

MODIFIED RUNOFF CURVE NUMBERS FOR ARID RHYOLITE BASINS

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ABSTRACT

Runoff curve numbers (CN) for rhyolite basins in the Indian arid zone were derived from rainfall and runoff data recorded over a period of 5 years from 1975-1979. As against the Soil Conservation Service Hand Book values of 90-92, the actual optimized CN was found to be 74, indicating a lesser volume of runoff from these basins than estimated by the SCS method. The hand book CN value overpredicted runoff by 31 to 54% for storms >100 mm, and by 88 to 267% for storms <50 mm. Reasons for the same have been discussed. A significant correlation ($r=0.82$, $n=89$) was found between the observed and predicted values using the modified CN based on the measurements.

INTRODUCTION

Hydrologically rocky pediment and plateaux in the arid and semi arid regions have high runoff potential and therefore, have been classified under category 'D' of the hydrological soil groups (SCS, 1972). However, due to the weathering of exposed rocky surfaces, fractures, loose stones and gravels, under the arid environments the total runoff volume decreases (Anonymous, 1982). Therefore, a need was felt to modify the SCS runoff curve numbers (CN) for arid rhyolite basins.

BASIN CHARACTERISTICS

The study was conducted in the arid north-west India at the Afforestation Research Station, Kailana of the Central Arid Zone Research Institute, Jodhpur (26.30° N, 73.03° E) for a period of 5 years from 1975 to 1979. Six contiguous rhyolite basins of 0.8 to 2.2 ha area, 3.6 to 25.0% slope and 70-90% impervious surface were equipped with standard raingauges, stage level recorders and 61 cm H-flumes to monitor the daily rainfall and runoff from each basin (Shankarnarayan et al., 1987). The study area receives a mean annual rainfall of 360 mm (80 year average) -87% of which is concentrated between July and September as summer monsoon rains. The soils are shallow to moderately deep, sandy loam type occurring in crevices, fractures and depressions. In the Kailana plateau the vegetation community *Euphorbia caducifolia-Acacia senegal* is common. The predominant land use is grazing followed by the stone quarrying in pockets.

STORM CHARACTERISTICS

A total of 24 storm events, resulting in discernible storm runoff during the study period, were analysed. No effort was made to screen the events to be included in this analysis. They were for the most part single burst events with fairly well defined hydrographs.

Observed storm rainfall amounts varied from 9.9 to 136.8 mm with average storm rainfall intensities ranging between 1.3 and 120.0 mm/h. Mean storm runoff volumes ranged between 0.07 and 93.04 mm. Figure 1 (a) shows that a wide and representative distribution of rainfall events are included. By way of comparison, the 1-year 24 hours rainfall in the study area is about 55.9 mm and for 10-year, 24 hours rainfall is 104.1 mm. Figure 1(b) indicates that the data set primarily consists of the more frequent events but it does include unusual (larger) events.

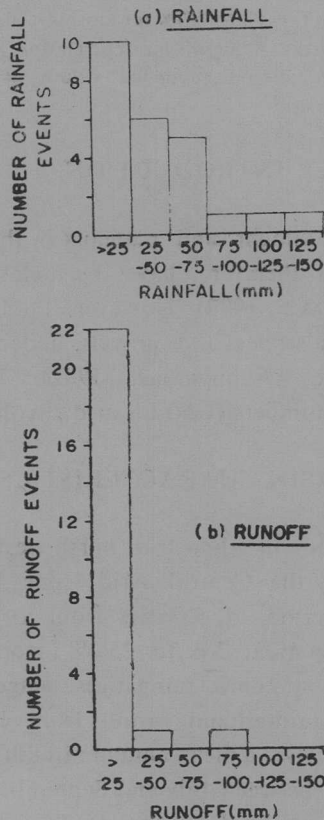


Fig. 1. Distribution of storm rainfall and runoff volumes among observed events

STUDY METHOD OLOGY

The SCS method of estimating runoff due to rainfall uses the equation :

$$Q = \begin{cases} 0, & \text{if } P \leq 0.2S \\ \frac{(P - 0.2S)^2}{P + 0.8S} & \text{if } P > 0.2S \end{cases} \quad (1)$$

In which Q is directed runoff, P is storm rainfall and S is potential maximum retention; all volumes are measured in mm. The retention parameter S is related to the dimensionless runoff CN by

$$CN = \frac{25.4 \times 10^3}{254 + S} \quad (2)$$

This procedure incorporates four soil classifications; three antecedent moisture classifications, and various cover complexes. The soil classification is broken into four hydrologic soil groups A, B, C, and D varying from relatively low runoff potential (A) to high runoff potential (D). Antecedent moisture condition I represents a relatively dry condition, II represents an average or normal condition, and III represents a wet antecedent condition. CN also reflects landuse, such as bare fallow, row crops, and pasture, as well as treatments or practices, such as straight row cultivation, contour farming and terracing (SCS, 1972). The usual SCS procedure is to determine CN from the handbook for the given soil and cover complexes and average antecedent moisture classification II. The CN for condition II is then adjusted for the existing moisture condition (SCS, 1972).

However, since observed rainfall and runoff data are available, equation (1) can be solved for S as

$$S = 5P + 10Q \pm 10(Q^2 + 1.25QP)^{1/2} \quad (3)$$

In this case, only the negative root has meaning. Therefore, substituting this relationship for S in equation (2), yields an observed CN as

$$CN_{obs} = 25.4 \times 10^3 / (254 + 5P + 10Q - 10(Q^2 + 1.25QP)^{1/2}) \quad (4)$$

The values of CN_{obs} were optimized by least squares analysis of the calculated versus measured runoff values. The objective function of best fit criterion for the determination of the optimized CN is

$$\text{to minimise } \sum_{i=1}^n (Q_i - \hat{Q}_i)^2$$

Where Q_i is observed runoff volume. \hat{Q}_i is predicted runoff volume using equation (1) i.e. a single CN for all storms, and n is the total number of observed events. Although our study included all storms, with runoff, in contrast to the

larger events, least squares procedure tended to give more weight to the larger storms. The calculated CN using all events compared closely with CN using only storms of 50 mm or more.

RESULTS AND DISCUSSION

The modified runoff CN for arid rhyolite basins using actual rainfall-runoff data was found to be 74 as against the published values in the SCS handbook (90 for a watershed having 50 to 75% impervious surface and 92 for hard surface). If the predicted values using the modified runoff CN are compared with observed values of runoff (Fig 2). the regression equation (5) is obtained

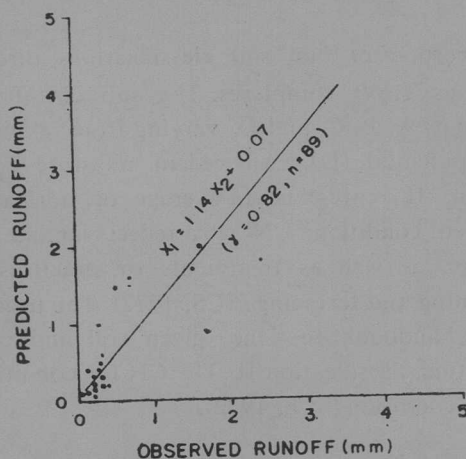


Fig. 2. Comparison of observed versus predicted runoff amounts from modified runoff curve numbers for arid rhyolite basins

$$X_1 = 1.14X_2 + 0.07 \quad (r=0.82, n = 89, P < 0.01) \quad (5)$$

where X_1 is observed runoff (mm), and X_2 is predicted runoff (mm) With a coefficient of determination (R^2) of 0.68, which shows an acceptable fit of the optimized CN. The equation is accurate enough for predictive purposes.

The handbook-CN overpredicted the runoff volume by 31 to 54% for large events (>100 mm) and 88 to 267% for the small events (< 50 mm). The rhyolite hills and associated rocky pediments in the Indian arid zone are highly weathered which result in the abundance of faults and fractures, cracks and crevices, and depression. Further, the surfaces are mantled with loose stones, pebbles and gravels. These resulted in the higher abstraction of rainfall, before the initiation of runoff which is evident from the high threshold rainfall (89 mm) and low runoff efficiency (35%) of these basins (Shankarnarayan et al., 1987). Hence, the actual runoff yield from arid rhyolite basins is less than that estimated by the SCS curve numbers.

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