ECOLOGICAL LAND UNITS OF BEAR CREEK WATERSHED
AND THEIR RELATIONSHIP TO WATER QUALITY

by

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ABSTRACT

During 1975 and 1976 a sedimentation study was conducted in the Bear Creek watershed, located in the southeastern corner of central Oregon's Crook County. A Rocky Mountain infiltrometer was used to simulate high intensity rainfall over 468 sedimentation plots. Rainfall and runoff were measured and a sample of the runoff was collected to determine the sediment potentials.

The Bear Creek watershed was divided into eight ecological land units which were further refined into 14 tentative habitat types and four unclassified communities. These divisions are based upon an association table developed from vegetation and soil field data.

One- and two-factor analysis of variance was used to analyze the differences within habitat types, between habitat types within a unit, and when appropriate, between treatments or ecological condition within the habitat type or unit.

Tractor logging in the mixed forest unit caused a significant increase in soil loss. Non-forest units exhibited a high natural variability in sediment production within the site tended to override any differences that may have resulted from a management treatment. Significant differences that did occur appeared to be closely related to differences in soils or ecologic condition.

Wildland watershed managerial implications are explored in the summary section.

KEY WORDS: Ecological Land Units, Bear Creek Watershed, Water Quality, Sediment Potential, Runoff, Watershed Management.

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INTRODUCTION

Management of semiarid range watersheds is based primarily upon the harvest of natural resources and the realization of non-tangible benefits from the land and its vegetation. Watershed management on these rangelands is concerned primarily with the quantity and quality of the water that is provided by these lands. Management for water quantity requires the maintenance of a vegetation and soil cover that is able to utilize and store precipitation at its maximum effectiveness. Arid rangelands, with high potential evapotranspiration deficits, experience periods of seasonal (summer) droughts which increase the necessity for maintaining and improving the soil storage component (Satterlund, 1972).

Management for water quality requires the protection of the vegetation and soil resource, maintaining it in a progressive, or at least stable, state and minimizing the impacts that result from the vegetation and soil manipulation.

Erosion and sedimentation are natural phenomena, which have their maximum expression on semiarid watersheds with 25 cm to 36 cm (10 in. - 14 in.) of precipitation annually. Such climatic zones receive sufficient rainfall to erode and transport soil but not enough to support a continuous vegetation cover (Langbein and Schumm, 1958).

Timber management, livestock and game/range management, and recreation are all interrelated with watershed management through their influence on the vegetation and its associated soil, therefore any management decision that disturbs the land surface for one use will ultimately be reflected by the watershed.

The purpose of this study was to determine those ecological land units which were most susceptible to surface erosion and whether the response is natural (geologic erosion) or a result of current management (accelerated erosion). This study also attempted to identify those factors within the unit which have the most significant effect on sediment production. The sediment production value calculated from these units should not imply a yield to Bear Creek or its tributaries, but a potential erodability which could ultimately contribute to the degradation of water quality. The following objectives were established to provide guidelines for accomplishing this project:

(1) Identify and classify the vegetation-soil units in the Bear Creek watershed.

(2) Determine habitat types where possible and the condition of these habitat types and other vegetation-soil units.

(3) Relate the condition and/or management treatment of each vegetation-soil unit to potential contribution to the turbidity of Bear Creek.

The Ecological Land Unit served as the basic interpretive unit for determining the relationship between the vegetation-soil complex and its sedimentation potential. An erodibility rating on sediment potential related expected soil movement from surface runoff (sheet erosion) to a high intensity rainstorm event similar to the summer convectional storms that occur in the Bear Creek area. The integration of a specific ecological land unit with its inherent potential for producing sediment provided a means to more objectively evaluate the affects of management on water quality.

STUDY AREA

Location

The Bear Creek watershed is located near the geographic center of the state of Oregon, in Crook County, approximately 75 km (40 mi) east of Bend, Oregon (Figure 1). It lies between $44^{\circ}10'$ and $43^{\circ}50'$ north latitude, and $120^{\circ}50'$ and $120^{\circ}15'$ west longitude. The watershed is bordered by the High Lava Plains to the south and west, and includes the western half of the Maury Mountains (the southwestern extension of the Blue Mountain Province) in the northeastern sector of the drainage. The Crooked River Canyon, with its Columbia River Lava plateaus, form the northwest boundary of the watershed. The Bear Creek drainage covers approximately 531 km^2 (205 mi^2) or 53,004 ha (131,200 ac) with elevations ranging from 988 m (3250 ft) at the Prineville Reservoir to 1909 m (6266 ft) as Drake Butte in the Ochoco National Forest. Bear Creek is a tributary of the Upper Crooked River Drainage with runoff storage in the Prineville Reservoir.

Bear Creek and Its Tributaries

Bear Creek is a third order stream (Chow, 1972) approximately 61 km (33 mi) long, fed by springs originating in the Maury Mountains, and Klootchman Creek and Antelope Flat reservoirs which store the runoff from spring snowmelt. Springs that occur at lower elevations often form intermittent streams which contribute direct runoff only during the spring runoff period or following a rainstorm event. This watershed has three

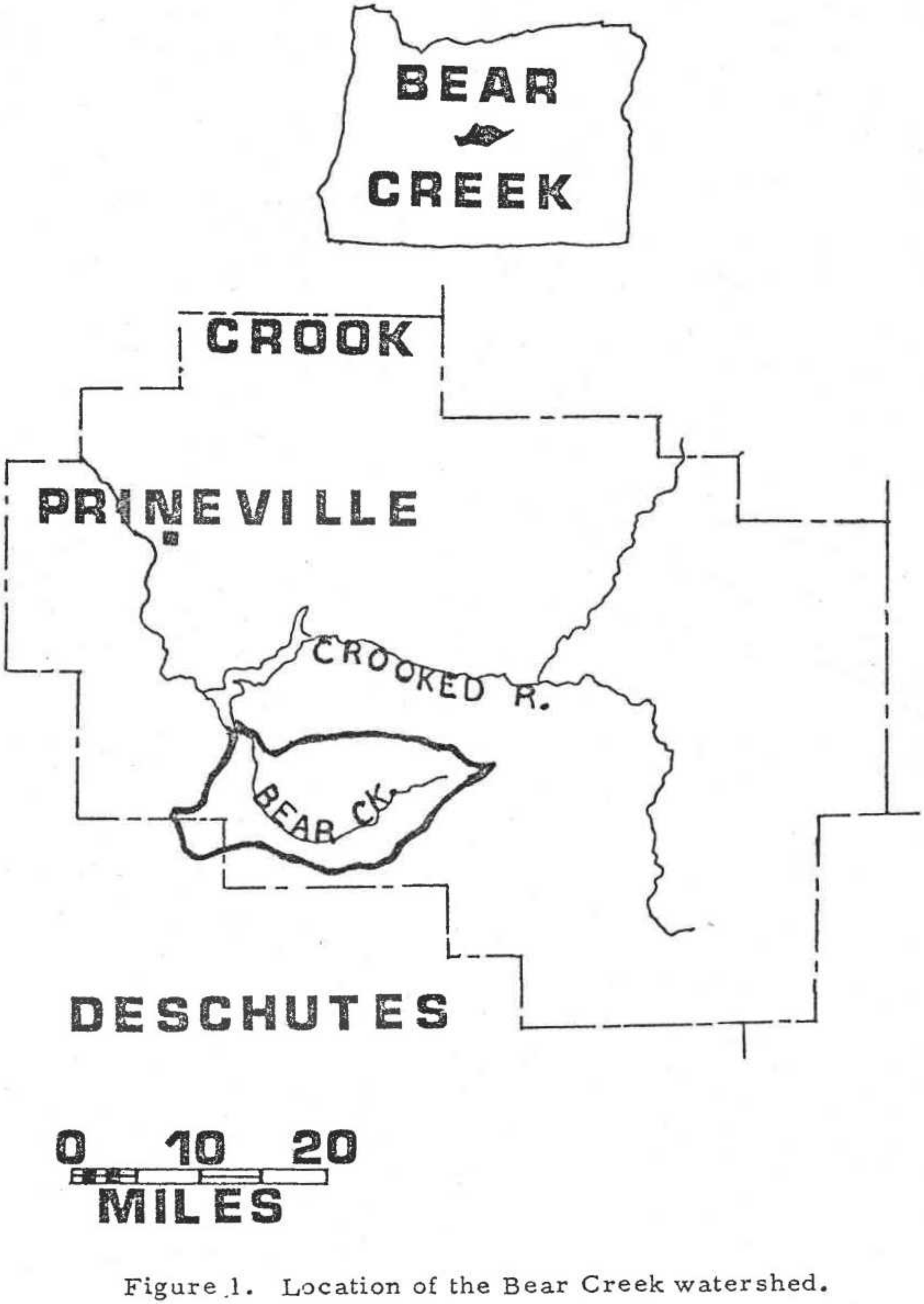


Figure 1. Location of the Bear Creek watershed.

second order streams, Little Bear Creek, Cow Creek and Klootchman Creek and seven first order streams, Calf, Ferguson, Friday, Deer, Faught, Soldier, and Antelope creeks. Ant Creek, Salt Creek, Spring Creek and Sage Hollow are intermittent or ephemeral drainages (Figure 2). The stream order concept was introduced by Horton (1945) and modified by Strahler (1952), to rank intermittent and perennial streams from their point origin to their confluence with another tributary (at which point the downstream segment represents the next highest order). Downstream tributaries were ranked from their point of origin in a similar manner. This concept was based on the premise that the order number is proportional to the size of the area of the contributing watershed, channel dimensions and stream discharge.

Bear Creek has a predicted average annual flow of approximately 5 cubic feet per second (cfs) (0.14 m^3/sec) based on the 1976 water year. Daily flows ranged from 0.5 cfs (low summer flow) (0.014 m^3/sec) to a flood peak of 850 cfs (24.1 m^3/sec) which caused a mean daily flow of 240 cfs (6.81 m^3/sec) (Gallino, 1977, personal communication) (Figure 3).

Bear Creek has a dendritic drainage pattern which typifies soft sedimentary rocks and volcanic tuffs; however, parallel patterns (indicating faults) occur in the north-central portion and radial patterns (indicative of volcanoes or domes) also occur, around Bear Creek Butte and West Butte. The drainage density is generally fine texture, which indicates high levels of surface runoff and soils with low permeability (Paine, 1975).

The upper portion of Bear Creek has approximately 9.25 km (5 mi) of rechannelization, plus an extensive network of diversion canals to

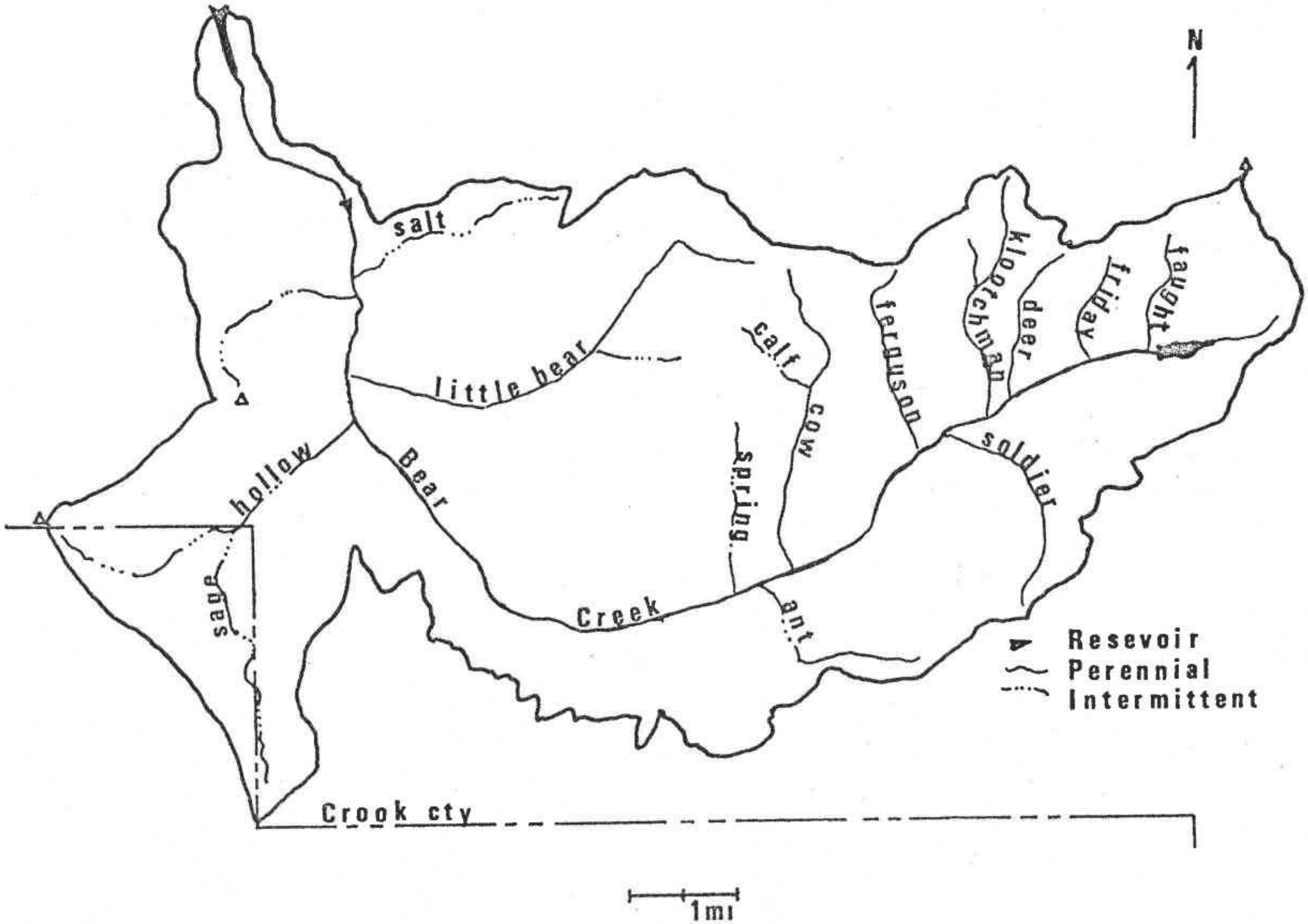


Figure 2. Bear Creek and its tributaries.

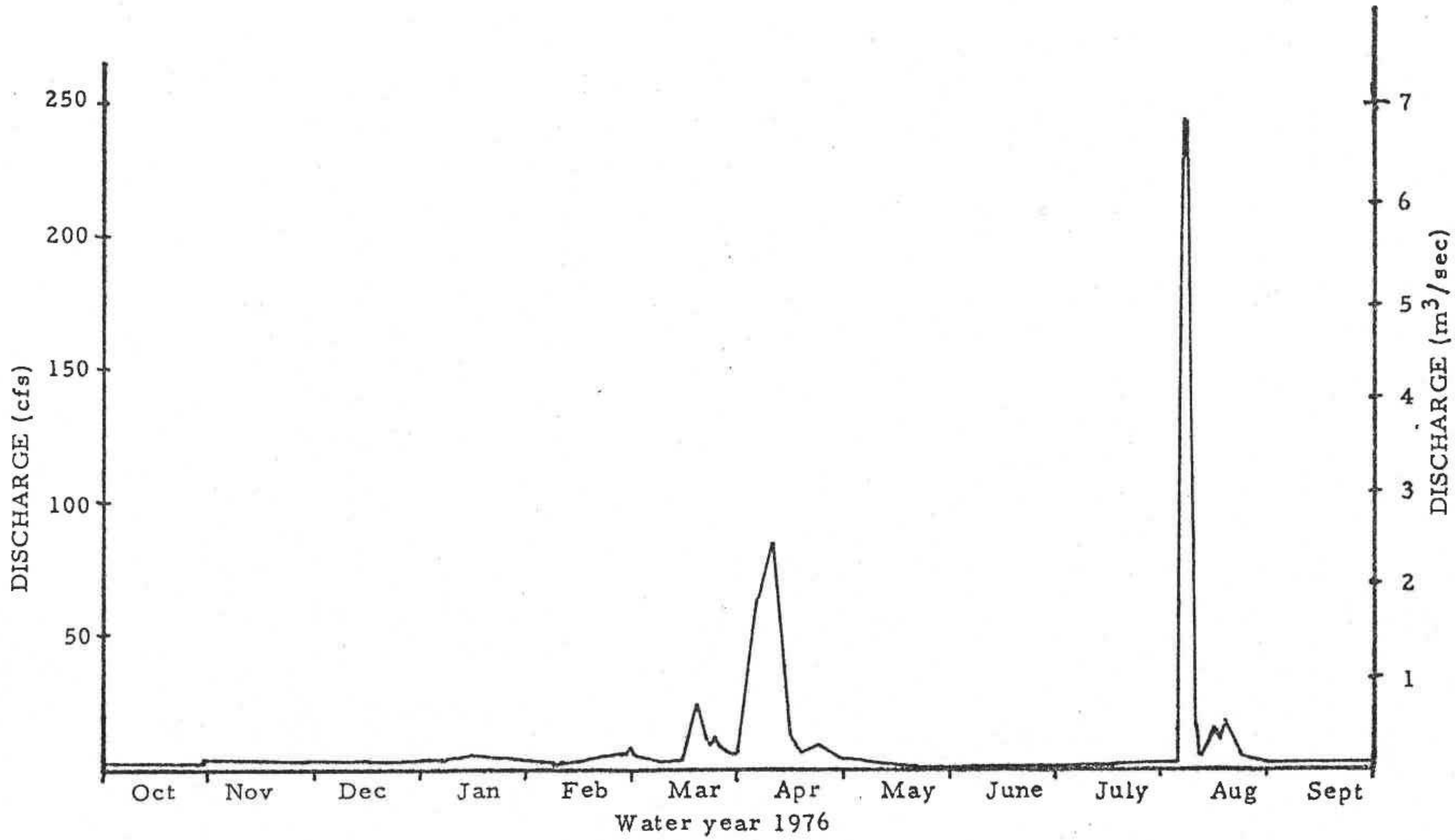


Figure 3. Monthly discharge of Bear Creek for the 1976 water year (USGS, 1977)

convert the bottomland into flood irrigated pastures. Runoff from sprinkler irrigation contributes direct runoff to the Bear Creek stream system.

In the lower portion of the drainage, rechannelization, and rock revetments are used to prevent channel erosion, where continued cutting threatens to damage the road. The BLM recently fenced off an area along the lower portion of Bear Creek to eliminate cattle disturbance to the channel.

The alluvial material that makes up the streambanks is highly variable, but generally appears to be lower in silts and clays than associated upland soils would suggest. Fine clay and volcanic ash tuff occur in localized spots. The straight-sided channels which occur in many places suggest low cohesiveness (Paine, 1975).

The Bear Creek watershed has been identified by the Bureau of Land Management (BLM) as one of the most critical areas in its Prineville District due to the high percentage of bare ground present, and the large sediment yields it contributes to the Prineville Reservoir (Bureau of Land Management, 1973). Prior to a turbidity study by Silvernale, Simonson and Harward (1976), Bear Creek was thought to be the primary contributor of an amorphous/clay complex found in suspended sediments that caused a persistent (long term) turbidity condition in the reservoir and in the Crooked River below the dam. The soils identified as capable of causing this turbidity, the Powder-Courtrock and the Simas-Tub-Soft Sedimentary Rock Associations, occur extensively throughout the watershed but presumably lacked sufficient amorphous material to form the persistent clay complex. X-ray diffraction of Bear Creek clay mineralology, from spring runoff samples, indicated the sediment for this period was originating primarily from sheet or surface erosion processes rather than deep cutting gullies. These authors also noted that the creek contained calcium in sufficient amounts to act as an effective flocculating agent for turbid suspensions during low flow periods.

Floods

Floods appear to be a common occurrence in the Bear Creek area, either as a result of rapid snowmelt generating high spring runoff or from stormflows caused by high intensity summer convectional thunderstorms. The Bureau of Land Management (1973) has documented a major destructive event at least once a year since 1969 and has cited the widespread 1964 flood as being the worst storm on record for the area.

While sedimentation increases as stormflows increase, it is important to understand that in the long run it is the more frequent intermediate-sized stormflows which may produce the greater amount of sediment (Hewlett and Nutter, 1969).

Turbidity

Oregon's Department of Environmental Quality found the turbidity (measured in Jackson Turbidity Units (JTU), but based on a Formazin standard) of Bear Creek to exceed the state standard of 5 JTU's during every season except the low summer flow period (Hose, 1977, personal communication). The 5 JTU standard established by the U.S. Public

Health Service as a Drinking Water Standard specifies that turbidity shall not exceed 5 units (McKee and Wolf, 1963). Current water quality standards for wildland streams in Oregon prohibit activities which would increase turbidities by more than 10 percent when natural turbidities are greater than 30 JTU and permit no increase when natural turbidities are less than 30 JTU (Brown, 1974). The 30 JTU standard was established as the maximum turbidity allowable for a productive fishery.

The Bureau of Land Management in conjunction with the U.S. Geological Survey established a monitoring station on the county bridge across lower Bear Creek in 1976. Sediment concentration is measured with a depth integrating sampler and calculated in milligrams per liter (Figure 4). The BLM estimated that 61,664 m^3 (80,650 yd^3) of sediment are lost annually from the Bear Creek watershed and this in turn causes the additional loss of 50 a-ft of storage in the Prineville Reservoir (Silvernale et al., 1976). Predicted losses calculated from the tentative and unpublished discharge records for the 1976 water year, for Bear Creek put the sediment discharge at 48,056 t (52,983 tons) (U.S. Geological Survey, 1977). This is equivalent to 18,134 m^3 (23,717 yd^3) and a 14.7 a-ft loss.

Channel Erosion

Rollins (1973) in his "Interviews with the Old Time Residents of Bear Creek," talked with two early residents, Frank Scott and George Pierce, about the numerous gullies that have formed in the watershed. According to Scott, Sage Hollow, an ephemeral drainage near the Scott homestead,

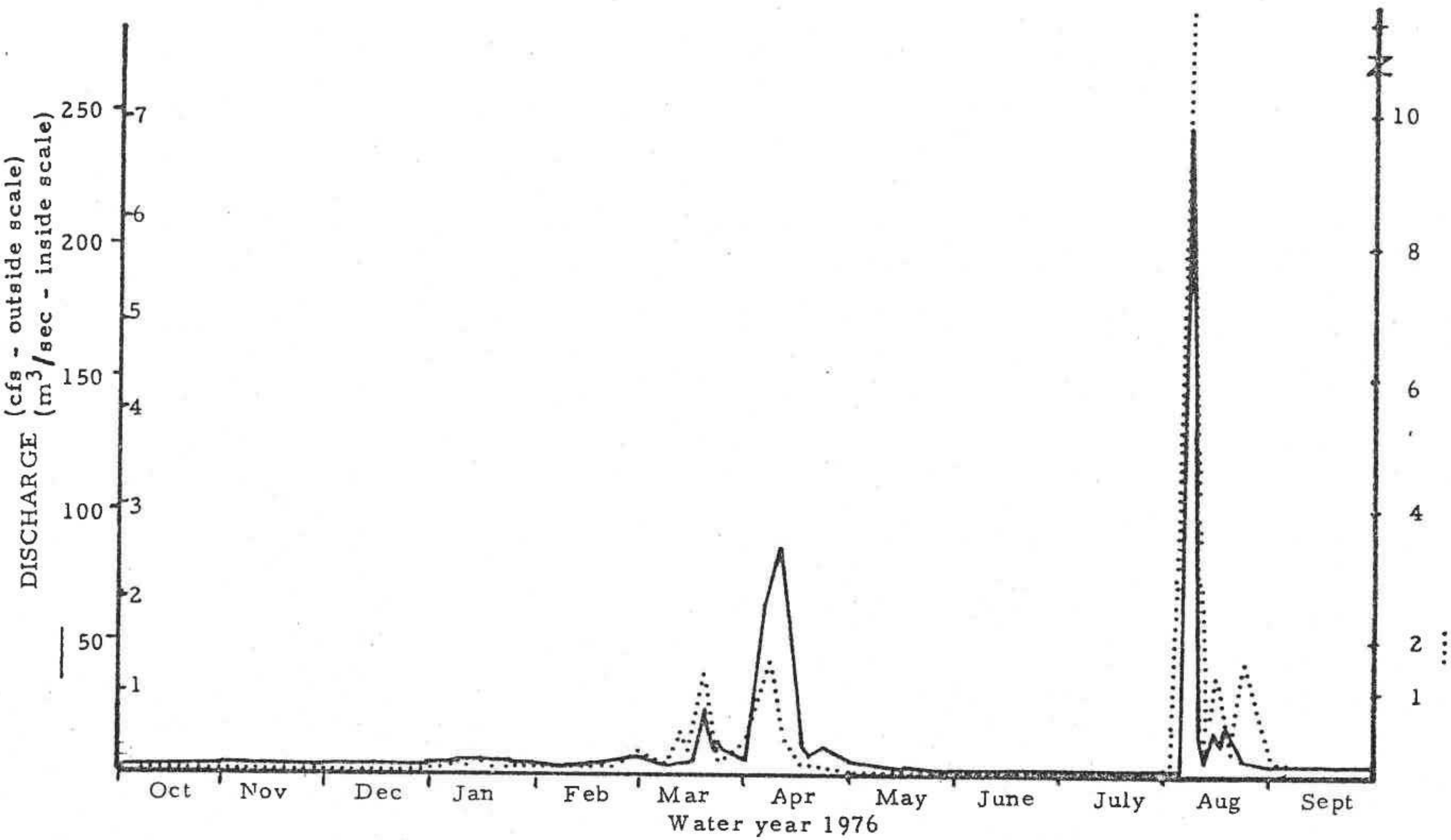


Figure 4. Bear Creek discharge and suspended sediment concentration for water year 1976 (USGS, 1977)

was 1.5 m (5 ft) deep and about 6 m (20 ft) wide in the late 1920's. Today the channel is 6 m (20 ft) deep and 14 m (45 ft) wide and a bridge is necessary to cross it. George Pierce stated that early residents were able to drive their wagons across Little Bear Creek whereas today it is 5 m (15 ft) deep and 6 m (20 ft) wide. It was the general consensus of the old timers that overgrazing served as the trigger for the acceleration of gully and streambank erosion.

According to a legislative report by Oregon's State Soil and Water Conservation Commission (1974), moderate streambank erosion occurred along 40 km (21.6 mi) of Bear Creek and minor erosion occurred along 3.7 km (2 mi) of Little Bear Creek. Moderate severity is a relative category based on the statewide maximums and minimums that falls near the mean.

It is obvious that the unstable channels found in the Bear Creek watershed must be playing a significant role in the contribution of sediment to the stream system.

Geology

The geology of the Bear Creek watershed is essentially volcanic in origin. The Ochoco Mountains, to the northeast, represent the oldest formations (Cretaceous) in the area, which may occur as remnants in the Maury Mountains that form the headwaters of Bear Creek (McKee, 1972). Swanson (1969) considered the Clarno Formation to be the dominant geologic formation within the watershed, since it covers most of the uplands to the north and east of the drainage. The Clarno Formation is a result of volcanism and sedimentation which occurred in the Oligocene Epoch, Tertiary period, and is derived from laval flows, mud flows, volcanic breccias and beds of volcanic ash. This formation serves as parent material for fine textured soils (Baldwin, 1964; McKee, 1972) (Figure 5).

The John Day Formation overlies the Clarno Formation on the west side of the lower portion of Bear Creek and occurs as scattered remnants within the Clarno area. This formation is composed of nearly pure volcanic ash, often welded into tuffs as a result of glowing avalanches which usually preceded eruptions. The John Day Formation generally occurs in three distinctly colored layers which reflect stages of weathering (Baldwin, 1964; McKee, 1972). This formation serves as the parent material for clayey textured soils found in this area (Simonson, 1976).

During the late Tertiary period and into the Quaternary period olivine basalt flows covered much of the Bear Creek watershed. The flows rim the watershed along the south side of the creek, providing the northern boundary of the High Lava Plains. More recent Quaternary basalt flows from Alkali Butte are found along the lowest extremity of Bear Creek creating a canyon similar to the Crooked River Canyon. The topography associated with the basalt rimrock generally creates steep slopes in excess of 100 percent (Swanson, 1969).

Faulting also occurred during this period, both in the lower portion of the watershed at its confluence with the Crooked River and in the north-central sector adjacent to the creek (Swanson, 1969).

Pleistocene glaciation is not evident in the Bear Creek watershed. At the end of the Ice Age volcanic activity resumed in nearby areas. Approximately 25,000 years ago, Paulina Mountain volcano, southwest of Bear Creek, collapsed forming the Newberry Crater, as a result of fissure

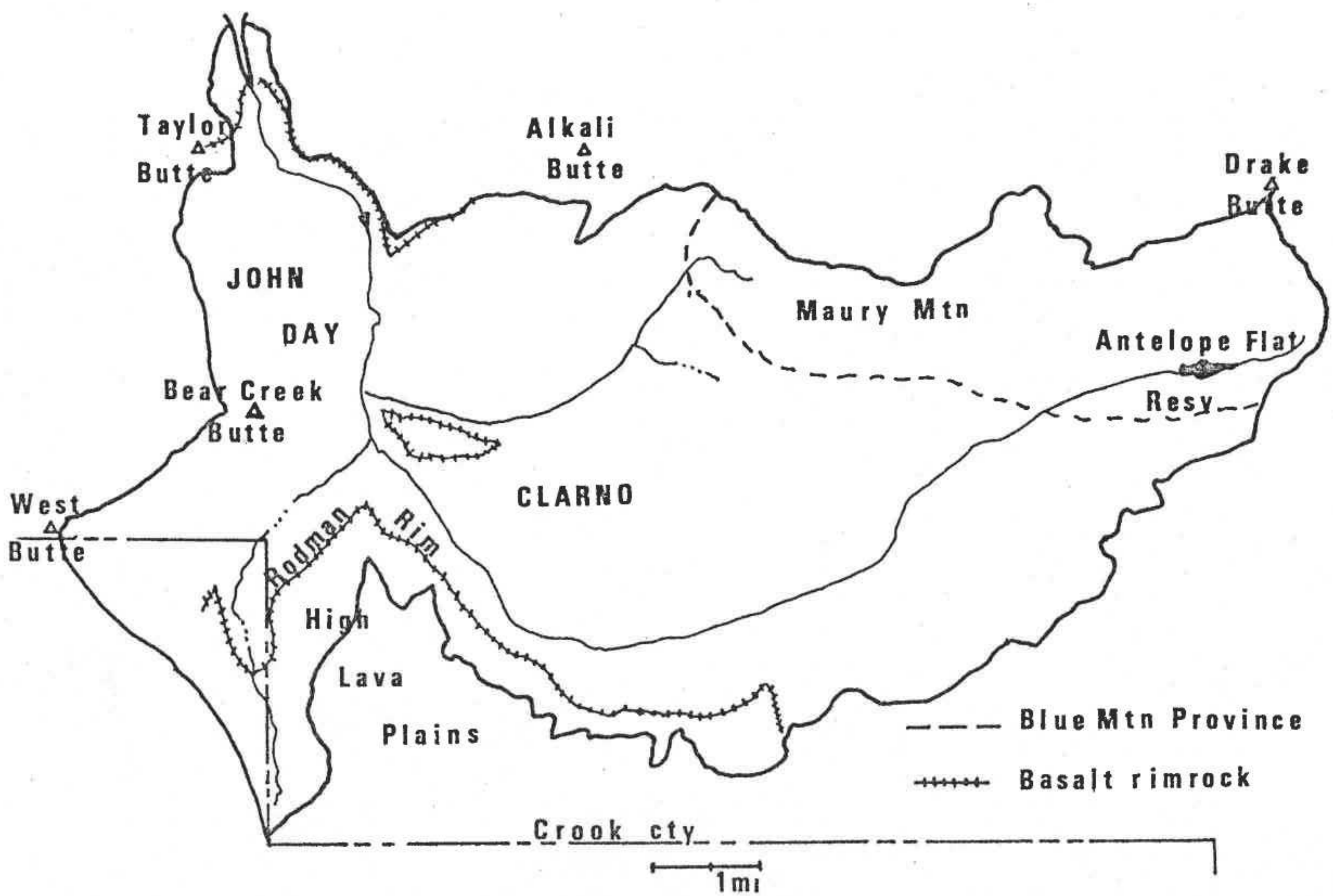


Figure 5. Geology of the Bear Creek watershed.

flows removing the lava that was providing the support for the mountain (Brogan, 1963). Approximately 6,600 years ago, Mount Mazama exploded, covering much of northeastern Oregon with a layer of pumiceous ash (Baldwin, 1964). This eruption presently is manifested to a large degree on the development of soils and possibly the vegetation found in the study area. Newberry Crater and its adjacent cinder cones are believed to have had the most recent activity, only 2,000 years ago, but documentation of the volcanic influences that followed the Mount Mazama eruption are not available (Williams, 1969).

The most recent geologic activities are the continuing processes of alluvial and aeolian deposition, though alluvial sedimentation is the most significant (Swanson, 1969). These processes have altered the Mazama ash layer by removing it from most of the south aspects (alluvial) and depositing it on north aspects (aeolian). It has also been incorporated into stream terraces and alluvial fans where it may range from a few inches to several feet in thickness (Hall, 1966).

Climate

Bear Creek watershed has a semiarid climate, typical of much of the Great Basin, receiving most of its moisture in the winter as snow and yet is subject to summer droughts caused by the Cascade Mountain rain shadow. This semiarid climate has prevailed for the last 5 million years (Baldwin, 1964).

Prineville, located 24 km (15 mi) north of the Prineville Reservoir, is the closest weather station with long term records (79 years). Brothers, Barnes and Pine Mountain Observatory located around the southern boundary of the study area have maintained records for the last 15 years, but may better represent the conditions for the Bear Creek area. The Thiessen method of apportionment for the Bear Creek watershed shows the Brothers station representing 79 percent of the study area, Barnes station another 17 percent and the Pine Mountain and Prineville stations accounting for two percent apiece (Figure 6). The Thiessen average annual precipitation for the study area is 27 cm (10.6 in) and the mean annual temperature is $8^{\circ}C$ ($47.6^{\circ}F$) (U.S. Weather Service, 1976).

Snow occurs primarily in December, January and February and may remain on the ground through April in the forested areas where accumulation is the heaviest.

May and June are often months of moderate rainfall, and are followed by dry July, August and September months. The summer precipitation is seldom effective due to the high potential evapotranspiration rates (BLM, 1973) (Figure 7).

While summer precipitation is generally light, high intensity convectional thunderstorms (downspouts) are common to this area.

Mayko and Smith (1966) predicted 6 to 12 thunderstorms annually for the High Lava Plains to the south and west of the study area and 15 to 25 storms per year in the upper valleys of the Ochoco Mountains. These authors also developed return periods for rainstorms in the Prineville area which related the amount of rainfall of a stated duration that may be expected in a specified number of years. One inch of rainfall in three hours has a return period of ten years; for the same rainfall in two hours the return

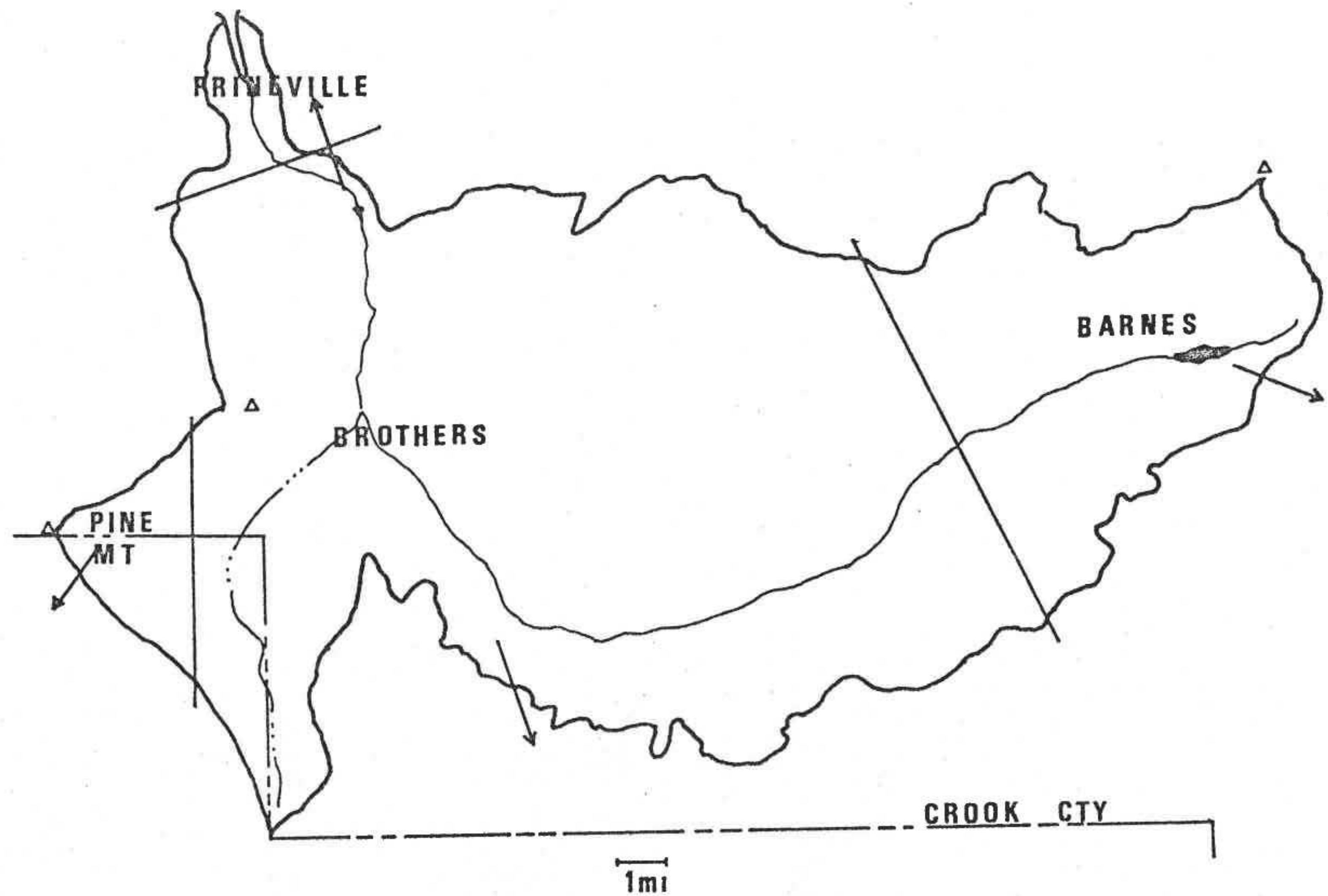


Figure 6. Thiessen apportionment of the Bear Creek watershed.

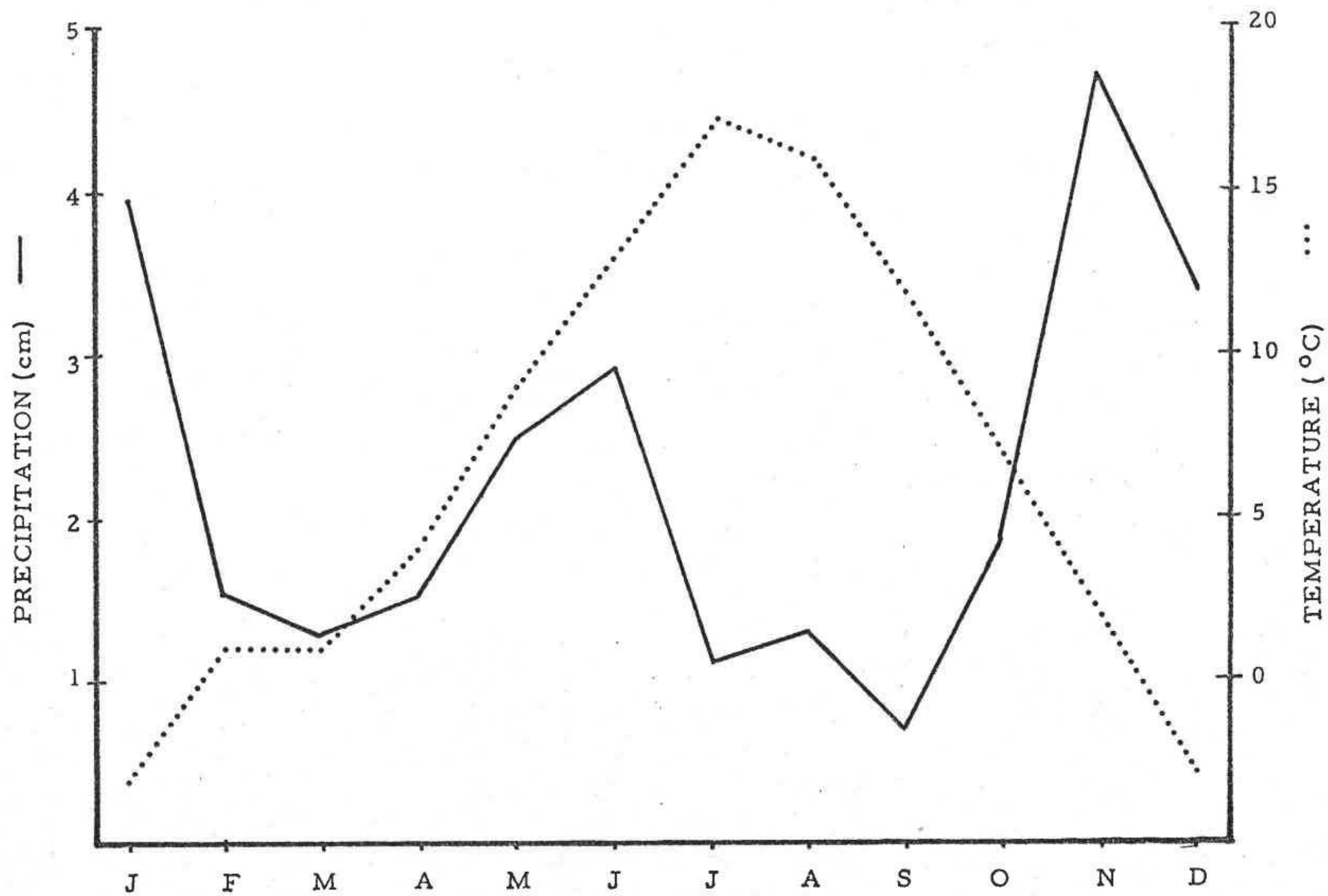


Figure 7. Average monthly precipitation and air temperature for the Bear Creek watershed (Thiessen method).

period is 25 years, and if it comes in one hour, one may expect a return period of 75 years.

The nights are cool and freezing temperatures may occur at any time during the summer. The average growing season varies from 32 days at Brothers to 86 days at Barnes.

Keen (1937) studied the effects a current drought in central Oregon was having on growth in ponderosa pine (Pinus ponderosa). Using dendrochronology techniques he studied several sites near the Bear Creek watershed and found the growth rings to adequately represent periods of climatic stress or more specifically the drought from 1918 to 1935. Field observations suggest further periods of climatic stress persisted until the 1950's as irregular cycles generally several years in length.

Vegetation

Vegetation is a function of climate, parent material (soil), biotic factors, initial state (current condition) and time (Jenny, 1958). A Mixed Forest covers approximately 17 percent of the watershed in the Ochoco National Forest and is managed primarily for ponderosa pine (Pinus ponderosa). Douglas-fir (Pseudotsuga menziesii), grand fir (Abies grandis) and western juniper (Juniperus occidentalis) are also present in the overstory. Mountain big sagebrush (Artemisia tridentata ssp. vaseyana), low sagebrush (Artemisia arbuscula) and stiff sagebrush (Artemisia rigida) occurred in small scattered communities throughout the forest. The herbaceous understory is predominantly Idaho fescue (Festuca idahoensis), pinegrass (Calamagrostis rubescens) and elk sedge (Carex geyerii) in the forest areas and Sandberg's bluegrass (Poa sandbergii), Idaho fescue and bluebunch wheatgrass (Agropyron spicatum) in the high elevation shrublands (Figure 8).

Western juniper woodlands are the most common vegetation type, and cover approximately 70 percent of the watershed. Understory vegetation is primarily big sagebrush, with low sagebrush becoming dominant on soils that have a shallow restrictive layer. Much of the area appears to be a western juniper climax since round-topped, old trees, supporting the lichen Letharia vulpina are present (Burkhardt and Tisdale, 1969); however, there has been considerable juniper regeneration with trees of less than 100 years of age. The overall density of juniper appears to have increased significantly. Sparse vegetation, typical of climax stands may mask the influence of this increase. Burkhardt and Tisdale (1976) believed fire played a dominant role in controlling invasion of juniper into other communities and in maintaining old growth climax juniper stands. The Bureau of Land Management employs fire suppression on these woodlands and apparently several trees are burned each year by lightning-caused fires. With the sparse vegetative understory the fires are generally restricted to the individual tree actually struck by lightning.

Shrublands, composed primarily of big sagebrush and rabbitbrush (Chrysothamnus spp.) cover the remaining 13 percent of the watershed. While this area contains nearly pure grasslands of bluebunch wheatgrass, Idaho fescue or needle and thread grass (Stipa comata), the shrub layer is still represented. Low sagebrush, buckwheat (Eriogonum spp.), greasewood (Sarcobatus vermiculatus), and stiff sagebrush dominate small communi-

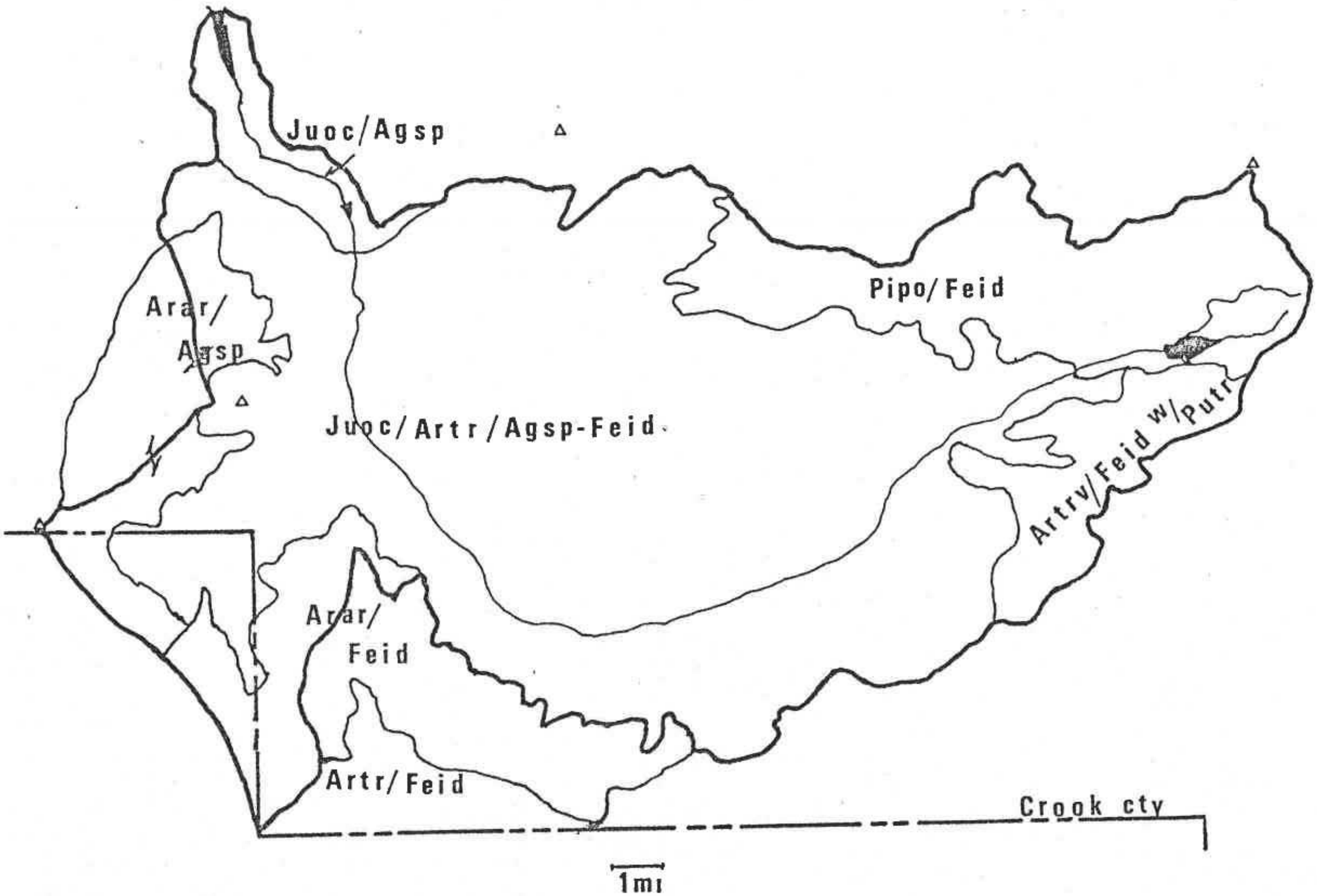


Figure 8. Vegetation of the Bear Creek watershed.

ties within this vegetation type.

Idaho fescue, bluebunch wheatgrass and Sandberg's bluegrass are generally the most dominant species in the herbaceous understory. Bottlebrush squirreltail (Sitanion hystrix), Thurber's needlegrass (Stipa thurberiana), Indian ricegrass (Oryzopsis hymenoides), and California mountain brome (Bromus carinatus) are important in other communities or in sub-dominant roles.

Soil

Soils, like vegetation, are influenced by parent material, biotic factors (includes vegetation), topography, climate and time (Jenny, 1958). The study areas are represented by four soil orders and three undifferentiated soil types (Figure 9).

Mollisols, one of the older soils, have developed from the Clarno and John Day formations and are high in sedimentary clay. This order would cover approximately 80 percent of the watershed and is primarily associated with the mixed forest and juniper woodland vegetation types.

Soils of the Aridisol order are younger, may be loamy or sandy in texture and developed from basalt, volcanic ash and pumice. These soils are associated with the shrubland vegetation found on the High Lava Plains, alluvial fans and stream terraces adjacent to Bear Creek.

A Vertisol, the Day clay, is characterized by a high shrink swell capacity that creates extensive deep surface cracking during the droughty summer months, and occurs as small inclusions throughout the watershed. These soils may be very productive, and generally support big sagebrush/

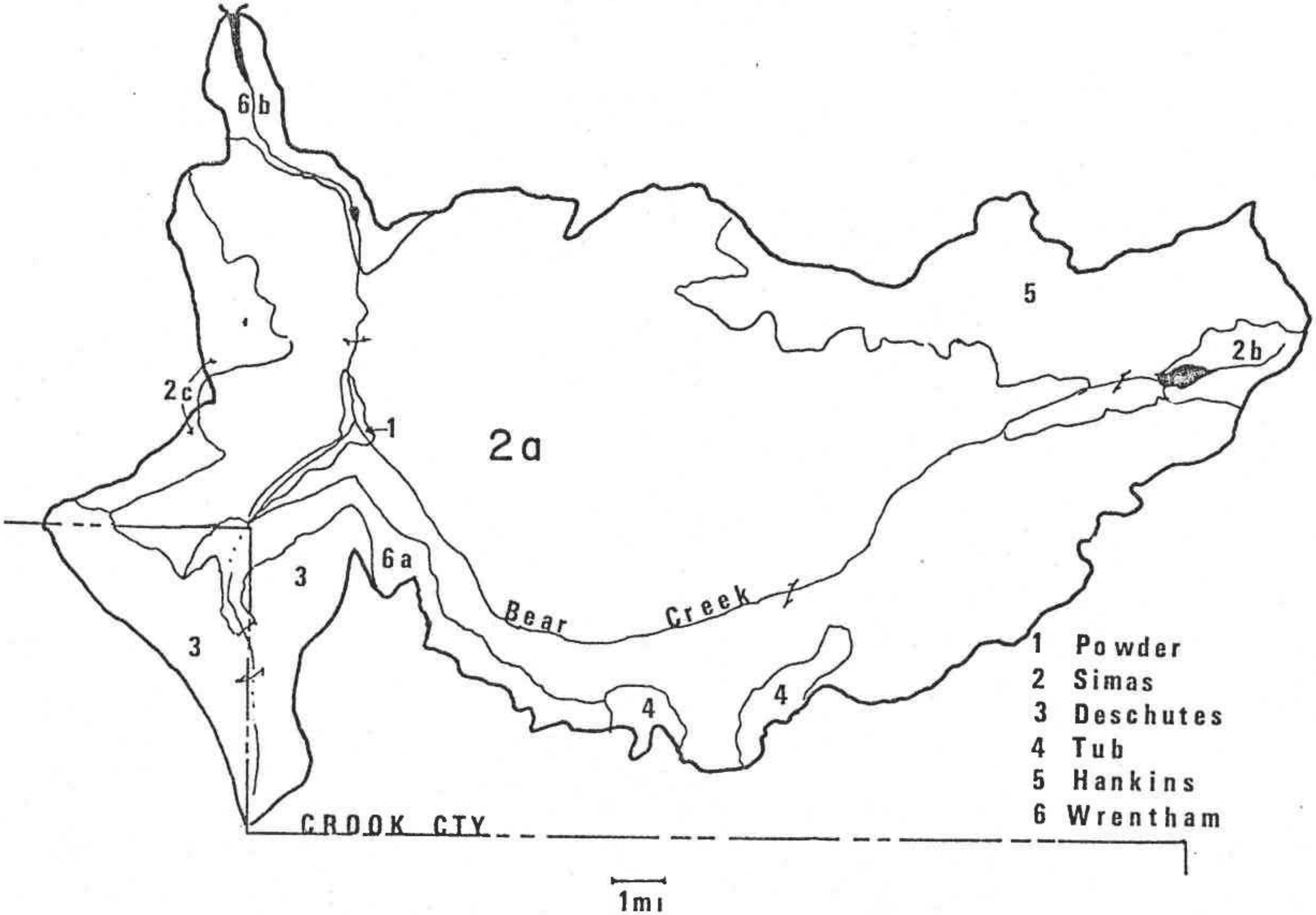


Figure 9. Soil associations of the Bear Creek watershed (Appendix B-1).

bunchgrass communities. Mountain brome may be a potential character species at lower elevations (Jeppesen, 1975, personal communication).

An unnamed Entisol is also found as scattered inclusions at lower elevations in the watershed and may be associated with recent exposures of old sedimentary formations. These soils are extremely fluffy and have calcium carbonates in the surface soil. Vegetation is sparse on these sites.

The undifferentiated soil types are the rockland category, which includes talus slides and rock outcrops which result from the weathering of the basalt rimrock; raw sediments, exposed John Day and Clarno formations; and an alluvial type for recent erosion deposition (Mayko et al., 1966; BLM, 1973).

Frost heaving occurs extensively in the non-forested areas and is believed to be primarily the result of the concrete type of frost (Jeppesen, 1976, personal communication). While none of the major soil types are skeletal (greater than 35 percent coarse material) their surfaces are often gravelly which may indicate residual as well as alluvial erosion pavement.

Debano (1968a) described a soil wetting phenomena, which he terms hydrophobic response, in which a drop of water balls up on the soil surface and does not infiltrate through the air-soil interface. A water drop penetration time test, described by Bond and Harris (1964), established a five second penetration time to separate the wettable soils from the hydrophobic soils. Debano (1968b) discussed the widespread occurrence of hydrophobic soils, citing two areas in central Oregon, south of the study area, where these soils were associated with juniper and rabbitbrush. He also found the hydrophobic conditions were often associated with volcanic parent materials and that amorphous materials, such as recent volcanic ash influenced the repellancy.

Based on the penetration time test, only one site on the Bear Creek watershed had soil with a penetration time greater than five seconds; however, several similar sites (clayey Mollisols) had times approaching five seconds.

History of Land Use

Prehistoric man, as evidenced by sandals found in a cave near Fort Rock may have been the first human visitor to the Bear Creek area. However, the area was still volcanically active at the time the sandals were made, so it is difficult to say just when the first humans did travel into the area. More recent aboriginal groups, such as Chief Paulina and the Walapi tribe of the Snake Indian Nation used Bear Creek for hunting forays, with arrowheads made from Newberry Crater's obsidian flow (Brogan, 1971).

The first white settlers moved through the area in 1853 when their wagon train got lost. The first residents of Crook County arrived from 1864-1870 with small herds of cattle, horses, and sheep (Brogan, 1971). The first documented homesteading in the Bear Creek watershed occurred prior to 1880. The homesteaders had small family herds that grazed year-long. Homesteaders and animal numbers both increased significantly in the early 1900's. The grazing animals reached their peak in the late 1920's. Old time residents put the number of cattle at approximately 2,500 head, at least 300 horses (a herd of 7,000 horses ran on the High Desert and moved in the Bear Creek drainage occasionally) and an unknown number of sheep. The local residents apparently raised some sheep, while transient Irish sheep herders maintained far greater numbers. The early residents believed overgrazing, erosion and increase in juniper was a result of the high animal numbers (particularly sheep and horses) grazing year-long. Bear Creek was ultimately homesteaded by over 30 families. These homesteads have subsequently been consolidated into five operating ranches, following the decline in animal numbers in the 1930's.

The Ochoco National Forest (including the Maury Mountain Unit) was established in 1905 (Figure 10). The primary objective of the Forest Service was to control fires, grazing use by livestock, and timber harvest. Cattle numbers have been reduced 250 percent in the Ochoco National Forest since 1905 and at present there are no sheep in the Bear Creek watershed. Deer and elk numbers are believed to have increased considerably, although no reliable census data are available. Extensive logging started about 1940 and continues. Logging at this time is primarily selective partial cutting (Hall, 1966).

The Prineville grazing district was established in 1935. The Bureau of Land Management has established seven major grazing allotments on their Bear Creek watershed which cover 16,700 ha (41,265 a) of public land. These allotments provide 2822 animal unit months of grazing for 237 cows grazing year-long, a considerable reduction from the 2,500 plus cows that grazed in the 1920's (BLM, 1973).

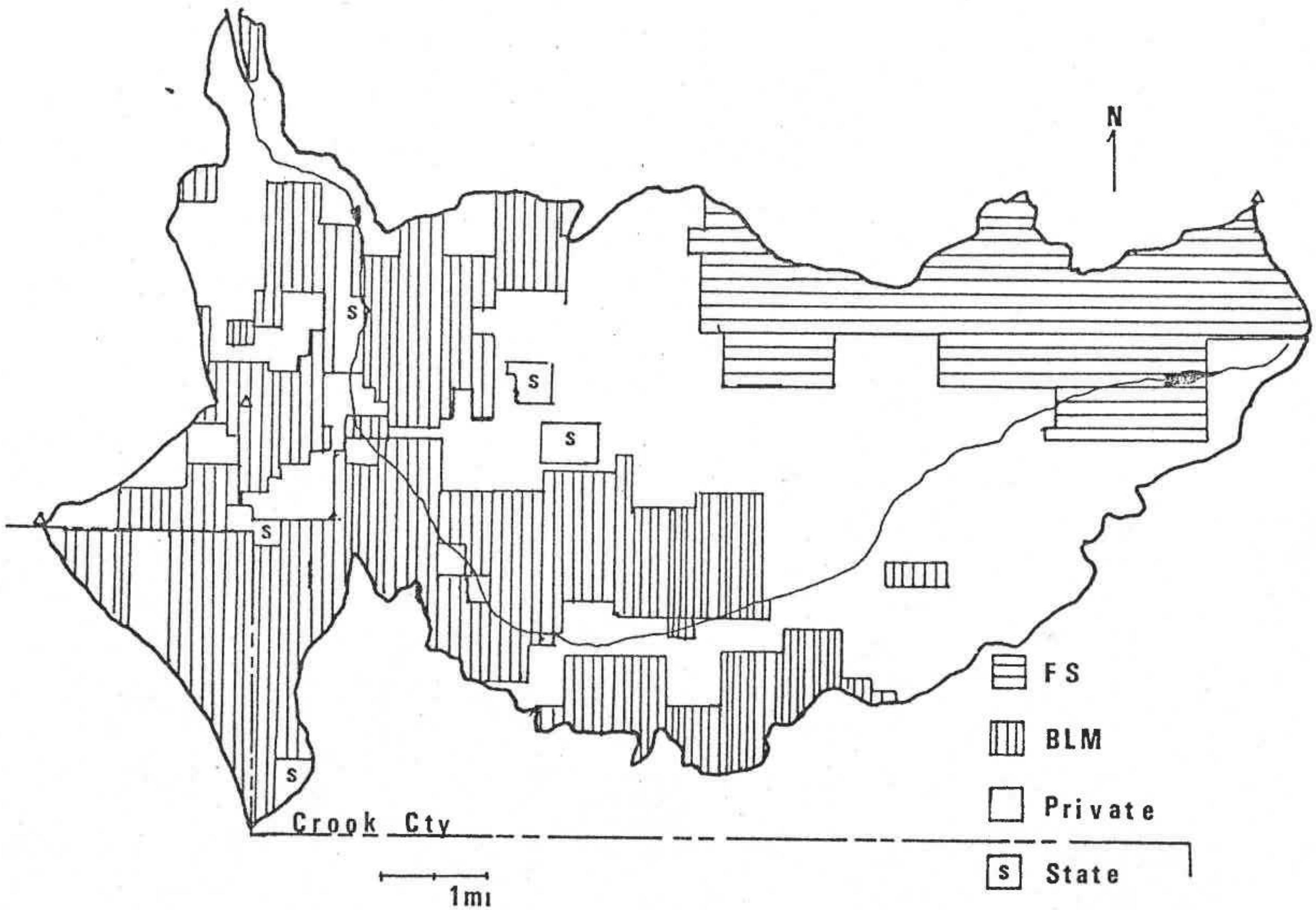


Figure 10. Land ownership of the Bear Creek watershed.

The remainder of the watershed is in private ownership although the state does control several small tracts.

More recently the watershed has seen a number of management treatments which involved vegetation/soil manipulation. Besides logging in the forested portion, the rangelands have undergone a juniper chaining in the Spring Creek drainage, sagebrush spraying on the High Lava Plains and in the Mixed Steppe area in the eastern sector and juniper dozing on small areas of private land. Juniper felling, with the trees left in place, is currently being used to increase soil moisture and herbaceous understory cover in areas where juniper has invaded or where their density has increased.

LITERATURE REVIEW

Sedimentation

Erosion is classified as geologic or normal for a natural environment; and accelerated, which is an additive amount that proceeds at a rate greater than normal for the same specific site due to the activities of man, or a natural catastrophy (Soil Consv. Soc. Am., 1976). Geologic erosion is a natural phenomena and varies considerably from one area to another. Likewise, accelerated erosion varies depending on the magnitude of the impact, and of the weathering factors that characterize the area (Branson, Gifford and Owen, 1972).

Langbein et al. (1958) found the semiarid region (21-30 cm; 9-12 in. of rainfall annually) had the greatest potential for yielding sediment, since there was sufficient rainfall for soil movement but not enough to support a continuous vegetative cover.

Erosion has been divided into three related processes:

1. Soil particle detachment.
2. Sediment transport (entrainment).
3. Sediment deposition (aggradation).

Soil particle detachment occurs when raindrop impact on bare soils causes soil particles to become dislodged and forced upward (splash). This impact may also seal the soil surface and reduce infiltration. The detached particles often remain in suspension and are carried downslope in overland flow (Branson et al., 1972). To put raindrop impact in perspective, and assuming the amount of water and the size of the areas are the same, the kinetic energy of the rainfall is 50.47 ft/lbs while that of the overland flow is only 0.02 ft/lbs (Hewlett et al., 1969). In a natural situation, however, the duration of the overland flow may be longer.

Sediment transport is primarily a function of the velocity of the flow, which in turn is influenced by the physiographic variables of slope and surface roughness (friction). Velocity increases with the square root of slope (a 40 percent slope has twice the velocity of 10 percent slope) and the sediment carrying power of runoff increases with the sixth power of the velocity (V^6); therefore, this potential carrying power or competence of surface runoff would theoretically increase with the cube of slope (Brown, 1974). The influence of vegetation and soil development create an inherent variability on land surfaces and tends to modify the potential carrying power (Smith and Wischmier, 1962). As the depth of water (often termed head) doubles, when it is concentrated in rills, gullies and channels, the mean velocity increases four times. When velocity is doubled, the cutting power is increased four times, the size of particles moved may increase 32 times, and the volume or weight (carrying power) transported theoretically increases up to 64 times (Hewlett et al., 1969). Surface roughness values as applied to rangeland watersheds are so broadly defined that they fail to differentiate between two areas with substantial differences in vegetation cover and biomass (Woolhiser, Hanson and Kuhlman, 1970).

Sediment deposition has not been empirically described (Wischmier, 1976). Semiarid watersheds exhibit considerable variation in microrelief and surface cover components. Since sediment deposition occurs as the velocity of the flow decreases or as surface roughness (friction) increases, it is possible to see the influence of slope and increased infiltration or transmission losses at the base of hills and porous ephemeral channels. The "losing stream" problem discussed by Renard and Hickok (1967), is a result of increased sedimentation due to deposition by diminishing volumes of stormflow caused by high transmission losses. The process is cumulative until an exceptional event occurs that is capable of removing old deposits. Plants, rock outcrops and coarse debris, which affect the surface roughness factor, are also capable of initiating sediment deposition (Anderson, 1974).

Wischmier (1976) stated that erosion is not synonymous with soil loss. Erosion may result from the impact of raindrops alone, while soil loss requires the transport of soil particles from the site, as a result of sheet and rill erosion processes. Sheet erosion is defined as the removal of a fairly uniform layer of soil from a land surface by runoff water (Soil Consv. Soc. Am., 1976) and may include splash erosion. Rill erosion is defined as the collection (of water) into rivulets, or numerous small channels (Hewlett and Nutter, 1969).

Wischmier further states that soil loss may represent sediment yield only when it is summed for all segments similar in soils, topography (slope steepness and length) and plant cover on the landscape.

Watershed sediment yield is then the summation of all upland soil losses, less sediment deposition plus estimates of gully and channel erosion (Renard and Simanton, 1975; Wischmier, 1976).

Influence of the Vegetation/Soil
Complex on Sedimentation

There is considerable literature on infiltration, runoff and sediment production for rangeland sites in most of the western states, but prior research from eastern Oregon is conspicuously lacking (Gifford, 1968).

Blackburn and Skau (1974) were the first to look for the relationship between an ecologically defined area (plant community) and its sediment potential. They studied 29 plant communities and soils on five semiarid watersheds in Nevada. Infiltration and sediment production rates varied considerably both within and between communities. Pinyon/juniper and big sagebrush communities had high sediment yields on several watersheds; however, none of the communities that occurred on more than one watershed were consistently high. Infiltration and sedimentation was more a characteristic of the watershed and its surface soil than of the associated communities. Pinyon/juniper communities produced the greatest sediment quantity on one community and the smallest amount from another. A big sagebrush/rabbitbrush community produced the greatest amount of sediment on two watersheds and the least on yet another. Vesiscular crusts forming on soils of the Aridisol group appeared to be the most erosive.

Forsling (1931) in Utah was one of the first to study the influence of vegetation cover on surface erosion. He discovered that while less than five percent of the annual surface runoff was caused by summer rainstorms, those summer storms caused nearly 85 percent of the erosion on sites with less than half of their original (potential) plant cover.

As succession progressed and the vegetation returned to original cover (approximately 40 percent), the annual sediment discharge decreased, most notably during the summer rainstorm period. Bailey and Copeland (1961), also from Utah, found that as vegetation and litter cover decreased, surface runoff and erosion increased. Lusby (1970) in Colorado found runoff to be directly related to percentage of bare ground present in the watershed. Aldon and Garcia (1973) investigating a semiarid watershed in the southwest found sediment to decline over a 17 year period as a result of increasing perennial grass size and litter production.

Meeuwig's (1970) results in northern Utah emphasized the importance of vegetation and litter cover in maintaining soil stability and infiltration capacity. Soils with high inherent erodibility needed more protective cover than those less erodible. Water retention was directly related to vegetation and litter cover, and erodibility was inversely related to vegetation cover.

In the northern California wildlands, André and Anderson (1961) showed the intensity and frequency of rainfall and the condition of the land were the most important factors needed to determine the erosion hazard of the area. In their study, grass cover was associated with the least erodible soils, forest cover with the moderately erodible soils, and shrub cover with those most erodible. In the semiarid southwest, Renard (1972) noted that where the vegetation was naturally sparse, its influence through litter accumulation and soil development may have been important as the protection of the land surface from the erosive force of rainfall impact. Desert brush cover was shown to contribute little to the reduction of runoff presumably because of the limited vegetation the area can naturally support (Simanton, Renard and Sutter, 1973).

Investigators studying the influence of rangeland soils on sediment production and sediment yields have found that fine textured (clayey) soils yielded over three times the sediment than those with medium textures (silts and sands) (Hanson et al., 1973). Blackburn et al. (1975) found a vesicular surface horizon to be a major factor contributing to lower infiltration rates and greater sediment production. His study, on semiarid watersheds in Nevada, found these vesicular crusts to be common in the interspace areas between the sagebrush. André et al. (1961), working in the northern California wildlands, found that soils developed on acid igenous rock produced more than twice the erosion as soils developed from basalt. In Hawaii, Yamamoto and Anderson (1967) studied soils derived from volcanic ash and basalt. The loose condition and the dispersive characteristics of the ash soils suggested that they may be twice as erodible as those soils derived from basalt flows or colluvium. Yamamoto and Anderson (1973) also looked at splash erosion on these soils, and their data suggested that ash and basalt colluvium had the greatest potential for erosion in the early phase of rainfall exposure.

Influence of Man on Sedimentation

Timber Harvest

Timber felling is usually insufficient to cause increased sedimentation. It is the yarding of logs to landings which generally creates the soil disturbance and leads to subsequent erosion (Likens et. al., 1970). The lack of erosion due to felling properly focuses attention on tree removal and transportation systems as the primary source of erosion problems. Drag systems which require higher densities of roads and ski trails have the greatest potential for surface erosion. Hi-lead, skyline and helicopter systems have a minimal effect on subsequent sedimentation. Uphill felling has also been useful for removing trees along streams, by avoiding the channel completely. Anderson (1970) predicted future forest harvests would increase sediment yields by a factor of four with roads accounting for 80 percent of the increase and logging practices the remaining 20 percent.

Buffer strips (no entry zone) along stream systems have proven useful in many situations, protecting channel banks and streambanks during logging. They may also reduce the amount of debris which would normally be transported to the stream. Debris accumulation during periods of high flows was the principle cause of failure for bridges and culverts (Rothacher and Glazebrook, 1968). Bethlahmy (1967) found erosion was related to the aerial extent of the exposure. His results showed that runoff and erosion were greater on southwest slopes than on northeast exposures, since the density of the stands on the northeast aspects tended to compensate for the disturbance caused by the selective removal. Similar densities were not present on the southwest exposures and even after careful selective logging practices erosion increased significantly.

Roads are generally associated with logging, as the transportation system necessary for tree removal. However, it is important to realize that the impacts of roads would be similar for other situations. Roads are often a significant source of sediment, because their compacted surfaces generally carry surface runoff during storms. This problem is compounded when culverts and drainage systems are inadequate or poorly maintained. Poorly planned roads may block normal subsurface flow patterns besides the reduction in infiltration. The amount of sedimentation from roads and skid trails is proportional to their density, and is often influenced by associated cross drainage (Brown, 1974). Declines in sediment yields that are directly attributable to roads may be slow, particularly when location and road drainage systems show poor planning (Brown, 1974).

With the exception of roads and skid trails, vegetation recovery following timber harvest usually occurs within the first few years following the removal and results in a corresponding reduction in sedimentation (Brown, 1974).

Grazing

Buckhouse and Gifford (1976) found that grazing and debris burning in a chained pinyon/juniper area did not significantly effect sedimentation due to the high natural variability of the area. Smeins (1975) found that although runoff increased after grazing it generally required severe overgrazing before significant erosion could be observed.

Rich and Reynolds (1963), in the southwest, observed that the amounts of sediment trapped were so variable from year to year that differences due to grazing were not statisically significant.

Although runoff increased slightly on the heavily grazed watershed the amount of change was not significant.

Sharp et al. (1964) looked at the effects of three grazing intensities on runoff. Their study in South Dakota found little difference between light and moderate intensities. Whereas the heavily grazed watershed produced more runoff for three storms, a fourth storm caused the lightly grazed watershed to produce the most runoff.

Woolhiser, Hanson and Kuhlman (1970) compared the influence of heavy and light grazing on the surface roughness of a rangeland watershed in South Dakota. They noted that while there were substantial differences in vegetal composition, cover and biomass there were no significant differences in the roughness component.

In western Colorado, Lusby (1970) found grazing increased sediment yields 45 percent due to the increase in bare soil and rock and a corresponding decrease in vegetative ground cover.

Light and moderate grazing intensities had little effect on sedimentation, while heavy grazing, and the long term reduction of vegetative cover may increase runoff and erosion.

Mechanical Treatments

Branson et al. (1972) and Gifford (1968) have reviews covering earlier research primarily in the pinyon-juniper and sagebrush areas of the Great Basin Region. They have found that sediment yields varied considerably with time (seasonal) and within a given storm event, and that treatments that disturb the soil may increase infiltration and decrease sediment or if the soil is already at field capacity, the response may be an increase in both runoff and sediment.

Gifford (1972) observed seasonal fluctuation in infiltration rates. Higher infiltration rates occurred in the spring from the increase in porosity caused by freezing and thawing over winter, while during the summer months the soil dried and was disturbed and/or sealed by convectional storms which in combination tended to lower the rate. The reduced infiltration rate could potentially increase surface runoff depending on the antecedent soil moisture conditions and the magnitude of the rainfall event.

Buckhouse (1975), studying chained areas in Utah, experienced a high natural variability among his study locations which he felt may have tended to mask any changes in sediment production caused by a management treatment.

Gifford and Busby (1974), working in a plowed big sagebrush site, found that soil cover characteristics did not adequately describe the potential hydrologic performance on areas that had been greatly modified by treatments such as plowing. They also found that grazing did not increase sediment production potentials over the increases expected as a result of the disturbance associated with plowing. In Arizona, Kincaid and Williams (1966) studied the effects of rainfall on surface characteristics following various range improvement treatments. They observed that exposed soil and litter (mulch) resulting from the treatments were washed away and erosion pavement was exposed but that surface characteristic appeared to stabilize after one summer's rainfall. They also found that vegetation crown cover had a greater effect in reducing surface runoff than soil treatments.

Gifford (1973), working in Utah, found sediment production was greatly reduced on chained sites with debris left in place as compared to chained areas with the debris windrowed. He predicted that 1.6 to 6 times the sediment could be expected from the windrowed sites than from adjacent undisturbed woodlands. The debris in place treatments were not significantly different in sediment production than the woodland control. Gifford believed that the debris that remained scattered over the bare soil surface maintained sufficient retention and detention water storage to compensate for the initial disturbance.

Skau (1961) found the surface pits left by uprooting juniper reduced overland flow and increased soil moisture storage.

In Wyoming, Sturges (1975), studying converted big sagebrush communities, believed that the treatment which minimized soil disturbance maintained the best watershed protection values following the conversion. Comparing undisturbed big sagebrush sites with sprayed (2,4-D) sites he could detect no differences in the suspended sediment concentration or bed load deposition and concluded that spraying was one of the best methods available since it maintained the watershed's protection.

Williams, Gifford and Coltharp (1972) looked at the relationship between vegetation and edaphic factors, and erosion at chained pinyon/juniper sites in Utah. The factors which influence sediment production were so variable between geographic locations that no consistent relationships were found.

The detrimental effects of a mechanical treatment are generally short-lived if there is an adequate response in vegetation recovery. The soil surface features stabilized after a single wet season (Kincaid et al., 1966).

Other Influences on Sedimentation

Fire

Wildfire or controlled slash burning following timber harvest are common occurrences on forests and rangelands, and interest in fire as a management tool is increasing. The effect that these fires have on soil erodibility is generally related to the intensity of the fire. Hot fires may consume litter and duff materials leaving the mineral soil exposed to raindrop impact. Light fires usually have little effect on erosion if sufficient organic material is left to protect the soil surface (Brown, 1974).

Fires may also induce a hydrophobic condition in the soil surface or as a discontinuous layer below the surface. This non-wettability appears to be a widespread phenomena, and when associated with fire it is believed to involve the chemical binding properties of essential oil residues interacting with soil particles (Debano, 1969a).

Raindrop impact may also influence the infiltration of water on burned areas by plugging soil pores with ash. Increases in sedimentation following slash burning are generally the release of sediment that was trapped and retained by the logging debris prior to burning. Megahan and Molitor (1975) believe proper slash disposal techniques are necessary to avoid the hazards created by an excessive accumulation of fuel for wildfires.

On rangelands the effect of wildfires is not well known. If the vegetation and litter cover are completely destroyed we may expect a response similar to the erosion that occurs on forested sites. When we consider the inherent differences in herbaceous vegetation and litter which characterize range communities, the effects of a light fire may be more complex.

Channel Scour

Stream banks are a natural source of sediment for streams. Anderson (1954) observed that about 50 percent of the sediment yields in the Willamette River could be attributed to bank cutting, another 25 percent to logging activity and the remaining 25 percent to agriculture. A study in northern California determined that stream bank erosion contributed an estimated 55 percent of the sediment discharge, while land surface erosion accounted for 20 percent (Anderson, 1970). In mountainous areas, channel erosion may be one of the principal geologic forces forming the landscape. Headward erosion within the channel often creates highly unstable banks, particularly at the top of channels where downcutting is most active (Brown, 1974).

Stream beds are also a common source of sediment. Porous gravel beds may hold significant amounts of fine material which have filtered out of suspension at lower flows and may be reentrained during large storm flows as the bed load shifts to accomodate higher flows (Brown, 1974).

One of the greatest threats to channel stability is the failure of the debris dams and the movement of large rocks, logs and coarse sediments when the channel is flushed out at high flows. While much of the debris is natural, its ability to erode or scour the channel system is no less detrimental. Jams caused by large debris may alter flow directions, causing the channel to shift and creating a new cycle of channel erosion.

It is important to realize that stream channels are highly sensitive to disturbance and if disturbed, there is usually an immediate influence on downstream sediment levels.

METHODS

Reconnaissance

The initial phase of identifying and locating the vegetation-soil units employed currently available aerial photography for Crook County, Oregon (U-2 Highflight, 72-114; 1:120,000 scale, color infrared and black and white 9x9 prints plus an uncontrolled mosaic). The mosaic had been delineated and subjectively verified for vegetation/land use and soils by an interdisciplinary group at Oregon State University in cooperation with the Environmental Remote Sensing Applications Laboratory (ERSAL), O.S.U., Corvallis, Oregon. The Ecological Land Units of this study reflect a synthesis of the ERSAL vegetation and soils maps, coupled with an extensive application of Daubenmire's (1968) habitat type classification for potential climax or original vegetation. The habitat type is defined as "the aggregate of all areas that support, or can support, the same primary vegetation climax. This terminal association is usually synonymous with original vegetation and may imply a climatic, edaphic or physiographic climax" (Daubenmire and Daubenmire, 1968).

A lower scale of aerial photography (U-2 Highflight 72-134; 1:30,000 scale, color infrared 9x18 positives) was used to further locate and define the vegetation-soil units. While these scales are too small for intensive ecological classification, they were the only scales currently available for this watershed and were adequate to meet the objective of determining the ecological land unit.

The vegetation-soil units which characterize the ecological land unit were located using the criteria established by Poulton, Faulkner and Martin (1971) (Figure 11). The identification techniques of Küchler (1967) and the color codes of Driscoll (1969) were also employed. These methods stratify the study area and use color, pattern, texture, tone and stereoscopic appearance to delineate the homogeneous areas. The classification legend was initially based on the dominant plant species and soil series or association and then refined by the field data to describe potential climax vegetation (using the presence or absence of differentiating character species) or simply retaining its initial vegetation-soil unit classification based on dominant vegetation. The final ecological synthesis phase of this classification was based on association tables developed from the vegetation frequency data. The association tables were constructed using the methods and procedures explained by Winward (1976, personal communication) and Schallig (1967) (Appendix A-1).

Field Methods

Site Location

Each vegetation-soil unit had to meet several preliminary criteria to be selected for sediment sampling.

1. Homogeneity in vegetation and soils.
2. Accessible to the mobile rainfall simulator.
3. Slopes less than 30 percent.

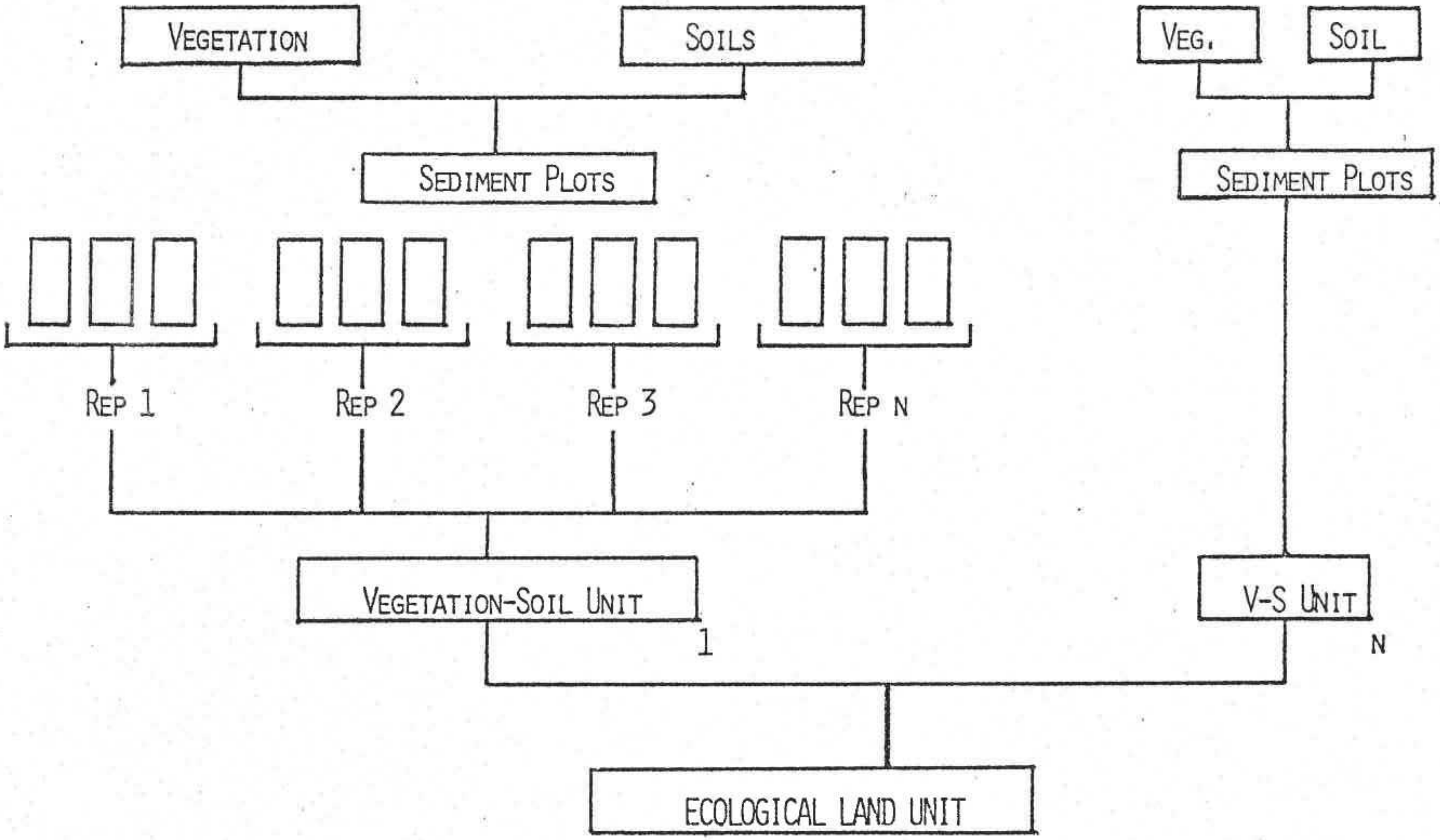


Figure 11. Flow chart for ecological land unit classification.

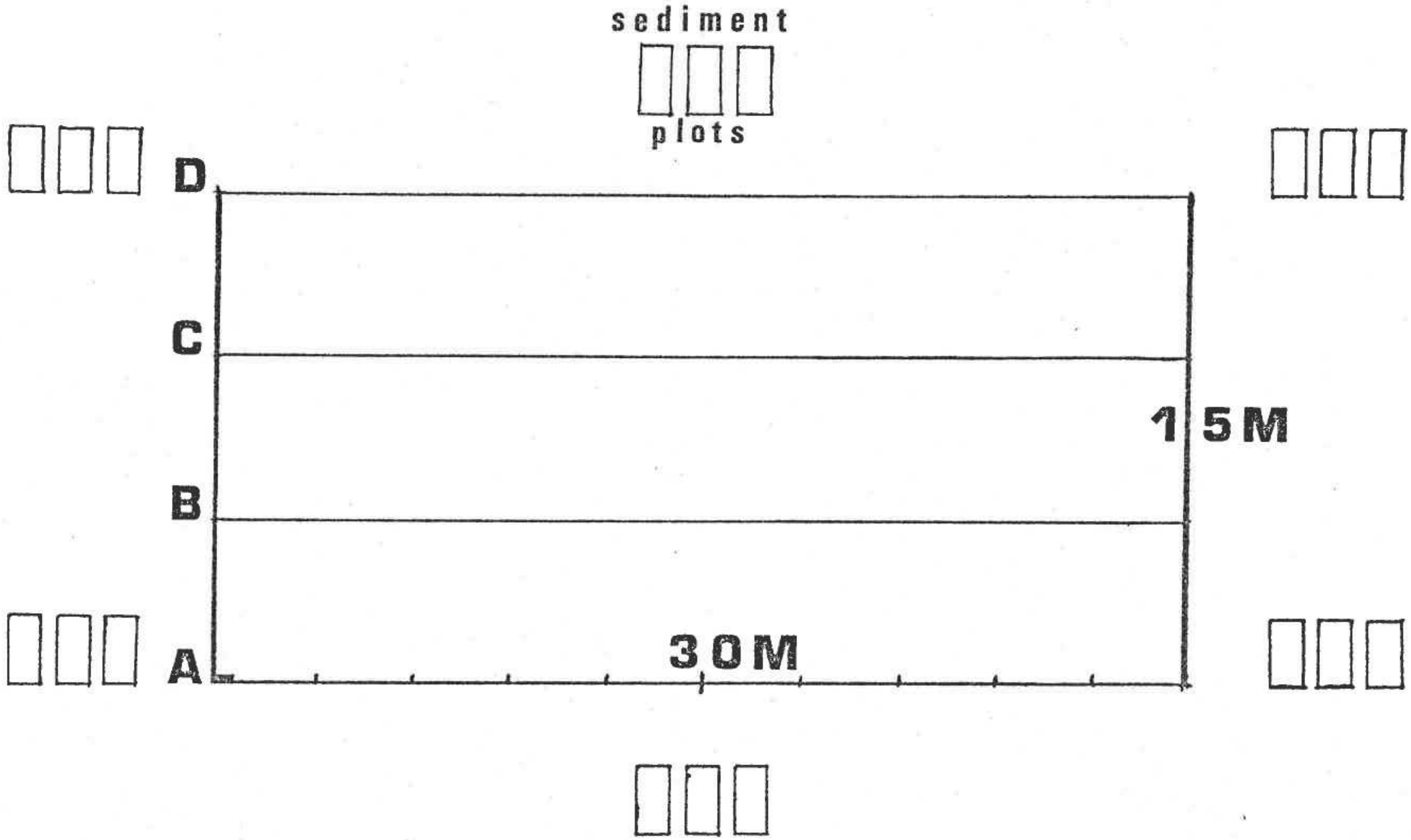
4. Soil surface horizon could not be excessively stony (subjective).

5. Juniper overstory could not restrict the placement of the rainfall simulator.

Criteria 2 through 5 are limiting factors inherent to the Rocky Mountain infiltrometer which is used to simulate rainfall. This system is not absolutely portable and incorporates in its design several features which reduce extraneous influences while at the same time creating other limitations. The affect of these limitations on sampling will be discussed in Appendix C.

Vegetation-Soil Methods

Field sampling to provide the ecological data base for the sedimentation phase was carried out on all major vegetation soil units using a modified approach of the macroplot method developed by Poulton and Tisdale (1961) (Figure 12). The procedure was designed to integrate vegetation and soil sampling techniques describing and classifying a plant community. Each vegetation-soil unit was examined for homogeneity, based on species composition and dominance and stratified if consistent differences in the various layers were evident. Ecotones were avoided. Units with young, and presumably invading, juniper which seemed to be accidentally dispersed were not considered ecotones; however, the presence of juniper was noted. After the determination of a homogeneous unit was made, a random reference point was located by pacing along a compass



MACROPLOT DESIGN

Figure 12. Field sampling design for vegetation and sedimentation phase.

heading. The direction and number of paces were selected at random for each site within the limitations imposed by the size and accessibility of the unit. The macroplot, which measured 15 m by 30 m, was oriented with the transects paralleling the contour to avoid the effects of gradient. The 15 m baseline was laid out upslope from the reference corner and four equidistant points (0, 5 m, 10 m, 15 m) served as the origins for the perpendicular transects.

A 30 meter tape was stretched at the lowest continually parallel height possible for each transect. The line intercept method of canopy coverage was used to measure all shrub species. Dead plants and dead material on living plants was not measured and openings due to growth form were ignored. The percent cover derived from this technique was used in the identification of the vegetation-soil unit.

Herbaceous cover was measured within each sedimentation plot with the ocular estimate method. This method also was used to estimate the relative amounts of litter, pavement (gravel and stones) and bare ground that occurred in each plot. A point frequency method, recorded at 100 points, was used in conjunction with the ocular estimate method on 10 percent of the plots and served as a means of checking the estimates.

The tree strata (individuals greater than 1 m in height) was measured with the crown diameter method for western juniper and a densiometer for ponderosa pine. The densiometer was read in the four cardinal directions at each corner of the macroplot. The crown cover method

$$cc = \left(\frac{d_1 + d_2}{4}\right) 2\P$$

with d = diameter measured in two directions (Mueller-Dombois and Ellenberg, 1974) was done for all juniper that were rooted within the macroplot (Daubenmire, 1970). These data were used to describe the tree component of the ecological land units.

Distribution and occurrence of vegetation was sampled with the frequency method which employs a nested plot technique (Mueller-Dombois, Ellenberg, 1974). The nested plot represents the minimum area in which one or two species will occur with 100 percent frequency (Daubenmire, 1968). Species area curves were developed for a vegetation-soil unit representative of an ecological land unit and also for those units which were extreme in species richness based on the 1975 field data using 30 microplots (25 cm x 75 cm) along three transects (Cain, 1938). Whereas curves suggested that three transects, 30 microplots, were adequate. The microplot frame (25 cm x 100 cm) was placed at 10 equidistant points (3 m spacing) along each of the four 30 m transects.

Frequency was recorded as the first occurrence of each species rooted within the boundaries of the appropriate nested plot in the microplot. The following plot sizes and frequency classifications were used:

Plot Size (m)	Frequency Class	Vegetation Type
10 x 10	0	Meadow
25 x 25	1	Forest, meadow, non-forest*
25 x 50	2	Forest, non-forest
25 x 75	3	Forest, non-forest
25 x 100	4	Non-forest

*The non-forest vegetation type consisted of juniper woodlands, sagebrush shrublands and grasslands.

Class 0 was used to describe the meadow type and class 3 adequately described the forest type. In the non-forest types class 4 was used and while frequency values greater than 65 percent are desirable for dominant species, lower values were often common.

A belt transect, 1 m x 30 m, was sampled to determine shrub density. Shrub species were tallied by height classes (0-15 cm, 15 cm-30 cm, and 30 cm plus) for living plants. If the plant was dead, but standing, a fourth category "dead" was used. In all cases the plant had to be rooted within the boundaries of the belt to be measured and recorded. These data provided species density, information on the condition of the area, and evidence as to whether the species was increasing, decreasing or remaining stable (Winward, 1976, personal communication).

Plant identification was accomplished by keying each unknown species through the taxonomic manual, <u>Flora of the Pacific Northwest</u> (Hitchcock and Cronquist, 1974) and by checking reference collections from the Crook County Extension Office and the Oregon State University Range Herbariums. The taxonomic authority used in the preparation of the species list for the Bear Creek Watershed was the <u>Northwest Plant Names and Symbols for Ecosystem Inventory and Analysis</u>, fourth edition (Garrison et al., 1976) (Appendix A-2).

Soil

The soil at each macroplot was examined from pit and core samples during the 1975 field season and described by the standard procedures listed in the Soil Survey Manual (U.S. Department of Agriculture, 1951). Since correlation of these data to the latest soil taxonomy (USDA, 1976) and the Soil Conservation Service's series descriptions was required, assistance from Darwin Jeppesen, Soil Scientist, Bureau of Land Management, Prineville, Oregon, was obtained. Additionally, past soil surveys were used extensively (Mayko et al., 1966; USDA 1975; Green, 1975). Soils were classified to series when possible and to most similar series or association where necessary (USDA, 1975) (Appendix B-1).

Sedimentation

A Rocky Mountain Infiltrometer (Dortignac, 1951) was used to determine the soil loss for each vegetation-soil unit. This infiltrometer consists of a three-headed sprinkler which is capable of simulating a high intensity rainstorm. The simulated rainstorms were representative of the summer convectional storms which occur in this area. The pump and sprinkler were set to approximate a storm producing about 10 cm of precipitation per hour (4 inches/hour). A wind screen was used to minimize the effects of wind.

The sedimentation trials consisted of randomly locating six replications of three plot frames (30 cm x 75 cm) along the contour above and below the macroplot for the non-forest vegetation-soil units, and three replications below the macroplot for the forest, meadow and bareground units. The first replication was placed near the reference point and replications 2 through 3 (or 6) were arranged around the periphery of the macroplot within 50 m of the first (Figure 12).

Prior to each trial the soil was pre-wetted to field capacity to eliminate the confounding effects of antecedent moisture. The simulated rainfall and runoff was collected and measured at an initial 3 minute interval and at 5 minute intervals thereafter over a 28 minute period. The runoff was saved in large containers providing a pooled sediment sample at the completion of the trial. The runoff for each plot was poured from the large collection containers into a quart jar (0.95 liters) (Figure 13). The jar was allowed to stand for 24 hours to permit the sediment to settle. The clear water was then decanted and the remaining slurry was oven dried ($T < 105^{O}C$). The dry sediment sample was weighed and the jar was cleaned, dried and reweighed. Sediment weights (to 0.1 grams) were derived from the difference. This sediment represents the soil loss that resulted from sheet and rill processes created by this particular rainfall event.

The sediment weights were converted to pounds per acre and tons per acre in order to facilitate comparison to other studies and for statistical analysis. These were also recorded in kg/ha. The formula, Runoff (liters) x Sediment (grams x 40.42 = Soil loss (lbs/a), was used. The correction factor 40.42 adjusts plot size and converts metric values to the English system. These data were used to determine the sediment production potential, or erodibility, of each vegetation-soil unit and served as the basis for evaluating variations within the ecological land unit. Pounds per acre was used for comparison with earlier studies.

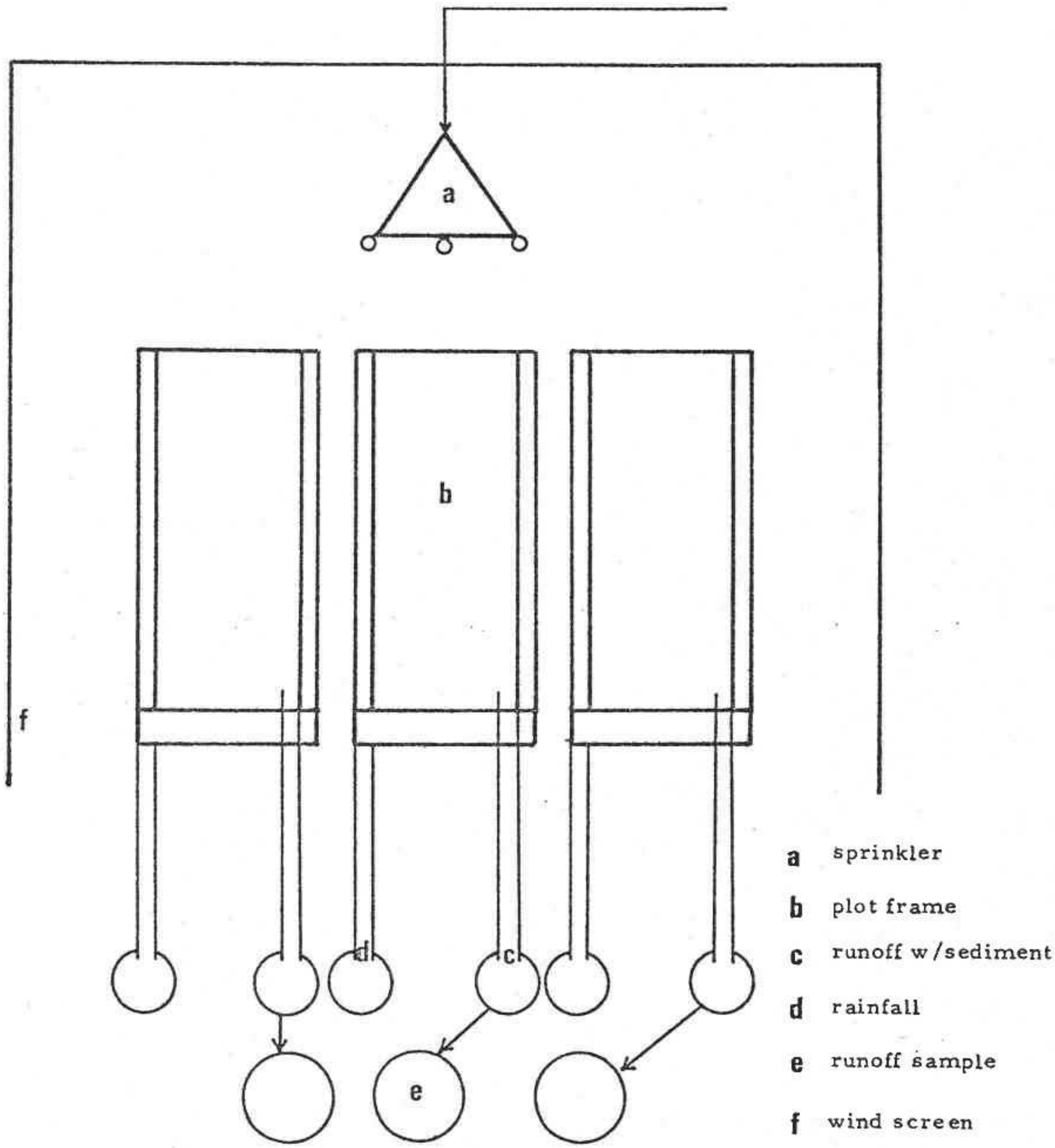


Figure 13. Rocky Mountain infiltrometer layout.

A hydrologic potential (runoff/rainfall) was calculated for each site, which indicated the relative response to a precipitation event (Hewlett and Nutter, 1969).

Assumptions

There were several assumptions made during the course of this study. The first was that the litter, pavement and surface soil characteristics were as homogeneous as the vegetation. It was assumed that the slope and aspect of similar vegetation-soil units would have a minimal influence on the soil loss. The disturbance caused by driving the plot frames into the ground was assumed to be the same for all plots. It was also assumed that the runoff generated was not confounded by translatory (subsurface) flow brought to the surface by the downslope boundary of the frame. The forest, meadow and bareground sites were essentially homogeneous in surface cover and permitted the assumption that each plot frame was equally representative of the site's surface characteristics. In the semiarid, non-forested areas the surface characteristics are heterogeneous so it was assumed that a cluster of three plot frames was more representative of those sites than a single plot would be. Therefore, six replications were used to describe such units (Figure 11).

Precipitation

Rainfall was monitored by four recording rain gages during the summer field season from mid-June to mid-September 1976. The gages have a recording period of 30 days, and the recording sheets were changed on the 20th of every month. Eight standard, non-recording rain gages were located in the central portion of the watershed between Freguson Creek and Sage Hollow, since this area appeared to respond to every high intensity storm event during the 1975 field season (Figure 14). The rainfall data are useful in determining the intensity, frequency and movements of the summer storm events.

Turbidity

Water samples were collected along Bear Creek when convenient, and within 24 hours following major storms (Figure 14). Samples were taken from the surface 15 cm at midstream, in 30 ml culture tubes and returned to the lab for processing. A Hach Engineers Laboratory DR-el/2® (model 2506) was used to measure the optical transmission properties (reflectance) of the water sample. The reflectance was measured in Formazin Turbidity Units; however, distilled water replaced formazin as the standard so the values are only suited to relative comparisons within the framework of the Bear Creek study. Serial dilution was used to remove the inaccuracies caused by the increased absorption capabilities of the higher concentrations of suspended sediment. The turbidity data were

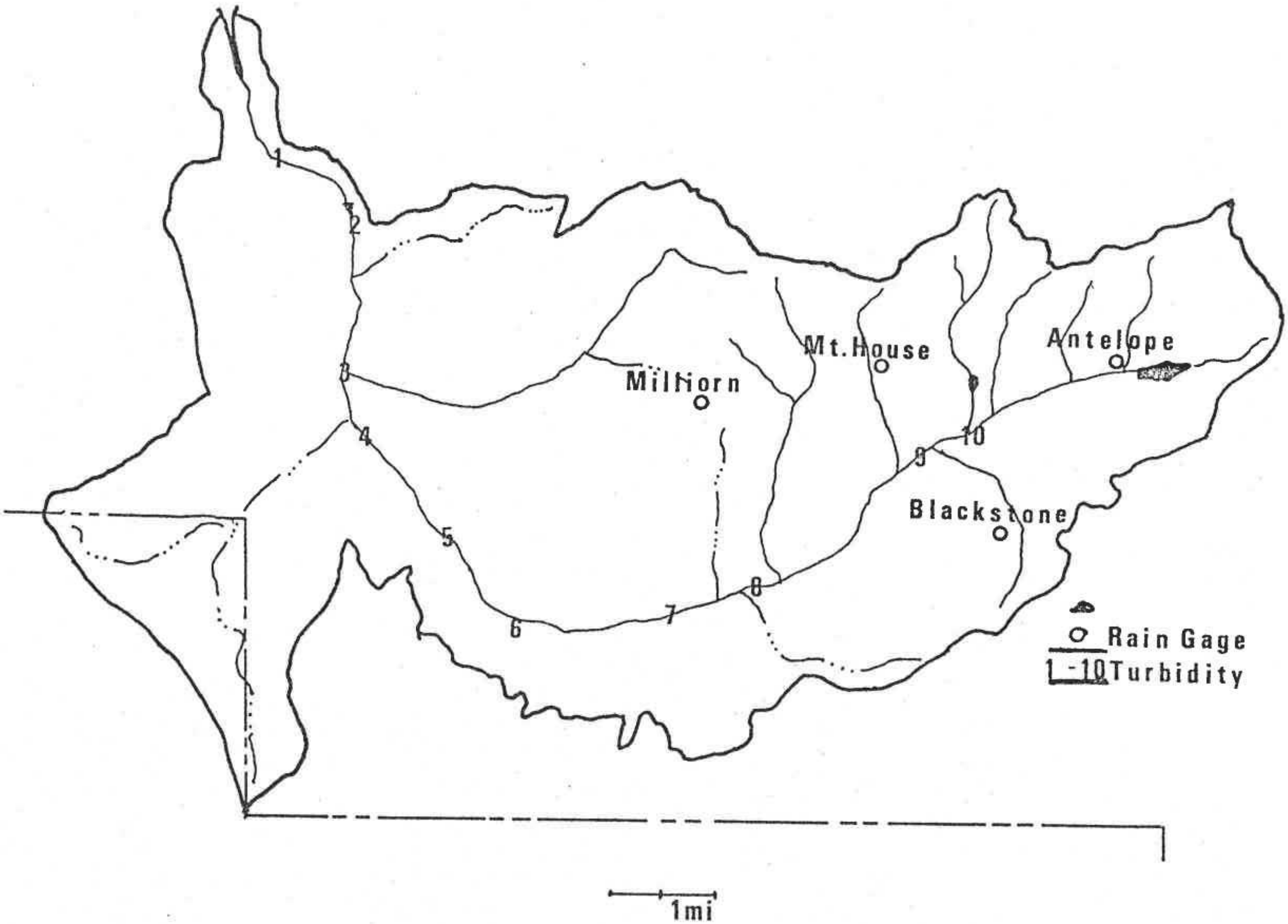


Figure 14. Location of recording rain gages and turbidity sampling sites in the Bear Creek watershed.

used to monitor the suspended sediment that occurred in Bear Creek and to identify areas which may be contributing unusual amounts of sediment following a major storm.

Experimental Design

Sample size (n) for the infiltrometer trials is based on Stein's Two Stage technique (Steel and Torrie, 1960),

$$\text{n-calculated} = \frac{t^2 s^2}{d^2} \quad .$$

The t-value is based on an alpha of .05, the standard deviation (s) is derived from the sediment production data collected during the summer of 1975 and the d-value is 10 percent of the mean ($\pm$ 10% $\bar{x}$).

A modified randomized block design was used to analyze the variation between and within the habitat types of a particular ecological land unit. Forest, shrublands were analyzed independently.

One-factor analysis of variance was used to analyze differences within habitat types and two-factor analysis of variance was used to compare different habitat types within an ecological land unit, and treatments.

The experimental design was as follows:

One Factor ANOVA

	Forest df	Non-forest df
Location (site)	1	1
Error	16	10
Total	17	11

Two Factor ANOVA

	Forest df	Non-forest df
Habitat type (treatment)	1	1
Location (site)	1	1
Habitat type x location	1	1
Error	32	20
Total	35	23

There were no missing data during the 1976 field season.

A t-test was used to analyze unequal sample sizes among two dryland fields and their respective habitat types. All statistical tables are shown in Appendix C.

RESULTS AND DISCUSSION

A preliminary analysis divided the Bear Creek watershed into six Ecological Land Units (Table 1) based on the ERSAL vegetation/land use aerial photography. The land units were further refined after the development of an association table (Appendix A-1), into eight Ecological Land Units, containing 13 tentative habitat types (Table 2). Ten of the 13 habitat types were sampled for sediment production, and generally reflect various stages of ecologic condition, and four management treatments. The four habitat types that were not sampled failed to meet previously established criteria, having steep slopes or excessive rock pavement, or they were subject to internal drainage (Table 2).

Eight of the tentative habitat types were previously identified and described by Daubenmire (1968, 1970) and six were classified to vegetation-soil units or associations by other investigators (Eckert, 1957; Driscoll, 1964; Burkhardt and Tisdale, 1969; Hall, 1973) (Table 2).

Due to the aerial extent and heterogeneity of the semiarid juniper and sagebrush rangelands, the emphasis of the sedimentation sampling was concentrated in that area.

The Ecological Land Units were divided into three general categories (forest, non-forest and meadow) for statistical analysis. The meadow category (and unit) is represented by only one sample site and was included to provide a relative means of comparison with the other units. Tentative habitat types that occurred within a unit

Table 1. Preliminary Ecological Land Units which served as the base for site selection.

Meadow (dry)

Mollisol soil

Mixed Forest

Pinus ponderosa/Calamagrostis rubescens-Festuca idahoensis

Mollisol soil

Mixed Steppe

Artemisia tridentata/Festuca idahoensis
Purshia tridentata phase

Simas-Tub-Day soil Association

Juniper Shrubland

Juniperus occidentalis /Artemisia tridentata/Agropyron spicatum

Simas - BLM 171 soil Association

Sandy Shrublands

Artemisia tridentata/Stipa comata

BLM 171 soil Association

High Lava Plains (Oregon High Desert)

Artemisia tridentata-Artemisia arbuscula/Festuca idahoensis

Deschutes soil Association

Table 2. Ecological Land Units of the Bear Creek Watershed and their respective tentative habitat types and unclassified communities.

Forest

Mixed Forest Unit

Pseudotsuga menziesii/Calamagrostis rubescens h. t.
Daubenmire (1968)

Pinus ponderosa/Festuca idahoensis h. t.
Daubenmire (1968)

Non-Forest

Mixed Steppe Unit

Artemisia tridentata ssp. *vaseyana/Festuca idahoensis* h. t.
Daubenmire (1970)

Juniperus occidentalis/Artemisia tridentata ssp. *vaseyana/Festuca idahoensis* h. t. similar to Driscoll (1964)

Juniper Woodland Unit

Juniperus occidentalis/Artemisia tridentata/Agropyron spicatum-Festuca idahoensis h. t. similar to Driscoll (1964)

Stipa thurberiana phase
Eckert (1957)

Juniperus occidentalis/Stipa thurberiana h. t.
an extension of Burkhardt et al. (1969)

Big Sagebrush Unit

Artemisia tridentata/Festuca idahoensis-Agropyron spicatum h. t.
Daubenmire (1970)

Low Sagebrush Unit

Artemisia arbuscula/Festuca idahoensis-Agropyron spicatum h. t.
Eckert (1957)

(Continued on next page)

Sandy Shrubland Unit

Artemisia tridentata/*Stipa comata* h.t.
Daubenmire (1970)

Adobeland Unit

Agropyron spicatum-*Poa sandbergii* h.t.
Daubenmire (1970)

Unclassified Communities

Juniperus occidentalis/*Poa sandbergii*

Chrysothamnus nauseosus/*Trifolium macrocephalum*-*Poa sandbergii*

Artemisia tridentata ssp. *vaseyana*/*Sitanion hystrix*

Ribes spp. /*Carex* spp.--Dry meadow
similar to Hall (1966)

Habitat types and unclassified communities not sampled for sedimentation

Artemisia rigida/*Poa sandbergii* h.t.

Artemisia cana/*Carex* spp. - unclassified community

Sarcobatus vermiculatus/*Distichlis stricta* h.t.
Daubenmire (1970)

Juniperus occidentalis/*Agropyron spicatum* h.t.
similar to Driscoll (1964)

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and their respective stage of ecological condition were compared within the unit and when possible within the habitat type. The ecologic condition is simply a comparison of the best sites to the worst sites based on the frequency data shown in the association table (Appendix A-1) and will be described as appropriate in the discussion of each ecological land unit.

Data pertaining to management treatments are limited. In the forest unit (and category) an area which had undergone a partial cut to harvest ponderosa pine was sampled and compared with an unlogged forest habitat type. Grazing in the forested upland areas appeared light and was not sampled. In the non-forest category, the grazing treatment was sampled in only the Mixed Steppe Unit. Animal use in other units accessible to the Rocky Mountain infiltrometer was too extreme (too light or too heavy) to satisfactorily represent the treatment, however ecological condition will reflect the cumulative effect of environmental stresses (which may include grazing) on these sites.

Dryland fields were sampled and statistically compared to adjacent habitat types with a t-test for uneven sample sites.

The rainfall generated for all sites (n=30) was 10.62 $\pm$ 1.35 cm/hr (4.18 $\pm$ 0.53 in/hr), and ranged from 8.1-13.7 cm/hr (3.2-5.4 in/hr).

The slope, measured with an Abney level, represented an average slope for the macroplot established within a habitat type and may have varied in micro relief by 5 percent, for those sites steeper than 5 percent. Upland sites generally reflected a midslope position. While slopes ranged from 1 to 19 percent, depending on the habitat type, the steeper sites exhibited geomorphic terracing which would tend to reduce the confounding affects of slope on sedimentation.

Forest

Mixed Forest Unit

The Mixed Forest unit was represented by two tentative habitat types:

Pseudotsuga menziesii/Calamagrostis rubescens h.t. (Psme/Caru)

Pinus ponderosa/Festuca idahoensis h.t. (Pipo/Feid)

The Psme/Caru h.t. is currently dominated by and managed for ponderosa pine. Elk sedge and the forbs, heartleaf arnica (Arnica cordifolia) and western hawkweed (Hieracium albertinum) occurred as important subdominants in the understory. This site had rolling slopes, of 10 percent, and an elevation of 1675 m (5500 ft). The soil, a silty clay loam similar to the Hankins series, is a deep, well drained, frigid Ultic Paleoxeroll. The 0 horizon, consisting primarily of pine needles, provides a continuous ground cover approximately 7.5 cm (3 in) thick. This site had no evidence of disturbance. The sediment produced from this habitat type ranged from zero to 73 kg/ha (65 lb/a) with a mean of 47 kg/ha (42 lb/a). The hydrologic potential for this site was 30.

The Pipo/Feid h.t. is currently dominated by ponderosa pine, with elk sedge and heartleaf arnica occurring in subdominant roles. The site has rolling slopes of 13 percent and an elevation of 1585 m (5200 ft). The soil is the Hankins series, with a 0 horizon, nearly continuous in ground cover and about 3 cm (1 in) thick. There is evidence of past logging adjacent to this site. Sediment production varied from 28 kg/ha (25 lb/a) to 1860 kg/ha (1660 lb/a) with a mean of 331 kg/ha (296 lb/a). The hydrologic potential for this site was 43 and bare ground accounted for 7 percent of the total ground cover.

Analysis of variance comparing the two sites showed no significant differences in sediment production.

The partial cut is a part of the Antelope Spring sale and involves tractor logging, with debris piled and burned. The sites sampled were located at the west end of the sale area near Badger Spring. The area was dominated by ponderosa pine and was similar to the Psme/Caru h.t. The elevation was 1675 m (5500 ft) and the slopes were 7 percent. Site 1 was adjacent to a yarding area and site 2 included a debris pile which had been burned. The sediment produced from site 1 ranged for 218 kg/ha (195 lb/a) to 2995 kg/ha (2674 lb/a) with a mean of 1365 kg/ha (1219 lb/a), and from site 2 varied from 85 kg/ha (76 lb/a) to 19,900 kg/ha (17,769 lb/a) with a mean of 7013 kg/ha 6262 lb/a). The plots located on the burned area yielded the greatest amount of sediment.

Analysis of variance showed no significant differences between the partial cut sites; however, when compared to the untreated sites they were significantly different (a=.05). Although there is considerable internal variation in both treatments, it was not sufficient to mask the expected differences. The increase in soil loss resulting from the tractor logging method of tree removal was highly variable within both disturbed sites. This suggests a differing magnitude in the severity of the impact within these sites. Compaction is often associated with tractor logging practices and may explain some of the variation measured within the sites. Highly skewed values (greater than four standard deviations from the mean) which were recorded for the site containing the burned debris suggest a potential repellancy may exist at the soil surface following a fire on these soils (Buckhouse, 1975).

Non-Forest

Mixed Steppe Unit

The Mixed Steppe unit was represented by two tentative habitat types:

Juniperus occidentalis/Artemisia tridentata ssp. *vaseyana/Festuca idahoensis* h.t. (*Juoc/Artrv/Feid*)

Artemisia tridentata spp. *vaseyana/Festuca idahoensis* h.t. (*Artrv/Feid*)

The *Juoc/Artrv/Feid* habitat type was characterized by two sites in different stages of ecological condition. The first site appeared to be in good condition, with Idaho fescue dominant and bluebunch wheatgrass and sedge (*Carex* spp.) in subordinate roles, and a diverse but inconspicuous forb component. Western juniper density was increasing. This site occurred near the meadow site and experienced some grazing pressure (to 10 cm (4 in) stubble height on bluebunch wheatgrass).

The second site appeared to be in a poorer condition, with Sandberg's bluegrass as the only species of grass widely distributed. The juniper at this site was primarily old growth, supporting the foliose lichen Letharia vulpinus (Levu) and having blunt crowns (Burkhardt and Tisdale, 1969). The forb component was dominated by low pussytoes (Antennaria dimorpha) and the moss, Tortula ruralis. This site had no recent disturbance.

Both sites occurred on the Tub soil series, a Calcic Pachic Argixeroll, which is a deep, well drained, clay loam formed in old sediments of volcanic origin. This series is essentially a deeper example of the Simas series. Both sites are hilly uplands and have slopes around 7 percent, north aspects, and occur at an elevation of approximately 1372 m (4500 ft). Bitterbrush (Purshia tridentata) and bluebunch wheatgrass would presumably play more significant roles than the data suggest.

The sediment produced from the first site average 7396 kg/ha (7705 lb/a) with a range of 1179-26,500 kg/ha (1053-23,664 lb/a) and a hydrologic potential of 56.

The second site varied for 198 kg/ha to 1717 kg/ha (177-1533 lb/a) with a mean of 851 kg/ha (760 lb/a) and a hydrologic potential of 50. Due to the high variability within both sites there were no significant differences (a=.05) between them.

The Artrv/Feid h.t. was characterized by two sites, both appearing in good ecological condition. The first site had more mountain big sagebrush (by canopy cover frequency), more bottlebrush squirreltail, and fewer forbs than the second site, which suggested some influence from past grazing. The area was currently being grazed (13 cm (5 in) stubble height on Idaho fescue). The soil, a silty clay loam, was similar to the Simas series, an Aridic Paleoxeroll.

The second site had a diverse forb component with Wyeth's buckwheat (Eriogonum heracleoides) as a suffretescent codominant. The soil has a silica hardpan, and would be similar to the Lamonta soil series, an Abruptic Aridic Durixeroll, with a loam texture. While this site had the steepest slope sampled (19 percent), it exhibited considerable terracing, almost a series of benches, which tended to reduce to the actual slope to around 7-10 percent. This site had no evidence of recent disturbance.

The sediment produced at the first site average 660 kg/ha (589 lb/a) and varied from 215 kg/ha to 1469 kg/ha (192-1312 lb/a) with a hydrologic potential of 27. The second site had the lowest hydrologic potential samples, 15, which was surprising considering the initial steepness of the slope. Sediment ranged from 1 to 673 kg/ha (1-601 lb/a) with a mean of 295 kg/ha (267 lb/a). This site reflected a more mesic environment than the juniper site and possibly a greater potential for a pyric (fire) climax. Analysis of variance showed that neither site was significantly different.

Comparison of the Juoc/Artrv/Feid h.t. to the Artrv/Feid h.t. indicated no significant differences between the habitat types and a further comparison of the grazed sites representing both habitat types to the ungrazed sites in both types also showed no significant differences. The high natural variability within these sites masks any differences that may occur between them.

Juniper Woodland Unit

The Juniper Woodland unit was represented by two tentative habitat types:

Juniperus occidentalis/Artemisia tridentata/Festuca idahoensis - Agropyron spicatum h.t. (*Juoc/Artr/Feid/Agsp*)

Juniperus occidentalis/Stipa thurberiana h.t. (*Juoc/Stth*)

The *Juoc/Artr/Feid-Agsp* h.t. was characterized by four sites. Two of the sites appeared to constitute a *Stipa thurberiana* phase described by Eckert (1957). This unit is as complex in soils as the mixed steppe unit is complex in vegetation. The highly dissected rolling hills have a considerable influence on the soils and subsequent vegetation. Big sagebrush (tentatively ssp. *wyomingensis*) was dominant on four sites; however, low sagebrush was often present within or adjacent to the site. Green rabbitbrush (*Chrysothamnus vicidiflorus*) and granite gilia (*Leptodactylon pungens*) occurred on all four sites.

The first two sites were located within the Spring Creek drainage at an elevation of approximately 4280 m (4200 ft), and south facing slopes, approximately 10 percent. Sandberg's bluegrass was the dominanat herbaceous species. Since Idaho fescue appeared to be restricted to the litter accumulation surrounding western juniper it is not a codominant with bluebunch wheatgrass in this particular habitat type. While there were several old juniper within the macroplot, 50/ha (45/a), there was an equal density of the younger trees also present. Low pussytoes and Hood's phlox (*Phlox hoodii*), dominated the forb component. The soil was an Aridic Paleoxeroll of the Simas series which is clay loam in texture.

Site one appeared to be in poor ecological condition. This site had no evidence of current disturbance. The hydrologic potential of the site was 55, with a mean sediment production of 3109 kg/ha (2776 lb/a), and although soil loss varied from 701-6144 kg/ha (626-5459 lb/a) it was consistently high.

Site two appeared to be in fair condition, and although Sandberg's bluegrass was still the dominant species, Idaho fescue and bluebunch wheatgrass had higher frequencies. This site had some evidence of grazing on the forb component. The hydrologic potential for this site was 49 and the mean sediment produced was 2715 kg/ha (2424 lb/a). The soil loss was more variable on this site ranging from 436-5888 kg/ha (389-5257 lb/a).

Analysis of variance indicated that these two sites were not significantly different.

The Stipa thurberiana phase of Juoc/Artr/Feid-Agsp was located in the Sage Hollow drainage and was characterized by Thurber's needlegrass dominating the herbaceous understory. Sandberg's bluegrass and Idaho fescue occurred as subdominants. In this phase, young juniper were conspicuously absent and the density of the old growth was about half (25 trees/ha) of that found on the Spring Creek sites. While these sites were mapped as the Simas soil series (BLM, 1973), and possessed the characteristics argillic horizon, the surface texture indicated less clay and more sand. These woodlands appeared more open, on sloping uplands of 5 percent and at an elevation of 1158 m (3800 ft). While both sites showed the presence of cattle, there was no evidence of recent grazing.

The first site had an average soil loss of 177 kg/ha (158 lb/a) with a range of 1-560 kg/ha (1-500 lb/a) and a hydrologic potential of 15. The second site produced an average sediment load of 645 kg/ha (576 lb/a) and had more variation than the first site, losing from 55-1459 kg/ha (49-1303 lb/a). The hydrologic potential for this site was 21.

The Stipa thurberiana phase sites were compared to the Spring Creek sites and indicated a highly significant difference (a=.01). It appears that the difference in the soils may explain some of the variation. Cover characteristics data (Table 3) showed more bare ground within the sedimentation plots located in the Stth phase, and although the juniper were not as dense in the Stipa locations, the relative crown cover was essentially the same (16 and 17 percent respectively). This would suggest that the vegetation component is having a similar effect on the soil losses from both types and that the soil and topographic factors are probably exerting the greatest influence. Another confounding factor was a low simulated rainfall rate on the first Stipa phase site of 8.4 cm/hr (3.3 in/hr). This site produced the least sediment (mean) for all of the non-forested sites.

The second tentative habitat type, Juniperus occidentalis/Stipa thurberiana, was represented by one site on Hook Ridge in the Fischer Canyon drainage. Green rabbitbrush was the only shrub present within the macroplot and its occurrence did not appear to be significant. Granite gilia was absent and Hood's phlox dominated the forb component.

Table 3. Vegetation Cover Characteristics.

Tentative Habitat Type (Site)	Tree Cover (%) Pipo	Tree Cover (%) Juoc	Shrub cover (%)	Sediment Plot Cover (%) Vegetation	Litter	Bareground
Mixed Forest						
Psme/Caru	50					
Pipo/Feid	57					
Mixed Steppe-Artrv/Feid						
w/Juoc 1		14	4.6	14	12	74
2		10	5.3	18	12	70
w/o Juoc 1		1	17.8	29	25	46
2		1	12.1	27	22	51
Juniper Woodland-Juoc/Artr/Feid-Agsp						
1		17	3	11	39	50
2		16	5.4	21	17	62
Stthph 1		20	7	11	13	76
2		13.5	6	13	13	74
Juoc/Stth		14	1.3	12	14	74
Big Sagebrush-Artr/Agsp-Feid						
w/Juoc 1		15	a	11	9	80
2		18.5	1	1	10	89
w/o Juoc 1		a	12	15	16	69
desert 2		a	1.2	26	14	60
Sandy Sagebrush-Artr/Stco						
1		a	9.5	13	8	79
2		a	1	12	5	83
Low Sagebrush-Artr/Feid-Agsp						
Desert		a	24	26	13	61
1		3	20.4	2p	9	70
2		a	13	27	18	55
B.C. Butte		a	13	29	34	37
Adobeland						
Agsp-Posa		4	1.5	21	16	63
Unclassified Communities						
Juoc/Posa		13	1.5	0	0	100
Chna/Trma-Posa		a	1	9	22	69
Artrv/Sihy		a	21.7	28	22	50
Meadow-Ribes/Carex		a	5	75	13	12

[a]Present but not sampled.

The occurrence of Sandberg's bluegrass was conspicuously reduced from the distributions found on the other woodland sites.

The soil was a Calcic Argixeroll, similar to the Gem series. The surface texture was a gravelly loam, with residual pavement covering much of the area. This site was located on a ridge with a south aspect and a slope of 10 percent and occurred at an elevation of 1219 m (4000 ft). The site showed no evidence of recent disturbance. The hydrologic potential was 41 and that was with the least amount of simulated rainfall measured at any of the sites in the study.

Analysis of variance showed significant differences in the sediment losses for the two Stipa thurberiana phase sites. The soil and vegetation were essentially the same and the condition appeared to be a little better on the second site although it produced the greater amount of sediment. The hydrologic potentials for both sites were low indicating a relatively good infiltration rate. These sites differed by 3.2 cm (1.3 in) of mean simulated rainfall, a factor which probably explains the variability.

The average soil loss for this site was 1528 kg/ha (1364 lb/a) with a range of 525-2585 kg/ha (469-2308 lb/a) from the nest of plots within the site. Since the Gem soil series is related to the Simas series and a part of the Simas Association it was compared to both sites in the Juoc/Artrv/Feid-Agsp h.t. and showed no significant differences. A further comparison with the Stipa phase of the Juoc/Artrv/Feid-Agsp h.t. was significantly different for only the first site. It would seem that the soil difference is responsible for the greater sediment losses associated with the finer textured soils. In this comparison, both sites received approximately the same mean rainfall, differing by only 0.25 cm (0.1 in). This should eliminate the confounding effects that were present in the earlier comparisons and indicate that more of the variation is accounted for by the soil difference.

Big Sagebrush Unit

This unit is represented by one tentative habitat type:

Artemisia tridentata/Festuca idahoensis - Agropyron spicatum h.t. (Artr/Feid-Agsp)

The big sagebrush habitat type (Artr/Feid-Agsp) was characterized by four sites and included a site in the High Lava Plains (which is a part of the Sage Hollow drainage). The Feid-Agsp grouping does not imply codominance but simply a limited data base. The site located in the High Lava Plains would presumably favor Idaho fescue. The other sites will be discussed with the appropriate site description. Juniper is dominant on two sites and present on all four. Although there are several old juniper in the stands where it is dominant, they comprise only 25 percent (4/16) of the current population. The sites were located along the terrace of the ephemeral channel, Long Hollow, an area which presumably would have had a pyric big sagebrush climax. Juniper felling has been conducted on one of the juniper dominated sites.

The first big sagebrush site (with western juniper) will probably become an Artr/Agsp h.t. now that the juniper have been cut. This may, however, be only a temporary stage since young juniper seedlings appear to be emerging at the rate of 680 trees/ha (275/a). Regrowth from uncut basal limbs is also occurring throughout the treated area. The soil on this site is a Calcic Pachic Argixeroll, representative of the BLM 118 soil type, an unnamed series. It is a light loam, occurring on a 7 percent slope at an elevation of 1219 m (4000 ft). The juniper on this site was cut in 1973. The site was being grazed for the first time since the cut during these trials.

Sediment production at this site averaged 2778 kg/ha (2480 lb/a) and ranged from 107 kg/ha (96 lb/a) to 7574 kg/ha (6763 lb/a). The hydrologic potential of the site was 37.

The second site with juniper was across the ephemeral channel from site one. This site had little understory vegetation. Western wheatgrass (Agropyron smithii) had the highest frequency. With the juniper present, Idaho fescue would potentially become the dominant grass since it is closely associated with the litter which accumulates around the base of the tree. Bluebunch wheatgrass would probably become dominant following the removal of juniper. Indian ricegrass (Oryzopsis hymenoides) would presumably have a subdominant role. The soil is a Cumulic Haploxeroll and may be similar to the Powder series. This soil is sandy loam, a little coarser than site one and occurs on a nearly level terrace with about 2 percent slope. Although cattle were present, there was no evidence of use within this site. The average soil loss for this site was 1145 kg/ha (1023 lb/a) varying from 86-3648 kg/ha (77-3257 lb/a). The hydrologic potential was 45.

Analysis of variance showed the sites were not significantly different.

The sites that had few juniper (one percent or less) were savannah like in appearance. Both sites were in fair to good condition, and had the same shrub cover (12 percent). The first site was located on the gently sloping toe of a steep north aspect. This site would probably favor bluebunch wheatgrass at climax, but presently is dominated by Sandberg's bluegrass, downy brome (Bromus tectorum) and needle-and-thread grass. This site is within a spring calving pasture so its condition may reflect an influence from past early spring grazing. The soil is mapped as the BLM 118 type (BLM, 1973), and appears to be a deep loam, Calcic Haploxeroll. The ash influence is very prevalent in the soil. The elevation is about 1219 m (4000 ft). The average sediment produced from the site was 1510 kg/ha (1349 lb/a) and ranged from 701-3533 kg/ha (626-3154 lb/a). The hydrologic potential was 48.

Analysis of variance indicated that this site was not significantly different from the previously mentioned sites with juniper overstory.

The last big sagebrush site was located on the High Lava Plains, and would presumably be an Artr/Feid h.t. Bottlebrush squirreltail was the most frequently occurring species at the present and green rabbitbrush was a codominant with big sagebrush. Thurber's needlegrass and Idaho fescue were currently subdominants. The sagebrush saprophyte, broomrape (Orobanche fasiculatus), may qualify as a character species for this type or as an indication of condition. The soil is a sandy loam, Xerollic Camborthid, and is mapped as the Deschutes series.

The site was gently sloping, about 5 percent, and at an altitude of 1372 m (4500 ft). The average sediment produced from this site was 318 kg/ha (284 lb/a) and varied from 12-1045 kg/ha (11-973 lb/a). This site had a hydrologic potential of 19.

Analysis of variance indicated this site was significantly different from the previous site and a further comparison between the habitat types with juniper to those without showed no significant differences; however, the variation with tentative habitat types was significant. The difference in soil would presumably account for most of the variation between the High Lava Plains site and its counterpart. Ground cover characteristics are essentially the same in vegetation (14 percent crown cover). The influence of grazing superimposed on different soils and conditions make it difficult to adequately assess the importance of either. Of the three confounding factors, it is believed that the soil would tend to exert the greatest influence. The remaining factors were too subjective to serve as comparable causative agents. The sandy loam soil found on the High Lava Plains and the lower hydrologic potential (19 versus 48) seem to support this conclusion.

Low Sagebrush Unit

This unit is represented by one general habitat type:

Artemisia arbuscula/Festuca idahoensis - Agropyron spicatum h.t. (*Arar/Feid-Agsp*)

The *Arar/Feid-Agsp* h.t. was represented by four sites. Two of the sites were closely associated with the Juniper Woodland Unit, as scabland inclusions within the woodland area. A third site was located on the High Lava Plains and on the last site, on the north side of Bear Creek Butte. Low sagebrush dominated all sites, with green rabbitbrush as a subdominant. Western juniper was present as an accidental invader. Sandberg's bluegrass was the most frequent species on three of the sites; however, all of the sites show a potential for Idaho fescue or bluebunch wheatgrass. Bottlebrush squirreltail was common on all sites. Hood's phlox, low pussytoes and cushion buckwheat (Eriogonum ovalifolium) had high (100 percent) constancy for all sites.

The first site was located in Norman Canyon drainage and appeared to be in good ecological condition. Cattle were present but there was no evidence of recent grazing within the site. Idaho fescue was dominant and junegrass (Koeleria cristata) occurred in a subdominant role. Juniper is invading downslope along the upper boundary of this site. The soil was a shallow Simas, an Aridic Paleoxeroll, that occurred on slopes of 7 percent, at an elevation of 1280 m (4200 ft). This site produces from 113-641 kg/ha (101-572 lb/a) of sediment with a mean of 340 kg/ha (304 lb/a). The hydrologic potential was 21.

The second site occurred within a juniper woodland area and was in the poorest condition of all of the low sagebrush sites. Sandberg's bluegrass and bottlebrush squirreltail were the most frequent grass species encountered. A small legume (possibly Astragalus ssp.) dominated the forb component. This site would appear to favor Idaho fescue as the dominant climax herbaceous species.

The soil was an Aridic Paleoxeroll, or shallow Simas series, clay loam in texture. There was rock and gravel in the surface horizon that appeared to be of both residual and alluvial origin. Rill erosion was also present on this location. The slope was 12 percent and the elevation was 131 m (4300 ft). This site produced the most sediment for this habitat type, with an average of 1347 kg/ha (1203 lb/a) and a range of

200-1883 kg/ha (267-1681 lb/a). The hydrologic potential of this site was 50.

The third site occurred on the High Lava Plains and appeared to be in good condition. Juniper occurrence was infrequent and green rabbitbrush was the subdominant of the shrub layer. Idaho fescue was the dominant grass species and Thurber's needlegrass occurred as the subdominant grass species. The soil is an Aridisol, the Deschutes series, a Xerollic Camborthid, with a sandy loam texture. The slope was 3 percent and the elevation of the site was 1372 m (4500 ft). Cattle were present in this allotment but there was no evidence of current grazing use. The average soil loss from this site was 630 kg/ha (567 lb/a) and it varied from 40-1230 kg/ha (36-1098 lb/a). The hydrologic potential for this location was 25.

The Bear Creek Butte site appeared to be in fair condition. Low sagebrush was more widely distributed on this site than any of the others. Green rabbitbrush was again the subdominant shrub. Western juniper was present but its distribution was scattered and it was uncommon within this type. Although Sandberg's bluegrass occurred with the greatest frequency, bluebunch wheatgrass likely is the potential herbaceous dominant. The soil for this site is a frigid Lithic Argixeroll and may be similar to the Ruckles series. It has loam texture, and a gravelly surface horizon (residual). This site had been lightly grazed (to 20 cm (8 in) in stubble height on Agsp). It occurred at an elevation of 1372 m (4500 ft) and had a slope of 7 percent. The mean sediment loss was 642 kg/ha (573 lb/a) and ranged from 399 kg/ha (346 lb/a) to 727 kg/ha (649 lb/a). The hydrologic potential was 37 for this location.

Analysis of variance showed the poorer condition sites (1 and 4) to have a highly significant difference from the better condition sites (2 and 3); however, the difference in soils may be responsible for some of this difference. A comparison within conditions showed a highly significant difference between sites 1 and 4 and no significant differences between sites 2 and 3. Analysis of variance between the Simas series soils 1 and 2 indicated a highly significant difference which may reflect in part their difference in condition. Site 2 was located on more of a plateau than site 1, and did not have a steep slope above it that site 2 had. While condition may explain some of the variance that has occurred, other confounding factors make it impossible to assess its actual contribution.

Sandy Big Sagebrush Unit

This unit was represented by one tentative type, and was located in an unnamed drainage in the central portion of the watershed:

Artemisia tridentata/Stipa comata h.t. (*Artr/Stco*)

This type was characterized by two sites. Juniper was present in and around the first site; however, it was conspicuously absent, along with big sagebrush, from the second location. While it appeared that fire possibly occurred on the second site neither charcoal or scarred trees were found to substantiate the observation. Needle-and-thread grass was the dominant grass on both sites. There were few forbs in this habitat type. The soil on both locations was the BLM 171 (unnamed series), a Xerollic Camborthid, similar to the Redmond soil series, but finer in texture. This silty clay loam was derived from alluvium that reflects a volcanic origin and is high in pumice and ash. The area had not been grazed since 1973, following a juniper cutting project in the upland areas of the allotment. There was evidence that juniper had been invading this habitat prior to the cutting. Both sites had gentle slopes of 5 percent and an elevation of 1158 m (3800 ft).

The first site was dominated by green rabbitbrush (9 percent crown cover) with big sagebrush as a subdominant (5 percent crown cover). Needle-and-thread grass was the dominant herbaceous species with bottle-brush squirreltail, Sandberg's bluegrass and downy brome playing sub-dominant roles. The high frequency of rabbitbrush, squirreltail and downy brome suggested past disturbance and would place the site in a poor ecological condition. The average sediment production at this site was 963 kg/ha (860 lb/a) and varied from 55-1823 kg/ha (49-1628 lb/a).

The second site was a homogeneous grassland with needle-and-thread grass as the obvious dominant. Downy brome was the subdominant species. The shrub component was inconspicuous and while big sagebrush was present within the macroplot, only a single green rabbitbrush was recorded for shrub cover (less than one percent). This site produced a mean sediment loss of 606 kg/ha (541 lb/a) and ranged from 237 kg/ha (212 lb/a) to 1518 kg/ha (1355 lb/a). The hydrologic potential for both sites was essentially the same, 30 and 31 respectively.

Analysis of variance showed no significant differences between these sites.

The Artr/Stco h.t. was compared to the Juoc/Artr/Feid-Agsp h.t. that occurred in the Juniper Woodland Unit, with the Stipa phase. Analysis of variance showed no significant differences between habitat types but did show a significant difference within the types. The difference in the rainfall at the first Stth phase site apparently was reflected again in this comparison.

Adobeland Unit

The Adobeland Unit is represented by a single tentative type:

Agropyron spicatum-Poa sandbergii h.t. (Agsp/Posa)

This habitat type was found on the Day clay soil series and is a Vertisol that has a high shrink/swell capacity which causes deep surface cracking during the periods of summer drought. Juniper is invading this location, for 90 percent of the trees present were young, probably less than 50 years old (crown less than 2 m in diameter). Big sagebrush (presumably ssp. tridentata) was present within the site but accounted for only 2 percent of the ground cover. This site was dominated by bluebunch wheatgrass with Sandberg's bluegrass as the subdominant species. The forb component was very diverse, similar to the Mixed Steppe Unit, but with more arid species. Hood's phlox and low pussytoes were the natural dominants in this component, which make the site similar to the low sagebrush types found on shallow soils. The soil was a deep, dark red clay of the Typic Chromoxerert subgroup. The average sediment produced at this site was 785 kg/ha (701 lb/a) with soil losses varying from 265-2039 kg/ha (237-1821 lb/a). The hydrologic potential was 34.

Unclassified Communities Unit

This unit is represented by three different communities:

Juniperus occidentalis/Poa sandbergii community (Juoc/Posa)

Chrysothamnus nauseosus/Trifolium macrocephalum-Poa sandbergii community (Chna/Trma-Posa)

Artemisia tridentata ssp. vaseyana/Sitanion hystrix community (Artrv/Sihy)

The Juoc/Posa community was dominated by western juniper and understory vegetation was sparse (less than 5 percent). Sandberg's bluegrass and Hood's phlox were presently the codominants in the understory component. Big sagebrush (tentatively ssp. tridentata) and green rabbitbrush were present within the site but were closely associated with the juniper and contribute only one percent each to the total ground cover. Spiny hopsage (Grayia spinosa) may be a character species for the site. Needle-and-thread grass was a subdominant in this community. The soil was an Entisol with a fluffy, calcareous surface horizon. The calcium carbonates on the surface indicate little soil development. The subgroup Xeric Torriorthent indicates a soil moisture regime more productive than the present vegetation suggests (USDA, 1975). The slope at this location is 7 percent and the elevation is 1097 m (3600 ft).

This community produced one of the largest amounts of sediment of all of the study sites. The average sediment loss was 19,598 kg/ha (17,498 lb/a) with a range of 5673 kg/ha (5065 lb/a) to 41,457 kg/ha (37,015 lb/a). The hydrologic potential was 59.

The Chna/Trma-Posa community was represented by one site, and at present was dominated by rubber rabbitbrush (Chrysothamnus nauseosus), bighead clover (Trifolium macrocephalum), and western needlegrass (Stipa occidentalis). Juniper and mountain big sagebrush occurred in adjacent communities and bluebunch wheatgrass was present within the site. This site could potentially become a western juniper/bluebunch wheatgrass habitat type but the ecologic information was not sufficient for that conclusion at this time. The soil at this site was a Lithic Haploxeroll, similar to the Lickskillet series. It was skeletal and shallow with a loam texture. The slope was 15 percent and although terraced, the modification was not as extensive as in the Mixed Steppe site. The elevation was 1676 m (5500 ft). This site produced the greatest range in soil losses, from 163 kg/ha (146 lb/a) to 67,738 kg/ha (60,123 lb/a) with an average loss of 13,052 kg/ha (11,654 lb/a).

The sampling at this site was completed during a rainstorm and the greatest soil loss occurred at this time. The site also had the highest mean rainfall of all the study sites, 13.7 cm (5.4 in). The cluster of plots that yielded the highest amount were located on a small alluvial bench that was essentially devoid of vegetation and apparently formed from recent deposition from an earlier runoff event. This single value may therefore be more representative of rill and gully erosion than of sheet erosion processes.

The Artrv/Sihy community was located within the Mixed Steppe Unit. This site was located near a cattle salting area and appeared to be in poor ecological condition with a dense population of mountain big sagebrush, and high subdominant population of rubber rabbitbrush. Bottlebrush squirreltail was the dominant species in the herbaceous layer. Mountain brome occupied the subdominant position in this layer. The forb component was comprised of species that respond to disturbance, such as tumble mustard (Sisymbrium altissimum) and autumn willowweed (Epilobium paniculatum). The soil at this site resembled the Day clay, a Typic Chromoxerert, and had extensive surface cracking. The site appeared to have the potential for an Artrv-Putr/Feid habitat type, with mountain brome serving as a character species reflecting the high clay soil. Neighboring communities supported good populations of antelope bitterbrush; however, the soils may have been different enough to restrict it from this community.

The slope at this site was 10 percent and the elevation was 1433 m (4700 ft). The hydrologic potential was 55, producing an average soil loss of 7225 kg/ha (645 lb/a). The variation within the site ranged from 3144 kg/ha (2807 lb/a) to 16,661 kg/ha (14,876 lb/a).

Analysis of variance indicated that this site was significantly different from the sites in the Artrv/Feid h.t.

The sites were very different in both soils and condition to the contribution of either is difficult to explain.

Fields (Dryland)

Sediment production was determined for two dryland fields, one recently plowed and one in cereal rye (Elymus spp.) stubble to see if they differed from their untreated naturally vegetated counterparts. The plowed field located in the Mixed Steppe Unit, produced the greatest mean sediment of the two field locations, 3191 kg/ha (2850 lb/a) versus 704 kg/ha (629 lb/a). Analysis of variance showed no significant difference due to the high internal variation within the plowed site.

The plowed site was then compared to the untreated habitat type it represented (the first Artrv/Feid h.t. site) and showed no significant difference, which again appears to be due to the variation within both sites. The stubble field was comapred to an adjacent Artr/Agsp-Feid site and also showed no significant difference. The stubble field had little internal variation; however, the untreated site varied considerably and consistently produced more sediment than the field. Both habitat types used in these comparisons had been grazed and were not in excellent condition however. It was interesting to note that the naturally vegetated soils had relatively similar potentials for soil loss. The fields may have improved infiltration characteristics that compensate for the lack of vegetation when exposed to rainfall events.

Dry Meadow Community

This community was dominated by Ribes spp. and Carex spp. and was located at the lower edge of the Mixed Forest Unit at the fork of Klootchman Creek and Bear Creek. Western juniper and mountain big sagebrush appeared to be encroaching on this site. Kentucky bluegrass (Poa pratensis) and fowl mannagrass (Glyceria stricta) were subdominant herbaceous species. The soil at this site as derived from alluvial parent material and similar to the Court series, a Calciorthidic Haploxeroll. The community occurred on nearly level terrain, with a slope of one percent, and at an elevation of 1524 m (5000 ft). The site was experiencing heavy grazing (approximately 3 cm or 1 in stubble height on all grass species present). The surface restricted the simple placement of sediment plots and required precutting along the outline of the frame with an axe. A high density of roots and/or compaction could have been responsible for this phenomenon. Rodent activity was also present throughout the area.

The sediment produced from this community was the least of the study sites. The soil losses ranged from zero to 8 kg/ha (7 lb/a) and averaged 2 kg/ha (1.5 lb/a). While this site is not meant to represent all dry meadows it serves to illustrate the affect a continuous vegetation cover, gentle slopes and apparently a well developed soil on sedimentation potentials. Table 4 illustrates the hydrologic and soil characteristics present on each tentative habitat site.

Habitat Types Not Sampled for Sedimentation

The four tentative habitat types not smapled for sediment production that did not meet the criteria established for selection were:

Artemisia rigida/Poa sandbergii h.t. (Arri/Posa)

Artemisia cana/Carex spp. (Arca/Carex)

Sarcobatus vermiculatus/unclassified community (Save)

Juniperus occidentalis/Agropyron spicatum h.t. Juoc/Agsp)

The Arri/Posa h.t. had a skeletal surface soil (greater than 35 percent rock and cobbles), which would have prevented the placement of the sedimentation plots. The site appeared in good condition and there was a diverse forb component dominated sedum (Sedum lanceolatus). Big-head clover was also common on the site. The soil was the Bakeoven series, a very shallow Lithic Haploxeroll. The habitat types occur on nearly level basalt plateaus. Although the vegetation is generally sparse on these site, the rock pavement would tend to compensate for the lack of vegetation.

Table 4. Hydrologic and Soil Characteristics.

Tentative Habitat Type (Site)		Hydrologic Potential (%)	Rainfall (cm/hr)	Sedimentation Mean (kg/ha)	Sedimentation Range (kg/ha)	Slope	Silt clay
		Mixed Forest					
Psme/Caru		30		47	0-73	10	55
Pipo/Feid		43		331	28-1860	10	55
		Mixed Steppe - Artrv/Feid h.t.					
Artrv/Feid w/Juoc	1	56	11.2	7396	1179-26, 500	7	50
	2	50	11.2	851	198-1717	5	50
w/o Juoc	1	27	9.1	660	215-1469	9	60
	2	15	10.2	295	1-673	19	40
		Juniper Woodland - Juoc/Artr/Feid-Agsp h.t.					
	1	55	11.7	3109	701-6144	6	55
	2	49	10.9	2715	436-5888	13	45
Stth/ph	1	12	8.4	177	1-560	5	20
	2	21	11.7	645	55-1459	7	30
Juoc/Stth		41	8.1	1538	525-2754	10	50
		Big Sagebrush - Artr /Agsp-Feid h.t.					
w/Juoc	1	37	9.1	2778	107-7574	2	49
	2	45	11.9	1145	86-3648	2	49
w/o Juoc	1	48	11.2	1510	701-3533	7	40
(desert)	2	19	10.7	318	12-1045	5	25
		Sandy Big Sagebrush - Artr/Stco h.t.					
	1	31	11.2	963	55-1823	5	40
	2	30	8.6	606	237-1518	5	45
		Low Sagebrush - Arar/Feid-Agsp					
(desert)		25	11.9	630	40-1230	3	40
	1	21	9.4	340	113-641	7	35
	2	50	11.2	1347	200-1883	12	60
(B.C. Butte)		37	10.2	642	399-727	7	55
		Adobeland - Agsp-Posa					
		34	8.9	785	265-2039	3	60
		Unclassified Communities					
Juoc/Posa		59	13.7	19, 598	5673-41, 457	7	50
Chma/Trma-Posa		47	12.2	13.052	163-67, 338	15	65
Artrv/Sihy		55	11.7	7225	3144-16, 661	10	60
		Meadow - Ribes/Carex					
		30	11.4	2	0-8	1	75

The Arca/Carex h.t. was located on the High Lava Plains and reflected internal drainage. Bottlebrush squirreltail was the only grass sampled on this site and its occurrence was infrequent. Forbs were generally absent. The soil for this type was similar to the Odin series, an Aquic Haploxeralf with fine pumiceous alluvium surface layer.

The Save community occurred along the road at the fork of the Bear Creek drainage with the Sage Hollow drainage. The site appeared to have restricted drainage resulting from the county road which intersected the area. Sandberg's bluegrass was the only grass sampled on the site. The soil would be similar to the Gabbut series, a Xerollic Calciorthid that is alkaline.

The Juoc/Agsp h.t. was located on a steep south-facing canyon wall which rims the lowest portion of Bear Creek. The habitat type was in very good ecologic condition with bluebunch wheatgrass dominating the area and Indian ricegrass occurring as a subdominant. Western juniper was present but appeared to occur as an accidental invader away from the ridgelines. Rubber rabbitbrush was the only shrub sampled within the site and it occurred infrequently. The forb component was generally absent. The soil is derived from colluvial basalt and wind laid sediments and may be a droughty version of the Wrentham soil series. The steep slopes and the skeletal ground surface with a considerable quantity of boulder-sized rocks, restricted sampling on the type.

Precipitation

The data from recording rain gages were plotted with a multiple mass analysis technique to determine whether the stations located within the Bear Creek watershed showed any similarity to the peripheral U.S. Weather Bureau stations at Brothers and Barnes (Figure 15). The Mountain House station, located near a homestead on Ferguson Creek, appeared to provide the closest approximation to the Brothers station, for the majority of the August storms. The Blackstone station located near an old homestead near the Brothers-Bear Creek road was approximately 8 km (5 mi) closer to Brothers, Oregon and appeared to be more representative of the High Desert storms than the Mountain House station. The Antelope station, located in the Ochoco National Forest at 1524 m (5000 ft) received the least rainfall of all the gages, due to poor placement in a small opening under ponderosa pine; the Milliorn station was located on the top of Milliorn Hill at 1585 m (5200 ft) and received the highest amount of precipitation, most likely as a result of poor site selection due to an enhancement of actual rainfall resulting from an eddy effect that commonly occurs on the lee side of a physiographic barrier. These data suggest that Ferguson Creek storm patterns may be similar to Brothers, and the difference that did occur is simply due to elevation.

The single season of precipitation data was not sufficient for any futher comparisons.

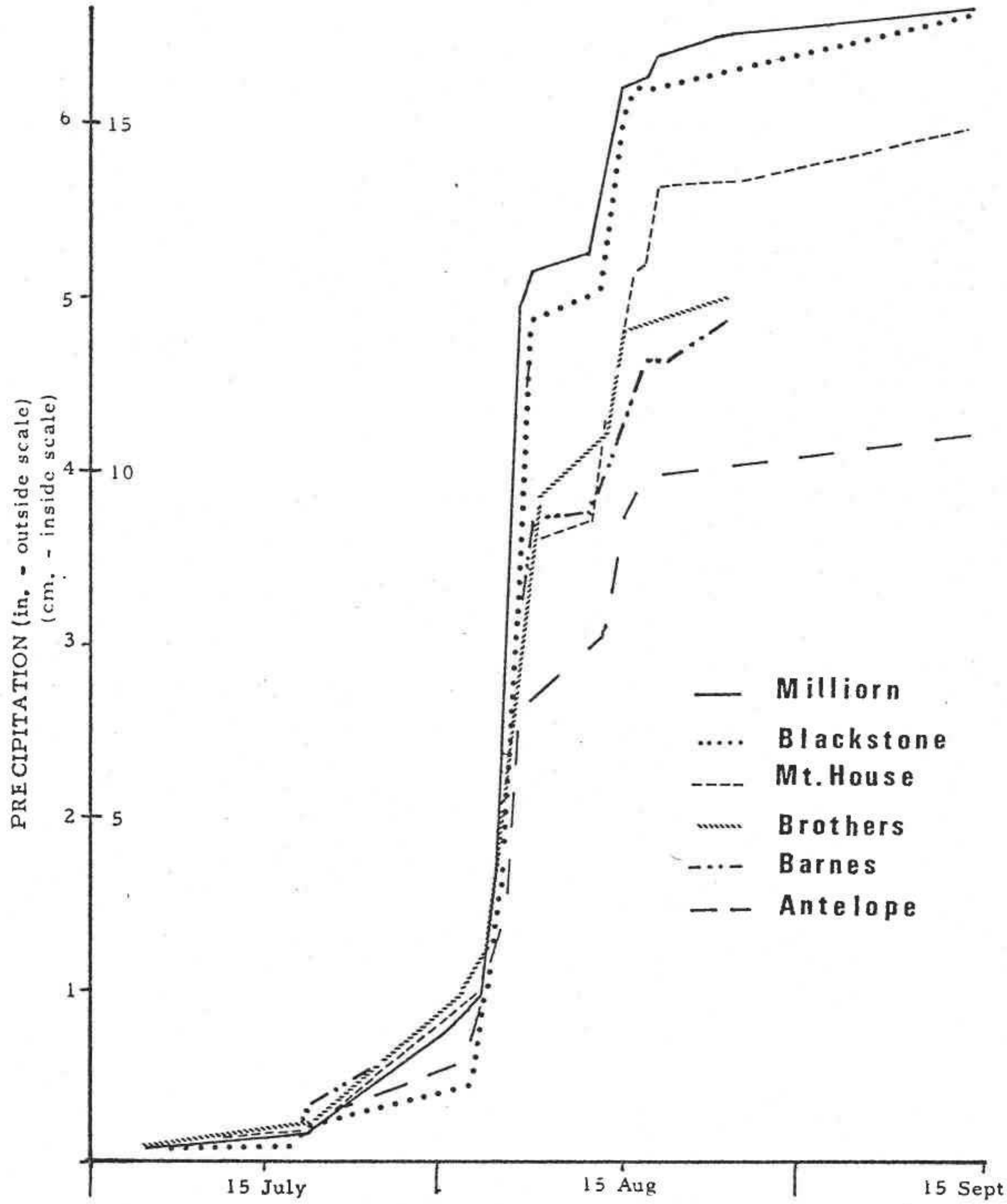

Figure 15. Mass analysis of the precipitation (summer 1976) relating Bear Creek to important adjacent U.S. Weather Bureau.

Turbidity

The turbidity data (Figure 16) show a general decline in suspended solids as the water moved downstream, similar to Miner's (1968) results in Alaska. The peaks and plateaus that occur at downstream stations indicate portions of the watershed that responded to the rainstorm/flashflood events in August 1976. The June 21 data are essentially a preflood baseline and the September 2 data should be comparable low flow postflood conditions. The dates listed within this period reflect the relative turbidity experienced immediately following a runoff producing storm event.

The irrigation dam on the lower portion of Bear Creek appears to be effective in reducing turbidity in the stretch below the dam. The gentle gradient of less than one percent in the lower 13 km (8 mi) must also play a part. The stream flow generally decreases downstream as water is removed for irrigation and by evaporation; however, some replacement by sprinkler irrigation runoff does occur.

Predicted streamflow for the September reading was over three times the flow for the June reading, 0.04 m^3/s (1.3 cfs) versus 0.01 m^3/s (0.41 cfs) (USAS, 1976), and may be responsible for some of the differences in the turbidities for the two dates. The flood related factors of channel scour and stream bank erosion could also be contributing factors.

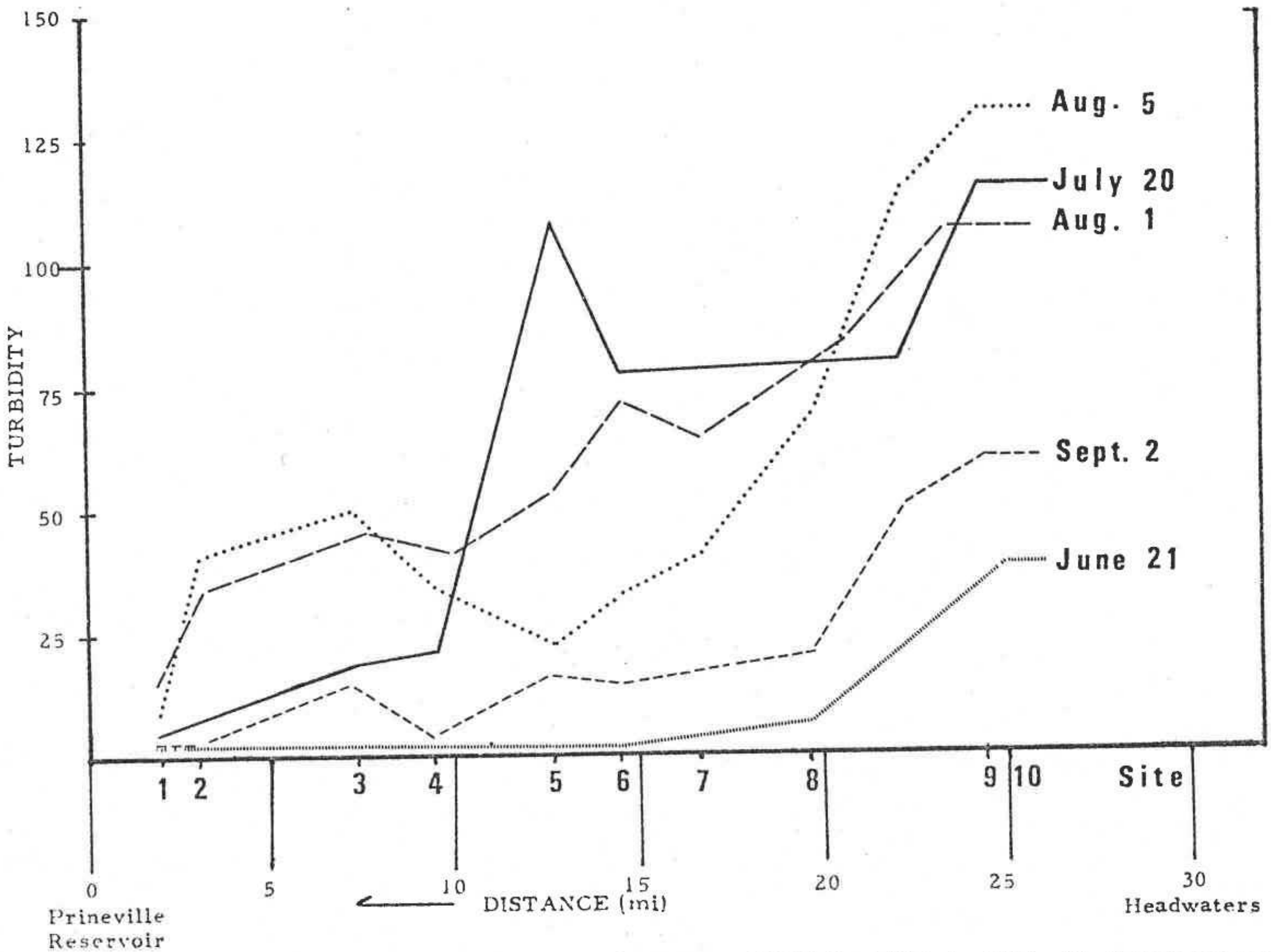

Figure 16. Turbidity of Bear Creek for the summer of 1976 (turbidity in FTU with distilled water standard).

SUMMARY AND CONCLUSIONS

During the summers of 1975 and 1976 a sedimentation study was conducted in the Bear Creek watershed, located in the southeastern corner of Crook County, in central Oregon. This area was selected because of a concern for high sediment loads it contributed to the Prineville Reservoir and because it had vegetation and soils that were representative of much of the central Oregon area. The study predicted soil losses that could be expected from different ecological land units that were defined by their potential vegetation.

During the 1975 field season, preliminary vegetation and soil identification and classification were accomplished to provide a data base for subsequent site selection. The sedimentation sampling was conducted during the 1976 field season, in eight ecological land units, with a Rocky Mountain infiltrometer to generate simulated high intensity rainstorms over 468 plots. The ecological land units were further refined into 14 tentative habitat types for statistical comparisons.

The ecological land unit approach for defining soil losses from upland range sites was too broad in its classifications to adequately describe the erosion potentials. Even the general habitat types described by Daubenmire (1970) are too extensive to properly assess the sediment that could be produced from these types. The wide amplitude of the vegetation in this area and the generalized soil limitations, such as restrictive layers or extreme chemical conditions (alkalinity) which influence that amplitude, lead to the development of habitat types which may not adequately represent the sites' true sediment potential from a hydrologic viewpoint.

A more intensive investigation of vegetation/soil complex is needed to eliminate the variation within habitat types that occurs due to differences in surface soil properties. While one should not necessarily expect a soil series correlation with a particular habitat type, the soil family level of classification may better reflect the degree of refinement necessary to describe the hydrologic parameters of the ecologic unit. A greater attention to those associated species that exhibit a high fidelity for a specific soil family would provide a means of separating soil texture classes, which influence soil loss potentials. The high inherent natural variability within the habitat types tended to mask any differences that may have occurred through a management treatment imposed by man. While the data suggests an increased sediment potential as a type retrogresses in ecological condition, the increase may not be significantly different than that which can be expected from the better site. Differences in potentials were often confounded by other factors which make it impossible to determine the greater influence without additional sampling.

The experimental design required to adequately sample this semiarid habitat type was beyond the scope of this study in both time and money. This study will hopefully serve as a pilot for more intensive investigations which may address themselves to specific problem areas within this watershed. While this study was concerned primarily with the upland soil losses caused by sheet and rill erosion processes, additional work is required to more accurately measure these potentials, with a sensitivity capable of discerning the variations in management treatments and ecological conditions. A better understanding of gully and channel erosion processes in semiarid watersheds is needed before we can use water quality standards in our decision making.

Although this study found little difference within the units due to the confounding caused by methodology, soils and multiple variables, a number of interesting patterns did emerge. The majority of the soils in this area are of the fine, montmorillonitic soil family. These soils are derived from volcanic parent material and exhibit a considerable influence from ash and pumice (Appendix B-1). This family was consistently high in sediment production when total ground cover was lacking, generally exceeding 1000 kg/ha. The Aridisol soils, found on the High Lava Plains, are members of the coarse loamy mixed family and rarely exceeded 1000 kg/ha. Mean sediment potentials were calculated for each ecological land unit to serve as a means of comparison with other units. Due to the similarity of conditions the High Lava Plains is listed as an extra unit (Table 5). It must be understood that these potentials were extrapolated from small sample plots to represent the ecological unit as a whole, and the simulated rainstorms that generated these potentials were unusual events. Therefore, the values indicate a relative magnitude at which the ecological land unit may respond to an actual storm event.

Sediment potentials, listed by tentative habitat type (Table 6), provide an improved means for comparing vegetation-soil complexes. Where character species, such as the Thruber's needlegrass phase of the juniper

Table 5. Mean Sediment Potentials for Selected Ecological Land Units within the Bear Creek Watershed.

Ecological Land Unit	Sediment Potential (kg/ha)	
Meadow	2	
Mixed Forest	380	
Mixed Steppe	2300	
Juniper Woodland	1660	(2460)
Thurber's needlegrass Phase		(420)
Big Sagebrush	1820	
Low Sagebrush	780	
Sandy Big Sagebrush	780	
High Lava Plains	480	

Table 6. Mean Sediment Potentials for Selected Habitat Types in the Bear Creek Watershed.

Tentative Habitat Type	Sediment Potential (kg/ha)
Psme/Caru	47
Pipo/Feid	331
Juoc/Artrv/Feid	4124
Artrv/Feid	477
Juoc/Artr/Agsp-Feid	2912
Juoc/Artr/Feid-Agsp Stth phase	411
Juoc/Stth	1538
Artr/Agsp-Feid w/Juoc	1961
Artr/Agsp-Feid w/o Juoc	914
Arar/Feid-Agsp	776
Artr/Stco	784
Agsp/Posa	785

woodland unit, allow one to identify variations in the soil's component which cause differences in the site's hydrologic response, we are approaching the degree of classification necessary for aridland watershed management.

Management Implications

Forest managers may find it necessary to have timber contractors plow and reseed the burned and compacted areas following tree removal, prior to the first rainfall season. This would also apply to skid trails and roads that are no longer being used. Rehabilitation of these disturbed areas immediately after the removal is completed should minimize the soil losses resulting from the harvest practices.

In the semiarid rangelands, managers may expect a high natural variability in the soil losses that occur in those areas. More intensive management may be required in areas with fine textured soils, since they appear to be the most susceptible to erosion. Water harvesting and diversion techniques should be considered to alleviate gully and channel erosion and prevent the natural soil losses from becoming a sediment yield, degrading downstream water quality. In those units where water is scarce, sufficient water could potentially be harvested to improve animal distribution.

The soil losses from the hilly uplands units do not necessarily imply a sediment contribution to the stream system. Much of the soil lost from the steeper slopes appears to be deposited on gently sloping terraces at the base of the hill, due to decreasing runoff velocities and increasing transmission losses through a more permeable, mixed textured soil surface.

Although the mixed forest unit was the only mechanical treatment sampled, it is reasonable to expect a similar response in the non-forest or meadow units to a treatment that completely removes the vegetation and litter cover and disturbs the soil. Treatments such as the juniper cutting or proper grazing management, that do not significantly alter the vegetation or soil cover characteristics, would not be expected to accelerate erosion beyond the range that naturally exists for the site.

While Silvernale et al. (1976) identified surface erosion as a major contributor of sediment during peak flows in the spring runoff period, this same relationship may not be true for the summer convectional storm period, which contributed 97 percent of sediment during the 1976 water year. Different processes are involved with summer storms which are not present during the spring snowmelt period. In several areas of the Bear Creek watershed there is a high potential for surface erosion and the erosion indicators, such as pedistalling and freshly cut rills are there, however, evidence of channel scour and streambank sloughing is also present.

Managers must be more objective in assessing the significance of the role geologic erosion processes play in semiarid lands. The influence of the natural phenomena, evapotranspitation, interspecific competition and erosion may explain more of the variation in an area's potential to contribute sediment than all the external variables combined. It becomes evident that additional research is necessary to determine the reason for the highly skewed responses that occurred within several of the sites.

LITERATURE CITED

Aldon, E. F. and G. Garcia. 1973. Seventeen-year sediment production from a semiarid watershed in the Southwest. USDA For. Serv. Res. Note RM-248. Rocky Mtn. For. and Range Exp. Sta. Fort Collins, Colo. 4 p.

Anderson, H. W. 1954. Suspended sediment discharges as related to streamflow, topography, soil and land use. Trans. Am. Geophys. Union 35:268-281.

Anderson, H. W. 1970. Principal components analysis of watershed variables affecting suspended sediment discharge after a major flood. Int. Assoc. Sci. Hydrol. Publ. 96:405-416.

Anderson, H. W. 1974. Indicators of soil movement on range watersheds. J. Range Manage. 27:244-247.

André, J. E. and H. W. Anderson. 1961. Variation of soil erodibility with geology, geographic zone, elevation and vegetation type in northern California wildlands. J. Geophys. Res. 66:3351-3358.

Bailey, R. W. and O. L. Copeland, Jr. 1961. Low flow discharges and plant cover relations on two mountain watersheds in Utah. Utah Int. Assoc. Sci. Hydrol. Pub. 51:267-278.

Baldwin, E. M. 1964. <u>Geology of Oregon</u>, 2nd ed. Edwards Bros. Inc., Ann Arbor, Mich. 165 p.

Bethlahmy, N. 1967. Effects of exposure on runoff and erosion. USDA For. Serv. Res. Note INT-161. Intermtn. For. and Range Exp. Sta., Ogden, Utah. 4 p.

Blackburn, W. H. and C. M. Skau. 1974. Infiltration rates and sediment production of selected plant communities in Nevada. J. Range Manage. 27:476-480.

Blackburn, W. H., R. E. Eckert, Jr., M. K. Wood and F. F. Peterson. 1975. Influence of vesicular horizons on watershed management. Watershed Manage. Symp. ASCE Irrig. and Drainage Div. p. 494-515.

Bond, R. D. and J. R. Harris. 1964. The influence of the microflora on the physical properties of soils. Aust. J. Soil Res. 2:111-122.

Branson, F. E., G. F. Gifford, and J. R. Owen. 1972. Rangeland Hydrology. Range Science Ser. No. 1. Soc. for Range Manage. 84 p.

Brogan, D. F. 1963. The Lava Butte Geological Area. USDA For. Serv., Deschutes Natl. For. 12 p.

Brogan, D. F. 1971. East of the Cascades. Binfords and Mort, Portland, Oregon. 304 p.

Brown, G. W. 1974. Forestry and Water Quality. O.S.U. Bookstores, Inc., Corvallis, Ore. 74 p.

Buckhouse, J. C. 1975. Water quality impact of burning and grazing on a chained pinyon-juniper site in southeastern Utah. Ph.D. thesis, Utah State Univ., Logan, Utah. 103 p.

Buckhouse, J. C. and G. F. Gifford. 1976. Sediment production and infiltration rates as affected by grazing and debris burning on chained and seeded pinyon-juniper. J. Range Manage. 29:83-85.

Bureau of Land Management. 1973. Bear Creek Watershed Management Plan, Prineville District, Prineville, Ore. 113 p.

Burkhardt, J. W. and E. W. Tisdale. 1969. Nature and successional status of western juniper vegetation in Idaho. J. Range Manage. 22:264-270.

Burkhardt, J. W. 1976. Causes of juniper invasion in southwestern Idaho. Ecology 57:472-484.

Cain, Stanley A. 1938. The species-area curve. Am. Midl. Natur. 19:573-581.

Chow, Van T. (ed.). 1972. Handbook of Applied Hydrology. McGraw-Hill Book Co., N.Y. 1418 p.

Daubenmire, R. 1968. Plant Communities: A Textbook of Plant Synecology. Harper and Row Publ., N.Y. 300 p.

Daubenmire, R. and J. B. Daubenmire. 1968. Forest vegetation of eastern Washington and northern Idaho. Wash. Agric. Exp. Sta. Tech. Bull. 60. 104 p.

Daubenmire, R. 1970. Steppe vegetation of Washington. Wash. Agric. Exp. Sta. Tech. Bull. 62. 131 p.

Debano, L. F. 1968a. Observations on water repellent soils in western U.S. Symp. Water Repellent Soils, Univ. Calif. Riverside. Proc. May, 1969. p. 17-29.

Debano, L. F. 1968b. Water movement in water repellent soils. Symp. Water Repellent Soils, Univ. Calif. Riverside Proc. May, 1969. p. 61-89.

Dortignac, E. J. 1951. Design and operation of the Rocky Mountain infiltrometer. U.S. For. Serv., Rocky Mtn. For. & Range Exp. Sta. Pap. 5. Fort Collins, Colo. 68 p.

Driscoll, R. S. 1964. Vegetation-soil units in the central Oregon juniper zone. USDA For. Serv. Res. Pap. PNW-19. Pac. NW For. and Range Exp. Sta., Portland, Oregon. 60 p.

Driscoll, R. S. 1969. Aerial color and color infrared photography--some applications and problems for grazing resource inventories. Aerial Color Photogr. Workshop Proc. 1969:140-149.

Eckert, R. E. 1957. Vegetation-soil relationships in some Artemisia types in northern Harney and Lake counties, Oregon. Ph.D. thesis, Oregon State College, Corvallis, Ore. 208 p.

Forsling, C. L. 1931. A study of the influence of herbaceous plant cover on surface runoff and soil erosion in relation to grazing on the Wasatch Plateau in Utah. U.S. Dept. Agric. Tech. Bull. 220. 71 p.

Garrison, G. A., J. M. Skovlin, C. E. Poulton, A. H. Winward. 1976. Northwest plant names and symbols for ecosystem inventory and analysis, 4th ed. USDA Gen. Tech. Rep. PNW-46. Pac. NW For. and Range Exp. Sta., Portland, Oregon. 263 p.

Gifford, G. F. 1968. Rangeland watershed management--A review. Nev. Agric. Exp. Sta. Proj. 3-37-5483. 50 p.

Gifford, G. F. 1972. Infiltration rate and sediment production trends on a plowed big sagebrush site. J. Range Manage. 25:53-55.

Gifford, G. F. 1973. Runoff and sediment yields from runoff plots on chained pinyon-juniper sites in Utah. J. Range Manage. 27:440-443.

Gifford, G. F. and F. E. Busby. 1974. Intensive infiltrometer studies on big sagebrush sites. J. Hydrol. 21:81-90.

Green, G. L. 1975. Soil survey of the Trout Creek-Shaniko area, Oregon. U.S. Dept. Agric. Soil Cons. Serv. Wash., D.C. 83 p.

Hall, F. C. 1966. Vegetation-soil relations as a basis for resource management on the Ochoco National Forest of central Oregon. Ph.D. thesis, Oregon State Univ., Corvallis, Ore. 207 p.

Hanson, C. L., H. G. Heinemann, A. R. Kuhlman and J. W. Neuberger. 1973. Sediment yields from small rangeland watersheds in western South Dakota. J. Range Manage. 27:215-219.

Hewlett, J. D. and W. L. Nutter. 1969. An outline of forest hydrology. Univ. Georgia Press, Athens, Ga. 137 p.

Hitchcock, C. L. and A. Cronquist. 1973. Flora of the Pacific Northwest. Univ. Washington Press, Seattle, Wash. 730 p.

Horton, R. E. 1945. Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology. Bull. Geolo. Soc. Am. 56:275-370.

Jenny, H. 1958. Role of plant factors in pedogenic functions. Ecology 39:5-16.

Keen, F. P. 1937. Climatic cycles in eastern Oregon as indicated by tree rings. Monthly Weather Rev. 65:175-189.

Kincaid, D. R. and G. Willimas. 1966. Rainfall effects on soil surface characteristics following range improvements treatments. J. Range Manage. 19:346-351.

Küchler, A. W. 1967. Vegetation Mapping. Ronald Press Co., N.Y. 472 p.

Langbein, W. B. and S. A. Schumm. 1958. Yield of sediment in relation to mean annual precipitation. Trans. Am. Geophys. Union 39:1076:1084.

Likens, G. E., F. H. Bormann, N. M. Johnson, D. W. Fischer and R. S. Pierce. 1970. Effects of forest cutting and herbicide treatment on nutrient budgets in the Hubbard Brook watershed-ecosystem. Ecol. Monogr. 40:24-46.

Lusby, G. C. 1970. Hydrologic and biotic effects of grazing vs. non-grazing near Grand Junction, Colorado. J. Range Manage. 23:256-260.

Mayko, R. W. and G. K. Smith. 1966. Soil survey of the Prineville area, Oregon. U.S. Dept. Agric. Soil Cons. Ser., Wash., D.C. 89 p.

McKee, B. 1972. Cascadia--the geologic evolution of the Pacific Northwest. McGraw-Hill Book Co., N.Y. 394 p.

McKee, J. E. and H. W. Wolf. 1963. Water Quality Criteria. Calif. State Water Resour. Control Board, Publ. No. 3-A. 548 p.

Meeuwig, R. O. 1970. Infiltration and soil erosion as influenced by vegetation and soil in northern Utah. J. Range Manage. 23:185-188.

Megahan, W. F. and D. C. Molitor. 1975. Erosional effects of wildfire and logging in Idaho. Watershed Manage. Symp., ASCE Irrig. and Drainage Div., Logan, Utah. p. 423-444.

Miner, N. 1968. Natural filtering of suspended soil by a stream at low flows. USDA For. Serv. Res. Note PNW-88. Pac. NW For. and Range Exp. Sta., Portland, Ore. 4 p.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons, N.Y. 547 p.

Oregon State Soil and Water Conservation Commission. 1974. Streambank erosion in Oregon. Report to the 57th Legislative Assembly. 149 p.

Paine, D. P. 1975. An Introduction to Aerial Photography for Natural Resource Management. OSU Book Stores, Inc., Corvallis, Ore. 314 p.

Poulton, C. E. and E. W. Tisdale. 1961. A quantitative method for the description and classification of range vegetation. J. Range Manage. 14:13-21.

Poulton, C. E., D. P. Faulkner and N. L. Martin. 1971. Application of ecology and remote sensing in the analysis of range watersheds. Final Proj. Rep., Oregon State Agric. Exp. Sta. 433 p.

Renard, K. G. and R. B. Hickok. 1967. Sedimentation research needs in the semiarid regions. J. Hydraulics Div., ASCE 93, No. HY 1, Proc. Pap. 5060:45-60.

Renard, K. G. 1972. Sediment problems in the arid and semiarid southwest. Proc. 27th Ann. Soil Cons. Soc., Ana 6-9 1972. p. 225-231.

Renard, K. G. and J. R. Simanton. 1975. Thunderstorm precipitation effects on the rainfall-erosion index of the universal soil loss equation. Hydrol. and Water Resour. in ARiz. and the SW., Am. Water Resour. Assoc. Sec., Ariz. Acad. Sci., Hydrol. Soc., Proc. April 11-12, 1975. Flagstaff, Ariz. p. 47-55.

Rich. L. R. and H. G. Reynolds. 1963. Grazing in relation to runoff and erosion on some chaparral watersheds of central Arizona. J. Range Manage. 16:322-326.

Rollins, M. B. 1973. Interview of old time residents of Bear Creek. In: Bear Creek Watershed Management Plan, BLM, Prineville, Dist. p. 92-100.

Rothacher, J. and T. B. Glazebrook. 1968. Flood damage in the national forests of Region 6. USDA For. Serv. Pac. NW For. and Range Exp. Sta. 20 p.

Satterlund, D. R. 1972. Wildland Watershed Management. Ronald Press, N.Y. 370 p.

Schallig, W. H. C. 1967. The preparation of association tables and the science of modern phytosociology. W-89 Regional Tech. Meeting, Oregon State Univ. 46 p.

Sharp, A. L., J. J. Bonc, J. W. Neuberger, A. R. Kuhlman and J. K. Lewis. 1964. Runoff as affected by intensity of grazing on rangeland. J. Soil Water Cons. 19:103-106.

Silvernale, C. E., G. H. Simonson and M. E. Harward. 1976. Soil and watershed characteristics in relation to turbidity of the Prineville Reservoir. Oregon State Agric. Exp. Sta. Spec. Rep. 453. 151 p.

Simanton, J. R., K. R. Renard and N. G. Sutter. 1973. Procedures for identifying parameters affecting storm runoff volumes in a semiarid environment. USDA, ARS-W-1. 12 p.

Simonson, J. 1976. Soils field trip--Crook County, Oregon. Mimeo. 6 p.

Skau, C. M. 1961. Some hydrologic influences of cabling juniper. USDA For. Serv. Res. Note RM-62, Rocky Mnt. For. and Range Exp. Sta., Fort Collins, Colo. 2 p.

Smeins, F. E. 1975. Effects of livestock grazing on runoff and erosion. In: Proc. of the Am. Soc. Civ. Eng. Watershed Manage. Symp. Utah State Univ., Logan. p. 267-274.

Smith, D. D. and W. H. Wischmeier. 1962. Rainfall erosion. Adv. Agron. 14:109-148.

Soil Conservation Society of America. 1976. Resource conservation glossary. J. Soil Water Cons. 31, enclosure. 63 p.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc., N.Y. 481 p.

Strahler, A. N. 1952. Hypsometric (area-altitude) analysis of erosional topography. Bull. Geol. Soc. Am. 63:1117-1142.

Sturges, D. L. 1975. Hydrologic relations on undisturbed and converted big sagebrush lands: the status of our knowledge. USDA For. Serv. Res. Pap. RM-140, Rocky Mtn. For. and Range Exp. Stat., Fort Collins, Colo. 23 p.

Swanson, D. A. 1969. Reconnaissance geologic map of the east half of the Bend Quadrangle, Crook Wheeler, Jefferson, Wasco, and Deschutes Counties, Oregon. USGS Misc. Geo. Investigations Map I-568, USGS, Wash., D.C. 1 p.

U. S. Department of Agriculture. 1975. Soil Taxonomy. U.S. Dept. Agric., Soil Cons. Serv., Agric. Handbook No. 436. 754 p.

U. S. Gelogocial Survey. 1977. Suspended-sediment discharge, water year October 1975 to September 1976, for Bear Creek, Station No. 440340. Unpublished records subject to revision, USGS, Portland, Oregon.

Williams, H. 1969. Ancient volcanoes of Oregon. Condon Lectures, Univ. Oregon Press, Eugene, Oregon 70 p.

Williams, G., G. F. Gifford and G. B. Coltharp. 1972. Infiltrometer studies on treated versus untreated pinyon-juniper sites in central Utah. J. Range Manage. 22:110-114.

Wischmier, W. H. 1976. Use and misuse of the Universal Soil Loss Equation. J. Soil Water Cons. 31:5-9.

Woolhiser, D. A., C. L. Hanson and A. R. Kuhlman. 1970. Overland flow on rangeland watersheds. J. Hydrol. 9:336-356.

Yamamoto, T. and H. W. Anderson. 1973. Splash erosion related to soil erodibility indices and other forest soil properties in Hawaii. Water Resour. Res. 9:336-345.

Appendix A-1. Association Table of Selected Plant Species and Their Tentative Habitat Types.

	Mixed Forest		Mixed Steppe				Juniper Woodland					Big Sagebrush			
	Psme/ Caru	Pipo/ Feid	Artrv w/Putr	/	Feid w/Juoc		Juoc /	Artr /	Feid – Stth phase	Agsp	Juoc/ Stth	Artr w/Juoc	/	Agsp –	Feid
Pipo	(50)[a]	(54)													
Psme	+														
Juoc	+	+	+(1)	3(1)	10(14)	10(10)	5(16)	3(17)	3(20)	+(14)	3(14)	cut(15)	13(19)	+(1)	+(1)
Artrv			23	50	15	18									
Putr	+		5	3	+	+									(3)
Erhe			68	3											
Chna					3	+					5				
Artr							10	13	5	3	+	+	+	43	35
Chvi			13	10	10	15	38	3	20	45			13	3	33
Arab				5	3		5								
Rice		3													
Arri															
Arca															
Save															
Caru	93														
Feid	6	55	98	80.	55	8	33	13	18	13	5	10	8	5	38
Agsp			55	65	35	+	20	3	10	10	8	5	+	33	5
Posa			63	73	65	90	85	58	43	28	8	8	30	80	3
Sihy	3		13	50	30	3	20	8	10	3	8	10	13	18	45
Kocr			18	45	18		13	5	8	5	3	15		10	18
Stth			10		5		5	8	45	35	78	13	13	13	33
Stco						3						18	3	43	8
Agsm															
Orhy								3			5	15	8		
Brte				5	5		5		3		3		23	40	8
Brca				5											
Glst															
Phpr															
Popr															
Carex	33	35	15	10	35		5		13						
Juncus															
Arco	97	60													
Jialt	60														
Acmi	40	13	10		13	5								8	
Andi			10		3	75	25	20		40		30	10	5	
Luca		3	20		5	8									
Erfi			38			33	3		3						6
Phho						5	20	48		5	68	25	13	5	
Lepu							3	3	13	3		3			
Ersp									3	3	2				
Erum					3	10	3	3							18
Pecu					10	3		10			5	3	5		
Erla					3									3	5
Seca								25		23		10	5		
Astragalus										5					3
Aspu						3	5	5				3			5
Eppa		3													
Trma															
Lotr															
Viam															
Pogr															
Toru				8	5	50	25	13	20	30	3	13	3	28	33

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Appendix A-1. (Continued)

	Sandy Big Sagebrush		Low Sagebrush				Adobe-land	Unclassified Communities							
	Artr	/ Stco	Arar/Feid		-	Agsp	Agsp-Posa	Juoc/Posa	Artrv/Sihy	Chna/Trma-Posa	Ribes/Carex	Agsp/Orhy	Arri/Posa	Arca	Save
Pipo															
Psme															
Juoc	+(1)	+(1)	+(1)	+(3)	3(3)	+	+(4)	+(13)	+	1	3				
Artrv									68		3				
Putr															
Erhe									3						
Chna									43	8		3			
Artr	15	+					1	8							
Chvi	53	5	28	15	3	35		8	8		3				
Arab			48	58	68	78	3								
Rice											8				
Arri													40		
Arca														100	
Save															97
Caru															
Feid			75	63	20	5	10		+		5				
Agsp				8	3	35	86	13		23		93			
Posa	58	56	13	85	78	100	48	43	+	67		3	83		
Sihy	43	13	20	8	55	10	20	33	85	23			37	7	
Kocr			10	40				13							
Stth	8		43	13		13		8		75					
Stco	85	98						23							
Agsm															
Orhy	5	3						15				43			
Brte	38	75					15	3	13			46			
Brca							+		48	5					
Glst											55				
Phpr											35				
Popr											88				
Carex											100			37	
Juncus											68			33	
Arco															
Hialt															
Acmi			3		5		20		10	13		6	3		
Andi	5	3	15	35	30	37		10							
Luca							13								
Erfl				23											
Phho			8	33	10	53		45							
Lepu															
Ersp			10					10		10					
Erum				3			8								
Pecu								5					13		
Erla															
Seca							5	8							
Astragalus					33	3		5		3					
Aspu			5	8		10									
Eppa															
Trma										85			40		
Lotr										70			+		
Viam											32				
Pogr											23				
Toru	43	8	63	35	30	63	18	35		5					

[a] Parentheses indicate percent crown cover.

Appendix A-2. List of Plant Species Occurring in the Bear Creek Watershed (Nomenclature according to Garrison et al., 1976).

Species Code	Scientific Name: Genus	Scientific Name: Species	Common Name
		Trees	
Abgr	Abies	grandis (Dougl.) Lindl.	grand fir
Juoc	Juniperus	occidentalis Hook.	western juniper
Pipo	Pinus	ponderosa Dougl. ex Loud.	ponderosa pine
Prvi	Prunus	virginiana L.	common chokecherry
Psme	Pseudotsuga	menziesii (Mirb.) Franco	Douglas-fir (interior)
		Shrubs	
Amal	Amelanchier	alnifolia Nutt.	Saskatoon serviceberry
Arar	Artemisia	arbuscula Nutt.	low sagebrush
Arcab	Artemisia	cana (Gray) Ward ssp. bolanderi	Bolander silver sagebrush
Arri	Artemisia	rigida (Nutt.) Gray	stiff sagebrush
Artrt	Artemisia	tridentata Nutt. ssp. tridentata	basin big sagebrush
Artrv	Artemisia	tridentata (Rydb.) Bettle ssp. vaseyana	mountain big sagebrush
Artrw	Artemisia	tridentata Bettle ssp. wyomingensis	Wyoming big sagebrush
Atca	Atriplex	canescens (Pursh) Nutt.	scurving saltbrush
Bere	Berebeberis	repens Lindl.	creeping hollygrape
Ceve	Ceanothus	velutinus Dougl. ex Hook	snowbrush ceanothus
Cele	Cercocarpus	lebidolius Nutt.	curlleaf mountain-mahogany
Canaa	Chrysothamnus	nausecsus (Nutt.) Rydb. ssp. albicaulis	rubber rabbitbrush
Chvil	Chrysothamnus	viscidiflorus (Hutt.) Greene ssp. lanceolatus	lanceleaf green rabbitbrush
Chviv	Chrysothamnus	viscidiflorus (Hook.) Nutt. ssp. viscidiflorus	Douglas rabbitbrush
Crdo	Crataegus	douglasii Lindl.	black hawthorn
Grsp	Grayia	spinosa (Hook.) Moq	spiny hopsage
Lepu 2	Leptodactylon	pungens (Torr.) Nutt.	granite gilia
Phle 2	Philadelphus	lewisii Pursh.	Lewis mockorange
Putr	Purshia	tridentata (Pursh) DC.	antelope bitterbrush
Riau	Ribes	aureum Pursh	golden currant
Rice	Ribes	cereum Dougl.	wax currant

(Continued on next page)

Appendix A-2. (Continued)

Species Code	Scientific Name		Common Name
	Genus	Species	
		Shrubs (continued)	
Rivi	Ribes	viscosissimum Pursh	sticky currant
Rowo	Rosa	woodsii Lindl.	woods rose
Saam	Salix	amygoaloides Anderss	peachleaf willow
Saex	Salix	exigua Nutt.	coyote willow
Sado 2	Salvia	dorrii (Kell.) Abrams	purple sage
Sace	Sambucus	cerulea Raf.	blueberry elderberry
Syal	Symphoricarpos	albus (L.) Blake	common snowberry
Teca	Tetradymia	canescens DC.	Gray horsebrush
Tegl	Tetradymia	glabrata Gray	little leaf horsebrush
		Grasses and Grasslike Plants	
Agca	Agropyron	cristatum (L.) Gaertn.	fairway crested wheatgrass
Acda	Agropyron	dasystachyum (Hook.) Scribn.	thickspike wheatgrass
Agsm	Agropyron	smithii Rydb.	western wheatgrass; bluestem wheatgrass
Agsp	Agropyron	spicatum (Pursh.) Scribn. & Smith	bearded bluebunch wheatgrass
Brca	Bromus	carinatus H. & A.	California brome
Brin	Bromus	inermis Leys.	smooth brome
Brte	Bromus	tectorum L.	cheatgrass brome
Carex	Carex	L.	sedge
Cafi	Carex	filifolia Nutt.	threadleaf sedge
Cage	Carex	geyeri Boott	elk sedge
Caru	Calamagrostis	rubescens Buckl.	pinegrass
Dagl	Dactylis	glomerata L.	orchardgrass
Daun	Danthonia	unispirata (Thurb.) Munro ex Maccun	onespike danthonia
Deel	Deschampsia	elongata (Hook.) Munro ex Benth.	slender hairgrass
Elci	Elymus	cinereus Scribn. & Merrill	giant wildrye
Eltr	Elymus	triticoides Buckl.	creeping wildrye
Feid	Festuca	idahoensis Elmer	Idaho fescue

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Appendix A-2. (Continued)

Species Code	Scientific Name		Common Name
	Genus	Species	
		Grasses & Grasslike Plants (continued)	
Feoc 2	Festuca	octoflora Walt	six weeks fescue
Glst	Glyceria	striata (Lam.) A.S. Hitchc.	fowl mannagrass
Juba	Juncus	balticus Willd.	Baltic rush
Kocr	Koeleria	cristata Pers.	prairie junegrass
Muri	Muhlenbergia	richardsonis (Trin.) Rydb.	short-leaved muhly
Orhy	Oryzopsis	hymenoides (R. & S.) Ricker	Indian ricegrass
Phpr	Phleum	pratens L.	timothy
Poam	Poa	ampe Merrill	big bluegrass
Pone 2	Poa	nevadensis Vasey ex Scribn.	Nevada bluegrass
Popr	Poa	pratensis L.	Kentucky bluegrass
Posa 3	Poa	sandbergii Vasey	Sandberg's bluegrass
Pose	Poa	secunda Authors not presl.	Sandberg's bluegrass
Sihy	Sitanion	hystrix (Nutt.) J.G. Sm.	bottlebrush squirreltail
Stco 2	Stipa	comata Trin. & Rupr.	needle-and-thread grass
Stoc	Stipa	occidentalis Thurb. ex Wats	western needlegrass
Stth	Stipa	thurberiana Piper	Thurber's needlegrass
		Forbs	
Acmi	Achillea	millefolium L.	yarrow
Agose	Agoseris	Raf.	agoseris
Alac	Allium	acuminatum Hook.	tapertip onion
Alal	Alyssum	alysoides L.	pale alyssum
Alto	Allium	tolmiei Ownbey	Tolmie's onion
Amte	Amsinckia	tessellata Gray	tesellate fiddleneck
Andi	Antennaria	dimorpha (Nutt.) T. & G.	low pussytoes
Anro	Antennaria	rosea Greene	rose pussytoes
Aqfo	Aquilegia	formosa Fisch.	Sitka columbine
Ardi 3	Arabis	divaricarpa A. Nels	rock cress

(Continued on next page)

Appendix A-2. (Continued)

Species Code	Scientific Name: Genus	Scientific Name: Species	Common Name
		<u>Forbs</u> (continued)	
Arho	Arabis	holboellii Horrem.	Holboell rockcress
Arsp 2	Arabis	sparsiflora Nutt.	sickle-pod rock cress
Arca 2	Arenaria	capillaris Poir.	sandwort
Arco 2	Arenaria	congesta Nutt.	ballhead sandwort
Arco	Arnica	cordifolia Hook.	heartleaf arnica
Arlu	Artemisia	ludovidiana Nutt.	Louisiana sagebrush; herbaceous sage
Ascr	Asclepias	cryptoceras Wats.	pallid milkweed
Assp	Asclepias	speciosa Torr.	showy milkweed
Ascu 2	Astragalus	curvicarpus (Sheld.) Macbr.	curvepod loco
Asfi	Astragalus	filipes Torr. ex Gray	
Asmi	Astragalus	miser Dougl. ex Hook	starved milk vetch
Aspu	Astragalus	purshii Dougl. ex Hook	Pursh loco
Asst	Astragalus	stenophyllus T. & G.	basalt milk vetch
Basa	Balsamorhiza	sagittata (Pursh) Nutt.	arrowleaf balsamroot
Blsc	Blepharipappas	scaber Hook.	blepharipappus
Borag	Borage	L.	borage
Cama	Calochortus	macrocarpus Dougl.	sagebrush mariposa
Camel	Camelina	Crantz	falseflax
Cadr 2	Cardaria	draba (L.) Desv.	whitetop
Cach 2	Castilleja	chromosa A. Nels	desert paintbrush
Cahi 2	Castilleja	hispida (Pennell) Ownbey	harsh penstemon
Cali 2	Castilleja	linariaefolia Benth	Wyoming paintbrush
Chdo	Chaenactis	douglasii (Hook.) H. & A.	Douglas chaenactis
Chal	Chenopodium	album L.	lambsquarters goosefoot
Chle	Chenopodium	leptophyllum (Moq.) Wats	slimleaf goosefoot
Cido	Cicuta	douglasii (DC.) Coult. & Rose	western waterhemlock
Ciar	Cirsium	arvense (L.) Scop	Canada thistle
Cifo	Cirsium	foliosum (Hook.) DC.	elk thistle
Civu	Cirsium	vulgare (Savi) Airy-Shaw	bull thistle

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Appendix A-2. (Continued)

Code	Scientific Name: Genus	Scientific Name: Species	Common name
		Forbs (continued)	
Clpu	Clarkia	pulchella Pursh	elkhorns clarkia
Copa	Collensia	parviflora Lindl.	littleflower collinsia
Cogr 2	Collomia	grandiflora Dougl. ex Lindl.	largeflower collomia
Coli 2	Collomia	linearis Nutt.	narrowleaf collomia
Coman	Comandra	Nutt.	comandra
Cora	Cordylanthus	ramosus Nutt. ex Benth.	bushy birdbeak
Crac	Crepis	acumenata Nutt.	tapertip hawksbeard
Cram	Cryptantha	ambigua (Gray) Greene	obscure cryptantha
Crin 2	Cryptantha	intermedia (Gray) Greene	common cryptantha
Dede	Delphinium	depauperatum Nutt.	slim larkspur
Denu 3	Delphinium	nuttallianum Autz. ex Walpers	upland larkspur
Depi	Descurainia	sinnata (Walt.) Britt	pinnate tansymustard
Dopa	Dodecatheon	pauciflorum (Durand) Greene	darkthroat shootingstar
Eppa	Epilobium	paniculatum Nutt. ex T. & G.	autumn willowweed
Ersp 4	Eriostrium	sparsiflorum (Eastw.) Mason	threadleaved eriastrum
Erch	Erigeron	chrysopsidis Gray	yellow fleabane
Erco 3	Erigeron	corymbosus Nutt.	purpledaisy fleabane
Erea	Erigeron	eatonii Gray	Eaton fleabane
Erfi	Erigeron	filifolius Nutt	threadleaf fleabane
Erli	Erigeron	linearis (Hook.) Piper	lineleaf fleabane
Erpo	Erigeron	poliospermus Gray	cushion fleabane
Erpu	Erigeron	pulmilus Nutt.	Low fleabane
Erhe	Eriogonum	heracleoides Nutt.	Wyeth eriogonum
Ermi	Eriogonum	niveum Dougl. ex Benth.	snow eriogonum
Erov	Eriogonum	ovalifolium Nutt.	cushion eriogonum
Erni	Eriogonum	microthecum Nutt.	slenderbush eriogonum
Ersp 3	Eriogonum	sphaerocephalum Dougl. ex Benth.	rock eriogonum
Erum	Eriogonum	umbellatum Torr.	sulfur eriogonum
Ervi	Eriogonum	vimineum Dougl.	broom eriogonum

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Appendix A-2. (Continued)

Species Code	Scientific Name: Genus	Scientific Name: Species	Common Name
		Forbs (continued)	
Erla	Eriophyllum	lanatum Pursh) Forbes	woolly eriophyllum
Erci	Erodium	cicutarium (L.) L'Her.	alfelaria; filaree; storksbill
Eroc	Erysimum	occidentale (Wats.) Robins	wallflower
Frvi	Fragaria	virginiana Duchesne	strawberry
Galiu	Galium	L.	bedstraw; cleavers
Gara	Gayophytum	ramosissimum Nutt. ex T. & G.	hairstem groundsmoke
Gevi	Geranium	viscosissimum F. & M.	sticky geranium
Getr	Geum	trifolorum Pursh	prairiesmoke avens
Giag	Gilia	aggregata (Pursh) Spreng.	skyrocket gilia
Giin	Gilia	inconspicua (Sm.) Sweet	shy gilia
Hacke	Hackelia	Opiz	stickseed hackelia
Hala 2	Haplopappus	lanceolatus (Hook.) T. & G.	landeleaf goldenweed
Hial 2	Hieracium	albertinum Farr	western hawkweed
Hial	Hieracium	albiflorum Hook.	white hawkweed
Hyca	Hydrophyllum	capitatum Dougl. ex Benth.	ballhead waterleaf
Hyfi	Hymenopappus	filifolius Hook.	hymenopappus
Irmi	Iris	missouriensis Nutt.	Rockymountain iris
Ivax	Iva	axillaris Pursh	poverty sumpweed
Lappu	Lappula	Moench	stickseed
Lepe	Lepidium	perfoliatum L.	clasping pepperweed
Lere	Lewisia	rediviva Pursh	bitterroot lewisia
Lipe	Linum	perenne L.	perennial flax
Libu	Lithophragma	bulbifera Rydb.	prairie star
Liru	Lithospermum	ruderale Dougl. ex Lehm.	wayside gromwell
Logo	Lomatium	gormanii (Howell) Coult. & Rose	Gorman biscuitroot
Lonu	Lomatium	nudicaule (Pursh) Coult. & Rose	barestem lomatium
Lotr	Lomatium	triternatum (Pursh) Coult. & Rose	nineleaf lomatium
Luca	Lupinus	caudatus Kell.	tailcup lupine
Lysp	Lygodesmia	spinosa Nutt.	thorn skeleton plant

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Appendix A-2. (Continued)

Species Code	Scientific Name		Common Name
	Genus	Species	
		Forbs (continued)	
Maca 2	Macheranthera	canescens (Pursh) Gray	hoary aster
Magl	Madia	glomerata Hook.	cluster tarweed
Mesa	Medicago	sativa L.	alfalfa
Meal	Melilotus	alba Desr.	white sweetclover
Meof	Melilotus	officinalis (L.) Lam.	yellow sweetclover
Meal 2	Mentzelia	albicaulis Dougl. ex Hook	whitestem mentzelia
Mela 2	Mentzelia	laevicaulis (Doug.) T. & G.	blazingstar mentzelia
Meob	Mertensia	obligifolia (Nutt.) G. Don	oblongleaf bluebells
Micro 3	Microseris	D. Don	microseris
Migu	Mimulus	guttatus DC.	common monkeyflower
Mina	Mimulus	nanus H. & A.	dwarf monkeyflower
Moun 2	Monotropa	uniflora L.	indianpipe
Nain	Navarretia	intertexta (Benth) Hook.	navarretia
Orfa 2	Orobanche	fasciculata Nutt.	clustered broomrape
Ortho	Orthocarpus	Nutt.	owlclover; owlweed
Osch	Osmorhiza	ohilensis H. & A.	mountain sweetroot
Pecu	Penstemon	cusickii Gray	cusick penstemon
Pede	Penstemon	denstus Dougl. ex Lindl.	scabland penstemon
Peer	Penstemon	eriantherus Pursh	fuzzytongue penstemon
Pesp	Penstemon	specidsus Dougl. ex Lindl.	royal penstemon
Peor 4	Petalostemum	ornatum L.C. Rich.	prairie clover; petalostemum
Phha	Phacelia	hostata Dougl. ex Lehm.	whiteleaf phacelia
Phli	Phacelia	linearis (Pursh) Holz	threadleaf phacelia
Phho	Phlox	hoodii Rich.	Hood's phlox
Phlo	Phlox	longifolia Nutt.	longleaf phlox
Plma 3	Plectritis	macrocera T. & G.	longhorn plectritis
Polyg	Polygonum	L.	knotweed
Pogr	Potentilla	gracilis Dougl. ex Hook	northwest cinquefoil
Ptan	Pterospora	andromedea Nutt.	woodland pinedrops

(Continued on next page)

Appendix A-2. (Continued)

Species Code	Scientific Name: Genus	Scientific Name: Species	Common Name
		Forbs (continued)	
Raaq	Ranunculus	aquatilis L.	watercrowfoot buttercup
Racy	Ranunculus	cymbalaria Pursh	shore buttercup
Saka	Salsola	kali L.	Russian thistle
Sangu	Sanguisorba	L.	burnet
Scute	Scutellaria	L.	skullcap
Sela 2	Sedum	lanceolatum Torr.	lanceleaved stonecrop
Seca	Senecio	canus Hook.	woolly groundsel
Sein	Senecio	integerrimus Nutt.	Lambstongue groundsel
Sior	Sidalcea	oregana (Nutt.) Gray	Oregon checkermallow
Sior 2	Silene	oregana Wats.	Oregon silene
Sial	Sisymbrium	altissimum L.	tumblemustard
Smra	Smilacina	racemosa (L.) Desf.	feather solomonplume
Smst	Smilacina	stellata (L.) Desf.	starry solomonplume
Sotr	Solanum	triflorum Nutt.	cutleaf nightshade
Soca	Solidago	canadensis L.	Canada goldenrod
Spmu	Sphaeralvea	muroana (Dougl.) Spach ex Gray	Munro globemallow
Taop	Taraxacum	officinale Weber	common dandelion
Thlas	Thlaspi	L.	pennycress
Tofl	Towensdia	florifer (Hook.) Gray	showy towensdia
Trdu	Tragopogon	dubius Scop.	yellow salsify
Trma	Trifolium	macrocephalum (Pursh) Foiret	bighead clover
Urdi	Urtica	dioica L.	stinging nettle
Vevi	Veratrum	viride Att.	American falsehellebore
Veth	Verbascum	thapsus L.	flannel mullein
Viam	Vicia	americana Muhl. ex Willd.	American vetch
Viad	Viola	adunca Sm.	Hook violet
Vinu	Viola	nuttallii Pursh	Nuttall violet
Zive	Zigadenus	venenosus Wats.	meadow death camas
Toru	Tortula	ruralis	moss
Levu	Letharia	vulpinus	lichen

Appendix B-1. Soil Associations of the Bear Creek Watershed.

1 Powder-Courtrock Association

2 Simas

(a) Simas-Tub Association
includes Ginser, Gem, and Day series

(b) Simas-Soft Sedimentary Rock Association
includes Day and Tub series

(c) Simas-Ginser-Ruckles Association

3 Deschutes-Redmond Association

4 Tub-Prag-Lamonta Association

5 Hankins-Boardtree Association

6 Wrentham

(a) Wrentham-Lickskillet-Rockland Association

(b) Rockland-Lickskillet Association

Appendix B-2. Soils Occurring in the Bear Creek Watershed.

Series	Subgroup	Family
Bakeoven	Lithic Haploxeroll	loamy, skeletal, mixed, mesic
Court	Calciorthidic Haploxeroll	coarse-loamy over sandy or sandy skeletal, mixed, mesic
Day	Typic Chromoxererts	very fine, montmorillonitic, mesic
Deschutes	Xerollic Camborthid	coarse loamy, mixed, mesic
Gem	Calcic Argixeroll	fine, montmorillonitic, mesic
Hankins	Pachic Ultic Argixeroll	fine, montmorillonitic, frigid
Lamonta	Abruptic Aridic Durixeroll	fine, montmorillonitic, mesic
Lickskillet	Lithic Haploxeroll	loamy skeletal, mixed, mesic
Powder	Cumulic Haploxeroll	coarse silty, mixed, mesic
Redmond	Xerollic Camborthid	fine, loamy, mixed, mesic
Ruckles	Lithic Argixeroll	loamy skeletal, mixed, frigid
Simas	Aridic Paleoxeroll	fine, montmorillonitic, mesic
Tub	Calcic Pachic Argixeroll	fine, montmorillonitic, mesic
Unclassified Units		
Rockland		
Raw sediments		

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Appendix B-2. (Continued)

Series	Subgroup	Family
Unnamed Units		
BLM-118	Calcic Pachic Argixeroll	fine, loamy, mixed, mesic
BLM-171	Xerollic Camborthid	fine, loamy, mixed, mesic
Related Series		
Gabbut	Xerollic Camborthid	
Odin	Aquic Haploxeralf	

Appendix C

Limiting Factors Associated with the Rocky Mountain Infiltrometer

There were a number of limiting factors that are inherent to the Rocky Mountain infiltrometer. The first assumes homogeneity in vegetation soils.

The second criterion, accessibility, limited site selection to those vegetation-soil units within 90 m (300 ft) of a road or trail, because the system was mounted on a vehicle or trailer and greater distances were beyond the design capabilities of the pump. Additional leeway in distance from the road was also required to allow random location of the macroplot within the vegetation-soil unit.

The third criterion required the avoidance of slopes greater than 30 percent. The difficulties in plot and sprinkler placement, the capabilities of the pump and the design limitations of the frames were the primary reasons for this limitation. The limited accessibility to areas with steep slopes usually restricted selection first.

The fourth criterion prevented the placement of sedimentation plot frames on rocky or stony soils, because of the surface soil disturbance that resulted from driving the frame into the ground. When this occurred during the placement of a nest of plots, the restricted frame was moved laterally away from the disturbed spot or the entire nest of plots was moved away from the macroplot and clear of the stony disturbed area.

The fifth criterion limited the placement of sediment plots under low overstory vegetation such as western juniper due to possible interception of the simulated rainfall, and its possible return to the plots is larger drop sizes as throughfall. The sprinkler system requires an operational clearance height of 4 m (13 ft) for the raindrops to approach terminal velocity. The growth form of juniper often restricted this placement. Nested plot frames were moved away from the macroplot and clear of the overstory on those stands which met the selection criteria.