text{Total Porosity (percent of total volume)} = \frac{\text{volume of pore space}^{1}}{\text{volume of soil}}$$

$$\times\ 100\%$$

$$\text{Total Porosity} = \frac{\text{saturated wt - tare wt - oven dry soil wt}}{\text{volume of retainer ring}}$$

$$\times \text{ specific volume of water} \times 100\%$$

Example:

$$\text{Total Porosity} = \frac{1076.1\ \text{gm} - 855.6\ \text{gm} - 144.6\ \text{gm}}{137.4\ \text{cm}^3} \times \frac{1\ \text{cm}^3}{\text{gm}} \times 100\%$$

$$= 55.2\%$$

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[1] The volume of pore space is the volume of water in the soil between the saturated (0 cm tension) and oven dry conditions.

Tension Table Moisture Content

The following equation was used to calculate the moisture content of a soil sample after each level of tension applied. It is similar to the total porosity equation except that the weight of the sample after each level of tension is substituted for the saturated weight.

Moisture Content (percent of total volume)

$$= \frac{\text{tension wt - tare wt - oven dry soil wt}}{\text{volume of retainer ring}} \times \frac{\text{specified vol}}{\text{of water}} \times 100\%$$

Example:

Moisture Content (10 cm tension)

$$= \frac{363.5 \text{ gm} - 153.4 \text{ gm} - 144.6 \text{ gm}}{137.4 \text{ cm}^3} \times \frac{1 \text{ cm}^3}{\text{gm}} \times 100\%$$

$$= 47.7\%$$

Non-Capillary Pore Space

Non-Capillary Pore Space (30 cm tension) = total porosity (%) - 30 cm tension moisture content (%)

Example:

Non-Capillary Pore Space = 55.2% - 41.8% = 13.4%

APPENDIX C

DATA

Column Identification	Description
A	Watershed and Treatment Identification **Coyote Creek Watersheds:** 11 = Watershed 1, Tractor Shelterwood 21 = Watershed 2, Tractor 22 = Watershed 2, Cable 23 = Watershed 2, Undisturbed 31 = Watershed 3, Tractor 32 = Watershed 3, Cable 43 = Watershed 4, Undisturbed 53 = Outside Coyote Creek Watersheds, Undisturbed **Hi-15 Watersheds:** 61 = Watershed 6, Tractor 62 = Watershed 6, Cable 71 = Watershed 7, Tractor Shelterwood 72 = Watershed 7, Cable Shelterwood 93 = Outside Hi-15 Watersheds, Undisturbed
B	Site Number (corresponds with Figures 3 and 4)
C	Original Plot Simulated Precipitation Rate (cm/hr)
D	Original Plot Infiltration Capacity (cm/hr)
E	Paired Plot Infiltration Capacity (cm/hr)
F	Original Plot Turbidity (ntu)
G	Paired Plot Turbidity (ntu)
H	Original Plot Suspended Sediment Concentration (mg/l)
I	Paired Plot Suspended Sediment Concentration (mg/l)
J	Original Plot Sediment Yield (kg/ha/hr)
K	Paired Plot Sediment Yield (kg/ha/hr)

Column Identification		Description
L	Summer	Infiltration Capacity (cm/hr)
M	Fall	Infiltration Capacity (cm/hr)
N	Summer	Turbidity (ntu)
O	Fall	Turbidity (ntu)
P	Summer	Suspended Sediment Concentration (mg/l)
Q	Fall	Suspended Sediment Concentration (mg/l)
R	Summer	Sediment Yield (kg/ha/hr)
S	Fall	Sediment Yield (kg/ha/hr)
T	Summer	Surface Bulk Density (gm/cm^3)
U	Fall	Surface Bulk Density (gm/cm^3)
V	Summer	Subsurface Bulk Density (gm/cm^3)
W	Fall	Subsurface Bulk Density (gm/cm^3)
X	Summer	Impermeable Layer Bulk Density (gm/cm^3)
Y	Fall	Impermeable Layer Bulk Density (gm/cm^3)
Z	Summer	Impermeable Layer Moisture Content (%)
AA	Fall	Impermeable Layer Moisture Content (%)
BB	Summer	Total Porosity (%)
CC	Fall	Total Porosity (%) [1]
DD	Summer	Moisture Content at 30 cm Tension (%)
EE	Fall	Moisture Content at 30 cm Tension (%) [1]
FF	Summer	Moisture Content at 60 cm Tension (%)
GG	Fall	Moisture Content at 60 cm Tension (%) [1]

[1] -0 = missing data.

Column Identification	Description
HH	Surface Bulk Density (gm/cm^3)
II	Subsurface Bulk Density (gm/cm^3)
JJ	Impermeable Layer Bulk Density (gm/cm^3)
KK	Impermeable Layer Moisture Content (%)
LL	Total Porosity (%)
MM	Moisture Content at 30 cm Tension (%)
NN	Moisture Content at 60 cm Tension (%)
OO	Macroporosity at 30 cm Tension (%)
PP	Macroporosity at 60 cm Tension (%)
QQ	Air Permeable Reading (lbs/in^2)
RR	Percent Rock Cover (%)
SS	Percent Bare Ground (%)
TT	Percent Live Vegetation Cover (%)
UU	Percent Litter Cover (%)
VV	Litter Thickness (cm)
WW	Litter Mass (kg/ha)
XX	Percent Slope (%)
YY	Soil Index

11 = Vena
21 = Carpenter
22 = Blue River
31 = Coyota
32 = Freezener
41 = Straight
42 = Dumont
51 = Deatman
52 = Fives
53 = Fives variant

ZZ Site Factor Index (cumulative summation of factors)

0 = Undisturbed
1 = Light Disturbance
2 = Moderate Disturbance
3 = Heavy Disturbance
1 = Light Compaction
2 = Moderate Compaction
3 = Heavy Compaction

Rocky Surface Horizon:
-1 = yes 0 = no

Site on or adjacent to skid trail or cable log path:
1 = yes 0 = no

Fired surface:
1 = yes 0 = no

A	B	C	D	E	F	G	H	I	J	K
11	1	10.52	10.28	5.72	481	330	674.2	954.9	14.7	133.8
11	2	7.68	6.93	5.95	35	372	131.5	572.9	8.4	78.1
11	3	10.52	10.10	3.84	82	125	189.4	252.8	6.3	87.2
11	4	17.73	17.65	7.47	39	20	171.0	66.9	1.9	1.7
11	5	7.68	6.74	7.33	122	105	209.3	203.1	15.6	5.9
11	6	7.68	7.19	5.72	271	373	372.3	694.7	14.9	44.7
11	7	7.68	6.20	6.37	249	70	411.5	159.9	53.3	11.2
11	8	10.52	10.27	9.81	332	121	822.8	236.8	19.4	15.4
11	9	10.52	9.73	10.20	34	39	137.7	37.1	9.6	2.9
11	10	17.78	17.74	14.10	10	25	80.0	115.1	.3	2.9
11	11	17.78	17.63	13.02	22	46	142.5	245.3	1.7	31.7
11	12	10.52	10.11	13.96	175	80	316.0	220.5	12.1	7.0
11	13	14.45	13.65	13.47	70	65	162.8	144.1	11.6	12.9
11	14	10.52	9.47	9.72	47	159	351.0	563.8	35.7	42.4
11	15	17.75	17.55	12.97	205	145	457.1	273.0	9.3	34.8
11	16	10.52	9.60	6.70	257	147	428.2	355.2	33.8	31.6
22	17	7.68	7.46	7.24	28	111	115.9	173.0	3.2	7.4
22	18	10.52	9.30	17.80	159	1	390.3	.1	27.4	.2
22	19	17.78	17.75	10.32	15	35	80.0	190.9	.1	4.2
22	20	17.78	17.72	13.64	20	70	80.0	149.9	.4	11.4
22	21	10.52	9.31	10.10	16	14	109.4	69.1	7.0	3.0
22	22	10.52	8.66	9.31	144	55	391.4	214.3	59.2	25.5
22	23	14.45	13.98	13.68	111	207	198.0	341.7	8.3	27.6
22	24	10.52	10.03	9.60	128	36	251.5	95.7	10.2	7.9
32	25	10.52	10.47	14.23	10	25	80.0	233.8	.3	4.1
32	26	7.68	5.80	6.15	723	208	1810.6	914.1	254.0	105.0
32	27	10.52	9.35	10.35	175	35	269.0	150.5	10.4	2.4
32	28	14.45	14.32	14.09	21	15	96.7	63.5	.9	2.2
32	29	17.78	17.80	17.80	1	1	.1	.4	.1	.6
32	30	7.68	5.68	7.38	17	17	134.6	141.4	12.5	3.6
32	31	7.68	7.48	7.47	33	23	106.9	56.0	2.0	.9
32	32	17.78	17.38	7.32	1	46	.1	138.5	.5	5.7
21	33	10.52	10.39	10.25	59	279	219.3	450.0	2.5	11.3
21	34	10.52	10.12	16.95	67	20	227.0	103.0	9.5	.5
21	35	14.45	14.22	15.53	78	155	236.6	437.8	3.5	2.9
21	36	7.68	6.97	9.90	179	144	326.3	242.7	18.8	10.9
21	37	14.45	14.22	10.25	466	661	599.1	725.7	10.3	17.7
21	38	7.68	7.28	6.33	152	849	336.3	2056.3	14.1	224.4
21	39	10.52	9.43	10.11	918	111	1298.7	235.5	112.7	8.5
21	40	16.02	15.91	12.54	155	55	531.3	124.5	4.5	22.1
31	41	7.68	5.14	6.29	1541	593	3191.4	933.2	720.4	112.1
31	42	7.68	4.72	5.37	339	219	1349.6	631.8	443.6	125.3
31	43	7.68	2.68	2.49	1878	983	3678.2	3740.7	1206.2	1271.2
31	44	7.68	7.04	5.76	696	1314	962.6	1931.9	54.9	272.2
31	45	7.68	4.03	6.88	72	919	422.0	1645.8	82.4	122.2
31	46	7.68	6.06	2.87	196	1735	390.8	4491.2	47.1	1430.9
31	47	7.68	6.92	7.44	144	338	256.2	500.0	17.6	11.9
31	48	14.45	14.32	5.24	1079	1495	1259.9	2936.3	14.5	596.0
23	49	10.52	9.93	9.54	22	73	97.3	179.5	3.1	6.6
23	50	14.45	13.45	13.29	112	366	252.2	713.9	23.1	79.9
23	51	17.78	17.69	17.39	74	52	245.2	196.2	2.4	8.2
53	52	10.52	9.38	9.25	62	19	174.4	101.3	9.7	12.4
23	53	10.52	9.45	9.14	53	344	151.5	1116.2	14.4	390.7
23	54	10.52	8.91	9.35	66	56	307.0	166.8	45.2	13.3
23	55	17.78	17.52	14.20	29	77	93.1	136.2	1.9	3.6
23	56	7.68	6.37	6.15	107	72	390.3	212.3	34.9	26.3
53	57	10.52	9.14	8.10	64	143	207.6	654.1	25.9	69.4
53	58	10.52	10.13	9.18	183	215	362.0	419.0	13.5	7.9
53	59	10.52	10.24	10.11	74	84	258.4	202.2	6.5	21.8
53	60	10.52	10.33	9.06	74	57	231.2	172.6	4.0	25.7
43	61	10.52	10.12	9.60	143	102	310.2	236.7	11.9	13.4
43	62	10.52	9.91	9.06	135	41	313.8	146.0	16.7	11.6
43	63	10.52	9.85	9.21	27	22	98.9	87.4	5.6	65.3
43	64	10.52	9.33	9.73	35	57	149.5	155.6	14.8	[illegible]
71	65	14.45	14.12	8.91	19	32	84.5	445.9	2.0	165.3
71	66	10.52	9.13	8.64	25	19	157.5	106.1	21.2	[illegible]
71	67	7.68	6.10	4.99	113	321	307.4	1070.0	38.5	[illegible]
[illegible]	68	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	69	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62	70	[illegible]	[illegible]	5.48	27	[illegible]	170.3	207.6	17.1	36.8
62	71	7.68	6.64	7.08	39	[illegible]	123.9	74.3	11.2	3.8
62	72	10.52	9.37	5.91	15	[illegible]	127.5	89.7	13.6	14.1
72	73	10.52	9.87	7.64	13	[illegible]	75.5	148.2	4.2	36.8
72	74	7.68	4.03	6.95	13	[illegible]	79.3	51.4	22.2	3.4
93	75	10.52	9.83	7.83	21	[illegible]	155.1	38.4	22.6	24.3
93	76	10.52	9.72	7.95	22	32	113.5	254.5	8.7	57.6
93	77	10.52	8.99	5.60	24	37	239.4	528.2	35.3	226.1

A	B	L	M	N	O	P	Q	R	S
11	2	5.95	9.95	372	177	572.9	393.0	78.1	32.5
11	3	3.84	9.99	126	215	252.8	597.7	80.2	27.6
11	7	6.87	10.41	70	376	159.9	1216.0	11.2	10.4
11	9	10.20	17.80	39	1	97.1	.1	2.9	.1
11	11	13.02	13.10	46	173	245.3	299.3	31.7	29.4
22	19	10.32	17.80	35	1	190.9	.1	4.2	.1
22	22	9.31	13.93	56	415	214.3	836.2	25.5	34.9
32	26	6.16	5.41	208	682	914.1	2643.0	105.0	507.9
32	30	7.38	10.23	17	219	141.4	573.9	3.6	13.4
21	36	9.90	14.00	144	357	242.7	486.0	10.9	19.4
21	40	12.58	13.72	55	275	124.5	384.6	22.1	24.8
31	43	2.49	3.68	983	1052	3740.7	2702.5	1271.2	906.7
31	45	6.88	6.31	919	738	1648.8	1098.8	122.2	74.1
23	49	9.54	14.20	73	152	179.6	238.8	16.9	5.4
53	59	10.11	17.00	84	20	202.2	80.0	7.9	.1
53	60	9.05	17.46	57	20	172.8	100.0	21.8	1.9
43	61	9.60	14.06	102	121	296.7	315.0	25.7	9.2
71	65	8.91	14.15	32	103	445.9	437.3	66.3	9.6
71	67	4.99	6.14	321	32	1070.0	120.8	166.2	15.1
61	69	17.49	9.75	30	168	176.5	441.9	2.8	100.7
62	71	7.08	17.80	15	1	74.3	.1	3.8	.1
72	74	6.95	13.52	9	24	51.4	161.9	3.4	10.1
93	75	7.83	13.26	8	15	98.4	45.3	24.3	4.5
93	77	5.60	7.76	37	16	528.2	87.2	226.1	18.8

B	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	GG
3	.932	.932	.981	1.120	.992	.932	25.7	43.4	60.7	57.8	39.2	43.5	36.2	40.2
9	.820	.737	.910	1.173	.910	1.173	20.0	41.9	60.9	56.8	40.5	45.8	37.5	42.9
19	.695	.711	.865	1.035	.865	1.035	13.7	38.0	62.3	71.2	36.5	41.9	33.0	38.8
30	1.214	1.377	1.187	1.191	1.714	1.377	17.5	40.4	50.6	55.8	42.0	39.9	39.2	36.7
36	.806	1.217	.937	1.241	.937	1.241	38.9	44.6	57.8	53.6	41.5	46.7	39.5	44.0
45	.831	1.069	1.064	1.034	.831	1.069	37.1	32.5	70.7	55.2	46.7	45.2	40.9	42.0
60	1.032	1.154	1.200	1.309	1.200	1.308	34.1	42.6	51.3	51.8	41.8	43.7	38.4	41.0
61	.874	1.026	1.399	1.403	1.339	1.403	33.2	32.0	43.0	47.2	35.4	38.9	32.0	35.8
67	.883	.855	.959	1.022	.958	1.022	43.6	41.9	62.4	56.9	47.6	53.0	42.5	50.2
69	.959	1.006	1.082	1.130	1.082	1.130	40.8	42.9	62.3	-0	45.0	-0	41.6	-0
71	1.059	.900	1.034	1.087	1.034	1.087	40.5	44.7	60.0	60.0	43.6	52.0	40.0	48.2
74	.861	.799	.918	.989	.918	.980	27.5	46.9	63.3	64.0	42.6	53.5	39.6	49.7
77	.778	.716	.860	.947	.860	.947	35.0	36.5	67.1	64.4	40.7	50.3	35.1	45.3

A	B	D	H	J	HH	II	JJ	KK	LL	MM	NN
11	1	10.28	674.2	14.7	.831	1.232	1.232	36.7	51.4	42.5	39.6
11	2	6.93	131.5	8.4	.984	1.075	1.075	31.1	56.8	36.6	33.4
11	3	10.10	189.4	6.3	.992	.981	.992	25.7	60.7	39.2	36.3
11	4	17.65	171.0	1.9	.927	1.116	1.116	29.8	54.3	35.3	38.8
11	5	6.74	209.3	15.5	1.024	1.052	1.059	24.2	51.0	47.4	32.2
11	6	7.19	372.5	14.9	1.190	1.260	1.190	17.5	55.7	41.9	44.9
11	7	6.20	[illegible]	53.8	.945	1.083	1.083	[illegible]	57.0	38.[illegible]	38.4
11	8	10.27	682.8	10.4	.888	.985	.955	21.0	60.9	40.[illegible]	35.[illegible]
11	9	9.73	137.7	9.6	.820	.910	.910	20.0	54.4	41.[illegible]	37.[illegible]
11	10	17.74	80.0	.3	.938	.553	.938	15.3	61.0	35.0	37.[illegible]
11	11	17.63	142.5	.7	.952	.845	.845	21.2	64.0	42.[illegible]	32.6
11	12	10.11	316.0	12.1	.803	1.083	1.083	23.7	53.[illegible]	49.[illegible]	38.5
11	13	13.66	152.8	11.6	.637	1.074	1.074	25.3	47.[illegible]	31.[illegible]	47.7
11	14	9.47	351.0	38.7	[illegible]	1.138	1.138	25.2	[illegible]	[illegible]	25.5
11	15	17.56	457.1	9.3	1.093	1.041	1.041	30.5	[illegible]	[illegible]	33.2
11	16	9.60	429.2	33.8	.960	.920	.920	25.4	40.4	[illegible]	32.8
22	17	7.46	115.9	3.2	.808	1.288	1.288	32.3	56.0	[illegible]	20.7
22	18	9.80	390.3	27.4	.576	.700	.700	20.0	52.3	[illegible]	33.0
22	19	17.75	80.0	.1	.695	.865	.565	23.7	53.2	[illegible]	43.6
22	20	17.72	80.0	.4	1.131	1.227	1.227	35.7	60.4	[illegible]	25.6
22	21	9.81	109.4	7.0	1.187	1.104	1.104	14.5	54.9	[illegible]	40.3
22	22	8.65	391.4	59.2	1.211	.915	1.211	25.3	50.6	45.[illegible]	37.4
22	23	13.98	194.0	8.3	.701	1.131	1.131	28.8	54.8	54.[illegible]	35.5
22	24	10.03	251.5	10.2	.989	1.133	1.137	33.0	55.6	37.[illegible]	34.[illegible]
22	25	10.47	80.0	.3	1.191	1.071	1.072	29.4	55.7	44.[illegible]	40.9
32	26	5.80	1310.6	264.0	1.127	1.267	1.127	23.0	[illegible]	37.[illegible]	34.3
32	27	9.85	259.0	10.4	.973	1.095	1.095	36.4	[illegible]	38.[illegible]	36.4
32	28	14.32	95.7	.9	1.048	1.083	1.093	23.8	[illegible]	42.0	39.2
32	29	17.80	.1	.1	1.273	1.195	1.273	21.0	[illegible]	39.[illegible]	35.5
32	30	6.68	134.6	12.8	1.214	1.187	1.214	17.5	[illegible]	50.2	42.7
32	31	7.45	105.9	2.0	.912	1.019	1.019	31.3	63.1	41.[illegible]	42.3
32	32	17.80	.1	.1	1.011	1.353	1.353	40.7	47.0	47.[illegible]	37.4
21	33	10.39	205.3	2.5	.845	1.156	.845	29.7	63.0	41.[illegible]	42.5
21	34	10.12	227.0	9.0	.830	.896	.896	26.7	61.5	35.[illegible]	38.5
21	35	14.22	235.6	3.5	1.013	1.148	1.149	40.3	[illegible]	37.[illegible]	36.4
21	36	6.97	326.3	18.8	.806	.937	.937	38.9	[illegible]	48.[illegible]	31.6
21	37	14.22	597.1	10.3	1.104	1.116	1.116	17.4	57.3	49.[illegible]	34.9
21	38	7.28	396.8	14.1	.898	1.059	1.069	19.0	53.0	54.[illegible]	47.6
21	39	9.43	1236.7	112.7	1.137	1.172	1.172	21.1	[illegible]	46.7	44.0
21	40	15.91	531.3	4.5	.937	1.275	1.275	48.5	52.3	47.8	49.9
31	41	5.14	3191.6	720.4	.871	.814	.871	47.2	53.9	54.2	53.7
31	42	4.72	1849.6	448.5	.823	.887	.823	40.2	64.6	37.0	40.4
31	43	2.68	3678.2	1206.2	.521	.867	.857	43.9	54.7	39.[illegible]	40.9
31	44	7.04	982.0	54.9	.933	1.234	.933	33.7	[illegible]	32.[illegible]	43.6
31	45	4.03	422.0	82.4	.831	1.054	.831	37.1	70.7	34.[illegible]	42.7
31	46	6.05	390.5	47.1	.809	1.016	1.016	35.1	59.1	31.0	45.[illegible]
31	47	6.02	256.2	17.5	.921	.958	.921	29.8	53.0	34.[illegible]	34.[illegible]
31	48	14.32	1256.9	14.5	1.169	1.071	1.071	46.5	[illegible]	39.[illegible]	36.[illegible]
23	49	9.93	97.3	3.6	1.001	1.048	1.001	18.0	[illegible]	37.[illegible]	39.[illegible]
23	50	13.45	252.2	23.1	.957	1.125	.957	16.3	[illegible]	35.[illegible]	23.[illegible]
23	51	17.69	245.2	2.4	.891	.949	.949	31.1	[illegible]	30.[illegible]	31.[illegible]
53	52	9.86	174.4	9.7	.804	1.010	.804	19.4	[illegible]	[illegible]	33.[illegible]
23	53	9.45	161.5	14.4	1.023	.910	1.023	14.7	[illegible]	[illegible]	32.[illegible]
23	54	8.91	397.0	45.2	1.039	1.055	1.055	17.7	[illegible]	[illegible]	26.[illegible]
23	55	17.52	97.[illegible]	[illegible]	.937	1.060	1.060	31.6	[illegible]	[illegible]	37.4
53	56	6.37	300.3	34.9	1.037	.935	.985	21.4	[illegible]	[illegible]	[illegible]
53	57	6.14	207.6	25.9	.770	1.045	1.042	23.8	[illegible]	[illegible]	[illegible]
53	58	10.13	258.4	13.5	.968	.955	.955	39.0	[illegible]	[illegible]	[illegible]
53	59	10.24	231.3	6.0	.891	1.099	1.099	35.0	[illegible]	[illegible]	[illegible]
53	60	10.33	311.2	4.0	1.032	1.200	1.200	34.0	[illegible]	[illegible]	[illegible]
43	61	10.12	318.8	11.9	.874	1.399	1.399	33.2	[illegible]	[illegible]	[illegible]
43	62	9.91	98.9	16.7	.814	1.157	1.157	23.4	[illegible]	[illegible]	[illegible]
43	63	9.85	149.5	5.8	.876	1.039	1.039	24.0	[illegible]	[illegible]	[illegible]
71	64	9.33	84.[illegible]	14.9	.913	.980	.913	19.5	[illegible]	[illegible]	[illegible]
71	65	14.12	167.5	2.0	.716	.343	.947	45.6	62.1	41.9	37.4
71	66	9.13	307.4	21.2	.862	.957	.987	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	67	6.10	[illegible]	33.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	68	17.55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	69	13.81	72.[illegible]	3.6	.943	1.032	1.082	[illegible]	62.7	43.6	40.6
62	70	6.54	170.3	17.1	.853	.912	.853	40.8	60.0	42.[illegible]	42.0
62	71	6.64	120.0	11.2	1.059	1.034	1.034	23.8	63.3	43.[illegible]	37.9
62	72	6.77	127.0	13.6	.874	1.057	1.057	40.5	63.7	42.[illegible]	39.0
72	73	9.87	75.5	4.2	.841	.954	.954	54.6	63.3	33.7	31.4
72	74	4.03	72.9	20.2	.641	.918	.918	37.5	60.4	40.4	34.8
93	75	8.83	155.[illegible]	22.3	.986	1.049	1.049	25.5	61.7	40.7	35.1
93	75	9.72	120.5	5.7	.632	.875	.876	21.8	[illegible]	[illegible]	[illegible]
93	77	8.89	239.4	35.3	.778	.850	.860	35.0	67.1	[illegible]	[illegible]

A	B	OO	PP	QQ	RR	SS	TT	UU	VV	WW	XX	YY	ZZ
11	1	5.9	11.8	13.0	5	0	40	55	3.5	9359	45	31	4
11	2	20.2	23.4	5.0	0	5	40	55	3.0	14711	38	32	4
11	3	21.5	24.5	7.5	0	0	75	25	4.0	3946	16	32	7
11	4	13.1	15.5	4.0	0	0	50	50	5.0	15379	13	32	4
11	5	26.2	29.3	9.0	5	5	60	30	4.0	3709	32	32	5
11	6	3.5	5.1	12.0	0	5	40	50	3.0	6119	30	32	8
11	7	13.8	17.3	6.0	0	25	10	65	3.5	10214	32	32	6
11	8	19.9	22.5	1.5	0	0	55	35	4.5	14040	35	32	1
11	9	20.4	23.4	2.5	0	0	55	35	5.0	15155	23	32	5
11	10	13.4	17.3	1.5	0	0	10	45	6.0	12719	17	32	5
11	11	26.8	25.2	1.0	5	30	40	85	5.0	12982	19	11	3
11	12	21.2	25.5	4.0	5	0	[illegible]	25	4.0	12247	34	11	4
11	13	4.0	5.3	4.0	0	0	10	35	3.5	5516	[illegible]	41	[illegible]
11	14	15.0	19.3	3.0	0	0	40	70	3.0	11267	[illegible]	41	[illegible]
11	15	18.9	22.0	3.0	0	0	30	65	4.5	14923	30	42	5
22	16	26.3	26.5	5.0	0	0	60	60	5.5	12149	42	42	5
22	17	17.9	19.7	3.0	5	10	40	60	5.5	12198	37	31	6
22	18	20.7	25.2	3.0	0	0	70	30	4.0	5030	39	32	4
22	19	25.8	29.3	1.0	0	0	50	60	6.5	8284	31	31	2
22	20	6.4	10.0	8.0	0	0	95	30	8.0	6631	54	41	2
22	21	25.7	27.5	.2	20	0	45	30	10.0	13041	40	41	2
22	22	6.5	10.9	2.0	0	0	60	5	2.0	4290	21	42	2
22	23	14.1	17.0	11.0	20	0	5	35	3.5	7567	23	51	6
22	24	15.5	18.4	4.0	5	10	15	25	2.5	1827	32	41	2
32	25	13.3	16.4	2.0	60	25	70	15	1.5	476	65	42	5
32	26	8.7	12.4	3.5	0	53	70	30	3.0	2452	31	51	5
32	27	16.6	19.9	8.0	0	10	2	20	5.0	5343	35	51	1
32	28	18.0	21.3	1.5	5	0	25	25	2.0	2223	56	52	6
32	29	21.9	24.3	.2	43	35	55	20	8.0	863	37	52	5
32	30	8.8	11.6	.5	0	0	65	75	5.0	3814	35	31	5
32	31	23.9	27.6	1.0	0	10	40	35	9.0	7236	42	31	3
32	32	3.7	5.1	4.0	0	5	80	30	3.0	6204	45	31	3
21	33	12.8	20.2	7.0	0	30	50	30	5.0	4943	26	32	3
21	34	20.1	24.1	1.0	0	0	40	20	4.0	23455	32	41	5
21	35	9.2	13.7	11.0	0	20	40	30	5.0	4362	25	42	8
21	36	16.3	19.3	6.0	5	0	50	55	4.0	6579	15	42	6
21	37	15.9	20.9	8.0	0	25	35	30	3.5	3154	43	32	5
21	38	17.5	21.4	11.0	0	25	[illegible]	25	1.5	5921	39	42	7
21	39	13.3	16.0	7.0	0	20	[illegible]	45	[illegible]	3677	25	33	6
21	40	3.4	4.7	13.5	0	0	[illegible]	30	[illegible]	3152	34	32	5
31	41	9.9	15.6	4.0	0	55	[illegible]	20	[illegible]	1379	23	33	8
31	42	5.3	9.6	9.0	0	45	[illegible]	25	[illegible]	6765	25	31	5
31	43	5.9	10.9	10.0	0	35	[illegible]	50	[illegible]	6302	35	32	6
31	44	9.7	14.3	10.0	0	30	[illegible]	45	1.0	5558	32	32	5
31	45	24.0	29.8	8.0	0	30	70	30	3.5	3965	13	41	5
31	46	13.2	15.5	10.0	5	0	25	65	2.0	8505	23	41	6
31	47	12.8	17.9	10.0	0	0	20	40	2.0	7935	30	53	6
31	48	9.7	12.0	14.0	0	0	5	40	1.5	3659	25	32	7
23	49	22.3	25.2	.4	0	0	15	90	1.0	15867	30	42	6
23	50	15.0	18.7	4.0	0	0	40	60	2.0	25989	34	41	6
23	51	17.4	19.7	2.0	0	0	0	38	7.0	14829	21	42	0
53	52	27.4	30.0	1.5	5	15	15	50	6.5	19944	50	42	1
23	53	17.1	21.0	.8	0	0	30	50	9.0	5528	45	[illegible]	0
23	54	23.1	25.7	1.5	0	0	10	65	6.0	33128	41	[illegible]	0
23	55	23.8	26.2	2.0	0	0	40	70	11.5	20290	37	[illegible]	0
23	56	24.3	27.4	8.0	0	0	60	40	3.0	11968	54	[illegible]	9
23	57	13.4	17.2	8.0	0	0	40	40	5.5	9437	25	[illegible]	2
53	58	24.3	27.7	4.5	0	0	30	15	6.0	10933	35	[illegible]	0
53	59	21.9	25.1	10.0	0	0	50	40	5.5	11130	35	[illegible]	0
53	60	9.5	12.9	11.0	0	0	35	20	5.0	10774	32	[illegible]	0
43	61	[illegible]	11.0	10.0	0	0	30	60	5.0	5699	34	[illegible]	1
43	62	13.6	17.9	1.5	0	0	60	40	7.0	16128	24	[illegible]	0
43	63	23.9	27.7	3.0	0	0	80	25	5.0	16250	[illegible]	[illegible]	0
71	64	21.4	25.2	1.2	0	0	60	30	6.0	13950	[illegible]	21	0
71	65	24.3	28.6	4.0	0	0	40	[illegible]	4.5	8239	[illegible]	[illegible]	0
[illegible]	66	16.4	20.2	[illegible]	5	[illegible]	60	[illegible]	4.0	5547	[illegible]	[illegible]	3
[illegible]	67	[illegible]	[illegible]	[illegible]	5	25	75	[illegible]	[illegible]	[illegible]	[illegible]	21	[illegible]
61	68	12.2	26.1	9.0	5	20	70	[illegible]	[illegible]	1089	[illegible]	21	7
61	69	17.3	20.7	12.0	5	[illegible]	70	15	1.0	2540	30	21	7
62	70	20.8	28.1	4.0	0	15	[illegible]	45	3.5	3746	29	21	6
62	71	16.4	20.0	10.0	0	0	60	20	1.5	2729	37	21	5
62	72	16.6	20.4	4.5	0	0	40	73	9.0	34151	34	21	7
72	73	15.5	21.3		0	0	30	70	7.0	31079	25	21	4
72	74	20.7	24.3	6.0	0	0	25	85	4.5	15729	51	21	7
93	75	26.7	29.0	.5	0	0	15	90	8.0	21559	41	21	9
93	76	21.3	26.9	2.0	0	0	10	60	7.0	18583	22	21	0
93	77	26.4	32.0	5.0	0	0	50	50	7.0	20043	26	21	0