3rd International Conference on Advances in Civil and Environmental Engineering (ICACEE-2024)

University of Engineering & Technology Taxila, Pakistan

Conference dates: 21st and 22nd February 2024; ISBN: 978-969-23675-2-3

Comparative Analysis of Flood Frequency Analysis Techniques: A detailed study in Nallah Mahal, District Bagh, AJK

Syed Umair Rasheed[1,*] , Usman Ali Naeem[1]

[1]University of Engineering and Technology, Taxila, Pakistan

*Corresponding author: umair5531@gmail.com

ABSTRACT

Flood Frequency analysis is done for calculating flood peaks for different Return Periods. Hydraulic Structures like Dams, Bridges, Weirs and Barrages etc are designed on the basis of Flood Frequency Analysis. There are different statistical methods that are used to calculate Flood Frequency Analysis. Results are solely based on the quality and quantity of data and method employed for calculation of Flood Frequency Analysis. Typically, focus is given on only one type of method and there is always an ambiguity exists whether which method should be used. In this study Flood Frequency Analysis has been performed for Nallah Mahal Bagh AJK using all the major methods like Gumble's Extreme Value Distribution, Log Normal (LN), Log Pearson Type III (LP III) Distribution and General Extreme Value Distribution (GEV) to make a comparison of different methods used for prediction of maximum flood peaks of different return periods. After data collection from reliable source Flood frequency analysis was performed using all four methods by dividing the data into different data sets A, B, C and D and then results ware compared with original data. After Detailed investigation it can be established that Gumble's Extreme Value Method is the most suitable approach for predicting the peaks against different return periods.

KEYWORDS: Flood Frequency Analysis, Nallah Mahal, Peak Flows

1 INTRODUCTION

Floods are the natural disasters that greatly effect lives, property, infrastructure, environment and ecology. Floods have long based effects on social and economic lives of people. Pakistan is also being affected by huge floods. The conservative flood management approach focusing on structural flood mitigation measures have now been shifted to a risk-based flood mitigation concept. Furthermore, the severity of flood hazard around the world requires to continue prevention to reduce their impact (Azouagh et al., 2018) [1]. Each year more than, 140 million people across the world are effected by floods (OECD, 2016) [2]. Flood hazard is the probability of a flood event will take place (Vojtek & Vojtekova, 2016) [3]. Flood modelling is very important for flood hazard assessment to show the magnitude of a flood with a convincing exceeded probability (Azouagh et al., 2018) [4]. Due to climate change the occurrence of natural disasters is increasing which results in increase of sea level [5]. When a natural disaster such as flood occurs the water due to its high velocity can wash away the belongings and can cause human causalities [6]. Floods may occur anywhere having different sizes and durations. In year

1931 the world's deadliest flood occurred and it caused the deaths of between 2 to 4 million residents living in China [7]. Pakistan suffered the most devastating floods of its entire history during the year 2010 which caused a great loss of human life as well as losses to the economy and infrastructure [8]. The Population of study area District Bagh is around 0.3 million out of which around 0.025 million population is living along the banks of Nallah Mahal Bagh due to urbanization. District Bagh is mountainous and flooded every year during monsoons which ultimately results in considerable damage to people and infrastructure. To mitigate such impacts, it is required to predict the future floods against certain return periods. Different methods are available to perform Flood Frequency Analysis. In this study an effort has been made to determine the most suitable method to be used for Flood Frequency Analysis in Nallah Mahal, District Bagh, AJK.

2 STUDY AREA AND DATA COLLECTION

District Bagh lies in Azad Jammu and Kashmir (33.9794 N and 73.777 E) with an altitude of 3405 feet (1038m). The City lies along the Nallah Mahal which originates from Lohar Bela which lies below Lasdana.

Figure 1: Location Map of the Study Area

The Nallah Mahal gets water from different tributaries which add water to Nallah Mahal until it reaches city Bagh. The catchment area of Nallah Mahal at Chatter no 2 is 136km^2 and discharge is 10.8 cumecs. The Major tributary to Nallah Mahal is Nallah Mahlwani which originates from

Ganga Choti and meets Nallah Mahal exactly at mid of the city Bagh whose catchment area is 290km^2 and discharge is 19.98cumecs. After adding up Nallah Mahlwani the area of Nallah Mahal becomes 500 km^2 and discharge becomes 31.8 cumecs. The annual peak discharge (m^3/s) of Nallah Mahal from 1970 to 2012 (41 years flood data) was collected from AJK Power Development Organization (PDO) [9].

3 METHODOLOGY

The acquired data was then segmented into four data sets as shown in Table 1. After that the flood frequency analysis, by using Log Normal distribution (LN), Log Pearson Type III distribution (LP3), Generalized Extreme value distribution (GEV) and Gumble's Extreme Value distribution was performed.

Table 1 Segmented Data for Nallah Mahal District Bagh AJK

Sr. No	Data Set	Duration in Years	Period Considered
1	A	11	1970 to 1980
2	B	20	1970 to 1990
3	C	30	1970 to 2001
4	D	41	1970 to 2012

Segmentation is performed to evaluate the performance of the above four mentioned methods under different data sets for Nallah Mahal. The flood peaks having return periods of 10, 15, 25, 50 and 100 years were estimated against each data set through Gumble's, LP3, GEV and LN approach. The estimated peaks were then compared with respective annual actual flows.

In case of Gumbel's approach, a series of annual peak data having N observations is required to be assembled in descending order from where the annual mean of the peak flow data

$\bar{x}$ is calculated and standard deviation σ_x is further computed which is given as in Equation 1.

$$\sigma_x = \sqrt{\frac{1}{(N-1)}\sum_{i=1}^{n}(x-\bar{x})^2} \quad (1)$$

By using Gumble's distribution Table [10]. the respective values of $\bar{y}_n$ and S_n are then noted against the N data observations. The values of $\bar{y}_n$ and S_n are then used to calculate the flood frequency factor K as given in Equation 2.

$$K = \frac{y_t - \bar{y}_n}{Sn} \quad (2)$$

y_t can be calculated by the following Equation 3, in which T is the desired return period value e.g. 5,10,25, 50 or 100 etc.

$$y_t = -[ln.ln.(\frac{T}{T-1})] \quad (3)$$

Finally, the above calculated values are put in Equation 4 to estimate the probable flood magnitude x_T of the desired return period (say 25, 50 or 100 years etc.).

$$x_T = \bar{x} + K.\sigma_x \quad (4)$$

In case of LP3 method the random hydrologic series X is transformed into Z variates logarithmic form (base 10) which is given in Equation 5.

$$Z = logx \quad (5)$$

From where the mean $\bar{Z}$ and standard deviation σ_Z is computed for the sample size N and is given in Equation 6.

$$\sigma_Z = \frac{\sum(Z-\bar{Z})^2}{(N-1)} \quad (6)$$

In LP3 the coefficient of skew C_S is calculated by using Equation 7.

$$C_S = \frac{N\sum(Z-\bar{Z})^3}{(N-1)(N-2)\sigma_Z/1^3} \quad (7)$$

While using LN the value of the coefficient of skew Cs is taken as 0.

With the help of coefficient of skew C_S the Frequency Factor K_Z is selected from Table 10.

The recurrence interval Z_T against Z series is calculated by using Equation 8

$$Z_T = \bar{Z} + K_Z\sigma_Z \quad (8)$$

Finally the magnitude of maximum flood X_T for return period T is computed by using the following Equation 9

$$X_T = antilog\ (Z_T) \quad (9)$$

In General Extreme Value Distribution Method K is calculated using equation 10 in which 0.5772 is value of y

$$k = \sqrt{6}/\pi\{0.5772 + ln[ln\ (\frac{T}{T-1})]\} \quad (10)$$

Mean and Standard deviation σ_x are calculated by the same method as described above

After the calculation of K, Q_T is calculated using equation no 11

$$Q_T = \bar{x} + K.\sigma_x \quad (11)$$

4 RESULTS AND DISCUSSION

For the whole data set E, the frequency analysis was carried out by using the four approaches against return periods of 5,10, 25, 50 and 100 years as shown in Figure 2 (Nallah Mahal Bagh). It is found that the peaks computed by Gumbel's method were much higher as compared to other three methods.

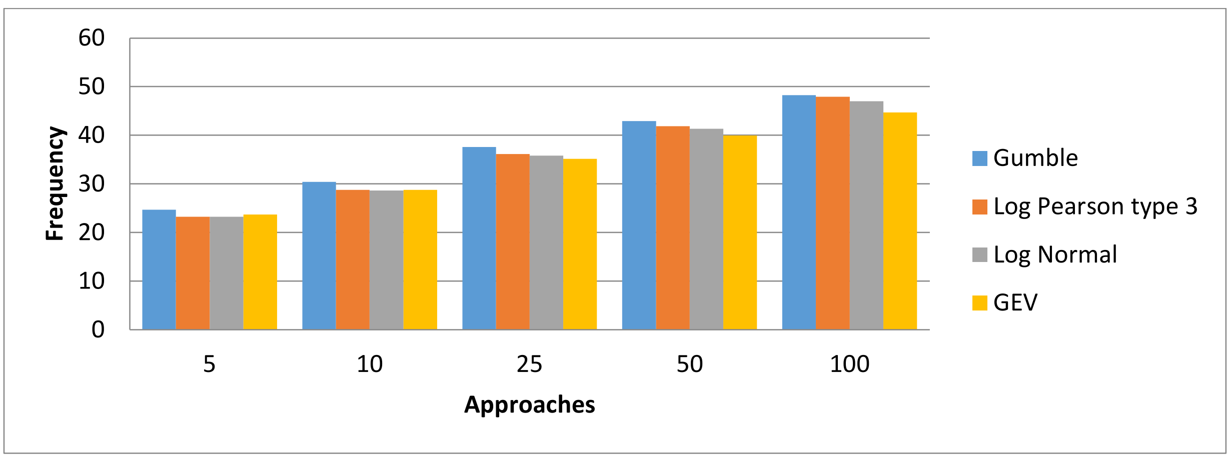

Figure 2: Frequency Analysis for Nallah Mahal Bagh

Maximum flood peaks against the return periods of 5, 10, 25, 50 and 100 years were computed by considering each data set as given in Table 1. After estimation of respective flood peaks, a comparison was established between the estimated and actual peaks which helped to determine the most suitable technique. Data sets show that the maximum flood for return periods of 5,10,25,50,100 years computed by Gumble's Extreme value distribution method was found close to the actual annual peak discharge.

Table 2: Maximum flood peaks compared and computed against different return periods for Nallah Mahal using Data Set A

	Estimated Flood in cumecs				Observed Flow in cumecs
Return Period	**Gumble's**	**LP3**	**LN**	**General Extreme value**	
5	18.31	16.82	16.8830625	16.70852371	22.79
10	22.26	20.14	20.02090371	19.6868113	26.05
25	27.25	24.52	24.01018669	23.44988556	45.37
50	30.95	27.89397713	27.00082121	26.24154902	45.37
100	34.62	31.39267962	30.00146669	29.01259927	45.37

Table 3: Maximum flood peaks compared and computed against different return periods for Nallah Mahal using Data Set B

	Estimated Flood in cumecs				Observed Flow in cumecs
Return Period	**Gumble's**	**LP3**	**LN**	**General Extreme value**	
5	19.93	19.48	19.40354491	18.91588385	26.05
10	23.64	22.56	22.85663534	22.01337981	27.23
25	28.34	26.19	27.21646477	25.92707416	45.37
50	31.826	28.74723017	30.4659873	28.83047621	45.37
100	35.28	31.1540827	33.71221463	31.71243999	45.37

Table 4 Maximum flood peaks compared and computed against different return periods for Nallah Mahal using Data Set C

	Estimated Flood in cumecs				Observed Flow in cumecs
Return Period	**Gumble's**	**LP3**	**LN**	**General Extreme value**	
5	19.95	19.39	19.32878742	19.07060361	45.37
10	24.03	23.15477379	23.27232005	22.60064205	45.37
25	29.17	27.8788987	28.3654277	27.06085497	45.37
50	32.99	31.24325157	32.23425065	30.36969571	45.37
100	36.77	34.7193517	36.15469595	35.56932254	45.37

Table 5 Maximum flood peaks compared and computed against different return periods for Nallah Mahal using Data Set D

	Estimated Flood in cumecs				Observed Flow in cumecs
Return Period	Gumble's	LP3	LN	General Extreme value	
5	24.68	23.23	23.26542024	23.67241	45.37
10	30.38	28.73107525	28.6630371	28.75586	45.37
25	37.59	36.10874919	35.80186236	35.17881	45.37
50	42.94	41.88611025	41.33365951	39.94372	45.37
100	48.24	47.90155092	47.02384296	44.67	45.37

5 CONCLUSIONS

In this paper Flood frequency analysis is done for Nallah Mahal Bagh using four statistical Distribution Methods namely Gumble's Extreme Value Distribution, Log Normal (LN), Log Pearson Type (III) and General Extreme Value Distribution Method (GEV).Data of 41 years was segmented so that forecasted discharge by above four methods could be compared with actual discharge. Initially the rate of Flood discharge was high for initial return periods of 5 and 10years. Later on the rate of increase of discharge for higher return periods remained constant. Gumble's Extreme value distribution gives Peak discharge in every case whereas for short length of data General Extreme Value Method contributed to least discharge and for maximum length of data Log Normal (LN) contributed lower discharge. The shapes of graphs are identical and follow the same pattern.

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