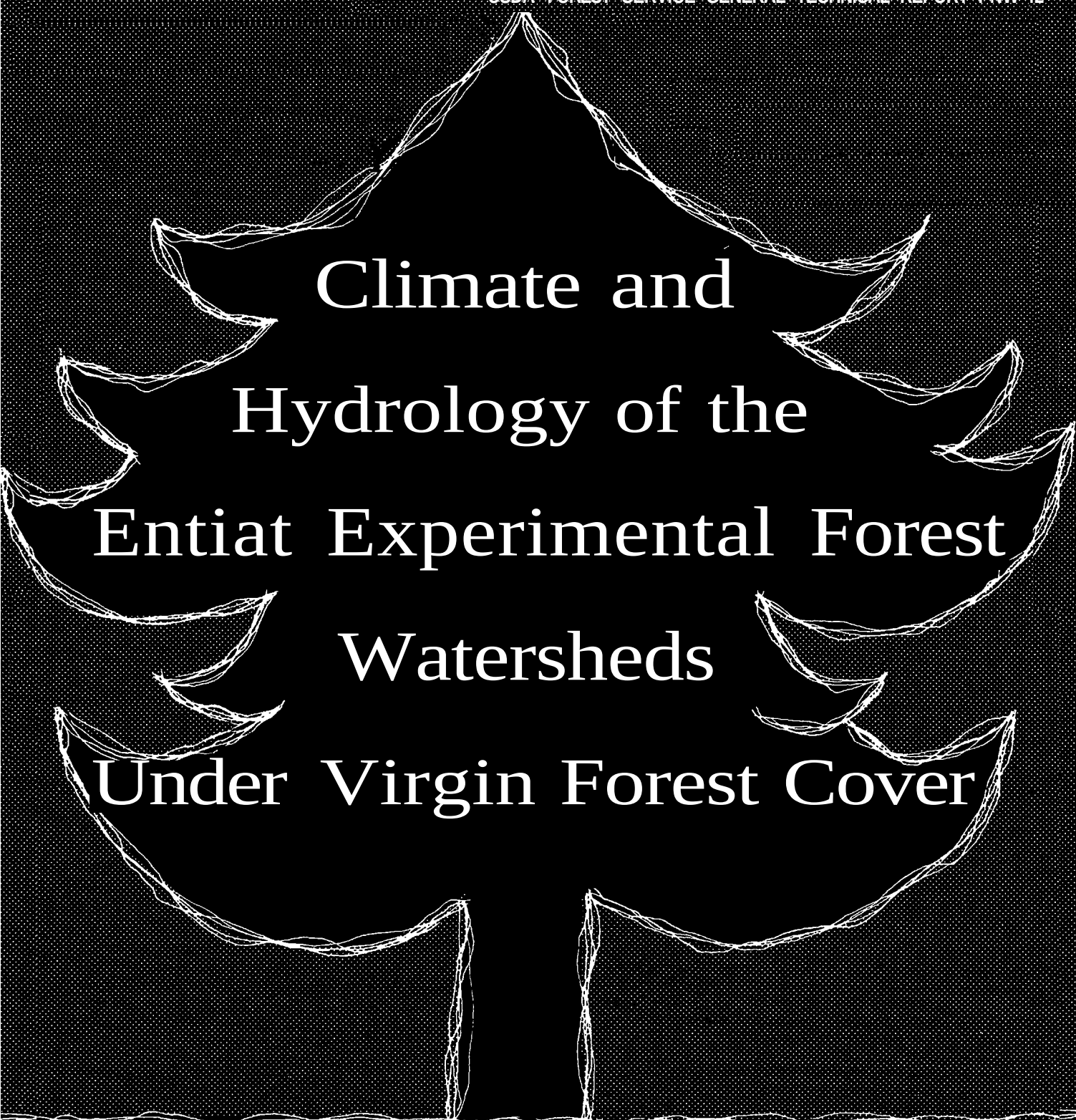




Climate and Hydrology of the Entiat Experimental Forest Watersheds Under Virgin Forest Cover

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PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
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ABSTRACT

Climatic and hydrologic measurements were made on three watersheds, each containing approximately 2 square miles (5.18 km²) of drainage area, for 9 years under natural forested conditions. This paper describes the watersheds with respect to soils and geology, morphology, vegetation, precipitation and other climatic parameters, and flow, sediment, temperature, and chemistry of streams during this period.

KEYWORDS: Watershed management, climate variation.

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Water is one of the most important natural resources of the mid-Columbia region of Washington because it supports a billion dollar economy in manufacturing, agriculture, mining, and recreation. Water in the streams originates almost exclusively as rain or snow in the forested headwater areas. The U.S. Forest Service, administrator of much of the upland watersheds, recognizes the need for a balanced research program in watershed management to insure that activities related to timber harvest and recreation do not jeopardize the quantity or quality of this water supply. The need for experimental watersheds where long-term studies can be completed is also recognized.

A search for a suitable area for watershed management research in the mid-Columbia region was started in 1949. Criteria for watershed selection included (1) a series of three or more drainages of 1 to 6 square miles (2.59 to 15.54 km²) each; (2) watersheds as nearly similar as possible in size, drainage pattern, aspect, topography, geology, soils, and cover type; (3) no disturbance by recent fire, heavy grazing, logging, or roadbuilding; and (4) reasonable access during all seasons. In 1957 after an exhaustive search, Fox, Burns, and McCree watersheds, containing 1.83, 2.18, and 1.98 square miles (4.74, 5.65, and 5.13 km²) of drainage area, respectively, were selected for calibration. Vegetation, soils, and climate of these catchments were similar to these factors on thousands of acres of forested land in north-central Washington. Therefore, results obtained from these study sites would have wide application. Instrumentation of the watersheds began in 1959.

The original plan was to measure precipitation, air temperature and humidity, streamflow, and sediment production on each watershed for several years under natural conditions, then test for changes in quantity, quality, and timing of runoff after

roadbuilding and timber harvest. Tentative objectives were to build two roughly parallel roads through McCree and Burns watersheds, study the effect of road construction on water quality for 2 years, then harvest timber from Burns watershed with a skyline system and from McCree watershed with conventional ground skidding methods such as tractors, jammers, etc. Fox watershed was to be left undisturbed to serve as a control for evaluating treatment effects.

The calibration period and timber harvest plans were nearly complete in 1970 when the entire area was burned by a wildfire caused by lightning. Since the burn, research objectives have been to evaluate the effects of wildfire and subsequent revegetation on water yield, stream temperature, stream chemistry, soil moisture, air temperature, and rates of revegetation. The objective of this paper is to describe the prefire watershed conditions with respect to location, topography, soils, vegetation, precipitation, and the patterns, temperature, and chemistry of streamflow. These data will be a useful addition to the hydrologic information collected from small, undisturbed watersheds in the United States. Also, this paper will serve as a reference, and the detailed information presented here will not need repeating in our future reports which describe postfire conditions.

LOCATION AND TOPOGRAPHY

The experimental watersheds (fig. 1) are located on the east slope of the Cascade Range in north-central Washington at latitude 47° 57' N and longitude 120° 28' W. Drainage is generally toward the southwest to the Entiat River which joins the Columbia River at Entiat, Washington. A glacier during the Wisconsin stage of the Pleistocene epoch scoured this part of the Entiat River, leaving the tributary streams as hanging valleys above the present valley floor. Consequently, the profiles of Fox, Burns, and McCree Creeks have

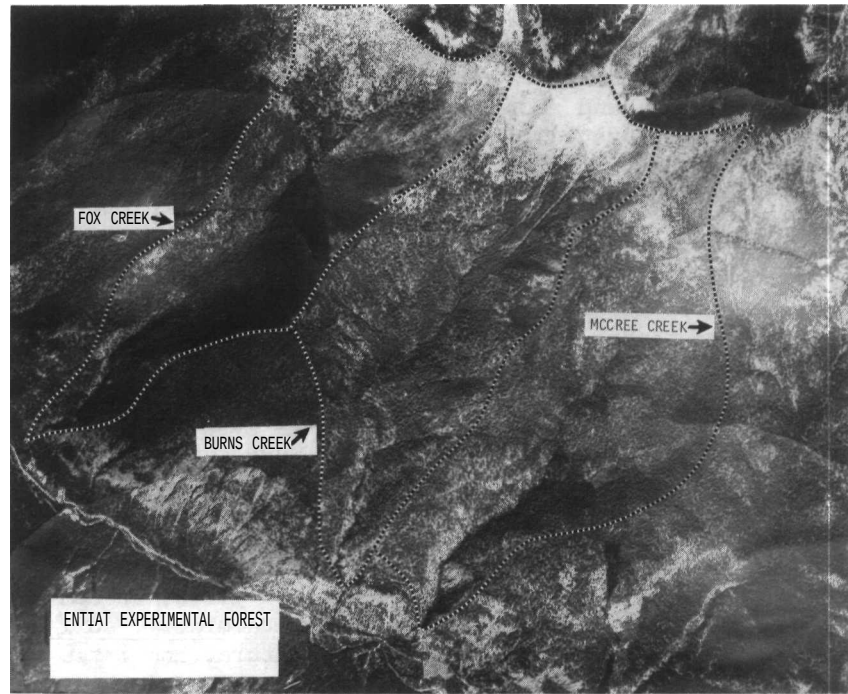


Figure 1.--Aerial mosaic of the three watersheds on the Entiat Experimental Forest.

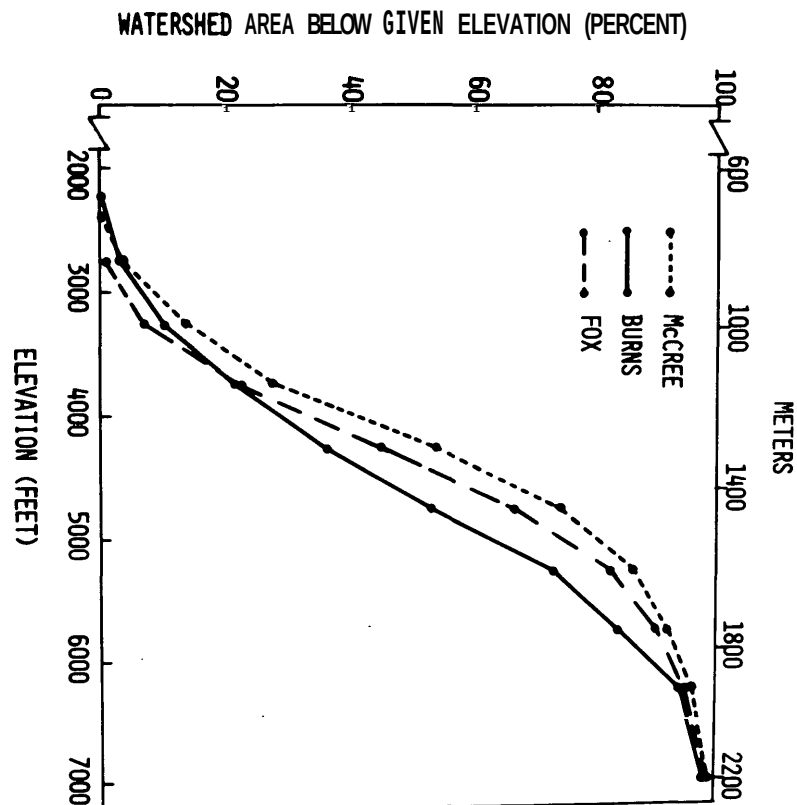


Figure 2.--Area-elevation relationships for the three experimental watersheds.

Table 1--Summary of some physical characteristics for three experimental watersheds in north-central Washington

Physical factor	McCree	Burns	Fox
mi^{-2}			
Mean elevation, ft (m)	4,420 (1 347)	4,600 (1 402)	4,900 (1 494)
Annual radiation index, ^{1/} percent	51.5	50.7	47.2

^{1/} Computed by the methods of Lee (1963) and defined by him as "the ratio between the daily total of potential insolation on that surface to the total of potential insolation which would be received on a surface that is constantly normal to the sun's rays during the possible daylight hours."

gradients of 40 to 70 percent in the glaciated area and more gentle gradients in the upper reaches. Mountain glaciers apparently did not form within the watersheds, but glacial cirques are evident in figure 1 north of the watershed divide.

Watershed elevations range from about 1,800 to 7,000 feet (549 to 2 134 m) above sea level. The mean land slope is about 50 percent, but slopes of 90 percent are common. Figure 2 illustrates the relationship between area and elevation; other physical characteristics of the watersheds are presented in table 1.

Fire scars on large trees indicate a history of periodic fires. Age of trees indicates that a fire similar to the one experienced in 1970 probably has not occurred during the past 200 years. Keen (1940) and Daubenmire and Daubenmire (1968) show fire occurring periodically from 15 to 36 years in eastern Washington, but these were principally ground fires that reduced understory fuels and scarred lower parts of the trees.

GEOLOGY AND SOILS

Bedrock throughout the watersheds consists primarily of granodiorite and quartz diorite. During the Pleistocene

period of glaciation, large amounts of fluvoglacial materials accumulated in the lower section of each drainage. Since the glacial period, much of the watersheds has been deeply covered by pumice and ash deposits, mostly originating from Glacier Peak 35 miles (56 km) to the northwest. There appear to be six different periods of volcanic deposits which presently range in depth from a few inches to more than 20 feet (6 m). There is no evidence of soil profile development in the glacial till and weathered diorite beneath the ash and pumice.

Two major soil series, both Entisols, have been identified on the watersheds, Choral soils occupy about 55 percent of the area. Rampart soils occupy about 35 percent with Rockland and rock outcrops accounting for 10 percent. The Choral soils are well drained and moderately coarse textured. Rampart soils are similar to Choral, but they occur at lower elevations and have developed under warmer climatic conditions. A description of the physical properties of a typical undisturbed Choral profile taken at the 5,000-foot (1524-m) elevation is given in table 2. Total nitrogen in the surface soil is generally below 0.10 percent. Surface soil pH is about 6.0, and cation exchange capacity is normally less than 10 meq/100 g. The major zone of root activity is 24 inches (61 cm) or less.

Table 2--Soil physical properties of a representative Choral series profile located on the Entiat Experimental Forest

Depth (cm ^{1/})	Bulk density ^{2/}	Percent moisture			Soil texture						Color and material
		0.1 bar	1.0 bar	15 bars	> 4 mm	2-4 mm	1-2 mm	1 mm-50µm	Silt, 50µm-2µm	Clay, >2µm	

^{1/}

VEGETATION

Before the fire, the area supported a mature stand of timber in which ponderosa pine (*Pinus ponderosa* Laws.) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) were the dominant species. Other overstory species included lodgepole pine (*Pinus contorta* Dougl.) , western redcedar (*Thuja plicata* Donn) , and whitebark pine (*Pinus albicaulis* Engelm.). A timber cruise in 1967 indicated volume summary:

Watershed	Total area		Timber volume	
	mi ²	km ²	Thousand bd ft ^{1/}	m ³ ^{2/}
McCree	1.98	5.13	23,368	55 113
Burns	2.18	5.65	19,363	45 668
Fox	1.83	4.74	11,563	27 271

^{1/} 1 board foot equals 1/12 cubic foot.

^{2/} 1 cubic meter equals 423.6 board feet.

Vegetation on side slopes between 1,800- and 3,000-foot (549- and 915-m) elevation consisted of an overstory of ponderosa pine with an understory of bitterbrush (*Purshia tridentata* (Pursh DC.))^{3/} and serviceberry (*Amelanchier alnifolia* Nutt.). Arrowleaf balsamroot (*Balsamorhiza sagittata* (Pursh) Nutt.), bracken fern (*Pteridium aquilinum* (L.) Kuhn.), spreading dogbane (*Apocynum androsaemifolium* L.), and bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. and Smith) were prominent herbaceous species. This zone is probably representative of the *Pinus ponderosa*/*Purshia*/*Agropyron* habitat type of Daubenmire and Daubenmire (1968). At elevations between 3,000 and 5,500 feet (915 to 1 676 m), Douglas-fir became more prominent, often occurring in almost pure stands on moister sites. Lodgepole pine normally occurred only in small, dense thickets. However, the southwest slope of Fox Creek was an almost pure stand of "doghair" lodgepole pine. Snowbrush ceanothus (*Ceanothus velutinus* Dougl.), willow (*Salix* spp.), and Sitka alder (*Alnus sinuata* (Reg.) Rydb.) were common shrubs. Half-shrubs

^{3/} Plants were identified by F. J. Hermann and Charles Feddema of the National Herbarium at Fort Collins, Colorado.

and low shrubs consisted primarily of Oregon boxwood (*Pachistima myrsinites* (Pursh) Raf.), birchleaf spiraea (*Spiraea betulifolia* Pall.), princess pine (*Chimaphila umbellata* (L.) Bart.), and kinnikinnick (*Arctostaphylos uva-ursi* (L.) Spreng.). Of the herbaceous species, pinegrass (*Calamagrostis rubescens* Buckl.), Ross sedge (*Carex rossii* Boott), spiraea, dogbane, and bracken fern were prominent. The intermediate elevations are characteristic of the *Pseudotsuga menziesii*/*Calamagrostis rubescens* habitat type described by Daubenmire and Daubenmire (1968). At elevations above 5,800 feet (1 768 m), whitebark pine was commonly encountered. A list of understory plants encountered is presented in the appendix.

SOLAR RADIATION

Solar radiation available to surfaces within the experimental watersheds as a function of slope and aspect is expressed in the radiation

index in table 1. This parameter indicates the radiation input to the watersheds compared with a slope constantly normal to the sun's rays. Variation between these values is very small, but Fox watershed receives slightly less radiation than the other two.

Daily total hemispheric radiation (sun plus sky) at **two** stations is shown in figure 3. Junior Point Lookout is located 3 miles (4.8 km) north of the Experimental Forest watersheds at 6,676-foot (2 035-m) elevation. Steliko Lookout is located **11** miles (17.7 km) south-southeast of the watersheds at 2,580-foot (786-m) elevation. **Two** features of this graph are important. Radiation input is generally greater at the higher station--31 points lie above the 1:1 line, 19 below. There were a number of days during this period (midsummer of 1963) when the more northerly and higher station (Junior Point) had radiation input reduced by cloud cover. Differences

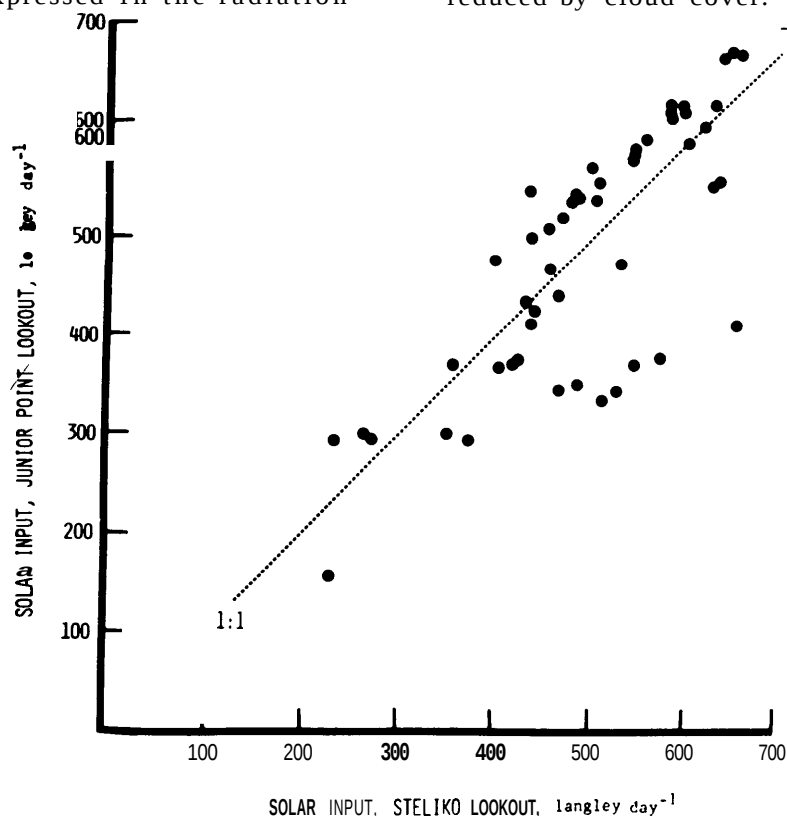


Figure 3.--Daily radiation input at **two** stations near the Experimental Forest boundary. Dashed line indicates 1:1 slope.

in elevation and variable cloud cover change receipt of the solar radiative input rapidly over short distances in mountainous terrain.

PRECIPITATION

Annual precipitation at 3,000-foot (915-m) elevation ranged from 8 to 31 inches (20.3 to 78.7 *cm*) and averaged 22.4 inches (56.9 *cm*) between 1961 and 1970 (appendix table 4). Usually, measurable precipitation falls during each month, but on the average only 14 percent of the annual total occurs from May through September. Annual precipitation and temperature are shown in figure 4. Summertime precipitation may occur as potentially high intensity convective storms of short duration. Snow accounts for about 70 percent of average annual precipitation. Precipitation increases with elevation and also from east to west (toward the Cascade crest) although the amount has not been accurately defined. The precipitation

network has been expanded, and this should help to clarify effects of elevation on amounts of precipitation.

AIR TEMPERATURE

An interesting feature of the graph of mean monthly air temperature (fig. 4) is the lag in response compared with solar heating. A lag of 1 month in temperature from the summer solstice is quite common at inland midlatitude stations. At the Burns Creek site, maximum mean monthly temperatures occur in August with the September average well above the June average. This 2-month lag of maximum monthly temperatures behind the solstice is unique compared with other stations in this area. Typical nearby mountain stations--Stevens Pass, Snoqualmie Pass, and Blewett Pass--although higher in elevation than the Burns Creek site and with deeper, longer duration snowpacks, show only a 1-month lag. Extreme sites--Mount Baker, 4,150 feet (1 265 m) and Mount Rainier (Paradise), 5,500 feet (1 676 m)--show

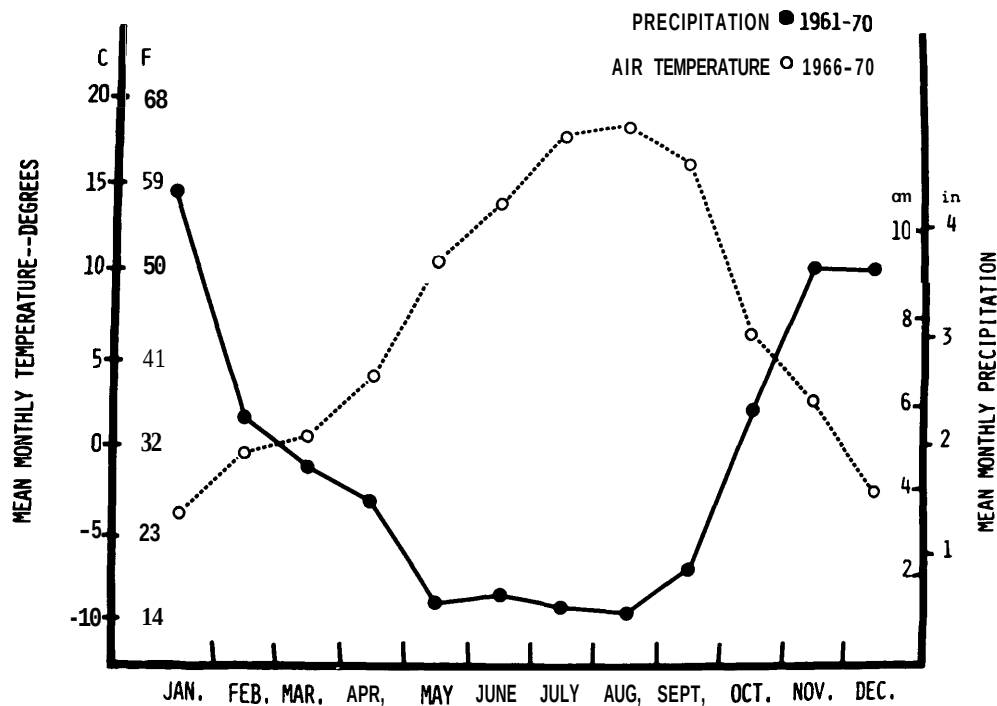


Figure 4. --Average monthly values of temperature and precipitation at 3,000-foot (915-m) elevation on Burns watershed.

a 2-month lag. Energy use in snowmelt and evaporation with local cold air drainage may delay substantially the early season rise in temperature. The record of only 4 years may not represent the long-term average condition at this site. More detailed studies of the thermal regime are underway.

Soil and plant surfaces are the active zone for the transformation of solar and infrared energy into sensible and latent heat (i.e., heating of the air and evaporating water). These energy use pathways create differences in the temperature of the active surface, differences which are a complex function of the physical characteristics, amount of cover, type of plant, age, height, etc. With an infrared thermometer and a photorecording system, measurements of the watersheds' surface temperatures were made on August 29, 1969. Measurements were taken during a 40-minute period from elevations of 200 to 300 feet (61 to 91.5 m) near the time of maximum air temperature (1330 hours). Sky conditions were clear. Of the 1,500 plus measurements taken during this flight, only midslope flight lines were selected for analysis here. Results are shown below.

	Mean surface temperature		Standard deviation		Number of photos
	$^{\circ}\text{F}$	$^{\circ}\text{C}$	$^{\circ}\text{F}$	$^{\circ}\text{C}$	
East-side McCree watershed	67.6	19.8	4.5	2.5	103
West-side McCree watershed	72.5	22.5	6.3	3.5	135
East-side Burns watershed	68.0	20.0	6.1	3.4	115
West-side Burns watershed	73.0	22.8	7.7	4.3	117
East-side Fox watershed	68.2	20.1	5.0	2.8	122
West-side Fox watershed	73.2	22.9	6.5	3.6	101

Although mean temperature in each watershed was higher on west sides, the variation between measurements was also greater. The null hypothesis of no significant difference between these aspects could not be rejected at the 0.10 probability level. Therefore, although a diversity of vegetal

types and elevations was covered, an overall similarity of surface temperatures was found between the watersheds. Comparisons will be made with surface temperatures at other seasons and after vegetative manipulation of these watersheds.

STREAMFLOW

Streamflow was measured with sharp-crested, 120° , V-notch weirs and instruments to continuously record water levels. Streamflow patterns are typical of areas in which precipitation is mostly in the form of snow. Snowmelt produces peak flow rates in May or June with a gradual decline to the annual low and fairly steady rate in September (fig. 5). Because flow is usually minimum in September, the water year is defined as extending from October 1 to September 30. Monthly water yield data from the three drainages between 1962 and 1970 are presented in appendix table 5.

Flow duration curves give a clear picture of the flow characteristics of a stream by indicating the percentage of time a selected discharge rate was equaled or exceeded during the period of interest. These curves were computed from mean daily discharge for each watershed during the period 1962-70 (fig. 6). Flow rates from McCree watershed were greater than $0.45 \text{ ft}^3 \text{ sec}^{-1}$ ($12.7 \text{ liter sec}^{-1}$) during 50 percent of the time. Comparable values for Fox and Burns watersheds were 0.68 and $0.73 \text{ ft}^3 \text{ sec}^{-1}$ (19.2 and $20.7 \text{ liter sec}^{-1}$), respectively. Minimum rates recorded were 0.16, 0.37, and $0.38 \text{ ft}^3 \text{ sec}^{-1}$ (4.5, 10.5, and $10.8 \text{ liter sec}^{-1}$), respectively, from McCree, Fox, and Burns watersheds. The lower flow rates from McCree watershed may be partly caused by the slightly higher radiation index (table 1) and by lower rainfall amounts compared with the other two watersheds. Also, the higher timber volume comprised largely of Douglas-fir on McCree watershed may have had an effect. For example, Lopushinsky and Klock (1974) found that the transpiration rates of Douglas-fir seedlings were less affected by moderate soil drying than

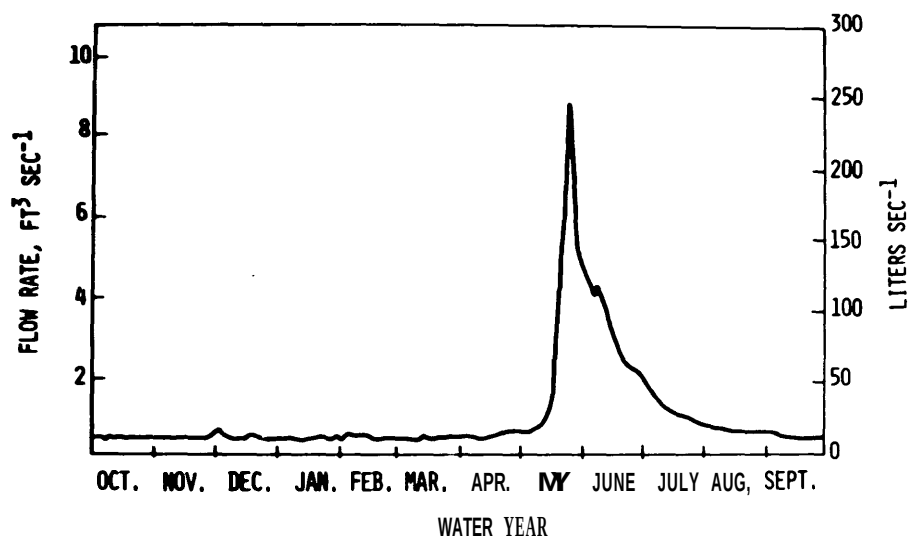


Figure 5.--The 1966-67 hydrograph from Burns Creek.

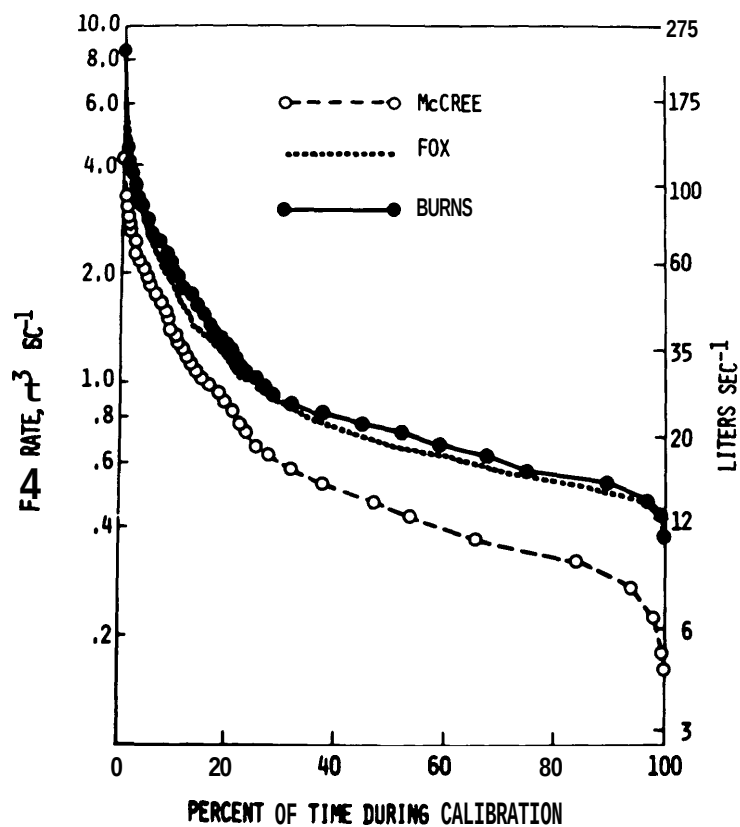


Figure 6.--Flow duration curves for the three watersheds.

transpiration rates of ponderosa pine and lodgepole pine. Also Helvey (1974), in a summary of rainfall interception by conifers, concluded that interception **loss** from Douglas-fir is greater than from the pine species.

Morisawa (1968) stated that the shape of the flow duration curve gives a clue to the water yield characteristics of the drainage basin; i.e., "if the curve is fairly flat, there is substantial storage, either on the surface or **as** ground water which tends to equalize the flow." The curves in figure 6 for the three watersheds are very flat compared with curves for other areas of comparable size but with different precipitation forms or amounts. For example, the ratio of maximum to minimum flow rates on these watersheds ranges from 23 to 37. Comparable values for 150- to 250-acre (60.7- to 101.2-ha) watersheds on the western slopes of the Oregon Cascade Range are about 1,800 (Rothacher et al. 1967). The relatively flat curves in

figure 6 reflect a combination of factors including moisture storage on the surface as snow during the winter months, slow rates of melting in the spring because of gradual warmup, deep soils along the streams which release water slowly during dry **summer** months, and the lack of large rainfall events common to the west slope of the Cascade Range.

Pronounced diurnal fluctuations in flow rates are evident during spring runoff because of fluctuating snowmelt rates and during **summer** months when daytime evapotranspiration demands are high (fig. 7). Daily peaks in **summer** months occur during early morning hours following the daily minimum transpiration demand. **As** transpiration losses increase during the day, flow rates decrease and reach a minimum value about sundown. Flow patterns are reversed during spring snowmelt; i.e., daily maxima occur at night and minima at midday just before appreciable snowmelt begins.

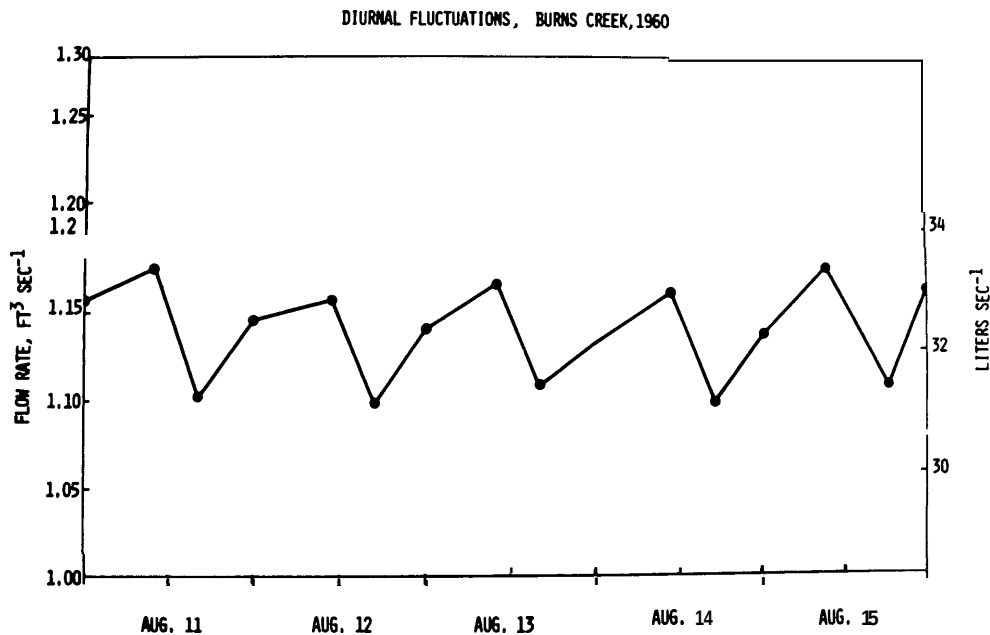


Figure 7.--Diurnal fluctuations of runoff from Burns Creek during midsummer.

WATER TEMPERATURE

Water temperature recorders were installed at each stream gaging station in 1968. As expected, water temperature trends follow closely the annual trend of air temperature during summer months. The streams are snow covered during winter months and air temperature has little or no influence on stream temperature (fig. 8). Daily maximum water temperatures during December to February 1970 averaged about 38°F (3.3°C) compared with 30°F (-1.1°C) for air temperature. Maximum water temperatures of $50\text{--}52^{\circ}\text{F}$ ($10\text{--}11^{\circ}\text{C}$) occur in July and August when maximum air temperature is near 90°F (32.2°C).

SEDIMENTATION

The watersheds were stable under natural conditions and sediment trapped by weir dams was extremely low. In fact, weir ponds on McCree and Burns watersheds did not require cleaning between 1961 and 1970. Fox Creek flows

through an area where side slopes are oversteepened and sparsely vegetated between 2,800- and 3,000-foot (845- and 915-m) elevations. Soil material dry-raveled into the stream channel during the summer months, and spring runoff carried it to the weir pond where it was trapped. Annual bedload from Fox Creek ranged from 5 to 18 tons (4.5 to 16.3 metric tons) and averaged 12 tons (10.9 metric tons) between 1966 and 1970.

Unfortunately, there are no data for suspended sediment production. This is a serious oversight because one main objective of the research program was to test for changes in total sediment production after roadbuilding and timber harvest. Some recent data from Lake Creek, located immediately west of Fox Creek and still undisturbed, gives a clue to the suspended sediment amounts from the experimental watersheds. The values from Lake Creek during the 1975 spring runoff were always less than 6 milligrams per liter--most of the

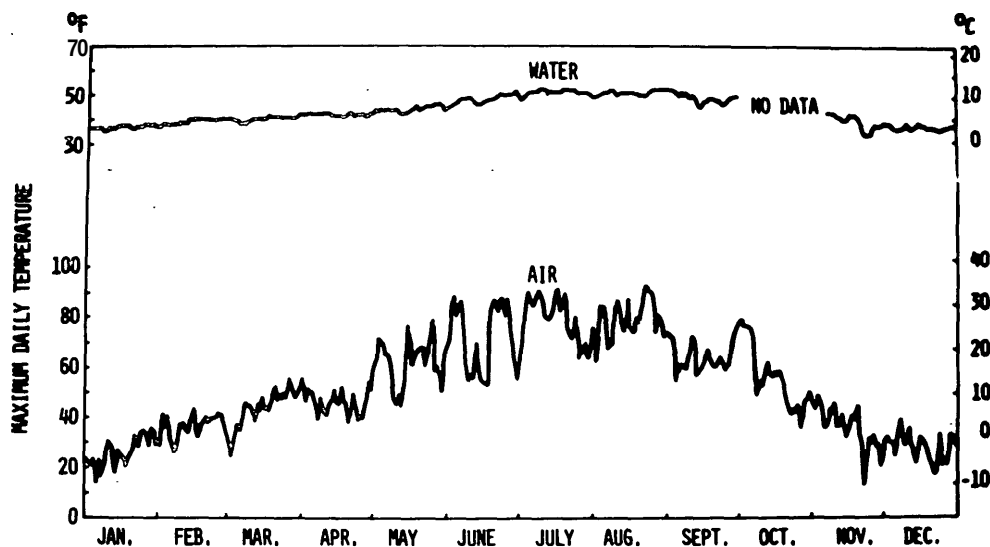


Figure 8.--Plottings of air temperature and water temperature on Burns Creek.

samples contained only 1 milligram per liter. Applying these values to the measured runoff from the experimental watersheds indicates an **annual** yield of less than 10 pounds per acre (11.2 kg per ha) per year.

CHEMISTRY OF STREAMFLOW

Measurements of dissolved chemicals and water chemistry were initiated in April 1970. Although the period of record before the fire is short, results indicate chemical stability of the watersheds under forested conditions. The most salient feature of water chemistry measurements was the low concentration of nitrogenous constituents (table 3). Results for nitrate nitrogen are a contrast to the concentrations observed at the mouth of the Entiat River where the levels ranged from 0.1 to 0.7 mg/liter (U.S. Geological Survey 1965). Values for concentrations of Ca, Mg, Na, K, electrical conductivity, pH, and total alkalinity were similar to those observed by the U.S. Geological Survey (1965) at the mouth of the Entiat River.

DISCUSSION AND CONCLUSIONS

The Entiat Experimental Forest was dedicated for the purpose of studying the effects of forest management on the water resource in the 20- to 30-inch (50.8- to 76.2-cm) annual precipitation zone of north-central Washington. Unfortunately, wildfire swept the entire area just as the calibration period was being completed; and the original objectives could not be fulfilled. Although the fire was a serious **loss** to planned watershed management research, it has provided **a** unique opportunity in the Northwest to study the effects of complete deforestation by fire on the quantity and quality of runoff and on other watershed values. This opportunity was possible only because the calibration data were available for comparison with postfire data.

The calibration data presented in this paper indicate that the watersheds were stable under forested conditions and that streamflow was extremely pure chemically. Quantity, quality, and timing of streamflow from other forested

Table 3--*Chemistry* of streams on the Entiat Experimental Forest, April–August 1970

Constituents or characteristics	Fox Creek		Bums Creek		McCree Creek	
NO ³ -N (mg/liter)	.006	.016	--	.003	.001	.004
Urea N (mg/liter)	0	0	.005	.025	.004	.010
Na (mg/liter)	2.5	2.8	2.5	3.1	3.0	3.7
K (mg/liter)	1.2	1.3	1.0	1.3	1.2	1.4
Mg (mg/liter)	1.1	1.1	1.2	1.5	1.6	2.1
Ca (mg/liter)	4.7	12.4	6.7	8.5	9.0	11.7
Total alkalinity (meq/liter)	.58	.68	.65	.89	.57	.66
Electrical conductivity (micro mhos/cm) ^{2/}	47	66	41	54	54	70
pH	7.1	7.5	7.2	7.6	7.1	7.6

^{1/} 1 mg liter⁻¹ = 2.72 pounds (acre-foot)⁻¹

^{2/} Taken from 1968 to 1970 (April-August).

areas in north-central Washington with similar geology and soils and comparable amounts of precipitation should be similar to the values presented in this paper.

POSTFIRE RESEARCH PROGRAM

Although the main objective of this paper is to describe the watersheds under prefire conditions, some readers may be interested in postfire activities. **As** of June 1, 1975, 12 papers dealing with nutrient cycling, water chemistry, yield, and temperature changes, vegetation dynamics, and economic impacts had been published, and 3 others were in press (see appendix). **Also**, a preliminary model was developed by J. Paul Riley (Utah State University) for

predicting daily runoff from inputs of precipitation, air temperature, and ground water conditions.

Watersheds of the Entiat Experimental Forest still possess considerable research value for enhancing our knowledge of dynamics of the recovery process after wildfire in north-central Washington. **Also**, with an extensive prefire and postfire data base, the watersheds can serve in the future as a natural setting for a socioeconomic analysis of the consequences of various resource management alternatives. Thus, we are continuing to monitor water yield and chemistry, sediment production, soil moisture, precipitation, air temperature, and vegetation dynamics.

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APPENDIX

LIST OF UNDERSTORY PLANTS OF THE ENTIAT EXPERIMENTAL FOREST

Shrubs

Ceanothus velutinus Dougl.
Salix spp.
Alnus sinuata (Reg.) Rydb.
Spiraea betulifolia Pall.
Pachistima myrsinites (Pursh) Raf.
Arctostaphylos uva-ursi (L.) Spreng.
Chimaphila umbellata (L.) Bart.
Vaccinium spp.
Purshia tridentata (Pursh) DC.
Prunus emarginata (Dougl.) Walp.
Rubus spp.
Amelanchier alnifolia Nutt.
Ribes spp.

Grasses and Grasslike

Calamagrostis rubescens Buckl.
Carex rossii Boott
Poa sandbergii Vasey
Agropyron spicatum (Pursh) Scribn. & Smith
Bromus carinatus H. & A.
Oryzopsis exigua Thurb.
Stipa occidentalis Thurb.
Bromus tectorum L.

(Continued)

Forbs

Lomatium brandegei (Could. & Rose) Macbr.
Lupinus sulphureus Dougl.
Calochortus lyallii Baker
Montia perfoliata (Donn) Howell
Sphaeralcea spp.
Anaphalis margaritacea (L.) B. & H.
Luina nardosmia (Gray) Cronq.
Senecio integerrimus Nutt.
Smilacina racemosa (L.) Desf.
Sedum stenopetalum Pursh
Erythronium spp.
Hydrophyllum capitatum Dougl.
Eriogonum spp. Michx.
Allium spp.
Clarkia rhomboidea Dougl.
Pteridium aquilinum (L.) Kuhn.
Apocynum androsaemifolium L.
Epilobium angustifolium L.
E. paniculatum Nutt.
Collinsia parviflora Lindl.
Cryptantha simulans Greene
Hieracium cynoglossoides Arv.-Touv.
H. albiflorum Hook.
Mentzelia dispersa Wats.
Gayophytum nutallii T. & G.
Achillea millefolium L.
Collomia grandiflora Dougl.
Collomia tinctoria Kell.
Balsamorhiza sagittata (Pursh) Nutt.
Phacelia hastata Dougl.
Zigadenus paniculatus (Nutt.) Wats.
Arnica cordifolia Hook.
Polygonum majus (Meisn.) Piper
Arenaria macrophylla Hook.
Erysimum asperum (Nutt.) DC.
Conyza canadensis (L.) Cronq.
Clematis columbiana var. *dissecta* Hitchc.

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Table 4--Monthly precipitation at 3,000 feet (915 m), near Burns Creek weir
(In inches^{1/})

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1961 ^{2/}	1.6	6.4	1.9	3.3	5.0	3.9	1.0	1.3	0.2	1.2	0.4	1.7	27.9
62	1.4	3.0	3.0	(3/)	(3/)	3.0	2.7	1.3	.4	(3/)	.9	(3/)	--
63	4.0	5.0	2.9	2.1	3.8	1.0	4.7	.7	.2	1.3	1.0	0.7	27.4
64	1.8	7.2	2.7	6.4	.6	2.0	.4	.1	1.5	.1	.6	2.3	25.7
65	.3	3.7	6.0	5.6	2.3	.6	1.8	.4	.5	1.0	1.2	.4	23.8
66	.5	2.0	3.1	5.5	.9	1.8	0	.6	1.3	1.1	0	.2	17.0
67	2.0	3.8	3.0	1.0	.8	1.9	2.4	.2	.8	0	0	.3	16.2
68	9.5	1.9	4.2	5.8	3.6	1.6	.3	.7	.6	0	.8	1.8	30.8
69	1.9	3.1	7.6	5.6	2.5	1.5	1.0	.4	.8	.1	0	.4	24.9
70	.3	.5	2.2	2.8	.7	.6	.5	0	0	.1	0	.1	7.8
Average	2.33	3.66	3.66	4.23	2.24	1.79	1.48	.57	.63	.54	.49	.88	22.4

^{1/} 1 inch = 2.54 cm.

^{2/} Water year 1961 extends from October 1960 to September 1961, etc.

^{3/} Missing data.

Table 5--Streamflow from three experimental watersheds on the Entiat Experimental Forest, 1962-70
(In inches^{1/})

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
BURNS CREEK													
1962	0.40	0.37	0.38	0.37	0.36	0.40	1.02	0.75	0.65	0.43	0.35	0.29	5.77
1963	.29	.31	.36	.37	.33	.45	.43	1.25	.80	.44	.33	.28	5.64
1964	.27	.26	.27	.28	.26	.29	.45	1.37	1.07	.50	.34	.28	5.64
1965	.27	.26	.27	.26	.28	.47	.92	1.50	.99	.51	.37	.31	6.41
1966	.29	.27	.28	.27	.24	.30	.82	.97	.48	.36	.28	.23	4.79
1967	.22	.23	.26	.24	.24	.26	.28	1.84	1.55	.66	.38	.29	6.45
1968	.30	.35	.38	.37	.58	.89	.82	1.41	.82	.51	.39	.34	7.16
1969	.35	.32	.30	.21	.25	.34	.95	2.37	1.04	.58	.43	.36	7.50
1970	.35	.32	.33	.31	.29	.38	.39	1.26	.74	.40	.30	.27	5.34
Average	.304	.299	.314	.298	.314	.420	.675	1.413	.904	.488	.352	.294	6.08
FOX CREEK													
1962	.44	.41	.40	.41	.43	.39	.59	.77	.83	.54	.40	.31	5.90
1963	.33	.37	.36	.32	.33	.37	.43	.99	1.14	.62	.42	.33	6.01
1964	.32	.32	.31	.30	.28	.33	.37	.90	1.49	.74	.47	.36	6.19
1965	.33	.31	.31	.32	.35	.37	.60	1.50	1.46	.71	.47	.37	7.10
1966	.33	.32	.32	.30	.27	.36	.44	1.01	.66	.45	.32	.25	5.03
1967	.26	.27	.31	.29	.27	.28	.29	1.42	2.44	.93	.50	.36	7.62
1968	.40	.36	.39	.44	.59	.81	.73	1.93	1.45	.74	.57	.48	8.89
1969	.46	.46	.43	.35	.30	.48	.78	2.75	1.69	.92	.65	.54	9.81
1970	.47	.41	.39	.37	.34	.41	.39	.88	.99	.57	.38	.34	5.94
Average	.371	.359	.358	.344	.351	.422	.513	1.350	1.350	.691	.464	.371	6.94
MCCREE CREEK													
1962	.28	.27	.27	.31	.30	.29	.75	.60	.51	.26	.20	.16	4.20
1963	.21	.27	.29	.25	.32	.33	.38	.95	.52	.25	.18	.14	4.09
1964	.17	.19	.19	.20	.22	.30	.43	1.00	.87	.26	.18	.16	4.17
1965	.17	.18	.19	.24	.33	.43	.81	1.21	.71	.28	.20	.17	4.92
1966	.17	.19	.18	.18	.17	.30	.60	.89	.32	.19	.12	.10	3.41
1967	.13	.16	.21	.19	.23	.21	.26	1.34	1.23	.30	.16	.12	4.54
1968	.20	.20	.23	.39	.49	.72	.55	1.21	.62	.28	.22	.18	5.29
1969	.21	.20	.23	.22	.21	.47	.87	1.48	.40	.25	.34	.26	5.14
1970	.21	.20	.20	.28	.24	.28	.29	.96	.48	.17	.13	.23	3.67
Average	.194	.207	.221	.251	.279	.370	.549	1.071	.629	.249	.192	.169	4.38

^{1/} 1 inch = 2.54 cm.

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

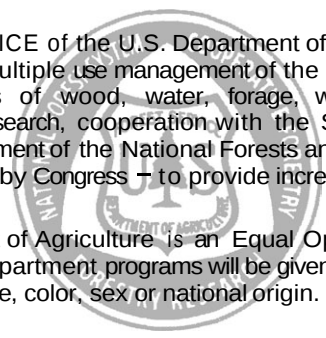
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2. Developing and evaluating alternative methods and levels of resource management.
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