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THIS ISSUE INCLUDES
FIVE PAPERS ON
LAND SUSIDENCE

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DISCUSSION

Proc. Paper 16283

INFORMATION RETRIEVAL

The key words, abstract, and reference "cards" for each article in this Journal represent part of the ASCE participation in the EJC information retrieval plan. The retrieval data are placed herein so that each can be cut out, placed on a 3 × 5 card and given an accession number for the user's file. The accession number is then entered on key word cards so that the user can subsequently match key words to choose the articles he wishes. Details of this program were given in an August, 1962 article in CIVIL ENGINEERING, reprints of which are available on request to ASCE headquarters.

*Discussion period closed for this paper. Any other discussion received during this discussion period will be published in subsequent Journals.

Erosivity Values for Individual Design Storms[a]

Discussion by George R. Foster[2]

The author developed regression equations for estimating maximum 30-min intensity and erosivity for Soil Conservation Service design storms. These equations can be improved by a more detailed analysis of storm energy.

Where rainfall hyetographs are smooth, continuous, single-peaked functions like the SCS curves, total storm energy E can be calculated from:

$$E = \int_0^D e\, i\, dt \qquad (8)$$

in which e = rainfall energy per unit rainfall; i = rainfall intensity as a function of time; t = time; and D = storm duration. Substituting the author's Eq. 1 for e in Eq. 8 gives:

$$E = 916\, P + 331 \int_0^D i \log i\, dt \qquad (9)$$

in which P = amount of rainfall in the storm. After normalization of intensity and time by $i_* = iD/P$ and $t_* = t/D$, Eq. 9 becomes:

$$E = P\left[916 + 331 \log\left(\frac{P}{D}\right) + 331 \int_0^1 i_* \log i_*\, dt_*\right] \qquad (10)$$

since $\int_0^D i dt = P$ and $\int_0^1 i_*\, dt_* = 1$. The sum in brackets gives average energy, $\bar{e}$, per unit rainfall for the storm. The term:

$$e_i = 916 + 331 \log\left(\frac{P}{D}\right) \qquad (11)$$

gives energy per unit rainfall based on the storm's average intensity (P/D). The term

$$e_n = 331 \int_0^1 i_* \log i_*\, dt_* \qquad (12)$$

accounts for the nonuniformity of rainfall intensity and depends only on the normalized distribution of intensity and not on volume or duration. Eq. 12 was numerically integrated for the SCS curves. The result is exact, except for errors due to numerical integration that can be made as small as desired. Values for e_n are given in Table 6. Therefore, Eq. 10 and Table 6 are a means of almost exactly computing energy for the SCS design curves.

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[a]June, 1980, by Keith R. Cooley (Proc. Paper 15462).

[2]Hydr. Engr., U.S. Dept. of Agric., Science and Education Administration, Agricultural Research, Dept. of Agricultural Engrg., Purdue Univ., Lafayette, Ind.

The author's Eq. 2 for maximum 30-min intensity can be rewritten as

$$I = \left(\frac{P}{D}\right)(\alpha' D)^{1+\beta} \quad \text{(13)}$$

in which α' = a constant to be determined. When D = 0.5 h, I must equal P/D, which can only occur if α' = 2. Therefore, Eq. 13 can be rewritten as:

$$I = \left(\frac{P}{D}\right)(2D)^{\gamma} \quad \text{(14)}$$

in which γ is evaluated from the author's β as $1 + \beta$. Values for γ are given in Table 7. Eq. 14 eliminated the author's parameter α.

TABLE 6.—Factor Accounting for Nonuniform Distribution of Rainfall for Computing Storm Energy for SCS Design Storms

Storm type (1)	Nonuniformity factor e_n (2)
IA	28
I	65
II	142
IIA	257

TABLE 7.—Exponent for Equation for Maximum 30-min Intensity

Storm type (1)	Exponent (2)
IA	0.44
I	0.60
II	0.75
IIA	0.864

Combining Eqs. 10, 12, and 14 gives an equation for EI that is very accurate, assuming that the author's equation for maximum 30-min intensity is very accurate:

$$EI = P^2\left[916 + 331 \log\left(\frac{P}{D}\right) + e_n\right] 2^{\gamma} D^{\gamma-1} \quad \text{(15)}$$

Storm erosivity can also be written as:

$$EI = \bar{e}\, P\, I \quad \text{(16)}$$

Assuming that average unit energy, $\bar{e}$, for a storm is a power function of average intensity, P/D, for the storm gives:

$$\bar{e} = \mu\left(\frac{P}{D}\right)^{\epsilon} \quad \text{(17)}$$

which substituted in Eq. 1 gives:

$$EI = \frac{\mu 2^{\gamma} P^{2+\xi}}{D^{\xi-\gamma+1}} \quad \text{(18)}$$

Eq. 18 has the form of the author's Eq. 3 where the exponent $2 + \xi$ was approximated with a function of rainfall duration, D. However, the exponent ξ depends on P, D, and SCS-type curve, as can be seen from Eq. 10, which suggests that the author's exponents fD and B should also be functions of duration, volume, and type of SCS curve.

An r^2 of 0.98 indicates that Eq. 3 did not fit perfectly. Although this is a very high r^2, indicating a very good fit, some indication of magnitude of

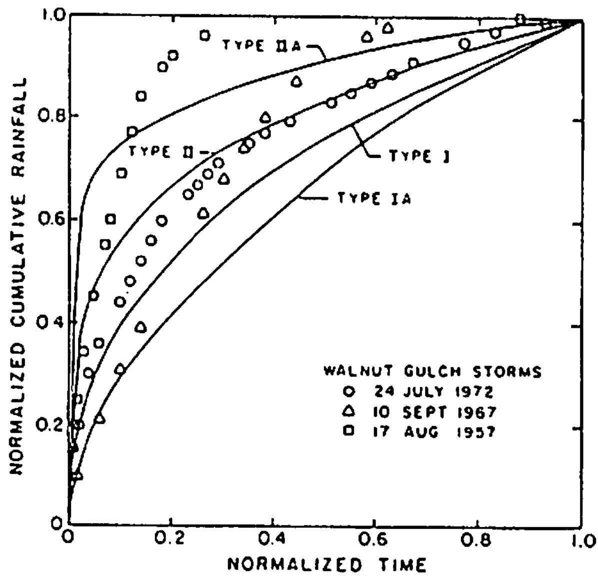

FIG. 5.—Cumulative Precipitation where Intensities Have Been Arranged from Largest to Smallest

errors and the condition of their occurrence is needed. Especially, were errors large for extremes of P, D, SCS-type curve, or their combination?

The author showed that SCS curves more nearly represent actual storm distributions when variables for time and precipitation are normalized. However, visual comparison of observed rainfall data with SCS curves is still difficult using the author's Fig. 2, because the time of peak intensity for the observed data and the SCS curves do not coincide. However, the curves can be replotted to facilitate the comparison.

Storm energy depends only on magnitude of intensities within a storm and not their order. For single-peaked storms, maximum 30-min intensity depends on cumulative precipitation on either side of the time of peak intensity. Therefore, EI can be computed from intensities that have been arranged in descending order. Fig. 5 is a plot of cumulative precipitation from intensities rearranged in this order. Although curves can be compared over the entire time duration their critical point is the normalized time, 30 min divided by storm duration. For example, the 30-min normalized time for the 3.53 h, August 17, 1957 storm is 0.14. At this point, the observed rainfall curve in Fig. 5 is above the Type-IIA curve, indicating that actual *EI* is at least as great as that estimated from a Type-IIA curve. The September 10, 1967 observed rainfall curve suggests an *EI* value slightly less than that for the Type-II curve. The actual value is about halfway between the values for Type-I and Type-II curves. The July 24, 1972 curve suggests an *EI* value slightly above that halfway between values for Type-I and Type-II curves. The actual *EI* is slightly above the *EI* for a Type-I curve. This shows that data from observed rainfall having a single peak intensity can be rearranged to allow visual selection of an SCS curve to compute *EI*.

This discussion was written in cooperation with the Purdue Agricultural Experiment Station (*Purdue Journal No. 8218*).