ESTIMATION OF MAXIMUM ONE-DAY POINT RAINFALL FOR THE KRISHNA BASIN USING NOMOGRAM METHOD

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ABSTRACT

A quick and simple procedure has been developed for evaluating maximum point rainfall for different return periods for any station in the Krishna catchment. Maximum one-day rainfall for different return periods of 2 to 100 years have been worked out using Gumbel's statistical method for all the stations in the Krishna basin. With the help of this data 2 and 100-year generalized rainfall charts for 1-day duration, frequency interpolation nomogram have been prepared.

Knowing the 2-year and 100 year rainfall values of any station in this catchment and with the help of this nomogram, rainfall magnitudes for intermediate return periods viz. 5, 10, 25 and 50 years can be obtained directly. Maximum 1-day rainfall obtained by this method for different return periods have been found to agree within the limits of ± 4% of the results obtained by Gumbel's statistical method.

1.0 INTRODUCTION

A knowledge of maximum point rainfall distribution over an area or a basin is essential for the proper planning and design of hydraulic structures such as culverts, highway bridges, urban and airport drainage works etc. In order to provide adequate waterways for such type of structures, their design is normally based upon maximum rainfall of a specific return period. For this purpose the design engineers would like to have a method which will readily gives them fairly reliable estimates of maximum rainfall for different return periods. With this in view, in this paper, a simple procedure has been devised, with the help of which maximum rainfall for any of the return periods such as 5, 10, 25 and 50 years can be obtained for any station in the Krishna basin.

2.0 RAINFALL CHARACTERISTICS OF THE KRISHNA BASIN

The Krishna river originating from the eastward slopes of the Western Ghats near Mahabaleshwar (1380 m msl), flows a distance of about 1400 km into the Bay of Bengal. The river with its tributaries (the Bhima, the Musi, the Munera, the Koyna, the Varna, the

Ghatprabha, the Malaprabha and the Tungabadhra) form an integrated drainage system in the central portion of the peninsular India.

The average annual rainfall in the catchment is about 88.8 cm with a standard deviation of 15.0 cm. In general, the rainfall in the river catchment is very large, in some places it amounts to 200 to 400 cm or even more than 600 cm per year. The most of the annual rainfall, the primary source of water in the catchment occurs in the southwest monsoon season of June to September. The rainy season lasts mainly from June to September during which nearly 77% of its annual rainfall is received. July is the month of maximum rainfall. On an average there are about 105 rainy days in a year and July and August are months with greatest rainy days. The variability in rainfall over the catchment has been examined. It is seen that the variability in the main rainy months from June to September is high and C.V. ranges from 29 to 36 percent (Kulkarni, et al., 1998).

3.0 RAINGAUGE NETWORK AND DATA USED

Long-period daily rainfall records are available for about 200 stations in and around the catchment. The longest period of record common to these stations begins from 1901 and therefore, daily rainfall data from the year 1901 was considered in this study. The rainfall data used in the study were obtained from the National Data Centre of the India Meteorological Department at Pune and covers the period 1901 to 1985.

4.0 MAXIMUM ONE-DAY RAINFALL AND ITS FREQUENCY OF OCCURRENCE

Hershfield and Kohlar (1960) after testing the various methods of frequency analysis have found that Gumbel's (1954) extreme value method is quite satisfactory for predicting the probability of occurrence of maximum rainfall of different magnitudes. Gumbel's (1954) extreme value distribution as modified by Chow (1964) has been used in this study for the analysis of extreme annual one-day rainfall data of each of the stations. For this distribution :

$$X_T = A + B\,K_T \qquad (1)$$

where

X = any variable subject to frequency analysis,

X_T = magnitude of x for the return period of T-years, the frequency factor

K_T = $-[1.1 + 1.795 \log_{10} \log_{10} (T/T\text{-}1)]$ and A and B are constants to be determined by the method of least squares.

For each observed annual maximum one-day value of rainfall, the corresponding value of K_T was determined using the formula

$$T = (N+1)/m$$

where N is the total number of years of record and 'm' is the rank number when N values are arranged in a descending order of magnitude.

The above method was applied to the annual maximum rainfall data of all the stations in and around the Krishna catchment and maximum one-day rainfall estimates for the return periods of 2, 5, 10, 25, 50 and 100-year were obtained for each of the stations.

Langbein (1949) has shown that by using annual maximum rainfall series, slightly less values are obtained for the low return periods up to 10 years. To obtain fairly accurate estimates of rainfall for low return periods, the technique of partial-duration series was used. As such the values of rainfall for return periods up to 10 years, were converted into partial duration series by the application of relevant conversion factors obtained by Dhar and Kulkarni (1970) for Indian conditions.

4.1 Preparation of one-day generalized rainfall chart for 2 and 100-year return period

Simple and easy to use procedures for estimating maximum point rainfall for any station have been developed for various regions of the country (Dhar et al., 1971, 1978). These consist of (i) preparing generalized charts for 2 and 100-year return period for a region and (ii) developing suitable nomogram which can directly be used to obtain maximum values of point rainfall for the intermediate return periods of 5, 10, 25 and 50 years. This technique has been used for the Krishna catchment for the estimation of maximum point rainfall of one-day duration for 2 and 100-year return periods.

Point rainfall values of 2-year and 100-year thus obtained for each station were plotted on separate large scale base maps of Krishna catchment and its neighbouring regions and smooth isopleths were drawn at suitable intervals. Figs.1 and 2 show the generalized 2 and 100-year one-day rainfall maps of the Krishna catchment. It is seen from these generalized charts that 2-year, 1-day rainfall and 100-year 1-day rainfall varies from 8 cm to 30 cm and 20 cm to 50 cm respectively.

4.2 Preparation of return period interpolation nomogram

A nomogram was then prepared using the technique developed by the US Weather Bureau (1961). The nomogram is shown in Fig.3. With the help of this nomogram, point rainfall estimates for this region for return periods of 5, 10, 25 and 50 years can be directly obtained with the help of 2 and 100-year generalized charts of rainfall (Figs.1 and 2).

4.3 Estimation of maximum one-day point rainfall of different return periods any station in the Krishna catchment

The procedure for obtaining estimates of maximum rainfall for any station in the Krishna catchment for different return periods of 5, 10, 25 and 50 year with the help of Figs.1, 2, and 3 are given below :-

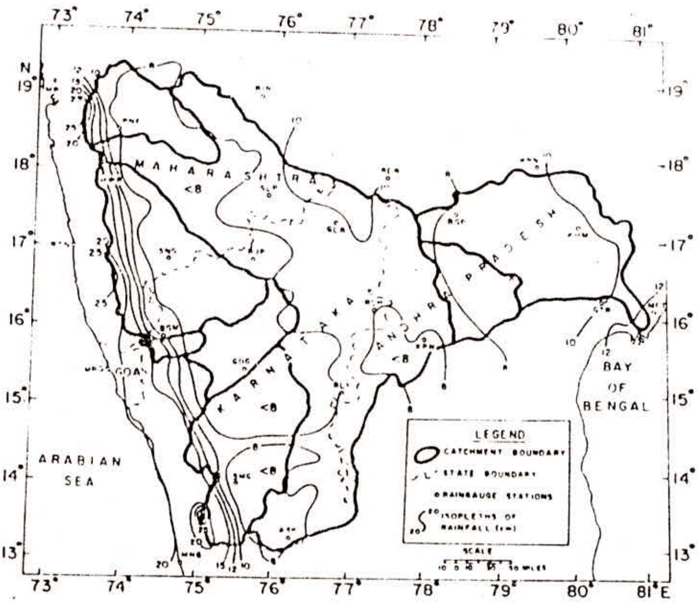

Fig. 1 : Generalized chart of 2-Year one-day maximum rainfall (in cm) of the Krishna Catchment.

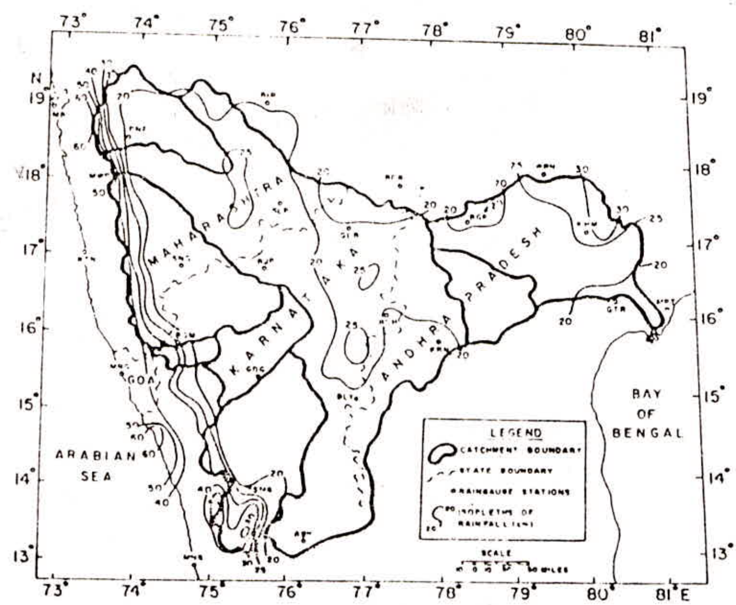

Fig. 2 : Generalized chart of 100-year One-day maximum rainfall (in cm) of the Krishna Catchment.

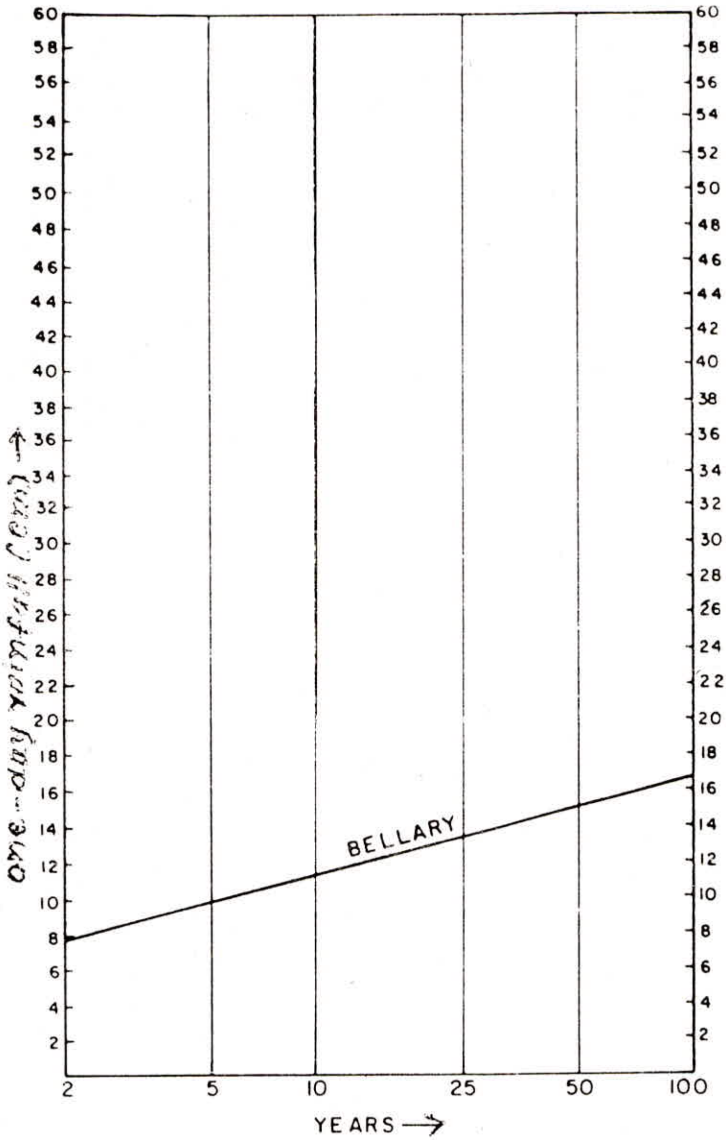

Fig. 3 : Return period interpolation diagram for the Krishna Catchment.

Suppose 25-year maximum one-day rainfall was required for a station, say, Bellary (Lat. 15° 09', Long. 76° 51'). The 2-year and 100-year one-day rainfall values for this station were directly picked out from the generalized charts given in Figs.1 and 2 respectively. The values are 8.0 cm and 17.0 cm respectively.

The 2-year and 100-year values of rainfall thus obtained for this station were then marked on the respective vertical ordinates of the nomogram (Fig.3), for estimating rainfall of the intermediate return periods of 5 to 50 years for this station. For this purpose a straight line was drawn joining 2 and 100-year values on the nomogram. The rainfall value for the return period of 25-years was then read at the intersection of the straight line joining 2 and 100-year values with the 25-year return period vertical line. This value from Fig.3 was found to be 13.5 cm. The actual value worked out directly by the Gumbel-Chow technique for this return period was found to be 13.6 cm. Rainfall estimates for any other station and return period can be obtained in this manner.

The rainfall estimates for different return periods obtained by the above procedure for about 50 randomly selected stations in the Krishna catchment were compared with those obtained directly by Gumbel-Chow procedure. It was observed that for most of the stations the values thus obtained were found to be within ± 4% of the computed values. This can be easily verified from Figs 4 (a to d), which shows the relationship between the values obtained directly by computation and by the nomogram procedure for return periods of 5, 10, 25 and 50 years.

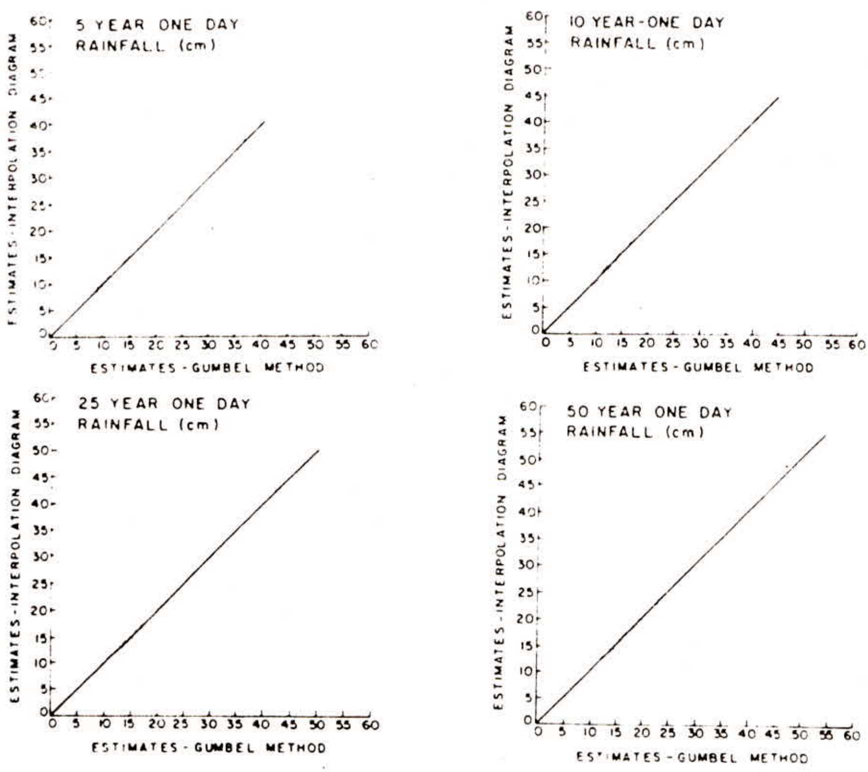

Fig. 4 : Relation between one-day rainfall obtained by Gumbel method and frequency interpolation diagram.

This method of obtaining estimates of maximum point rainfall of different return periods for a station does not require any detailed analysis of the data and hence can be used by planners and hydrologists for their preliminary estimates.

5.0 SUMMARY AND CONCLUSIONS

Maximum one-day rainfall of return periods of 2 to 100-year have been worked out for stations in the Krishna catchment and its neighbourhood using 85 years rainfall data. It is seen that maximum 1-day rainfall for 2-year return period for stations in the region ranges from 5.8 to 31.2 cm while in 100-year return period from 12.6 to 57.6 cm. With the help of this data 2 and 100-year generalized charts and frequency interpolation nomogram given in this paper, estimates of maximum 1-day rainfall for return periods from 5 to 50 years for any station in the Krishna catchment can be easily obtained. It is seen that values obtained directly by using Gumbel technique and the nomogram method are well comparable and lie between ± 4% of the computed values.

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