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#387

VOLUME 11

HYDROLOGY and WATER RESOURCES in ARIZONA and the SOUTHWEST

PROCEEDINGS OF THE 1981 MEETINGS
OF THE
ARIZONA SECTION —
AMERICAN WATER RESOURCES ASSN.
AND THE
HYDROLOGY SECTION —
ARIZONA - NEVADA ACADEMY OF SCIENCE

MAY 1-2, 1981, TUCSON, ARIZONA

POINT-AREA-FREQUENCY CONVERSIONS FOR SUMMER RAINFALL IN SOUTHEASTERN ARIZONA

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INTRODUCTION

Air-mass thunderstorm rains dominate rainfall-peak discharge relationships on many small watersheds (up to 150 km^2) in southeastern and southcentral Arizona, southwestern New Mexico, and northern Sonora, Mexico. Intense rain cells within these storms usually last only minutes and cover relatively small areas. In the Southwest, for watersheds larger than 2 km^2, estimates of maximum point rainfall are inadequate for most rainfall-runoff models. To estimate rainfall values within the watershed, frequency of point values should be revised upward to account for the greater likelihood that intense rain would have been recorded within an area, as opposed to a point, and then reduced for average rainfall over the watershed. For larger watersheds, it may also be necessary to position the event and route it through the channel system to obtain the accuracy needed. In this paper, a method is presented to convert air-mass thunderstorm rainfall at a point to areal values for use on watersheds up to 150 km^2. Limitations are stated, and the reader is referred to other published information if flood routing procedures are needed as well.

REGION OF APPLICABILITY

The curves for point-area-frequency conversion of thunderstorm rainfall were developed with records from a network of over 90 recording raingages on the 150-km^2 Walnut Gulch Experimental watershed near Tombstone, Arizona (Fig. 1). Rainfall and runoff records have been collected on Walnut Gulch and its subwatersheds since 1954, and the networks of recording raingages and runoff-measuring stations were completed by 1965 (Renard, 1970). Walnut Gulch was originally chosen as representative of the rangelands in southeastern Arizona. It is also representative of a climatic region encompassing much of southeastern and southcentral Arizona, southwestern New Mexico, and northern Sonora, Mexico (Fig. 2). Although rainfall frequencies are not identical throughout the regions, runoff from similar semiarid watersheds up to 150 km^2 is dominated by air-mass thunderstorm rainfall.

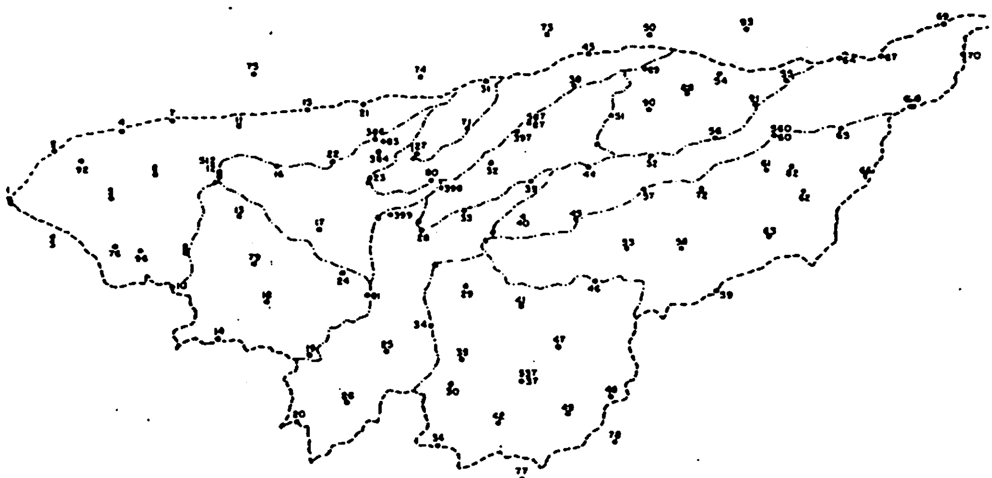

Figure 1. Recording raingage network, USDA Walnut Gulch experimental watershed, Tombstone, Arizona.

POINT-AREA-FREQUENCY-CONVERSIONS

Air-mass thunderstorms can produce very high rainfall intensities for short durations over relatively small areas. Point rainfall values are based on the chance of an extreme event being centered on, or very near to, a recording raingage. The chance of a single watershed rain gage recording runoff-producing rainfall during a runoff-producing storm decreases with increasing watershed size. In fact, in southeastern Arizona, raingages that are 5 km or more apart can be considered independent sampling points for thunderstorm events of this type (Osborn et al., 1979). Figure 3 shows the expected maximum 30- and 60-min rainfall depths for a return period up to 100 yr for a single point on Walnut Gulch and for the entire 150 km² watershed. Also shown are similar point values from NOAA Atlas 2 (Miller et al., 1973). The curves for Walnut Gulch are based on 20 yr of record from a dense network of recording raingages. The curves from NOAA Atlas 2 are based on data from a longer period of record from a few widely scattered recording gages.

The chance of runoff-producing rainfall occurring someplace on a watershed increases with watershed size (Fig. 3). At the same time, average watershed rainfall decreases with area (Miller et al., 1973; Osborn et al., 1980). An easy method of converting point frequency rainfall amounts for maximum 30-min and 60-min depth to use as input to determine sexpected peaks and volumes of runoff is shown in Figs. 4 and 5. Maximum 30-min values are given because several investigators have found high correlations between maximum 30-min rainfall and peak discharge for small watersheds (Reich and Hiemstra, 1965; Osborn and Laursen, 1973). Maximum 60-min values are shown because 1-hr rainfall is a generally accepted standard in many runoff-predicting methods, particularly for runoff volume.

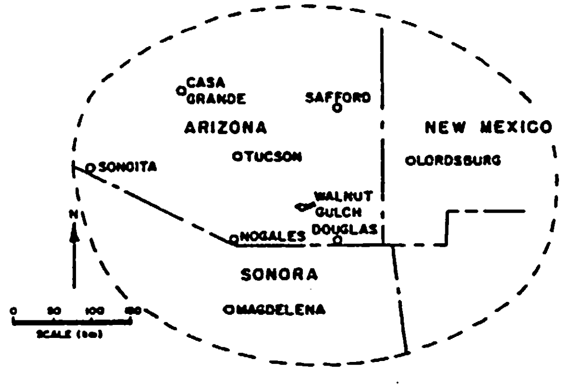

Figure 2. Region in which watershed runoff is dominated by air-mass thunderstorm rain similar to that at Walnut Gulch.

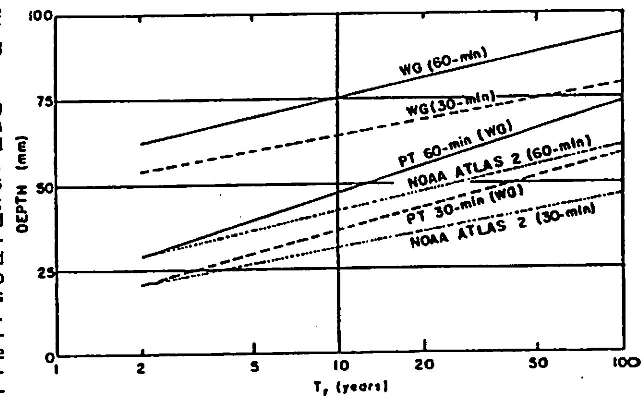

Figure 3. Point (pt) rainfall depths (mm) for return periods (T_r) up to 100 years for Walnut Gulch (WG), as compared with values taken from NOAA Atlas 2 (1973).

The graphs can be used to determine rainfall input for models predicting peak discharge or runoff volumes. For example, the maximum 30-min rainfall at a single point for a 50-yr return period is 53 mm (2.1 in), and there will be an average of four such events (i.e., the T_r = 12.5 yr) every 50 yr on a 50-km² (20-mi²) watershed (Fig. 4). On a watershed basis, the maximum 30-min rainfall for a 50-yr return period is 64 mm (2.5 in) (Fig. 4). For runoff volume, the maximum 60-min rainfall for a single point for a 50-yr return period is 66 mm (2.6 in), and the average rainfall over the watershed is 44 mm (1.8 in) (Fig. 5). On a watershed basis, there will be an average of three such events every 50 yr (Fig. 5).

LIMITATIONS

Some precautions must be taken in using the relationships in Figs. 4 and 5. The relationships are generally applicable throughout the region shown in Fig. 2. However, if better estimates of, for example, the 100-yr, 60-min rainfall are available at a specific location, such values should be used. Assuming the same relationship between point and areal frequency, the user may start with the new depth on the upper vertical scale rather than with the 100-yr value from the right horizontal scale. The point and areal frequencies and the average depth can be determined in the same way as the example and compared to the point frequency derived from Walnut Gulch data.

Duckstein et al. (1973) analyzed 7 yr of summer rainfall data from a network of recording raingages in the Santa Catalina Mountains. They found that the number of storms and the amount of rainfall increased with elevation, which might imply that runoff-producing storms with a given frequency occurring in the "valley" would occur more often in the mountains. This may be true for the more frequent events--2-yr, 5-yr, and, possibly, even the 10-yr events, but Osborn et al. (1979) found no significant correlation with changing elevation for the expected 100-yr rainfall on Walnut Gulch (elevation ranging from 1220 to

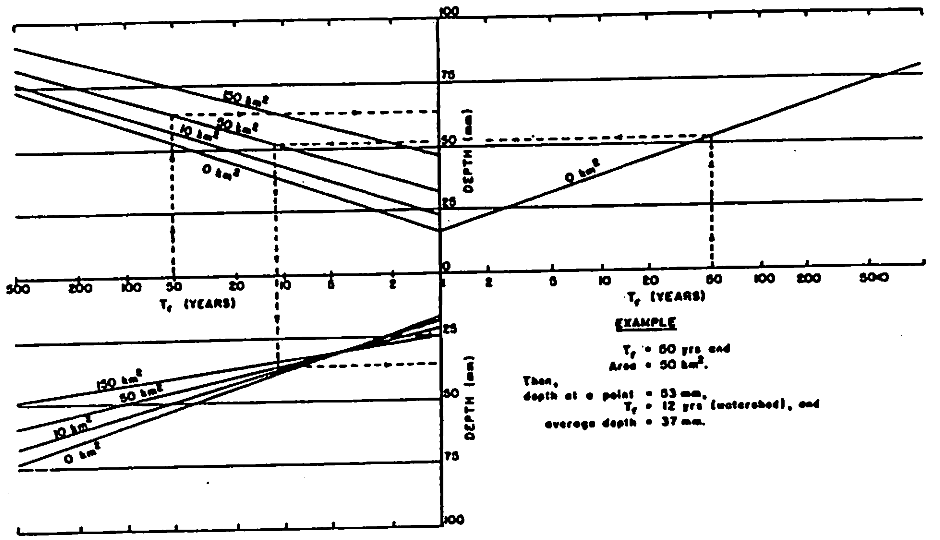

Figure 4. Conversion of maximum 30-min point rainfall depths (mm) for given return periods (T_r) to areal recurrence intervals and point-to-area (km²) reductions based on Walnut Gulch data.

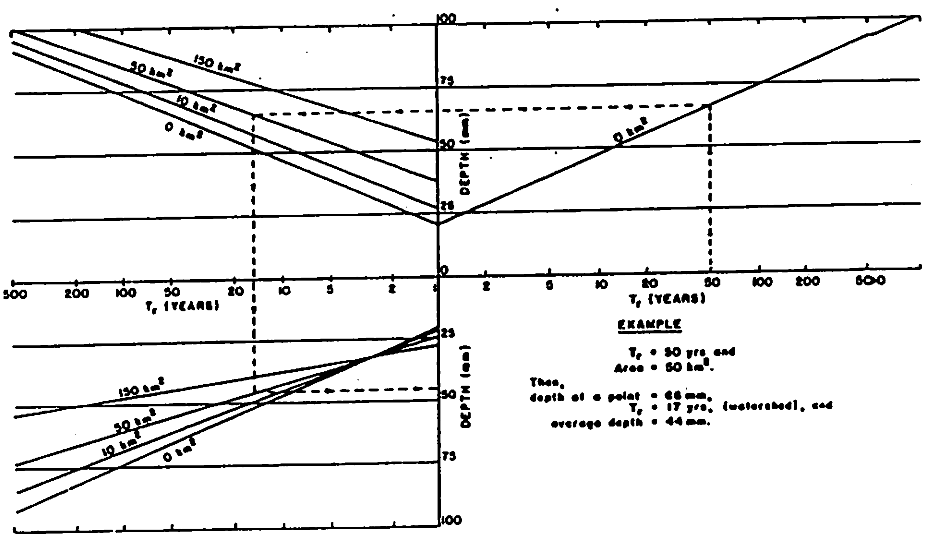

Figure 5. Conversion of maximum 60-min point rainfall depths (mm) for given return periods (T_r) to areal recurrence intervals and point-to-area (km²) reductions based on Walnut Gulch data.

1620 m). Furthermore, Osborn and Laursen (1973) noted that record peak discharges for small watersheds (under 150-km^2) in Arizona and New Mexico have been recorded from watersheds that do not originate at high elevations. Therefore, Figs. 4 and 5 are probably applicable without local elevation correction for flood peaks with return periods longer than 10 yr.

There is a general increase in extreme storm frequency from west to east in southern Arizona which corresponds in general to an increase in elevation. For this reason, where frequency data are available at a specific "valley" location, these data can be used with the Walnut Gulch curves. Again, the relationships should be used without adjustment for local differences in topography such as mountain ranges.

RUNOFF

Runoff-producing rainfall from air-mass thunderstorms generally covers no more than 50 km^2 within a larger watershed. The storms may be centered within the larger watershed or may overlap onto a smaller watershed. Furthermore, many rangeland watersheds are drained by abstracting sand-bottomed channels which may reduce flood peaks as they move downstream. However, Osborn and Laursen (1973) found good correlations between maximum 30-min rainfall and peak discharge for extreme events on watersheds up to 150 km^2 in size. They hypothesized that, for the larger (more infrequent) events, channel abstractions were satisfied in the rising limb of the hydrograph, and flood peaks were maintained for several miles downstream from the storm area. With smaller events, the channels abstracted water from the flood peak and reduced the peaks as they moved downstream. In the extreme case, the flood peaks did not reach the outlet of the larger watershed.

The relationships in Figs. 4 and 5 can be used in two ways. For small watersheds--up to possibly 10 km^2--average areal rainfall can be used directly to estimate flood peaks. For watersheds with extensive alluvial channel networks and for larger watersheds, a routing procedure is needed for accurate estimates of peak discharge. Lane (1981) has developed a distributed model for small semiarid watersheds that is particularly applicable in southern Arizona. Rainfall estimates are used as input to the distributed (Lane) model to establish flood peaks for desired frequencies from ungaged watersheds. This model can be used for any storm frequency, not just the more common events.

SUMMARY

A graphical procedure is presented to convert point rainfall data to areal rainfall values for use in predicting peak discharge and storm runoff from rangeland watersheds in southcentral and southeastern Arizona, southwestern New Mexico, and northern Sonora, Mexico.

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