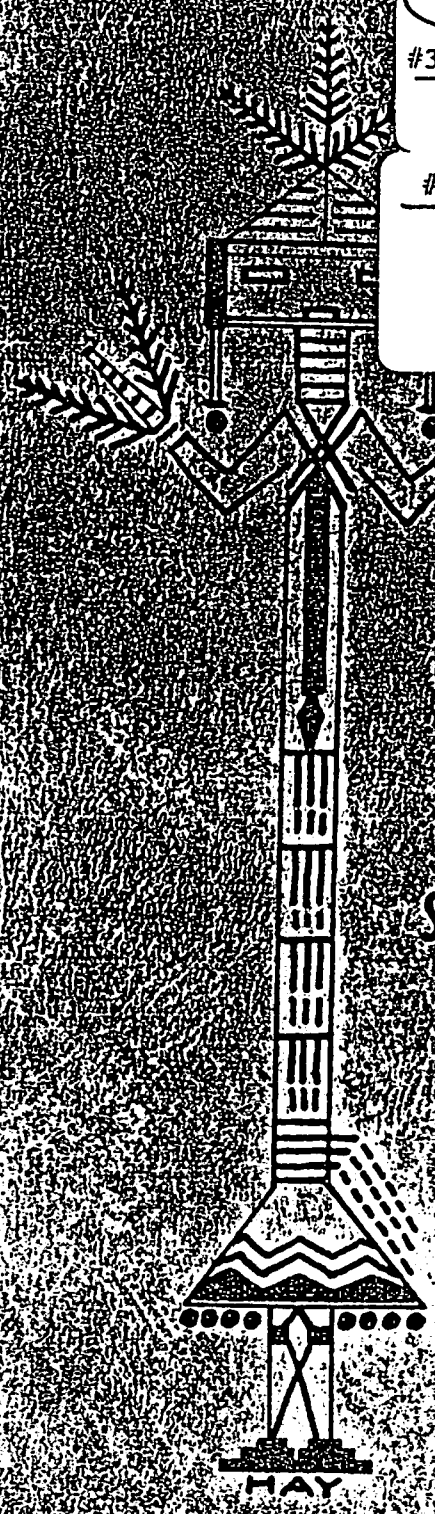
3-3(a)-4

#3 = Keppel - p. 39
Water Yield fr. SW Grassland.

#3(a)= Gardner - p. 1 (Introd. to Symp.)
Water Yield in Relation to Envir..

#4 = Fletcher - p. 51
Water Yield in Rel. to Environ. in Southwestern United States.



WATER YIELD IN RELATION TO ENVIRONMENT IN THE SOUTHWESTERN UNITED STATES

edited by Barton H. Wannock
and
J. L. Gardner

WATER YIELD FROM SOUTHWESTERN GRASSLAND

by

Robert V. Keppel

The climate of nearly a half million square miles in the Southwestern United States is semiarid (Thornthwaite, 1941). The area under consideration, which is used principally for the grazing of livestock, is characterized by hot summers and mild winters. Vegetative cover varies from typically good grassland through mixed grass and brush to cover which is dominated by brush. The annual precipitation of seven to fifteen inches falls over much of the area in two distinct seasons—summer and winter—separated by protracted periods of little or no rainfall. Storm characteristics during these two seasons differ markedly: winter precipitation results from widespread frontal storms of low intensity; summer rains, which cause nearly all of the water yield, typically occur as convectional thunderstorms of small areal extent, short duration, and high intensity.

Water yields from the semiarid grass and brush lands are, generally speaking, very low. For the arid-zone portions of Arizona, Colorado, New Mexico, and Utah, Dorroh (1955) has estimated that only 2% of the water falling as precipitation reaches a point of downstream use.

Many of the data referred to herein are from the Walnut Gulch, Arizona, experimental watershed, which includes an area of 58 square miles. In addition to the main watershed, four subwatersheds ranging in size from 0.9 to 44 square miles are gaged. All gaging sites are founded on bedrock; consequently, there is no subsurface flow at any of the sites. Vegetation is typical of the black grama grasslands of southern Arizona which have been partially invaded by mixed stands of creosotebush, whitethorn, and tarbush.

The distribution of water yield by months for a typical watershed is shown in Figure 1. Ninety-six percent of the annual yield from this watershed occurs during the months of July and August, the period during which most of the summer convectional thunderstorms occur. Runoff data from other semiarid grass-brush watersheds in the Southwest show similar seasonal distributions (U.S.D.A., 1957).

A distinctive feature of the runoff pattern is large transmission losses. These losses result from the peculiar nature of the runoff-producing storms, the highly ephemeral nature of the flow events, and the porous nature of the channel alluvium. Runoff generated from small-diameter thunderstorms may flow through an extensive network of dry and highly absorbent channels before reaching the watershed outlet. A significant portion of the runoff water may be absorbed by the channel alluvium during the flow event (fig. 2 and 3). A typical summer convectional thunderstorm on the upper portion of Walnut Gulch watershed is portrayed in the isohyetal map (fig. 2). Locations of gaging stations on the watershed are also shown on the map. Figure 3 shows the flow hydrographs measured at stations 1 and 2 for the runoff event caused by the thunderstorm shown in Figure 2. The hydrograph at station 2 had a peak of 850 c.f.s. and a total volume of 56.9 acre feet. At station 1, four miles downstream from station 2, the peak discharge had diminished to 70 c.f.s., and the volume was reduced to 5 acre feet. The transmission loss for this event was 4.3 acre feet per mile of channel per hour of flow duration. Losses such as this are quite typical of many of the semiarid grassland watersheds under study and are somewhat greater than those reported by Babcock and Cushing (1942) for a typical desert wash.

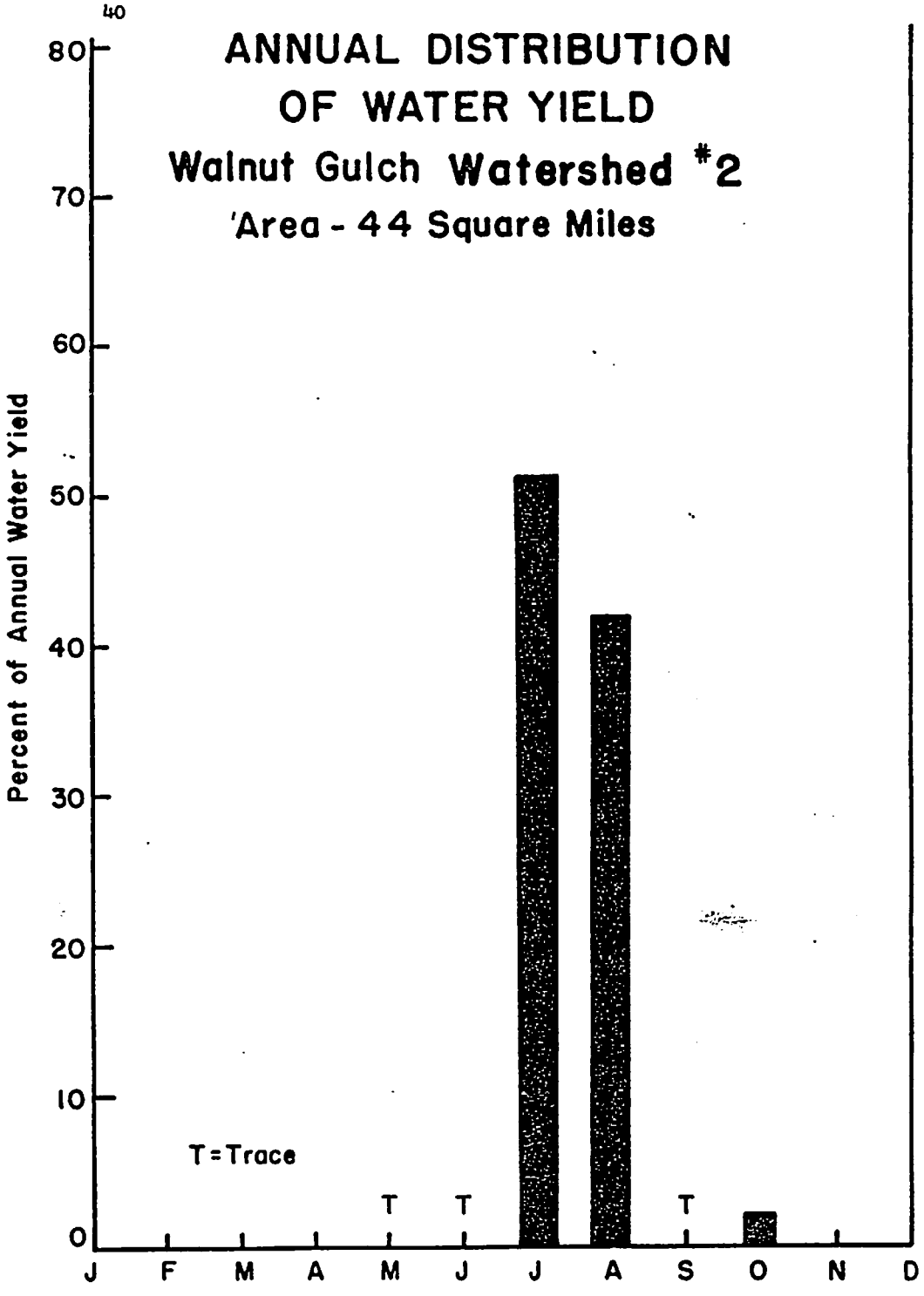
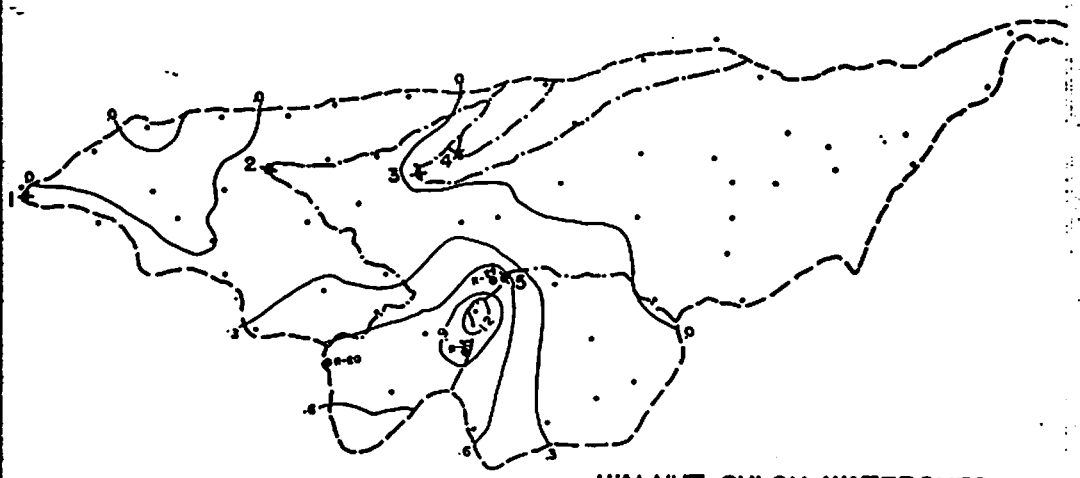

ANNUAL DISTRIBUTION
OF WATER YIELD
Walnut Gulch Watershed #2
Area - 44 Square Miles
Percent of Annual Water Yield
80
70
60
50
40
30
20
10
0
T=Trace
T
T
T
J
F
M
A
M
J
J
A
S
O
N
D

FIGURE I.



WALNUT GULCH WATERSHED
Isohyetal Map
Storm of July 8, 1959

⊙ Recording Raingage

✱ Gaging Station

FIGURE 2

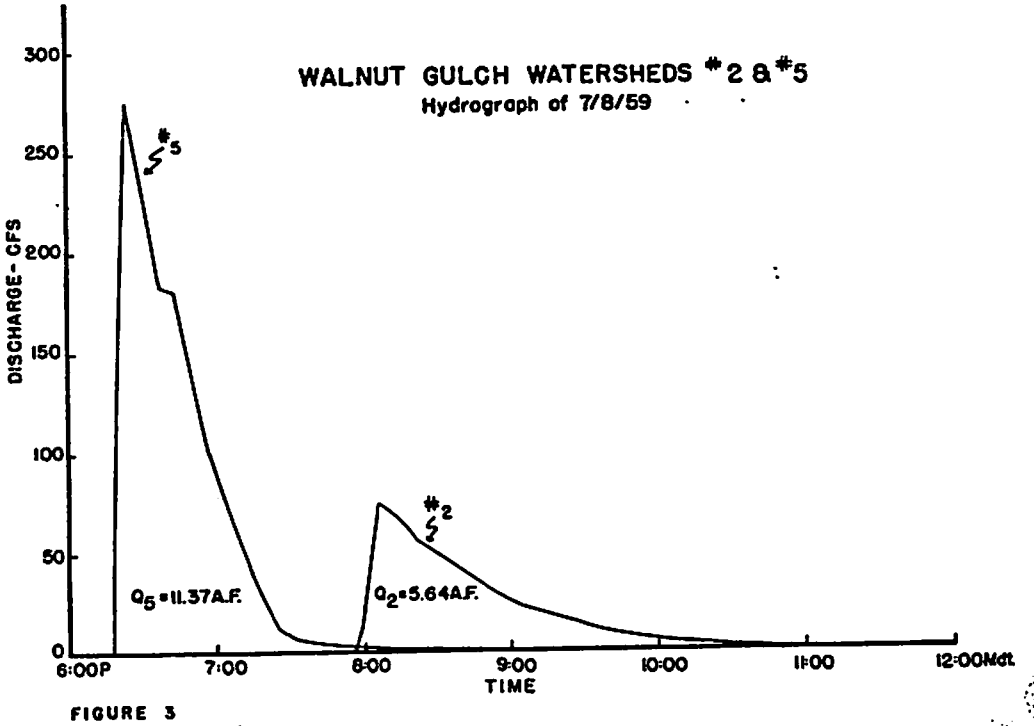

WALNUT GULCH WATERSHEDS #2 & #5
Hydrograph of 7/8/59
DISCHARGE - CFS
300
250
200
150
100
50
0
#5
#2
Q5 = 11.37 A.F.
Q2 = 5.64 A.F.
6:00P
7:00
8:00
9:00
10:00
11:00
12:00Mdt
TIME

FIGURE 3

Whether or not the water lost in the channel systems reaches the permanent groundwater table depends on the geology of the individual watershed considered. Where the geology is conducive to recharge to permanent aquifers, a portion, and in some cases a major portion, of transmission-loss water moves downward to the water table and cannot properly be thought of as a "loss." Under geologic conditions unfavorable to recharge, the transmission losses are largely dissipated by evapo-transpiration. This appears to be the case on the Walnut Gulch watershed.

The two factors discussed and illustrated above—transmission losses, and small size of the runoff-producing storms—combine to produce a situation in which water yield decreases with increasing watershed size. As watershed area increases, there is a smaller probability of having the entire area covered by a storm of high enough intensity to produce runoff. Also, the larger the watershed area, the more extensive the channel system and the greater the chance that transmission losses will be significantly large.

Figure 4 shows the relation between water yield and watershed area for Walnut Gulch watersheds. It should be emphasized that the period of record for these watersheds is quite short and includes one year of extremely high summer precipitation and runoff. Consequently, the magnitude of the water yields is probably much greater than the long-time average for this area. It is likely, however, that the relation between yield and area is typical of many semiarid grassland watersheds.

Figure 5 shows the relation between water yield and watershed area for the Santa Cruz River Basin in Southern Arizona, which has an area of 9,000 square miles. Although a much longer period of record is represented here than is the case for the Walnut Gulch watersheds, and although there is much less homogeneity in the Santa Cruz Basin than in Walnut Gulch watershed with respect to geology, soils, and vegetation, the regression equations for the two relationships are remarkably similar.

On Walnut Gulch watersheds:

$$Q = 1.95\ A^{-.31}$$

and for the Santa Cruz Basin:

$$Q = 1.75\ A^{-.34}$$

where:

Q is annual water yield in inches
A is watershed area in square miles

A major objective of our watershed research on Southwestern rangelands is to ascertain what effect vegetational changes have on the net yield of usable water from such watersheds. There is rather widespread belief that any improvement in the kind or amount of vegetation may reduce the already small yield of water from these areas. Any complete answer to this question must await more hydrologic records and analysis and detailed vegetational surveys. It seems unlikely, however, that where essentially all of the water yield is generated by cloudburst type thunderstorms whose intensities greatly exceed infiltration capacities, vegetational changes alone will greatly alter the water yield.

SUMMARY

Water yields from semiarid grassland watersheds are low, and they comprise only a small percentage of the total water supply. Essentially all of the water yield comes from small-diameter, intense summer convectional thunderstorms. Typically, at least 90 percent of

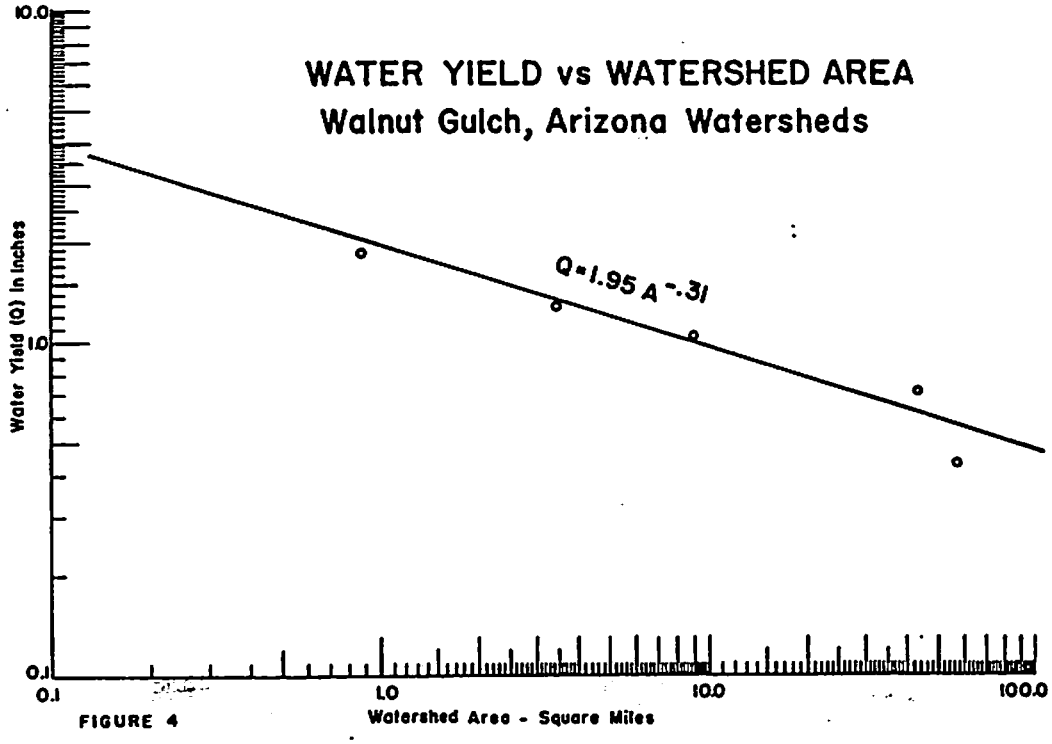

WATER YIELD vs WATERSHED AREA
Walnut Gulch, Arizona Watersheds
Q=1.95 A^-.31
Water Yield (Q) in Inches
10.0
1.0
0.1
0.1
1.0
10.0
100.0
Watershed Area - Square Miles

FIGURE 4

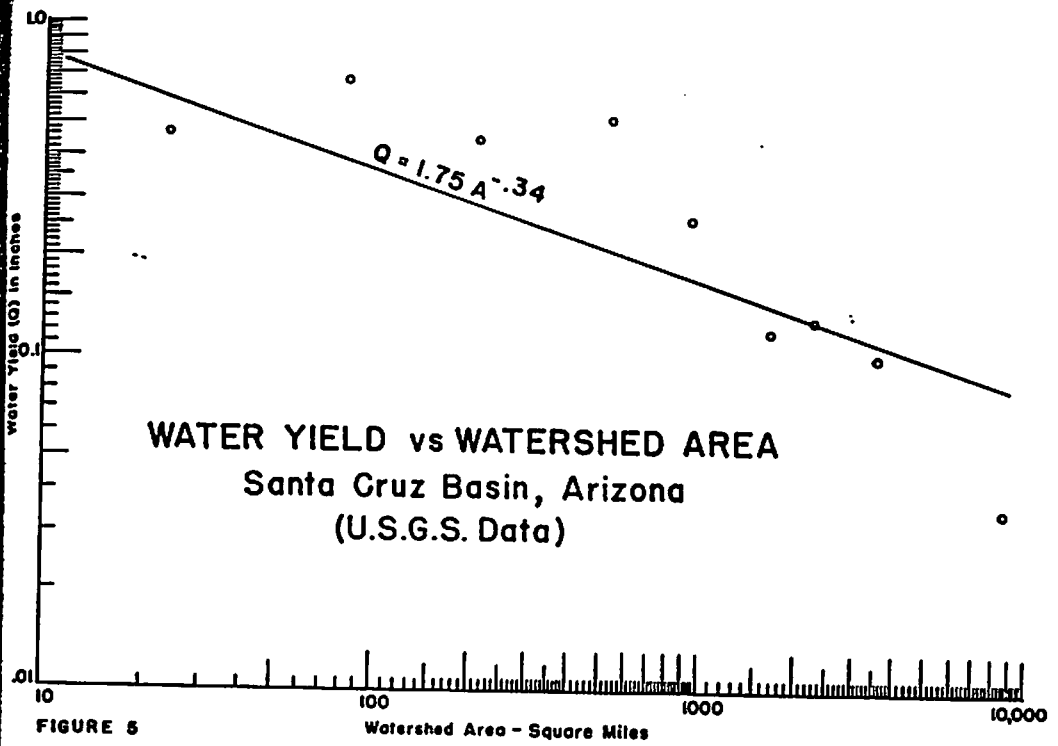

1.0
0.1
.01
Water Yield (Q) in Inches
Q = 1.75 A^-.34
WATER YIELD vs WATERSHED AREA
Santa Cruz Basin, Arizona
(U.S.G.S. Data)
10
100
1000
10,000
Watershed Area - Square Miles

FIGURE 5

the annual yield occurs during the months of July and August. Transmission losses in the channel systems are a significant factor for the highly ephemeral type of flows characteristic of such watersheds. The geology of each individual watershed must be carefully considered in deciding whether the water lost in the channel system may percolate to the groundwater table or whether is is removed by evapo-transpiration. The relation between water yield and watershed area is very similar for the Walnut Gulch watersheds and for the much less homogeneous subwatersheds comprising the Santa Cruz River Basin.

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