Hydrologic Regimes of Forested Areas in the Beaver Creek Watershed

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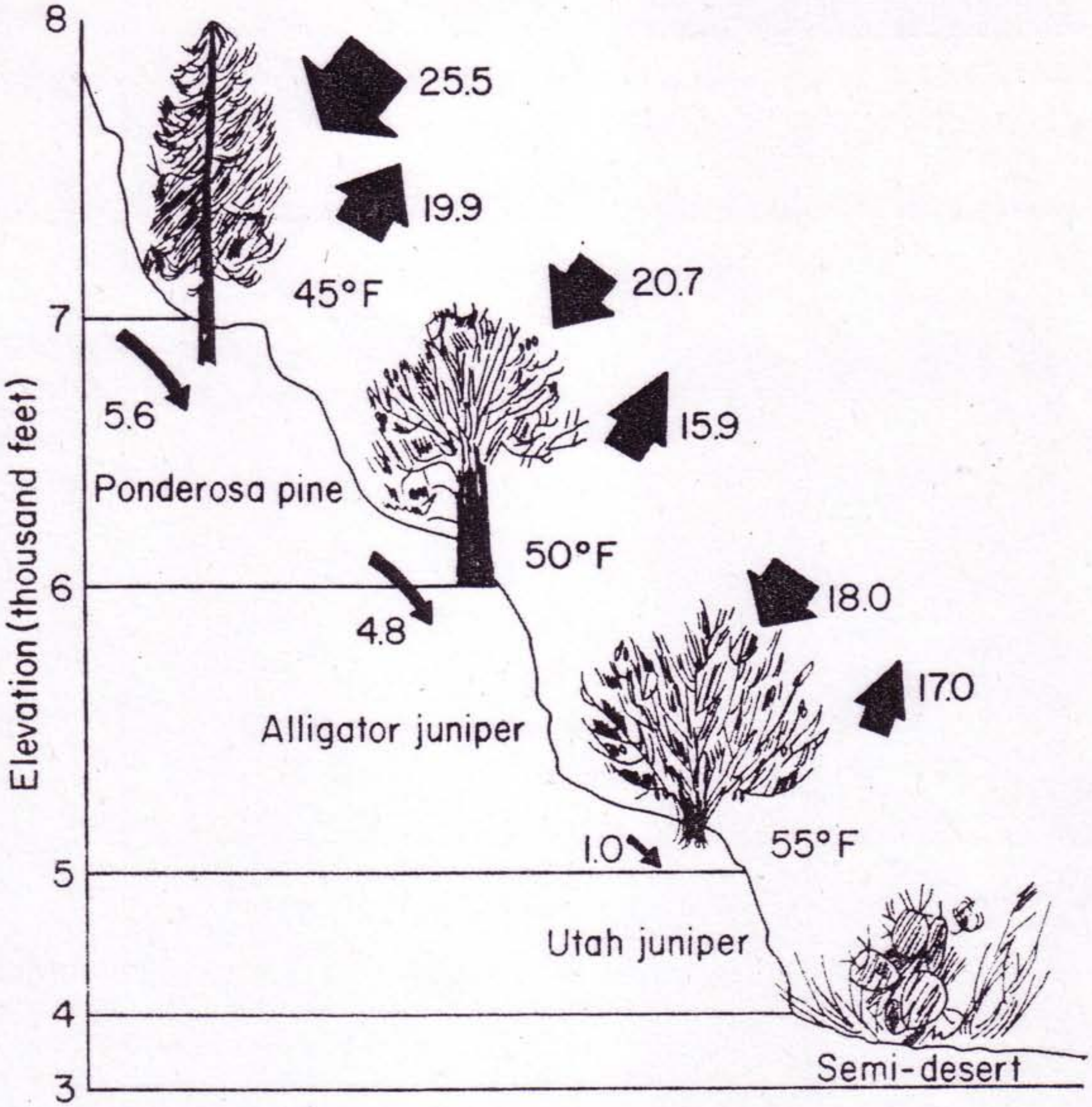

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Abstract

The hydrologic regimes of watersheds in the Utah and alligator juniper woodland and ponderosa pine forest type on volcanic-derived soils along the Mogollon Rim in north-central Arizona are described. Winter precipitation is shown to be most important to the streamflow regimes in this area. The data indicate that the best opportunity for increasing water yield by vegetation manipulation is in the ponderosa pine type. Mean annual peak discharges are higher in the two juniper vegetation types and are more frequent in the summer than those occurring in the pine type.

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Management Implications

Winter precipitation is the precipitation which is most important to the streamflow regimes along the Mogollon Rim in Arizona. The mean peak water equivalent of the snowpack in the ponderosa pine type is 4 inches (10 cm). Vegetation manipulation can affect snow accumulation and melt and evapotranspiration. Consequently, it can influence the major portion of annual streamflow, which is produced from the melting snow. However, longterm potential increases in water yield by vegetation manipulation are limited by the relatively small accumulation of snow.

Summer precipitation occurs at a time of high evaporation stress and high moisture demand by vegetation. The generally small summer storm events produce little water yield or flooding, even from storms with recurrence intervals of 25 and 50 years.

The inherently low water yield (10% of mean winter precipitation) from untreated Utah juniper watersheds on volcanic-derived soils limits this vegetation type from significantly increasing water yields. The naturally high water yield (37% of mean winter precipitation) from the alligator juniper watersheds and their characteristic low vegetation density, sparse litter cover, and soil type also limits the use of vegetation manipulation in this type. Water yield from the ponderosa pine type (33% of mean winter precipitation) has been shown to be responsive to vegetation manipulation.

Average annual peak discharges are characteristically higher in the two juniper vegetation types than in the pine type because of their soil type, vegetation density, and sparse litter cover. Annual peak discharges are also more frequent in the summer season from the juniper watersheds. Mean annual peak discharges of 117, 112, and 90 $ft^3 \cdot s^{-1} \cdot mi^{-2}$ (1.3, 1.2, and 1.0 $m^3 \cdot s^{-1} \cdot km^{-2}$) from the Utah and alligator juniper and pine type, respectively, do not adequately characterize the flood hazard from these untreated vegetation types. A few large flood events have skewed the distributions of the annual peak flows. Annual peak discharges that have been equalled or exceeded 50% of the time in the Utah and alligator juniper and pine types, respectively, are 32, 74, and 44 $ft^3 \cdot s^{-1} \cdot mi^{-2}$ (0.4, 0.8, and 0.5 $m^3 \cdot s^{-1} \cdot km^{-2}$).

Introduction

Demands for water from Arizona's National Forests continue to increase even as public demands for timber, range, and recreational uses are increasing. Although it is impossible to maximize all resource products and land uses from the same area, there are opportunities for managing forest land for an optimal mix of outputs determined by economic and environmental analyses. However, to manage our forest lands effectively, land managers first need baseline information on how watersheds behave under their natural conditions as well as how they respond to various types of management manipulations.

The Salt-Verde River Basin, along Arizona's Mogollon Rim, is the state's major water production area (fig. 1). Ponderosa pine forests and pinyon-juniper woodlands occupy nearly 50% of this watershed. The ponderosa pine type yields nearly one-half of the total runoff in the basin and the pinyon-juniper woodland yields approximately 10% (Barr 1956).

In the mid-1950's, the Forest Service initiated a number of watershed management studies to determine the feasibility of increasing water yields from the different vegetation types in the Salt-Verde Basin (Brown et al. 1974). The 275,000-acre (111,375-ha) Beaver Creek watershed was chosen to represent the pinyon-juniper and ponderosa pine types on volcanic soils along the

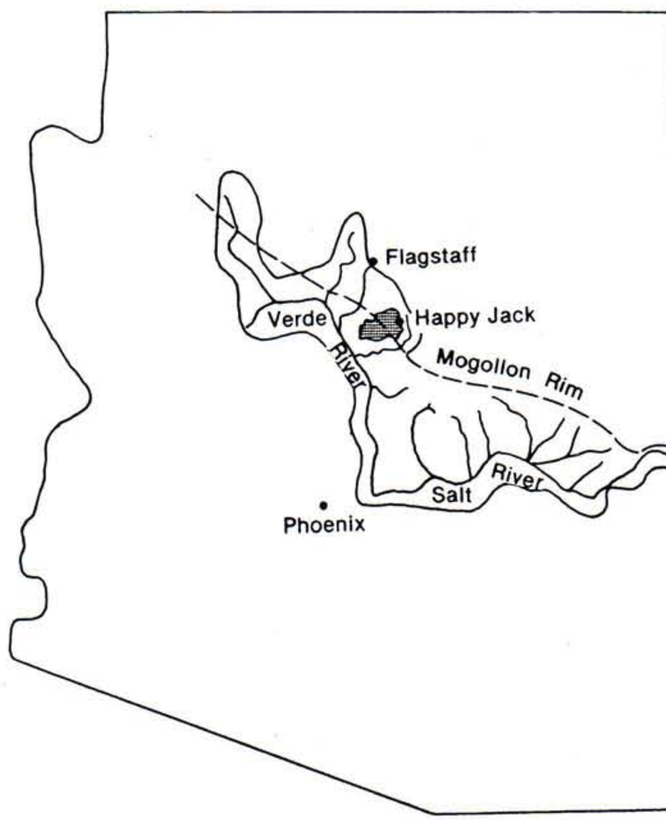


Figure 1.—Location of the Salt-Verde Basin and Mogollon Rim in Arizona. The Beaver Creek watershed is shaded.

Mogollon Rim. Because 57% of the ponderosa pine forest in the Salt-Verde Basin is on volcanic soils (the remaining 43% is on sedimentary parent material), knowledge of the hydrology on Beaver Creek can provide useful baseline data for land managers. This hydrologic information can also help provide an understanding of the hydrology of other naturally vegetated watersheds on volcanic soils along the Mogollon Rim. The intent of this paper is to present an analysis of research concerning the hydrologic regimes of the natural woodland and forested areas on Beaver Creek. The information is based on 22 years of research.

Study Area

The Beaver Creek Experimental area is in the Colorado Plateau physiographic province within the Mogollon Slope.[2] The regional dip of the Mogollon Slope is northeast; however, a major flexure north of the Beaver Creek Watershed (the Mormon Mountain anticline) reverses the regional dip in the Beaver Creek area.[3] The drainage is situated across the Mogollon Rim, which separates the Colorado Plateau and the Verde Valley.

The Beaver Creek drainage ranges in elevation from 3,100 to 8,000 feet (945 to 2,438 m) and contains four vegetative types: semidesert, Utah juniper (*Juniperus osteosperma* (Torr.) Little), alligator juniper (*J. deppeana* Steud.), and ponderosa pine (*Pinus ponderosa* Laws.) (fig. 2). Soils are derived from parent materials

[2] *Rush, R. W., and D. Smouse. 1968. Geological investigations of experimental drainage basins 15-18 and Bar-M Canyon, Beaver Creek Watershed, Coconino County, Arizona. Rocky Mountain Forest and Range Experiment Station, Flagstaff, Ariz. (unpublished report).*

[3] *Rush, R. W. 1965. Report of geological investigations of six experimental drainage basins, Beaver Creek Watershed, Yavapai County, Arizona. Rocky Mountain Forest and Range Experiment Station, Flagstaff, Ariz. (unpublished report).*

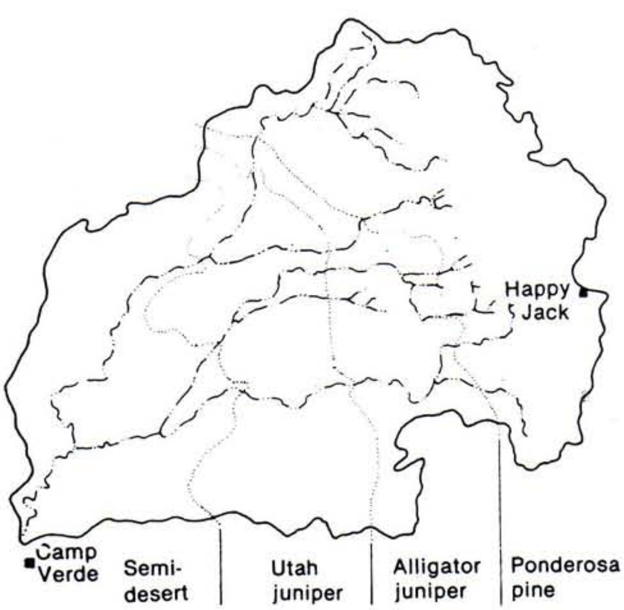


Figure 2.—The Beaver Creek Watershed.

of sandstone and limestone below the 5,000-foot (1,524-m) elevation and from basalt and volcanic cinders above. All experimental watersheds are above the 5,000-foot (1,524-m) elevation, and their soils range from clay to clay loams averaging 2.5 feet (0.7 m) in depth (Williams and Anderson 1967). Soils developed on these volcanic surfaces are generally dark in color, usually red, and have little free silica. They often have low permeability rates which restrict water infiltration and percolation.

Volcanic parent material covers the Beaver Creek area at depths from zero at the lower elevations to an estimated 1000 feet (305 m) near some of the cinder cones in the area.[4] The average thickness is believed to be approximately 500 feet (152 m), based on the projected position of the erosion surface of the Kaibab Formation on which the volcanics were deposited.[3]

The sedimentary rocks below the volcanic cover are porous and permeable because of their origin and the abundant fracture systems developed in them. Water that penetrates the volcanic mantle may be expected to continue through the sedimentary beds to the regional water table, estimated to be between 1,000 and 2,000 feet (305 and 610 m) below the surface.[3]

Of the rock types exposed on Beaver Creek, the basaltic and andesitic lavas are the least porous and permeable. When unfractured, they are essentially impervious to water. The cinder deposits are highly porous even when cemented. Water falling on the cinder cones percolates downward and produces very little surface stormflow. However, because the cones are built upon a lava base, the permeability of this base determines whether the water continues downward to the regional water table or seeps out along the base of the pyroclastic material.

The general topography of the Beaver Creek area has developed as the result of outpouring of successive lava sheets that are inclined towards the Verde Valley.[4] The slope-controlled distribution of streams has produced a subparallel drainage system of numerous, closely spaced streams.

In their untreated condition, the vegetation density of the Utah juniper averages 60 square feet per acre (14 m^2/ha) of basal area; basal areas for the alligator juniper and ponderosa pine are 20 and 125 square feet per acre (5 and 29 m^2/ha), respectively.[5]

Overland flow results from precipitation which does not infiltrate or pond in small soil surface depressions, but moves downhill over the soil surface (Storey et al. 1964). Overland flow, if of sufficient quantity, is an important element in the formation of flood peaks (Linsley et al. 1958). Forest basins typically have permeable soils and relatively large soil water storage capacity that result in sustained flow and a relatively small

[4] *Beus, S. S., R. W. Rush, and D. Smouse. 1966. Geologic investigation of experimental drainage basins, 7-14, Beaver Creek Watershed, Coconino County, Ariz. Rocky Mountain Forest and Range Experiment Station, Flagstaff, Ariz. (unpublished report).*

[5] *Ffolliott, Peter F. Overstory inventories of the vegetation types on the Beaver Creek Watershed Evaluation Project. Office Reports. Rocky Mountain Forest and Range Experiment Station, Flagstaff, Ariz.*

ratio between floodflow and mean flow. Under typical forest conditions (except those areas where logging, grazing or fire has exposed mineral soil), overland flow is virtually absent (Lull and Reinhart 1972; Hewlett and Hibbert 1967).

The pinyon-juniper woodland type is on the Springerville soil series, which has a predominately clay texture. The infiltration rate for this series ranges from 0.8 to 2.5 inches (2.0 to 6.4 cm) per hour with a permeability rate of less than 0.05 inch (0.1 cm) per hour. Water storage capacity for this soil series is over 18 inches (46 cm).

The Brolliar soil series comprises about 90% of the area in the ponderosa pine forest type. The infiltration rate for this series ranges from 0.8 to 2.5 inches (2.0 to 6.4 cm) per hour, and it has a permeability rate that ranges from 0.05 to 0.2 inch (0.1 to 0.5 cm) per hour. Water storage capacity is between 6 and 18 inches (15.2 to 45.7 cm). The remaining 10% of the area is composed of the Siesta-Sponseller soil series, which has the same ranges of infiltration and permeability rates as the Brolliar soil series. Water storage capacity is over 18 inches (45.7 cm). When an upper soil horizon is thin and the permeability rate of the next lower soil horizon is limited, soil saturation of the upper soil horizon is rapid (Betson and Marius 1969). Such an area then becomes a source of streamflow, producing either surface or subsurface flow.

Watersheds, such as on Beaver Creek, with soils of low permeability and small soil water storage have high ratios of peak discharge to mean flow and often zero flow between streamflow events. Streamflow typically stops shortly after the end of rainfall or snowmelt, even after precipitation events that have recurrence intervals of 100 years.

Stream gages were installed in the late 1950's and early 1960's within the Beaver Creek drainage to establish 20 experimental watersheds ranging in size from 66 to 16,000 acres (27 to 6,480 ha) (fig. 3). Fourteen of the watersheds are in the ponderosa pine type, and six are in the pinyon-juniper type. The study area is discussed in detail in Brown et al. (1974) and Clary et al. (1974). The results of this study are based on measurements from 1958 through 1979.

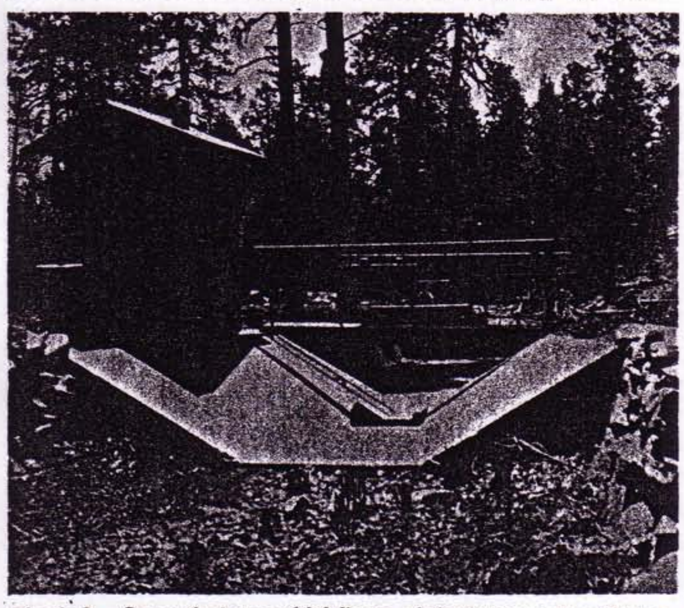


Figure 3.—Concrete trapezoidal flume of the type used on Watersheds 1-18 on Beaver Creek.

Hydrologic Regimes

General Characterististics

The Beaver Creek watershed is in the plateau climatic region of Arizona. Two major precipitation seasons characterize this region. The most important is the winter season from October through April (fig. 4). Winter precipitation accounts for over 60% of the annual precipitation. Most of the remaining precipitation falls during July, August, and September.

Over a period of 22 years (1958-79), mean annual precipitation on Beaver Creek increased with elevation. Precipitation at the lower elevation of 3,180 feet (969 m) averages 11.70 inches (29.7 cm), increasing 3.3 inches (8.4 cm) for every 1,000-foot (305 m) increase in elevation along the axis of the watershed perpendicular to the Mogollon Rim.

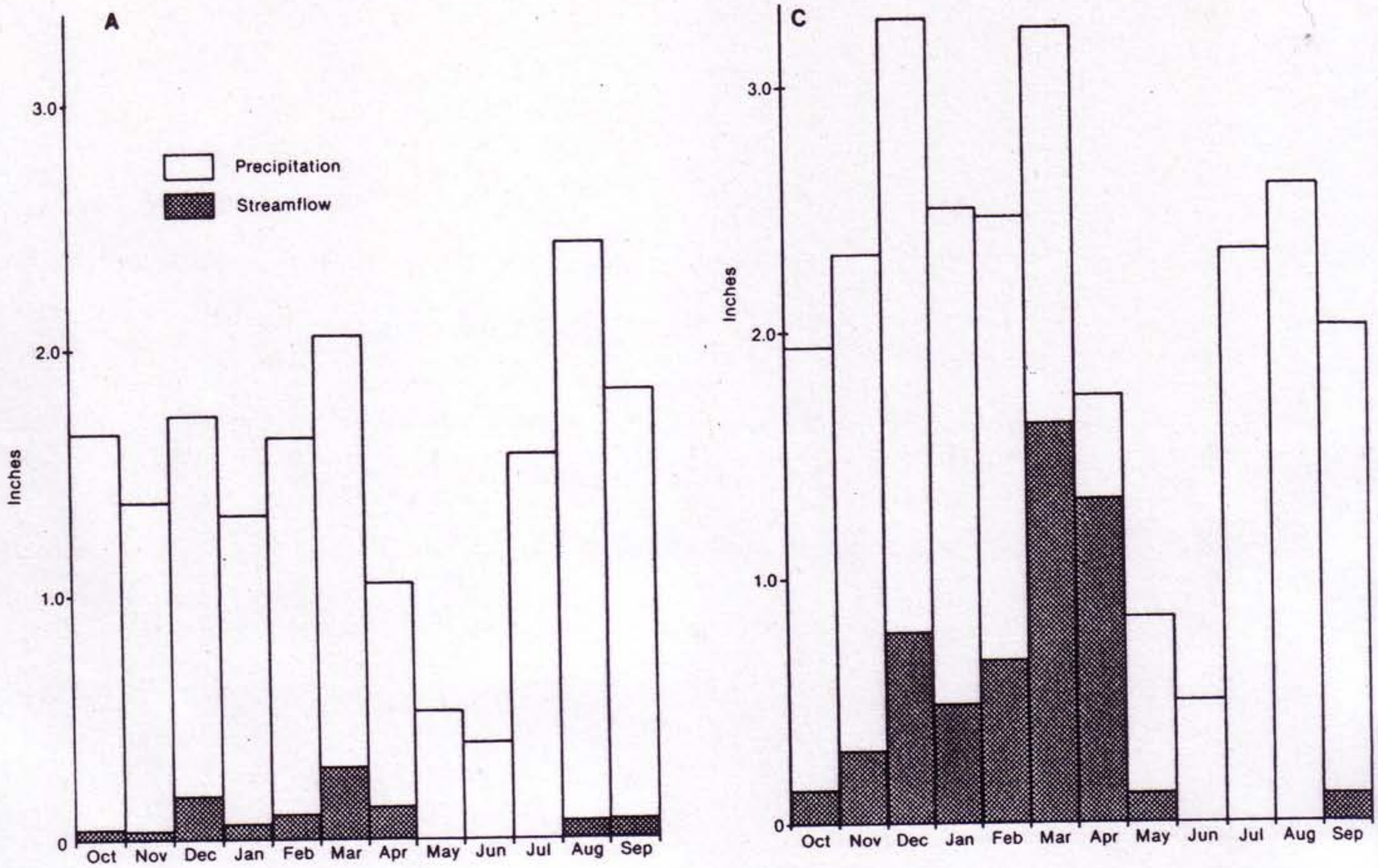
Widespread, protracted, frontal storms and prolonged flows are common along the Mogollon Rim during the period from November through March and provide the major portion of annual water yield. Precipitation in May and October varies but is most nearly like that of the winter period. Precipitation in October is composed principally of storms that are preceded by dry weather. Therefore, much of the water from these storms is absorbed by dry soil and over a period of years contributes little to total streamflow.

Point rainfall intensities in Arizona are generally not excessive (Sellers and Hill 1974). However, cloudbursts occasionally produce up to 3 inches (8 cm) of rain in less than 30 minutes. These events are generally in the summer over the mountainous country, but they are much less frequent than the extremely light rain showers that barely wet the ground. Rainfall intensities greater than 4 inches (10 cm) per hour have only been recorded for durations of 15 minutes or less.

The greatest rainfall intensities ever recorded on Beaver Creek during the May-October period are (these were, except where noted, in the pine type in 1970):

Duration *minutes*	**Intensity** *inches per hour*
5	10.01
15	5.26
30	3.21 (Alligator juniper, 1960)
60	2.09 (Alligator juniper, 1960)
120	1.45
360	0.64
1440	.28

Differences between precipitation and streamflow may be assumed to represent total evapotranspiration



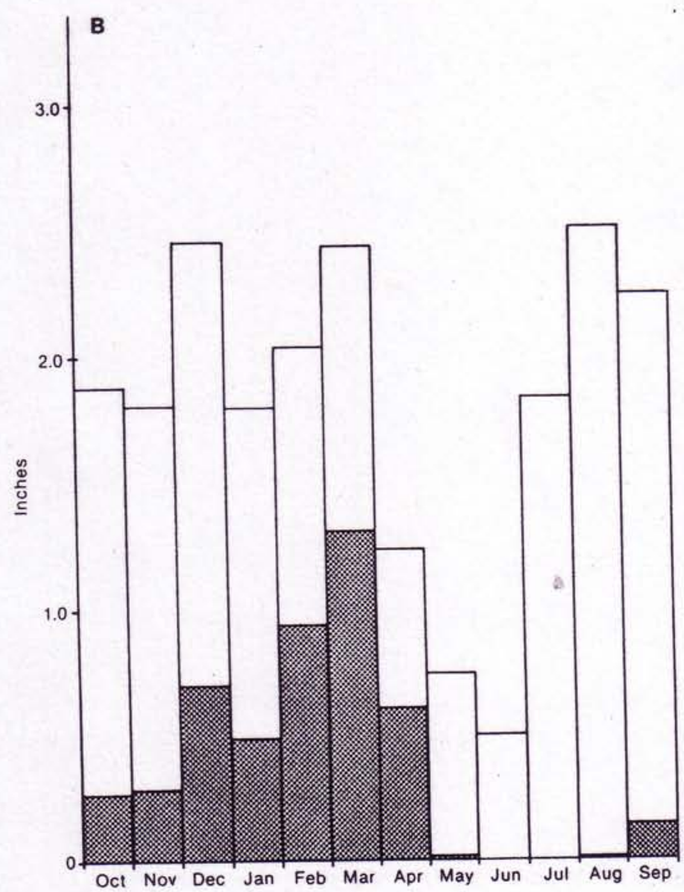


Figure 4.—Distribution of monthly precipitation and streamflow on Beaver Creek in (A) Utah juniper, (B) alligator juniper, and (C) ponderosa pine.

(ET) (table 1). There is little if any carryover effect in soil water storage from one water year to the next. Summer rains have generally ceased by early or mid-September and the soil profile has begun to dry by the beginning of the new water year. Streamgages on Beaver Creek are sealed to relatively impervious bedrock and significant leakage is not evident.

Differences in the average ET index between vegetation types (table 1) reflect differences in precipitation and temperature with elevation and in timber basal area.

This is a simplistic approach for obtaining an estimated index of ET, but it can be used successfully on Beaver Creek because of the lack of significant loss of precipitation to deep seepage. One major factor influencing water yield from these areas is the distribution of precipitation. Only winter precipitation has a significant chance of contributing to streamflow. If more of the annual precipitation were produced in the summer season, proportionately less streamflow would probably be produced.

Generally, streamflow is directly related to precipitation. However, during some years this relationship i changed as a result of anomalies in the distribution of precipitation. For example, in 1970 nearly average annual precipitation produced below average water yield because of low precipitation from December through February. Mean annual water yields and ranges for the three vegetation types on Beaver Creek are shown in table 1 and figure 5.

All watersheds in the three vegetation types lie on lava flow surfaces that yield a maximum of stormflow and a minimum of deep seepage.[3] Each lava flow has one distinct set of vertical contraction joints that do not penetrate from one flow to the next. Investigations suggest that these contraction joints are not conducive to transporting large volumes of water to the subsurface.

The water producing characteristics for the Mogollon Rim have been summarized by Feth and Hem (1963). They estimate that 98% of the precipitation that falls on the Mogollon slope leaves the region as streamflow, evaporation, and transpiration.

The lava bedrock that covers the Beaver Creek watershed is relatively impervious and prevents water intake except in fractured zones that extend to the sedimentary rock below. Evidence suggests that most of the experimental watersheds on Beaver Creek are tight, with only 2 out of 20 basins or 6% of the study area having any indication of water loss through deep seepage. This supports the previously mentioned conclusions of ground water investigators who estimate that only 2% of the precipitation that falls on the Mogollon Slope reaches the sedimentary aquifers below the lava cover.

Precipitation

Annual Precipitation.—Annual precipitation mean and range for the three vegetation types on Beaver Creek are presented in figure 5. These values reflect changes in elevation across the Mogollan Rim. Snowfall accounts for 18, 27, and 37% of the annual precipitation in the Utah and alligator juniper and pine types, respectively.

Seasonal Distribution.—August has the greatest amount of precipitation in both juniper types (fig. 4). In the pine zone, December and March have the most precipitation followed by August. May and June typically have the least precipitation in all three vegetation types.

Winter precipitation is normally associated with frontal storms. Winter averages are presented in table 1 and shows the increase in precipitation amount with elevation from the Utah juniper to the pine type. Snowfall commonly begins in November and increases into December. Usually snowfall declines in January and February followed by an increase to a peak in March.

Average peak water equivalent of the snowpack in the pine type near Beaver Creek is 4.0 inches (10.2 cm). This average is based on 30 years of data from the Soil Conservation Service snow courses at Mormon Lake, Mormon Mountain, Happy Jack, and Newman Park (U.S. Department of Agriculture 1975). The snow regimes on Beaver Creek are characteristic of these and other locations along the Mogollon Rim. Typically the snowpack is intermittent in the juniper types while a continual snowpack is common in the pine.

Nearly all summer precipitation occurs as thunderstorms and, although they occur frequently, individual storms usually cover relatively small areas. Mean summer rainfall is similar in the three vegetation zones with an average of 7.0 and 8.0 inches (17.8 and 20.3 cm) in the two juniper types and 8.5 inches (21.6 cm) in the pine (table 1). Summer rains generally begin in July and reach their peak in August (fig. 4).

Annual Precipitation Frequencies.—Probability distributions of annual precipitation in the three vegetation types were determined and using the 25th and 75th percentiles to define extreme events, annual pre-

Table 1. Annual and seasonal precipitation, water yield, and evapotranspiration for three vegetation types on Beaver Creek

	Utah juniper[1]			Alligator juniper[2]			Ponderosa pine[3]		
	Mean	Standard deviation	Coefficient of variation	Mean	Standard deviation	Coefficient of variation	Mean	Standard deviation	Coefficient of variation
	inches	*inches*	*percent*	*inches*	*inches*	*percent*	*inches*	*inches*	*percent*
Precipitation									
Winter	11.01	4.50	41	12.74	5.40	42	16.97	6.79	40
Summer	7.02	2.30	33	7.97	2.19	28	8.53	2.67	31
Annual	18.03	4.14	23	20.71	5.03	24	25.50	6.54	26
Water Yield									
Winter	0.90	1.48	164	4.61	5.27	114	5.42	4.94	91
Summer	0.16	0.38	238	0.16	0.46	288	0.14	0.44	314
Annual	1.06	1.44	136	4.77	5.22	109	5.56	4.87	88
Evapotranspiration									
Annual	16.97	3.13	18	15.94	2.88	18	19.94	3.30	17

[1]49 station years of data
[2]48 station years of data
[3]154 station years of data

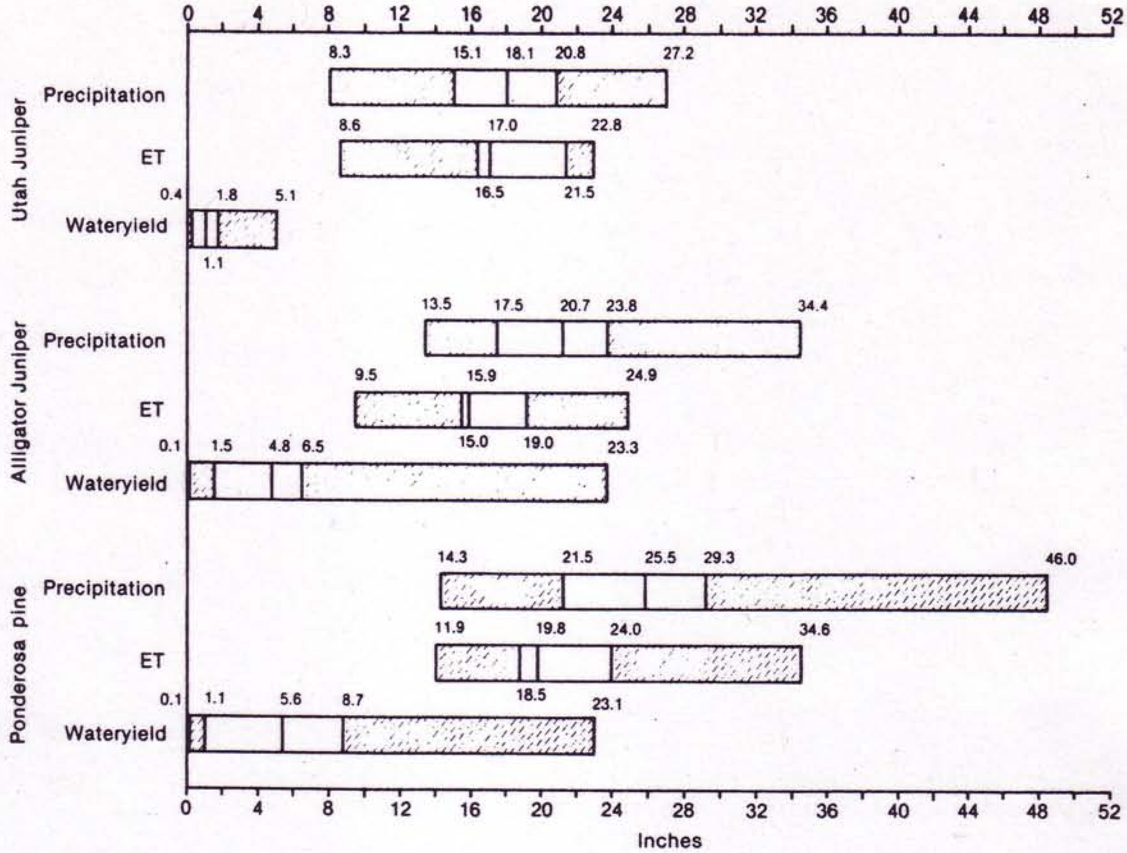


Figure 5.—Mean annual precipitation, evapotranspiration, and water yield and their ranges by vegetation type on Beaver Creek (left and right hatched area represent the 75th and 25th percentiles).

cipitation amounts in the hatched area of each bar may be considered relatively high and low, respectively (fig. 5).

Evapotranspiration

Annual Evapotranspiration.—In the Utah juniper types with a mean annual precipitation of 18.0 inches (45.7 cm), there is a mean annual ET of 17.0 inches (43.2 cm). In the alligator juniper, mean annual precipitation is 2.7 inches (6.9 cm) higher and ET is reduced 1.1 inches (2.8 cm). Decrease in ET is the result of 70% less timber basal area in the alligator juniper type. There is also the effect of a lower ET stress because of a 5° F (2.8° C) reduction in mean annual temperature at the higher elevation. Mean annual precipitation in the pine type is 7.5 inches (19.0 cm) higher than in the Utah juniper and has 2.9 inches (7.4 cm) additional ET. The average basal area of the pine type is 2 times that in the Utah juniper. This factor apparently outweighs the influence of the lower mean annual temperature of 10° F (5.6° C) in lowering ET stress. Annual ET ranges for the three vegetative types are illustrated in figure 5.

Annual Evapotranspiration Frequencies.—Probability distributions of annual evapotranspiration were also determined and using the 25th and 75th percentiles to define extreme events, annual evapotranspiration amounts in the hatched area of each bar may be considered relatively high and low, respectively (fig. 5)

Streamflow

Annual Streamflow.—Mean annual water yields have averaged 10, 37, and 33% of mean winter precipitation in the Utah juniper, alligator juniper, and pine type, respectively (table 1). Since the majority of the annual water yield on Beaver Creek comes during the winter season, mean annual runoff efficiency (ROE) is defined as the ratio of mean annual water yield to mean winter precipitation.

ROE on all pine watersheds range from 20 to 38%. Much of this variation results from differences in mean winter precipitation that ranges from 14 to 19 inches (36 to 48 cm) and from differences in watershed topographic orientation. ROE is often greater in the alligator juniper than in the other two vegetation types. This increased ROE reflects the influence of the less dense overstory, sparser litter cover, and soil type.

Seasonal Distribution.—Seasonal distribution of streamflow on Beaver Creek follows the pattern typical of areas that are dependent upon snowmelt (fig. 4). Winter water yield accounts for 85% of the total annual streamflow in the Utah juniper and 97% in the alligator juniper and pine type (fig. 4). Winter streamflow, which is relatively low in October and November, increases in December. Watersheds in all three vegetation types reach their maximum water yield in March. Streamflow is essentially nonexistent in May (except where residual flow may continue from winter snowmelt), June, and July. Summer streamflow usually only occurs in August and September and is least frequent in the pine. Summer flow generally terminates by early September in all three vegetation types.

May and June have the least amount of precipitation in the Utah juniper type and result in essentially zero streamflow. By August the soil water storage capacities of watersheds in this vegetation type begin to replenish as a result of the summer rains and streamflow may be initiated. There is streamflow about 2 years out of 10 from August through January and about 5 years out of 10 in February and March, the most reliable months for streamflow in the Utah juniper type.

Winter precipitation in the Utah juniper type comes as either rain or snow. The snow generally melts rapidly because the lowest mean monthly temperature is in January at 38° F (3.3° C). Soil water storage approaches capacity in the early winter period and evaporation rates are low. Water percolating through the shallow soil mantle soon reaches bedrock and becomes increasingly more available for streamflow. The watersheds, therefore, are considered primed for the spring snowmelt season.

Spring snowmelt in the juniper types is during February, March, and April. Because nearly the whole watershed is often charged, streamflow rises rapidly to its peak in March. Water yield then drops sharply in April as the residual snowpack is depleted and stored soil water is reduced. Residual flow from spring snowmelt is usually terminated in March or early April.

May and June also have the least amount of precipitation in the pine type. Streamflow frequency and amount increases during the fall and winter water yield reaches an early winter high in December and remains there until March.

Spring snowmelt in the pine type is during March, April, and May. There is a sharp increase in snowmelt in March when the mean monthly temperature reaches 34° F (1.1° C); because nearly the whole watershed is charged, average streamflow rises rapidly. Water yield drops sharply in early May as the residual snowpack is depleted, leaving the major part of the month with zero flow.

The summer rainfall season in the pine follows the spring and early summer dry period and is during the time of highest ET demand, resulting in little flow being produced. There is streamflow in September and October 12 and 18% of the time, respectively. This indicates that most summer precipitation in the pine type is used to recharge soil water storage and to provide water for ET.

Annual Streamflow Frequencies.—Again using the 25th and 75th percentile from probability distributions of annual streamflow to define extreme events, annual streamflow amounts in the hatched area may be considered relatively high and low events, respectively (fig. 5).

Annual Peak Discharge.—Average annual peak discharge in the Utah juniper is 117 $ft^3 \cdot s^{-1} \cdot mi^{-2}$ (1.3 $m^3 \cdot s^{-1} \cdot km^{-2}$), 112 $ft^3 \cdot s^{-1} \cdot mi^{-2}$ (1.2 $m^3 \cdot s^{-1} \cdot km^{-2}$) in the alligator juniper, and 90 $ft^3 \cdot s^{-1} \cdot mi^{-2}$ (1.0 $m^3 \cdot s^{-1} \cdot km^{-2}$) in the pine (fig. 6). In the Utah juniper type, annual peak flows are more heavily influenced by the orographically produced rain events that have been responsible for 39% of all peak discharges. The peak discharge pattern in the alligator juniper type is similar to that in the pine type during the winter but is more heavily influenced (31% of the peak discharge) by summer thunderstorms. In the pine type only 11% of the annual peak discharges occurred in the summer season.

The average annual peak discharges presented above do not adequately characterize the flood hazard from these vegetation types. The average annual peak discharges are equalled or exceeded only 25% of the time in the Utah juniper and 30% of the time in the alligator juniper and pine type. The median peak discharge is 32 $ft^3 \cdot s^{-1} \cdot mi^{-2}$ (0.4 $m^3 \cdot s^{-1} \cdot km^{-2}$) in the Utah juniper and 74 $ft^3 \cdot s^{-1} \cdot mi^{-2}$ (0.8 $m^3 \cdot s^{-1} \cdot km^{-2}$) and 44 $ft^3 \cdot s^{-1} \cdot mi^{-2}$ (0.5 $m^3 \cdot s^{-1} \cdot km^{-2}$) in the alligator juniper and pine types, respectively. Using the 25th and 75th percentile to define extreme events, peak discharges in the hatched area may be considered relatively high and low events, respectively (fig. 6).

Summary and Recommendations

Winter season precipitation is important to the streamflow regimes along the Mogollon Rim because vegetation manipulation can affect the snowpack and

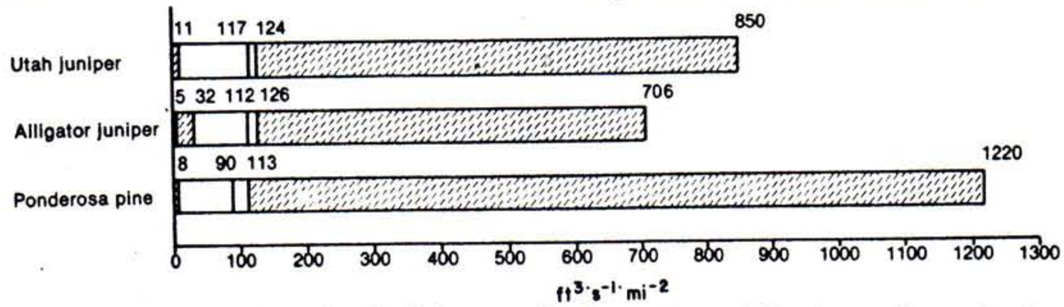


Figure 6.—Mean annual peak discharge and their range by vegetation type on Beaver Creek (left and right hatched area represent the 75th and 25th percentiles)

the evapotranspiration process and, consequently, can influence streamflow from the melting snowpack. By reducing forest densities, soil water depletion may be reduced, the snowpack may be manipulated, and consequently, more winter precipitation may be made available for streamflow. Although opportunities exist to manipulate the snowpack along the Mogollon Rim, potential mean increases in water yield are restricted by the 4.0 inch (10.2 cm) mean peak water equivalent in the pine type.

Summer precipitation in the forest types along the Mogollon Rim occurs after a 2 month dry period, at a time of high evaporation stress, and high moisture demand by vegetation. This creates a high demand upon available soil water. Nearly all summer precipitation occurs as thunderstorms and although frequent, individual storms cover relatively small areas. These small storm events generally produce no significant summer water yield or flooding even from storms with recurrence intervals of 25 and 50 years.

Mean annual water yield consists of 10, 37, and 33% of the mean winter precipitation in the Utah juniper, alligator juniper, and pine types on volcanic-derived soils, respectively. The inherent low water yield in the Utah juniper limits this vegetation type for considerations of significantly increasing water yields. The existing vegetation or its replacement is often capable of utilizing the available water supply. The relatively high soil water deficit, the seasonal precipitation pattern, and typical ephemeral snowpack conditions are not conducive to management manipulation. In contrast the naturally relatively high water yield from the alligator juniper type and its characteristic low vegetation density limits it from vegetation manipulation alternatives for the purpose of increasing water yields.

Water yield from the ponderosa pine type has been shown to be responsive to vegetation management alternatives (Brown et al. 1974).

Average annual peak discharges of 117 and 112 $ft^3 \cdot s^{-1} \cdot mi^{-2}$ (1.3 and 1.2 $m^3 \cdot s^{-1} \cdot km^{-2}$) are characteristically higher in the Utah and alligator juniper types, respectively, than the 90 $ft^3 \cdot s^{-1} \cdot mi^{-2}$ (1.0 $m^3 \cdot s^{-1} \cdot km^{-2}$) in the ponderosa pine because of their characteristic soil type, vegetation density, and sparse litter cover. Peak discharges also are more frequent in the summer season in the juniper types.

Average annual peak discharges do not adequately characterize the flood hazard from these vegetation types because a few large flood events have skewed the distributions of the annual peak flows. Median discharges in the Utah and alligator and pine types, respectively, are 32, 74, and 44 $ft^3 \cdot s^{-1} \cdot mi^{-2}$ (0.4, 0.8, and 0.5 $m^3 \cdot s^{-1} \cdot km^{-2}$).

These baseline data from three vegetation types on Beaver Creek can be used to evaluate the potential water yields of vegetation manipulation. These data also provide an understanding of the upland hydrology of naturally vegetated watersheds on volcanic-derived soils along the Mogollon Rim in north-central Arizona.

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U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

Southwest

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

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