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Assessment of Flood Frequency Using Maximum Flow Records for the Euphrates River, Iraq

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Abstract: A flood frequency analysis (FFA) on Euphrates River in Iraq has been carried out. Gumbel, generalized extreme value (GEV) and log person type III (LP3) probability distributions were employed for the simulating of flood flow using annual peak flow data from two gauging stations on Euphrates River. The first gauging station is Qaim station and recorded data for the period (1981-2018) was adopted the second gauging station is Hit station and its adopted records are for the period (1985-2018). The collected data was evaluated and tested for independency, stationary and homogeneity. The predicted flood flows of different return periods (Tr) i.e., 5, 10, 25, 50, 100 and 200 years are obtained and compared. The results show that the estimated flows of all the return periods does not exceed the current average carrying capacity of the river and this is due to the large number of dams built outside Iraq in Turkey and Syria. The estimated values for 100 and 200 years return period for Qaim gauge station are 2030 and 2250 m3/sec respectively while for Hit gauge station are 1480 and 1580 m3/sec respectively. Also, the results reveal that the river's flow can be satisfactorily expected by any one of the used probability distribution methods; however, the generalized extreme value (GEV) was found to be the better fitted as shown by the goodness of fit test

Keywords: Flood frequency analysis, Gumble, generalized extreme value, log- Person type III, Euphrates River

1. Introduction

River engineering projects and cities planning need prediction and quantify the flood flows at a specified position of a river on required time intervals and these can be achieved by using a statistical process known flood frequency analysis (FFA) [1]. Flood frequency analysis is a dimensionless mechanism used to find the relation between the magnitudes of maximum flow events and their frequency of occurrence (return period) by using probability distributions based on past records of flow data at different gage stations along the river [2]. Flood frequency analysis is very important for rivers like Euphrates River due to the importance of the river for Iraq. Euphrates River originates in the mountains of southern Turkey and it runs about 1782 km before reaching Iraqi- Syrian boarders, it runs about 1178 km in Turkey and 604 km in Syria, the length

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of the river in Iraq is 1160 km, Figure 1. During the last four decades Euphrates River suffers from discharge decreasing. The main factor causes this is the construction of dams on the Euphrates in Turkey and Syria. In addition, the global climate change and bad management of water resources cause the decrease of flow in the river [3].

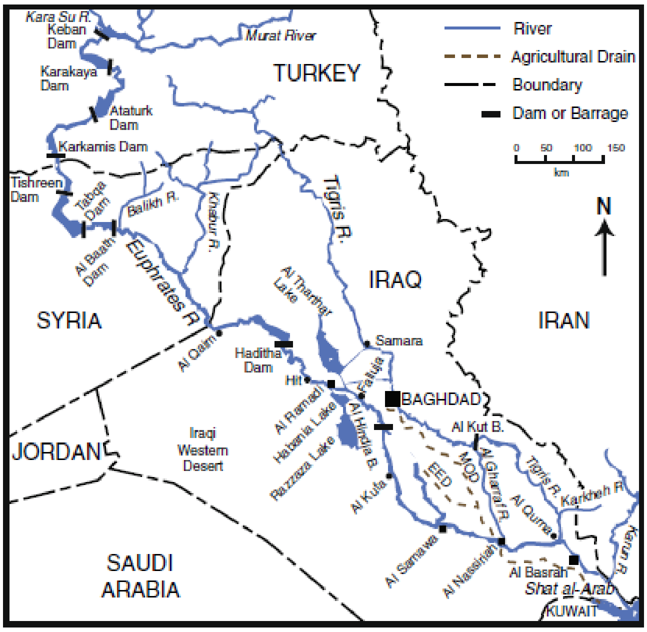

Figure 1. Euphrates catchment area and the locations of Qaim gauge station and Hit Gauge stations [4]

In Turkey six dams were constructed on Euphrates River and its tributaries, the first one known Kaban dam which was operated in the year 1975 and the last one which is Karkamis dam was operated in the year 1999, in addition there are still eight proposed dams [5]. In Syria three major dams were constructed, the first one known al- Forat dam was operated in the year 1978 with capacity of 14.163 km^3 and the last one operated in the year 2000 which is Teshreen dam, the total capacity of these three dams is 16.93 km^3 [6]. In Iraq one dam was constructed which is Haditha dam and put in operation in the year 1985 [7]. Flow river variation along the period 1932-2018 is shown in Figure 2. These data were recorded by Hit gage station. The records show a major change in the river behavior. For instance, it was usual to record the peak values in the months of April and May but since 1975 this feature was changed, and the flow of the river depends mainly on the release from Haditha dam (see Figure 3).

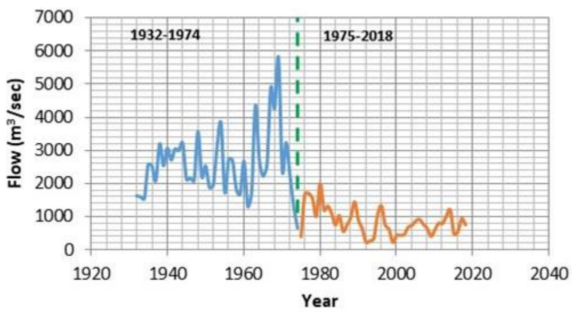

Figure 2 Annual peak flow records at Hit gauge station for the period 1932-2018, data source [8]

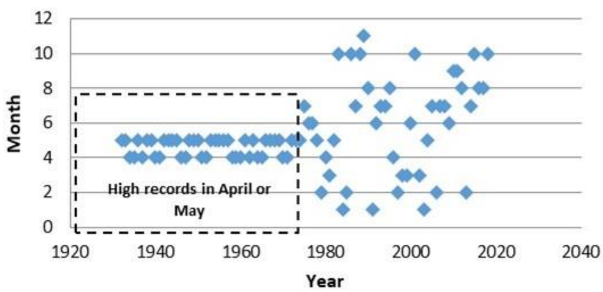

Figure 3. Changes in Euphrates River Hydrology, data source [8]

In this study, we applied the flood frequency analyses on the Euphrates River reach in Iraq using the maximum flow value records at two gauge stations

2. Data Collection and Evaluation

2.1. Data and Adopted Gauge Stations

An efficient design of any hydraulic project can be achieved only as a result of a combination of frequency, cost and risk studies [9]. All frequency techniques are dependent on data where the parameters of any hypothetical distribution function are estimated [10,11]. Dams construction or any other land development may change the basin behavior; consequently, change the hydrologic properties of a river over time, and thus change the way a river responds to floods [2, 12,13]. This phenomenon was observed in Euphrates river, where the hydrological behavior started to change since 1975 when the first dam in Turkey was put into operation and this is clearly shown in Figures 2 and 3. Since the FFA is not applicable for the data prior to the basin changes [2], so data before the dams construction were omitted In this study two gage stations were considered to analyze the flood frequency of the river. The data was collected from USGS data series 540 and The Iraqi Ministry of Water Resources [8, 14]. The first gauge is Qaim station which is located near the Iraqi- Syrian border, the period of record is from 1981 to 2018 with missing data for the years 1995 and 1998 (Figure 4).

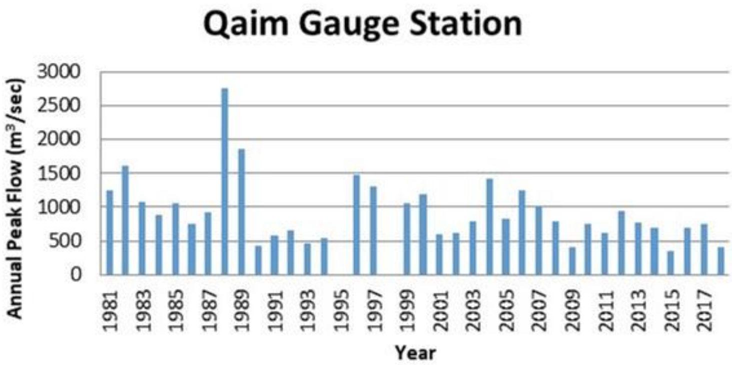

Figure 4. Annual peak flow records at Qaim Gauge station for the period 1981- 2018 [14,8]

The second gauage is Hit station which is located 221.1km downstream the first gage station, the adopted period of the records is from 1985 to 2018 with missing data for the years 1988 and 1992 (Figure 5). Haditha dam is situated between these two gauage stations. The distant of the dam from Qaim gauge station is about 134.1 km and the distant of Hit gage station from the dam is 87 km.

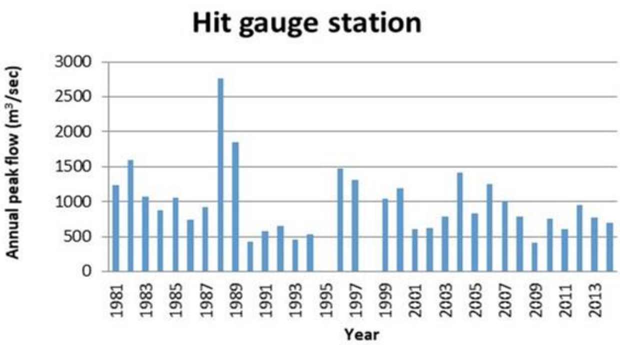

Figure 5. Annual peak flow records at Hit Gauge station for the period 1985- 2018 [14,8]

2.2 Data Analysis

The first step in flood frequency analysis is to be sure that the data series is well behaved, which means that the data is stationary, independence and homogeneous [15, 16]. Therefore, it is necessary to test the data for consistency before using it in analysis, because any inaccuracy in the records will affect the results. Different reasons may cause the data to be faulty, like observation errors. Also, smaller size of recorded data or data breaks leads to inaccuracy of estimates by flood frequency analysis. A minimum 30 years of records with no gaps is considered as satisfactory period [17, 18]. Several tests can be made to analyze the data, like independence test, stationary test, homogeneity test, consistency test and basic statistics, etc. In this study, data have been analyzed using independency, stationery and homogeneity tests. For the mentioned tests, the level of significance was expressed as a p-value which is in the most statistical is 5%. The frequency analysis and the most statistical tests had been made by HYFRAN plus (HYdrologic FReuency ANalysis) program. The HYFRAN plus program provides the ability to make Wald- Wolfowite independence test, Mann-Kendall stationary of data test and Wilicoxon test in order to check the homogeneity of the data series [19, 20]. To assess the state of the river and the effect of the constructed dams on it, the cumulative moving average (CMA) of the data series at Hit gage station was computed. The CMA for any given year is equal to average value of all annual floods that have occurring from 1932 through that particular year [13] (Figure 6). The CMA sequence reveals that since 1975 there has been a progressive decrease in the mean value of the annual peak-flow series. Therefore, in order to better reflect the conditions that today influence the river flow the analysis treats the regulated period. The Hit gage station considered the best because it provides a complete preview of the flowing state of the river for a long period (1932-2018) (Figure 6).

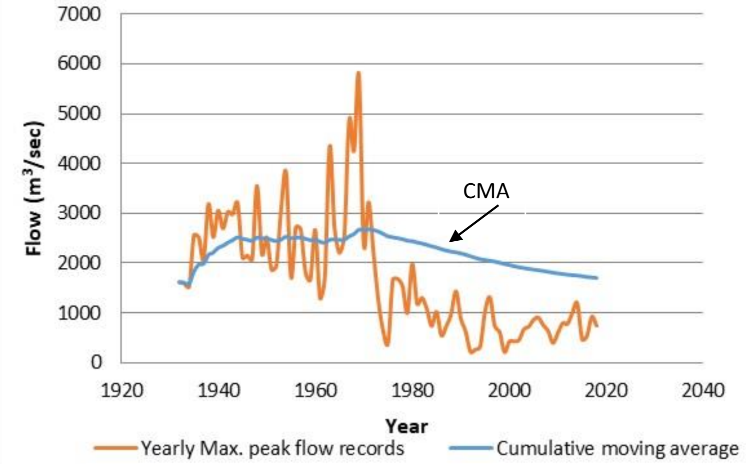

Figure 6. Cumulative moving average for Annual peak records of Hit gauge station for the period 1932-2018

Annual peaks recorded prior to regulation by Hadith dam were excluded from the frequency analysis; it means; the data records for Hit gauge station from 1985 (34 years) were considered. In this time series other problems were faced like missing values and outlier records. In the time series of Qaim gauge station the water years 1995 and 1998 are missing and for Hit gage station the records of water years 1988 and 1992 are missing as mentioned before. There are several techniques to deal with missing data like replacing missing data with statistical estimates. Mean, median and mode can be used as imputation value or using the most common approach which is simply to discard from analysis [21]. In this study the mean value was used to replace the missing data.

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The other problem is the outlier records which checked using the 17B bulletin of WRC (1981) procedure [22]. For Qaim gauge station the recorded peak of the water year 2015 (340 m^3/sec) found to be outlier and it excluded from the analysis. Also for Hit gage station the recorded peak of the water year 1999 (220 m^3/sec) found to be outlier and consequently has been excluded from the analysis.

3. Results and Discussion

3.1 Data Validity

The results of independency, stationery and homogeneity tests for the two adopted stations, Qaim station and Hit station are shown in Table 1. According to (Table 1), the data records of the two stations are independent, stationary and homogeneous. The p-value for the test is greater than 5%, the null hypothesis (H_o) accepted.

Table 1: Data tests for Independency, Stationary and Homogeneity

Station	Independency		Stationary		Homogeneity	
	p-value	IUI	p-value	IKI	p-value	IWI
Hit	0.067	1.83	0.78	0.279	0.679	0.414
Qaim	0.166	1.38	0.0548	1.92	0.203	1.27

3.2 Flood Frequency Analysis

The occurrence of different flow sizes can be determined through probability distribution techniques of different types. The most common techniques are Person type III (P3) distribution, log person III, Generalized Extreme Value (GEV), Gumbel distribution (GUM), generalized logistic (GLO) distribution and three-parameter log-normal (LN3) distribution [23, 24]. A flood frequency analysis was performed on the annual maximum flood (AMF) series of the recorded data.

In the current study log-person type III distribution, Generalized Extreme Value distribution and Gumbel distribution were adopted. These distributions are well known and will not be described here; many references are available about probability distributions and their parameter estimation methods [25]. The output for each distribution method fitting of the recorded data of Euphrates River at Qaim gage station and Hit gage station are shown in Figures (7-12). The best fitted probability distribution function was indicated by annual maximum peak flows data lay within the upper and lower limit of control bands of 95% confidence intervals (Figures 11, 12).

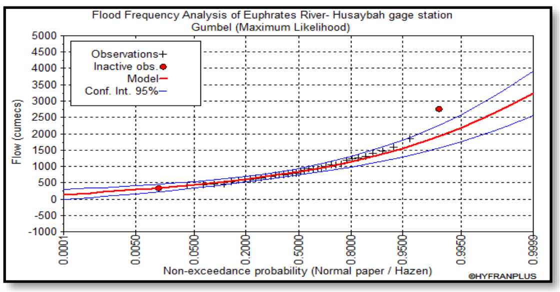

Figure 7. Gumble Distribution for Qaim Gauge Station

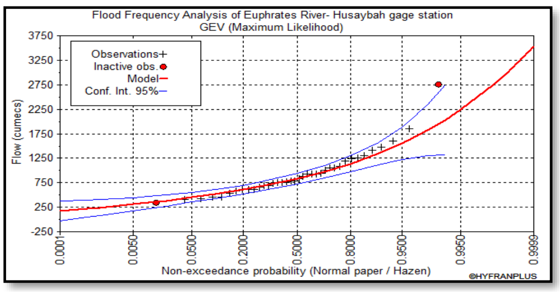

Figure 8. GEV Distribution for Qaim Gauge Station

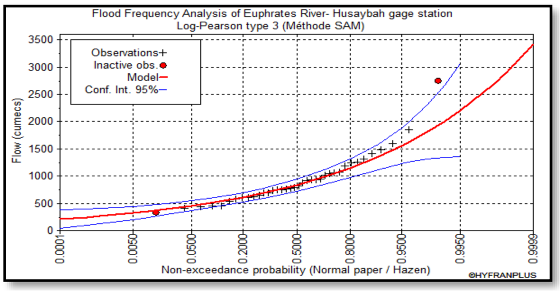

Figure 9. Log-Person Type III Distribution for Qaim Gauge Station

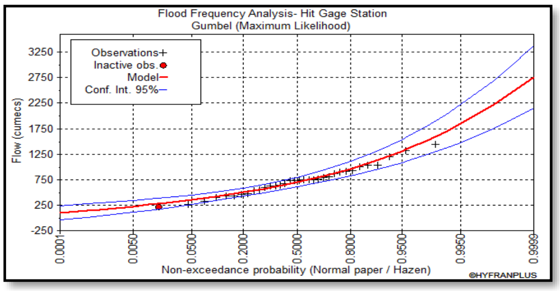

Figure 10. Gumble Distribution for Hit Gauge Station

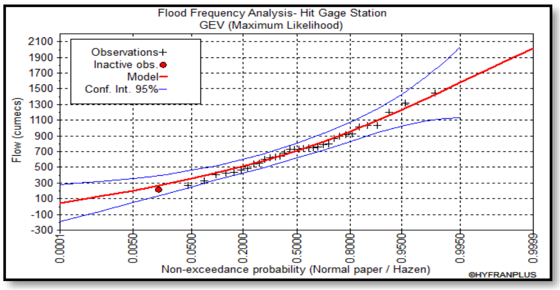

Figure 11. GEV Distribution for Hit Gauge Station

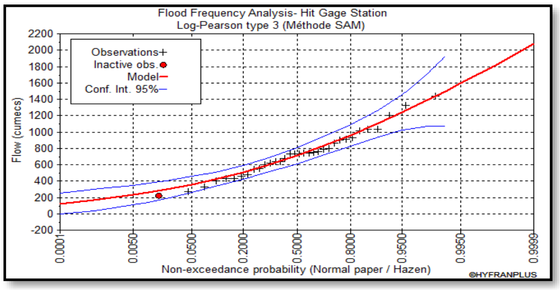

Figure 12. Log-Person Type III Distribution for Hit Gauge Station

The expected discharge for all floods with various return periods (Tr) (5, 10, 25, 50, 100 and 200 years) are presented in Table 2. The frequency and correspondent discharge magnitudes of various floods derived through log- Person III, GEV and Gumbel distributions for the two adopted gauge stations are presented in the Figures (13, 14). Figure 15 shows a comparison between the expected flows for Qaim gage station and Hit gauge station using GEV method

Table 2: Flood frequency estimates of River Euphrates using GEV distribution for Qaim and Hit gage stations

Station	Expected discharge of floods with various return periods (m^3/sec)					
	5 Yr	10 Yr	25 Yr	50 Yr	100 Yr	200Yr
Qaim	1140	1350	1620	1820	2030	2250
Hit	953	1100	1270	1380	1480	1580

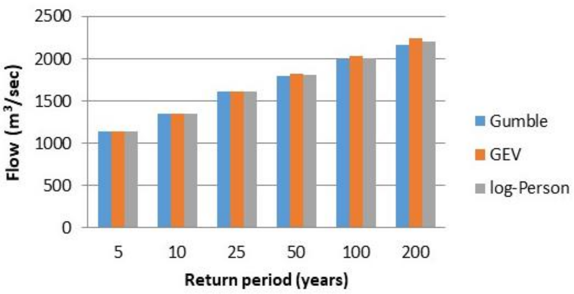

Figure 13. Comparison of flood frequency estimates of River Euphrates at Qaim gage station obtained through log-Person III, GEV and Gumble probability distributions

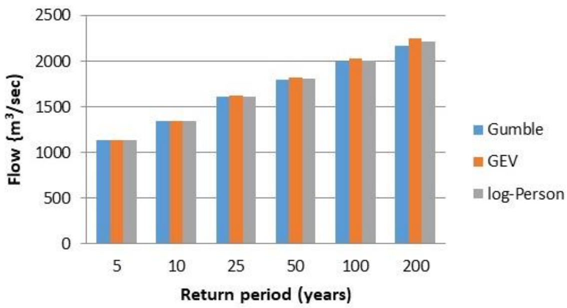

Figure 14. Comparison of flood frequency estimates of River Euphrates at Hit gauge station obtained through log-Person III, GEV and Gumble probability distributions

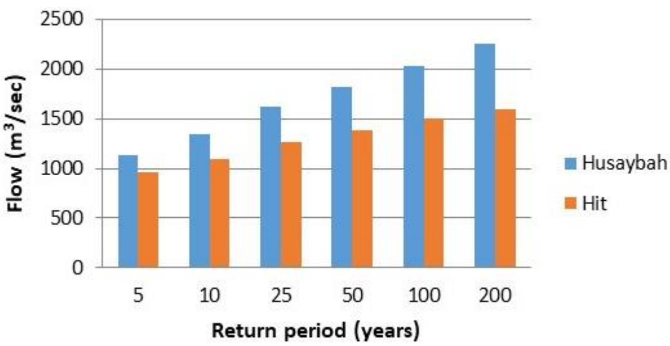

Figure 15. flood frequency estimates of River Euphrates at Qaim and Hit gage stations obtained through GEV probability distributions

3.3 Goodness of Fit

After getting the results, the flood frequency measures it is required to assess the stability of the used probability distributions by placing the results in goodness of fit test, this achieved by using Chi-square test. A summary of Chi-square test for each of the Probability Distribution Frequency (PDF) is presented in Table 3. The p-value for the three PDFs> 0.05. Thus, the null hypothesis was accepted at significant level 5%. For Qaim gauge station the smaller value of Chi-square test is for GEV and Gumble distribution, while for Hit gage station the smaller value is for log-Person III and GEV distributions. Therefore, GEV distribution was identified as the best fit to the simulated AMF data.

Table 3: The Chi-square test

Station	Log-Person III		GEV		Gumbel	
	X^2	p-value	X^2	p-value	X^2	p-value
Qaim	2.22	0.695	0.89	0.9261	0.89	0.971
Hit	5.50	0.2358	5.55	0.2358	6.03	0.3033

4. Conclusion

Flood frequency analysis (FFA) is appreciate approach to predict the long term behavior of a river. With the help of broadly used probability distribution models (log-Person, GEV and Gumble), this study come up with flood frequency estimates at two gage stations located at the upper part of the Euphrates River reach within Iraqi territory. Between these two gage stations Haditha dam is located. The first one is Qaim gauge station which is located at the Iraqi- Syrian border in the region of entry of the Euphrates River to Iraq and upstream Haditha dam which was operated in 1985, the other is Hit gage station which is located downstream the Haditha dam by about 87 km and from it the river heads towards the central and southern regions of Iraq where the major water projects are located. Expected discharge of the floods with varying recurrence intervals (5, 10, 25, 50, 100 and 200 years) was determined for all stations. The analysis shows that any discharge rate having recurrence interval 100 and 200 years not exceed the carrying capacity of Euphrates River. The estimated values for 100 and 200 years return period for Qaim gauge station are 2030 and 2250 m^3/sec respectively and for Hit gauge station 1480 and 1580 m^3/sec respectively. These results reveal the impact of external and internal factors which are especially represented in the construction of dams along the river reach and also reveals the highly need to good management of water resources inside Iraq.

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