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VOL.108 NO.IR2. JUNE 1982

# JOURNAL OF THE IRRIGATION AND DRAINAGE DIVISION

PROCEEDINGS OF
THE AMERICAN SOCIETY
OF CIVIL ENGINEERS


ISSN 0044-7978

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## Unsteady Drawdown in 2-D Water Table Aquifer[a]

**Closure by David T. Higgins,[4] M. ASCE**

Noutsopoulos and Papathanassiadis have made a useful point in suggesting the importance of including the seepage surface in the unsteady drawdown problem. In his paper, the writer listed the omission of the seepage surface as one of his simplifying assumptions. However, he should have shown a seepage surface in the sketch of his sand flume which was to model a real aquifer (Fig. 3).

Most of the remainder of the discussion seems akin to beating a dead horse: the horse being the writer's instantaneous drawdown equation, Eq. 24. In both his introduction and conclusion, the writer admitted that his analysis did not improve the prediction of water table motion.

Noutsopoulos's and Papathanassiadis's stress on the better fit of Eq. 25 with experimental data also seems beside the point. As they point out, Eq. 25 can be derived entirely on the basis of one-dimensional hydraulic theory. That theory is based on a flow model very unlike the flow near the outflow face at early time in an instantaneous drawdown problem. For this domain, vertical velocities are important, unsaturated flow is important, and so is the seepage face.

The Hele-Shaw analog is based on the similarity of viscous flow equations to those for flow through a saturated porous medium. There is no a priori reason why a Hele-Shaw apparatus should model correctly the unsaturated flow. The writer would be grateful to receive information about comparative unsteady drawdown tests in Hele-Shaw and granular models.

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## Simplified Method for Rainfall Intensities[b]

**Discussion by Herbert B. Osborn,[2] and Kenneth G. Renard,[2] Members, ASCE**

The author has introduced a method for estimating maximum monthly precipitation from mean monthly precipitation, and has presented other relationships

[a]September, 1980, by David T. Higgins (Proc. Paper 15696).

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[b]September, 1981, by George H. Hargreaves (Proc. Paper 16513).

[2]Research Hydraulic Engr., United States Dept. of Agric.-Agricultural Research Western Administration, Southwest Rangeland Watershed Research Center, 442 East Seventh Street, Tucson, Ariz. 85705.

between recorded data and intensity. He states, however, that local verification is needed before the methods are used in any particular locality or region.

The writers used 25 years of record from 30 rain gages, each on the Walnut Gulch and Alamogordo Creek Experimental watersheds in southeastern Arizona and eastern New Mexico, respectively, to examine the relationship between monthly maximum rainfall and monthly mean rainfall. Rainfall in southeastern Arizona is dominated by airmass thunderstorms, while more massive and intense storms can occur from frontal-convective buildup in eastern New Mexico. Higher intensities have been recorded on Alamogordo Creek than on Walnut Gulch for all durations (9). The relationship between 30-years maximum monthly and mean monthly rainfall suggested by the author (Table 1) for the United States is

$$\text{PMX} = 76 + 1.75\ \text{PM} \qquad (11)$$

For Walnut Gulch, this equation, using a 30-gage average, generally overpredicted (PMX) by 21–47% for the summer months. Also, for the summer months, estimates for individual stations (Eq. 11) ranged from −12%–92% of actual. In general, $R^2$ values between the predicted (Eq. 11) and the observed were low, ranging from 0.30–0.50. We used data from the summer thunderstorm period only (July–September), the period when about two-thirds of the annual precipitation occurs. When the writers used Walnut Gulch data to compute the regression relationship, the relationship became

$$\text{PMX} = 65 + 1.25\ \text{PM}; \quad \overline{\text{PMX}} = 140; \quad S = 34; \quad R^2 = 0.51 \qquad (12)$$

which is still a rather weak correlation between PMX and PM. The method might be used to obtain a rough estimate for a particular study, but the user should be aware of the probable error of estimate and how this might affect the study.

A similar analysis of Alamogordo Creek data indicated that in eastern New Mexico the average of predicted values was similar to the average of actual values. However, the range of values for summer months for individual stations was −35–180% of measured values, which is a much greater variability than on Walnut Gulch. Values for $R^2$ ranged from about 0.32–0.62, and *SD*'s were higher than in Walnut Gulch.

For Alamogordo Creek, the recomputed regression equation is

$$\text{PMX} = 42 + 2.24\ \text{PM}; \quad \overline{\text{PMX}} = 155; \quad S = 52; \quad R^2 = 0.73 \qquad (13)$$

Again, although the relationship might be used as a rough guide in some studies, the large probable error must be considered. Several comments regarding Table 1 should be noted:

1. The table would have greater utility if $\overline{\text{PMX}}$ were listed in addition to the standard deviation, *S*. By itself, the standard deviation does not provide meaningful information.
2. The coefficient of determination, $R^2$, between the regression coefficients for all of the countries was 0.63.
3. The writers suspect that the relationships for many of the countries, including the United States, include data from more than one type of precipitation (different climatic province), and we are surprised at the many high $R^2$ values.
4. It would probably be more useful if the station grouping in the table had

been segregated on some basis other than country boundaries. Thus, for example, if the criteria had been based on climate or meteorologic conditions (e.g., coastal versus mountain versus interior continental, or arid versus semiarid versus humid, or thunderstorm versus snow, or frontal versus convective versus orographic), we suspect the data might be extrapolated more readily to areas of limited data.

5. The utility of 30-years maximum monthly rainfall is awkward, since current engineering practice is to use 10-, 25-, 50-, or 100-years frequency estimates for most design applications. Furthermore, the maximum monthly precipitation in a 30-year data set may not be indicative of what one would expect once in 30 years.

The author also developed a relationship to determine the amount of rainfall that would rarely be exceeded. For the United States, the author states that the residual relationship is

$$R\,PMX = 156 + 1.14\,(76 + 1.75\,PM) \qquad (14)$$

The author then (arbitrarily?) adds 180 mm to arrive at the maximum expected monthly rainfall. Based on this method, the envelope limits for monthly rainfall on Walnut Gulch and Alamogordo Creek would be 514 and 508 mm, respectively. The recorded mean monthly rainfall for stations on Walnut Gulch and Alamogordo Creek are 89 and 86 mm, respectively, and the maximums that have occurred in 25 years of record are 204 mm on Walnut Gulch and 269 mm on Alamogordo Creek. The writers are unsure of what, if any, value this equation

**TABLE 2.—Ratio of Storm Rainfall Depth for Various Durations to One-Hour Rainfall for 37 Storms of Greater than 25 mm for Walnut Gulch**

| Extent | Duration, in minutes | | | | | |
|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 | 60 |
| Average | 0.28 | 0.50 | 0.66 | 0.76 | 0.88 | 1.0 |
| Range | 0.05–0.54 | 0.28–0.77 | 0.38–0.92 | 0.47–0.96 | 0.66–1.0 | — |
| Sept. 10, 1971[a] | 0.17 | 0.31 | 0.41 | 0.53 | 0.72 | 1.0 |

[a]Maximum one-hour point rainfall (88 mm): The only measured one-hour amount greater than 75 mm on Walnut Gulch (1955–71).

**TABLE 3.—Ratio of Storm Rainfall Depth for Various Durations to One-Hour Rainfall for 37 Storms of Greater than 25 mm for Alamogordo Creek**

| Extent | Duration, in minutes | | | | | |
|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 | 60 |
| Average | 0.25 | 0.41 | 0.56 | 0.68 | 0.81 | 1.0 |
| Range | 0.13–0.47 | 0.25–0.67 | 0.35–0.98 | 0.45–0.99 | 0.63–0.99 | — |
| June 5, 1960[a] | 0.20 | 0.39 | 0.54 | 0.69 | 0.84 | 1.0 |
| Aug. 21, 1966[b] | 0.20 | 0.34 | 0.46 | 0.55 | 0.68 | 1.0 |

[a]Maximum one-hour point rainfall (103 mm) on Alamogordo Creek (1955–77).

[b]Maximum one-hour point rainfall (91 mm) for second greatest event on Alamogordo Creek.

or "limit" would be to users or how accurate or dependable it might be.

The author also found a relationship between P10,24 and PMX (Eq. 3). For an average PMX of 160 mm for Walnut Gulch, the predicted P10,24 would be 70 mm. Walnut Gulch data indicate the actual P10,24 is about 60 mm, which is reasonably close. For Alamogordo Creek, PMX is about 200 mm, and the predicted P10,24 would be 82 mm. Data from Alamogordo Creek indicate that P10,24 is about 70 mm; so again, the prediction is a little low, but reasonable.

The author included a table of ratios of short duration to 1-hour rainfall. Osborn, et al. (10) reported somewhat different values (Tables 2 and 3).

Although these average ratios (Tables 2 and 3) do not differ greatly from those listed by the author, the range of ratios indicates the problems of using average ratios to distribute 1-hour precipitation depths to shorter durations.

## Appendix.—References


9. Osborn, H. B., Renard, K. G., and Simanton, J. R., "Dense Networks to Measure Convective Rainfall in the Southwestern United States," *Water Resources Research*, Vol. 15, No. 6, 1979, pp. 1701–1711.
10. Osborn, H. B., Shirley, E. D., Davis, D. R., and Koehler, R. B., "Model of Time and Space Distribution of Rainfall in Arizona and New Mexico," *USDA-SEA Agricultural Reviews and Manuals*, ARM-W-14, 1980, 27 p.