

THE SEVEN SPRINGS EXPERIMENTAL GRASSLAND WATERSHEDS

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Water is a critical resource in the Southwestern United States. The demands for reliable regional water sources have always been present but are increasing as the human population continues to grow, especially in the Metro-Phoenix Area, which once supported Sonoran Desert ecosystems. While much of the land has been converted from farming to houses and other urban developments that use less water, the need for a reliable water supply is not diminished. The Phoenix Area's main supply of surface water is the Salt-Verde River System. These two rivers originate in the mountains to the north and east of Phoenix in a region known as the Central Arizona Highlands. These mountains, which receive more annual precipitation than the deserts, are covered with ponderosa pine (*Pinus ponderosa*) and mixed conifer forests, mountain grasslands, pinyon-juniper woodlands and chaparral scrublands. These vegetation types sustain high quality streamflow, forest resources, forage, wildlife, and provide recreational opportunities for the populations of neighboring urban centers and are managed under the concept of multiple use. Several dams and reservoirs have been created on each river to capture surface runoff and to distribute it to the communities below.

The Arizona Watershed Program was initiated by public agencies and private groups interested in obtaining more water for future growth while maintaining the state's watersheds in good condition (Ffolliott 1999). The objectives were to determine if vegetation manipulations could produce additional runoff without producing negative impacts on other watershed resources. A research program was begun by the Rocky Mountain Forest and Range Experiment Station of the U.S. Forest Service and its cooperators to determine if surface runoff can be increased and if treatments imposed will impact other watershed resources. Streams in these vegetation types were instrumented with weirs and flumes and supplemental ecosystem data were collected. The forest and woodland vegetation types received the initial emphasis because several management options were available to manipulate the natural cover. Hibbert (1981) reported that potential

annual water yield increases could range from less than a half inch in the pinyon-juniper woodlands to 3 to 4 inches in the mixed conifer forests. However these increases would be reduced by multiple use considerations. Watersheds in other vegetation types were also instrumented including the two Seven Springs Watersheds in the grasslands of eastern Arizona. The objective of this paper is to review the history of research on these watersheds, and add some additional information and analyses.

THE HIGH ELEVATION GRASSLANDS

High elevation grasslands occur above 9,000 ft. in the White Mountains of eastern Arizona where they cover about 80,000 acres in large continuous blocks. These grasslands contain islands of mixed conifer forests and are surrounded by mixed conifer forests. Thompson and others (1976) estimated, based on Schmidt's (1972) snow transport model that snow particles would completely sublimate during 1,800 ft. of air travel under average snow-season climatic conditions at Seven Springs. They calculated that accumulating this blowing snow behind shelterbelts or snow fences would increase average water yields from the grasslands by approximately 10,000 acre-feet a year. Hibbert (1981) was less optimistic about these potential increases in water yields from the grasslands because of concerns about visual quality related to snow fences in scenic areas and to questions about the validity of Schmidt's equations for Arizona conditions.

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The paired experimental watersheds on the East and West Forks of Seven Springs were instrumented by the Rocky Mountain Forest and Range Experiment Station (now the Rocky Mountain Research Station) and the Apache National Forest in 1964 (now the Apache-Sitgreaves National Forests) as part of the Arizona Watershed Program. A 120° V-notch weir was constructed on two adjacent drainages. The objective was to learn more about the hydrology of these high-elevation grasslands

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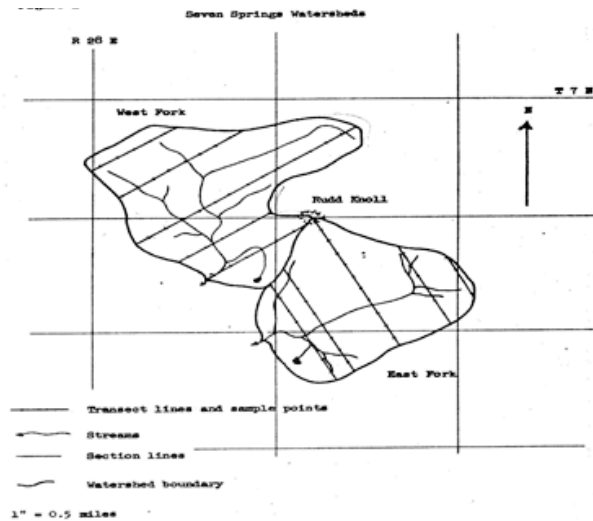


Figure 1.

and about the feasibility of increasing streamflow by using windbreaks, such as snow fences as was done in Wyoming or, alternatively, of creating tree shelterbelts. Much of the information from Seven Springs was summarized by Thompson and others (1976). The watersheds are east of Big Lake, Arizona and 11 miles south of Springerville, Arizona. The procedure followed in a paired watershed study is that one watershed is treated, by windbreaks in this situation, and the other is left untreated as a hydrologic control after a suitable calibration period.

Elevations at Seven Springs range from about 9,200 ft. to 9,765 ft. The East Fork watershed covers 748 acres and the West Fork watershed covers 482 acres (figure 1). The plant cover is dominated by Arizona fescue (*Festuca arizonica*) and includes mountain muhly (*Muhlenbergia montana*), pine dropseed (*Blepharoneuron tricholepis*), and longtongue mutton bluegrass (*Poa longiligula*). The watersheds are underlain by 4,000 to 8,000 ft. of Tertiary basalt. Volcanic cinders cones, such as Rudd Knoll at the top of the watersheds, are a predominant feature of the landscape (figure 1). Grassland soils are generally 12 to 32 inches deep. Surface soils are gravelly loams or gravelly sandy loams.

A weather station was established near the confluence of the two stream channels. Snow courses were established perpendicular to the channels to determine snowpack water conditions. (Figure 1). Data from Seven Springs was often compared to data from the gauged mixed conifer forested watershed at Burro Mountain which was operated by the Apache National Forest as

an administrative inventory site. The watersheds are inaccessible to regular vehicles in the winter because of the continuous and deep snowpack but were visited regularly during the study using mechanized over-snow equipment.

The objective of this paper is to review the Seven Springs record and to add some additional information and analyses. The 1976 paper by Thompson and others provides the basis for much of the information. Additional information comes from the files of the Rocky Mountain Research Station in Flagstaff. The snow fences were never constructed at Seven Springs because of projected construction costs and the feeling that the fences in this important tourist travel corridor to Big Lake would not be esthetically pleasing. It should be noted that snow fences, using a design which allowed them to be laid down during the summer, were eventually constructed in the adjacent grasslands along scenic Arizona Highway 260.

WEATHER DATA

The weather station at Seven Springs was established in 1964 with instruments to measure precipitation, temperature, wind speed and direction, and evaporation. Average annual precipitation (with standard deviation) between 1964 and 1979 was 16.7 ± 2.4 inches. While these watersheds are usually associated with snow cover, almost two-thirds of the annual moisture occurs during the summer monsoon period from June through September. Greatest precipitation occurred in the 1973 and 1979 water years (October-September) when 19.5 and 20.6 inches were measured, respectively. The average winter wind speed during the first 10 years was 10 miles per hour but gusts of 50 to 65 mph were common. The predominant wind direction was from the southwest quadrant with 65 percent of the winds originated in the south, southwest and west quadrants (Thompson and others 1976). Minimum temperatures between December and March for the initial period first were 11 to 15° F.

Since wind is such an influence on snow accumulations, snow characteristics were measured on sample points located on 5 permanent transects on each watershed throughout the winter. There were 36 points on West Fork and 41 points on East Fork. The federal snow tube was used to measure snow depth and water equivalents. Surveyors travelled by snowshoe or occasionally worked from the back of the snow machine. There were between one and five surveys in a year. Not all points or watersheds were visited during a trip because of logistics and time constraints. A comparison

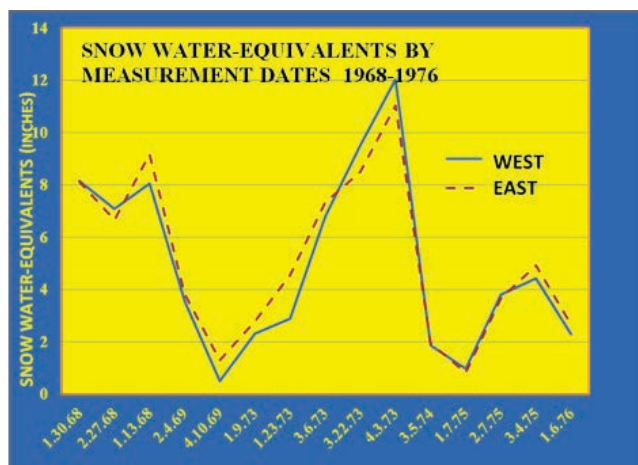


Figure 2.

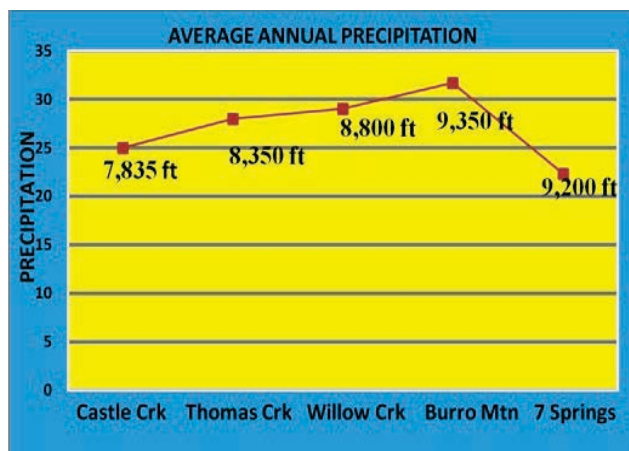


Figure 4.

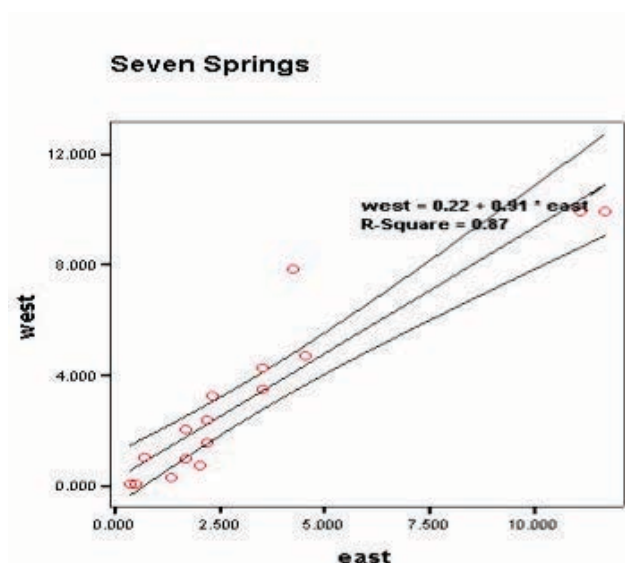


Figure 3.

of snow data for common dates between 1968 and 1976 is presented in Figure 2. There appears to be a good relationship between the measurements on the two areas although these data were not compared statistically.

STREAMFLOW

Streamflow for the two watersheds compared well (Figure 3) with a coefficient of determination (r^2) value of 0.87. The linear regression is statistically significant. Better relationships between watersheds have been determined for neighboring mixed conifer covered watersheds, for example, the relationship between the South Fork and North Fork of Thomas Creek was 0.99 (Gottfried 1991). Several regression

models were tested with the Seven Springs streamflow data in an attempt to better account for the two years of high flows; however, none of the models improved the r^2 value appreciably. Average annual runoff (with standard error) was 3.36 ± 0.84 inches for East Fork and 3.29 ± 0.83 inches for West Fork. Average winter runoff amounts are equivalent to 95 percent and 99 percent of the annual flow, respectively. Streamflow measurements at East Fork were slightly higher than West Fork for the same weather station record. Greatest winter streamflow occurred in the wet years of 1973 and 1979 when East Fork yielded 10.91 and 11.49 inches and West Fork yielded 9.87 and 9.81 inches, respectively. Winter precipitation for those years was 14.15 and 12.84 inches.

A comparison of annual streamflow with annual precipitation indicates that 14 percent of the precipitation eventually becomes streamflow with the r^2 values of regressions for these two variables are 0.44 and 0.48. Approximately 17 percent of the annual precipitation at Burro Mountain runs off. If part of the precipitation at Seven Springs is never measured because of winds and sublimation, the average runoff could be just 10 percent (Thompson and others 1976). If the relationship between winter precipitation and winter runoff is examined, the r^2 values are improved to 0.66 for West Fork and 0.86 for East Fork.

Thompson and others (1976) graphed the relationship between elevation and precipitation for four gauged forested watersheds on the Apache-Sitgreaves National Forests and for Seven Springs. Seven Springs at 9,200 ft. had an annual precipitation of 22.1 inches (in 1975), less than any of the other areas (Figure 4). They concluded that the Seven

Springs weather station is not measuring the total moisture input because of high winds. Thompson and his associates suspected that the gauge was reading 30 percent low and that actual precipitation could be 6 to 8 inches greater. They compared snowmelt generated runoff accounts between Seven Springs and Burro Mountain. Ninety-six percent of the annual streamflow at Seven Springs and 80 percent of the annual runoff from adjacent forested watersheds could be related to snowmelt. The difference can be attributed to frozen soils at Seven Springs that reduce infiltration and produce rapid surface runoff. Some hydrologists also were concerned that the two weirs discharged flows into the prevalent strong winds that could affect streamflow stage heights and flow velocities.

WHERE ARE THE TREES?

There is a sharp divide between trees and the grasslands on the windward sides of the larger cinder cones. However, there appears to be a continuum between trees and grasslands on the lee-sides of hills and on relatively low cinder cones that support trees on all sides. Thompson and others (1976) attempted to determine the reason for the lack of trees on some sites. Grassland soils are relatively shallow, about 12 to 32 inches deep, compared to forest soils which are between 12 and 48 inches deep. These researchers found some significant differences between grassland and forest soils but they were not sufficiently different to affect vegetation. They believed that soil moisture controlled the vegetation differences because of high summer evaporation in the grasslands, sublimation of snow in winter, and the absence of barriers to trap snow and reduce sublimation.

Thompson and his associates attempted to create natural windbreaks by planting containerized seedlings in the grassland in 1974. They used Arizona native Engelmann spruce (*Picea engelmannii*) and blue spruce (*P. pungens*), and introduced species such as Scotch pine (*Pinus sylvestris*), Austrian pine (*P. nigra*), and limber pine (*P. flexilis*). Limber pine is not common in Arizona and is mainly found in the Rocky Mountains to the north. An overall average of 76 percent survived the first growing season and 60 percent survived after two growing seasons. However, the trees did not grow appreciably because of bud loss due to drought or frost and to low vigor. Gophers (*Thomomys spp.*) killed 19 percent of the trees. A cursory visit to the site in the mid-1990s did not indicate many surviving trees. The Seven Springs installations were decommissioned in 1979.

CONCLUSIONS

The high-elevation grasslands of eastern Arizona are an important component of the state's landscape. Watershed managers considered the 80,000 acres of snowpack as a potential source for additional water for the Salt-Verde River System. The Seven Springs Watershed Experiment was designed to increase an understanding of grassland hydrology and, eventually, to test methods of trapping more snow and reducing sublimation losses. Although the watersheds were never treated, they did provide interesting information about the hydrology of the high elevation grasslands. Thompson and others (1976) summarized the first 10 years of information from the watersheds, and this paper attempts to supplement the record with additional analyses and data that were collected before the installations were closed in 1979.

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