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Frequency analysis of flood flow in krishna river using gumbell distribution at vijayawada station, andhra pradesh, India

Khan Mujiburrehman

Environmental Engineer, Dar al Handasah, Makkah, Saudi Arabia

Abstract

This paper presents a frequency distribution study on fitting of maximum monthly flood magnitude in Krishna River at Vijayawada station using commonly used probability distributions for periods from 1901 to 1979. The Lognormal, Log Pearson type III and Gumbell distributions are proposed and tested together with their single distributions to identify the optimal model for maximum monthly flood. The selected model will be determined based on the minimum error produced by some criteria of goodness of-fit (GOF) tests. The results indicated that Gumbell distribution is better than the other distributions in modeling maximum monthly flood magnitude for Krishna River. These results however can vary between the rain gauge stations which are strongly influenced by their geographical, topographical and climatic changes. The frequency analysis was performed with Gumbell distribution and peak value of monthly runoff was evaluated for return periods (T) from 500 to 2 years. The following study can be used by planners and designers for designing the various hydraulic structures such as dam, bridges, spillways, canals and levees etc. The study further can be extended into flood forecasting methods and flood inundation map.

Keywords: Krishna River, Flood, Goodness of Fit test, Gumbell distribution.

1. Introduction

India has a large network of rivers which are spread out over the country. They are a great source of prosperity and energy if properly harnessed. Floods are natural hazards causing loss of life, injury, damage to agricultural lands, and major property losses [1]. One method of decreasing flood damages and economic losses is to use flood frequency analysis for determining efficient designs of hydraulic structures. In hydrology, estimation of peak discharges for design purposes on catchments with only limited available data has been a continuing problem [2]. A promising and elegant approach to this problem is the derived flood frequency curve. Reliable estimates of flow statistics such as mean annual flow and flood quantities are needed, however, historical data that are needed to estimate these statistics are not always available at the site of interest or available data may not be representative of the basin flow because of the changes in the watershed characteristics, such as urbanization [3][4]. In practice, design floods often are estimated on the basis of a single site and/or regional flood-frequency analysis (Burn, 1990). An optimum design can be achieved with proper flood frequency and risk analyses [5]. However design floods estimated by fitted distributions are prone to modeling and sampling errors [6]. Several researchers have investigated different distributions for application to flood-frequency analysis [2] [5]. [7] Opined that the most commonly applied distributions now being the Gumbel (EV1), the Generalized Extreme Value (GEV), the Log Pearson Type III (LP3), and the three parameter Lognormal (LN3). Modeling flood flow data using various mathematical models has been an important research in hydrology for the last 30 years. The use of mathematical models of annual flow has been applied worldwide in order to give a better understanding about the flood pattern and its characteristics. The planning engineers are often concerned with flood flow for various recurrence intervals for planning and designing of dams, spillways, canals, headwork and levees etc. This paper tries to give the value of flood for different return period which can be useful for further hydraulic structures design.

In this paper, we will focus on basic two and three parameters distributions in order to find the best model in fitting maximum annual flood data. In order to verify the suitable distribution that best describes the maximum monthly flood, the new method of goodness-of-fit tests

Corresponding author- Khan Mujiburrehman
Email Id: mujibkhan87@gmail.com

(GOF) based on the likelihood ratio statistics which has been developed by Zhang [8]. The final result on the best fitting distribution will be chosen based on the minimum error specified by these GOF criteria. The Gumbell method of frequency analysis will be used for determination of peak for various return periods.

2. Materials and methods

2.1 Study area description

The Krishna River is the second largest eastward draining interstate river in Peninsular India. It rises in the Mahadev range of the Western Ghats at an altitude of 1,337 m near Mahabaleshwar in Maharashtra State, about 64 km from the Arabian Sea. It flows for a distance of 305 km in Maharashtra, 483 km in Karnataka and 612 km in Andhra Pradesh before finally out falling into the Bay of Bengal. The length of the river is about 1,400 km Krishna basin lies between latitudes 13º 07' N and 19º 20' N and longitudes 73º 22' E and 81º 10' E. Drainage area of the basin is 258,948 km^2 [9] . The location of Krishna River has been shown in Figure 1.

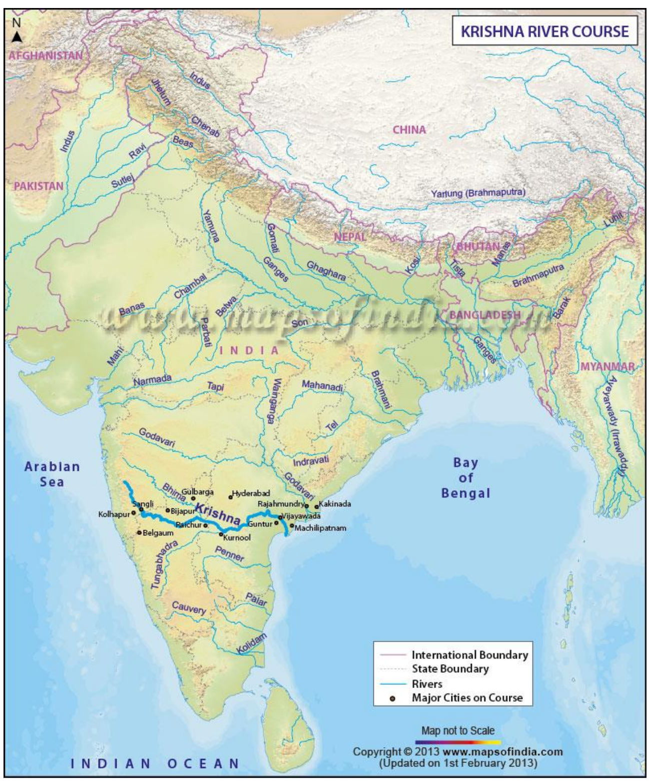

Figure 1: Location of Krishna River

2.2 Major Tributaries and sub-tributaries

The largest tributary of the Krishna River is the Tungabhadra River. A stream formed by the Tunga River and Bhadra River downstream of their sources in the Western Ghats of Karnataka [9].

2.3 Flooding problem

In 2009 October heavy floods occurred, isolating 350 villages and leaving millions homeless, which is believed to be first occurrence in 1000 years. The flood resulted in heavy damage to Kurnool, Mahabubnagar, Guntur, Krishna and Nalagonda Districts. The entire city of Kurnool was immersed in approximately 10 feet (3.0 m) water for nearly 3 days. Water inflow of 1,110,000 cuft/sec (31,000 m^3/s) was recorded at the Prakasam Barriage, which surpassed the previous record of 1,080,000 cuft/sec (31,000 m^3/s) recorded in the year 1903 [10].

2.4 Stream Gauging Network

The data has been collected with courtesy from Centre for Sustainability and Global Environment web site. The discharge site is Vijayawada (21.92 N, 73.65 E) and has been shown in Figure 2.

Figure 2: Location of Flow gage at Vijayawada station

3. Modeling maximum monthly flood at Vijayawada station

Models of maximum monthly flood amount are described as follows with their probability density functions and cumulative distribution functions. Note that X is the random variable representing the Maximum monthly flood magnitude. The maximum monthly flood at Vijayawada has been shown in Figure 3.

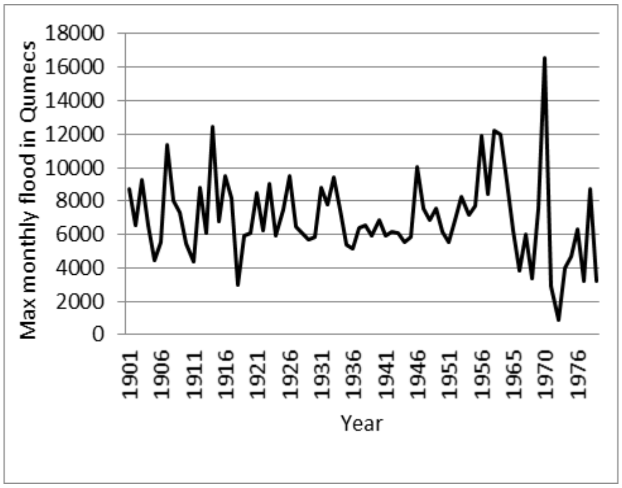

Figure 3: Maximum Monthly flood at Vijayawada

3.1 Estimation of parameters

Many methods are available for parameter estimations, which include the method of moments (MM), maximum likelihood estimation (MLE), the least squares method (LS), L-moments and generalized probability weighted moments (GPWM).The MLE method is considered in this study because it provides the smallest variance as compared to other methods. The idea of this method is to find a set of parameters that will maximize the likelihood function. The parameters are obtained by differentiating the log likelihood function with respect to the parameters of the distribution. The all parameters was estimated by creating formulas in Microsoft excel 2010 and have been shown in Table 1.

Table 1: Parameters of selected distributions

Distributions	Parameters				
	μ	σ	α	β	ϒ
Lognormal	8.7309	0.39971	--	--	--
Gumbell maximum value	5574.6	1860.7	--	--	--
Log Pearson Type	--	--	4.0067	0.2038	9.5475

4. Goodness-of-fit tests (GOF)

Three different commonly used GOF tests have been used in this study to identify the best fit models. The chosen distribution that best fits the maximum monthly flood amount is based on the minimum error indicate by all these seven tests. The description of all tests can be found in any basic statistics books. The results have been shown in Table 2.

Table 2: GOF value for selected probability distributions

Distributions	Kolmogorov Smirnov		Anderson Darling		Chi-Squared	
	Statistic	Rank	Statistic	Rank	Statistic	Rank
Log Pearson Type III	0.0984	2	0.3059	1	0.4387	2
Gumbell Maximum value	0.0923	1	0.3604	2	0.188	1
Lognormal	0.1242	3	0.403	3	0.6054	3

5. Results and discussions

The excel sheet was developed for calculation of all statistics and result were prepared. The guidelines given by Flood Flow Frequency Bulletin 17B [11] was adopted for all calculations. The results have been summarized in Table 1 and 2. The Goodness of fit test was done for all distribution using three methods. The rank has been given on the basis of minimum value of error given by GOF test.

5.1 Descriptive statistics

The frequency analysis was performed on 79 years of flood record. The flood data was missing in-between 1961 to 1964 and 1975 which were omitted from calculation. The basic parameters of flood record have been shown in Table 3. A quick glance of observed data shows that a maximum flow of 16555 cumec was recorded at Vijayawada on the 1970 and a minimum of 894 cumec on the 1972. The higher value of C_s indicates that data is highly unsymmetrical and it can be easily fit by Log Pearson or Gumbell distribution curve. The high value of kurtosis indicates peakedness of flood. The average value of flood at Vijayawada is 7023.51 cumecs.

Table 3: Basic Parameters for flood record

Parameters	Symbol	Values
Avg	$\bar{X}$	7023.51
Std Deviation	s	2518.32
Variance	s^2	6341931.29
Coefficient of Skew	C_s	0.84
Kurtosis	C_k	2.28
Maximum	X_{max}	16555.00
Minimum	X_{min}	894.00

5.2 *Estimation of Flood magnitude for various design return period*

The Gumbell method was adopted for frequency analysis of flood data. The procedure given in flood flow frequency, Bulletin 17B has been adopted. The result in have been shown in Figure 4 for design return periods of 200, 100, 50, 25, 10, 5, 2, and 1.25 years so that its value can be used in different applications.

6. Conclusion

The estimation for the best fitting distribution for Maximum monthly flood data amount has been the main interest in several studies. Various forms of distributions have been tested in order to find the best fitting distribution. Different tests of goodness-of-fit have been attempted in the studies.

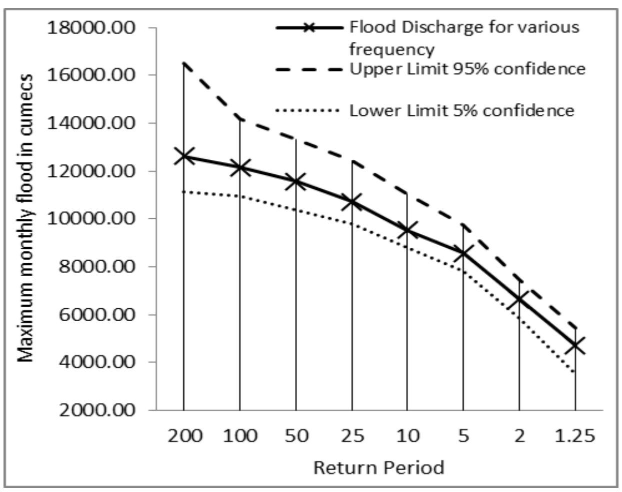

Figure 4: Flood magnitude for various design return period

In this study, the Gumbell distribution curve has been identified as the best fitting distribution for flood data in Krishna River. However the flood data should be further analyzed and corrected for missing data, Historical data and Zero flood value. The study should be further extended to account for outliers involved in the data. Based on this study the Gumbell distribution curve has been found as most suitable distribution for analysis of maximum monthly flood data of Krishna River at Vijayawada. The study should for further extended for preparation of flood inundation map for various return periods. The study can be also applied in field of flood forecasting management.

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