Flood Forecasting for the Greater Zabb Tributary of Tigris River Using the Probability Techniques

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Flood Forecasting for the Greater Zabb Tributary of Tigris River Using the Probability Techniques

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***Abstract*—The climate change in Iraq from 1933 until 1992 that caused fluctuation of rainfall led to fluctuation of rivers discharge. The increasing of rainfall intensity may cause flood which will impact on human by flooding the neighboring town that lead to damage the houses and human loss; while the decreasing of rainfall causes the scarcity. Therefore accurate forecasting must be done to measure the maximum incomes of discharge by statically analysis in rivers through 56 years to predict the maximum discharge through recurrence interval (T) 10 ,25 ,50 ,100 ,200 ,1000 ,10000, and 105years. In this study the data of Greater Zabb river in Aski Kelek station will be used because of it is not controlled by dams. In this research analyzing river flood is done by utilizing of Gamble, Log person type III., Normal distribution, Log normal distribution, Weibull distribution and GEV(General extreme value) that used by PWM (Power weighted method) distribution. The obtained results of this research were close in all used methods of T = 1000 year except the log normal distribution and GEV, whereas they were higher than the other distributions. Moreover; the outcomes of previous study for suggested dam (Bakhma dams) on the river which are Japanese report 1979, the study of Swiss consultants 1985, study and water resource design 2005 were close to t the outcomes of this research. The many distributions give a lot of probabilities of flood to obtain a clear view of maximum inflow (flood) to river and best design of reservoir.**

***Keywords*—Flood forecasting, Great Zabb river, Probability, Tigris river.**

I. INTRODUCTION

The flow rate variation of rivers due to climate change effects on the temperature, the rainfall, the radiation, and the wind speed in catchment areas, and because of that the streams may lead to influence on discharges when it becomes more or less than expected of incomes. Therefore, the amount of maximum discharge which comes to rivers need to be researched and estimated so as to prevent and control flood dangerous by using the probability theories and methods. [1] utilized the likelihood theory and math-statistics in hydrology too late. The statistical ways in hydrology engineering and in economy sides as well, have been found to be of liveliness importance, via successfully solution of a lot of considered problems of the hydrological laws and the amount prediction of a lot of properties of various hydrological regimes. The applying of the statistical ways should not be utilized officially because it might lead to error concluding, that will give inaccurate dimensions of the hydrologic technology. The solution of many hydrological troubles can be done by using statistical methods. [2] was the first of companies introduced hydrologic study in Iraq of many return period (T) (1:100, 1:500, 1:1000, 1:1000, and PMF) and estimating volume of flood to one, two, three and five days. [3] points out in his research to Canadian dams association to evaluate dams safety by spillway capacity is usually depending on criteria flood design which give either risk or consequences of failure of dams. This required estimation of PMF to design the spillway. [4] Studied Greater Zabb river which belongs to Tigris river in Iraq that connect with Tigris stream in Mosul city in Iraq. It has 4 tributaries named Shamdinan, Haji-Beg, Rawandooz, and Khazir–Gomal streams, as well as 10 small seasonal streams. The searched catchment was 13708 Km2 of Iraq, Turkey and Iran. The basin of the stream is divided into 4 sub-basins and fifth represents the river. The catchment is covered by carbonate rocks, marl, limestone, and gypsum. [5]states watershed of Greater Zabb which is the biggest tributary of the Tigris river is currently being plagued by water shortage and pollution problems. The studies of blue and green waters of basin have been manifesting raising and variability to many severe scarcities and floods apparently because of climate variation. So as to gain more appreciation of the influence of climate variation on water resources in the research area is done by using the SWAT, Soil and Water Assessment Tool. [6] found that Greater Zabb provides the largest flow volumes into the Tigris stream. The impacts of climate variation on water resources of the search region in near future (2049-2069). Also, in distant future (2080-2099) SWAT was used. The conclusion was shown a decline in water resources availability in the future. [7] Studied The analysis of flood flow rate for Greater Zabb stream by utilizing various statistical models. The models

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were used to yearly flood series for Greater Zabb stream at Aski-Kelek. The amount of flood was calculated for various return periods. [8] state that hydrologic models are methods enable monitoring precipitations transformation into river flow. The GIS based hydrologic model SWAT is utilized in Greater Zabb river for flood forecasting. The mean flow rate for the year 1976-2006 was 392.32 m3/s that agreed with the model concluding of 390.2 m3/s for the same period. While the simulation result for 2015 - 2075 was 333.70 m3/s is showing a reduction in average flow rate between two periods nearly 15%. [9] studied the accumulating sediment because of low discharge in upstream of Al-Hindyia barrage and it points out the high discharge will curry sediment to downstream of dams, barrage and regulators but through low discharge sediment will accumulate in upstream. The aim of the current research is to do the best estimation of flood which happens in Greater Zabb river that is branch of Tigris river and how are controlled on it by constructing dams to save water in reservoir and avoid flood routing in rivers via working program, and scenario to flood wave routing in rivers in order to prevent damage in regions and town on the riversides.

II. Experimental work

A. Description of Study Area

The research is conducted on Greater Zabb river of Aski-Kelek station. The Aski-Kelek station is located on Greater Zabb stream river which is tributary of Tigris river and extends from Amadiya city in Arbil province until Mosul city of Mosul governorate. The research place was located of Latitude between 35º25'00"-37º20'00"N and longitude between 43º 00'00"-45º 12'00" E. Figure 1 explains the map of the research site, and Figure 2 shows the study site of Iraq map. The Greater Zabb river has four tributaries, branches rivers, feed it. They were named as Haji-Begi, Rawandooz, Shamdinan, and Khazir-Gomal rivers as shown in Figure 3 .The Greater Zabb river basin feeds by rain, snow, and ground water. The catchment area of Greater Zabb river is about 13708 km2 in Iraq, Turkey and Iran countries. The lengths of basins of the Grater Zabb tributaries that mentioned above are 208.67 km, 41.83 km, 49.08 km, 56.13km, and 86.97 km respectively. While the widths of basins of these tributaries are 801 m, 85 m, 103 m, 95 m, and 378 m respectively.

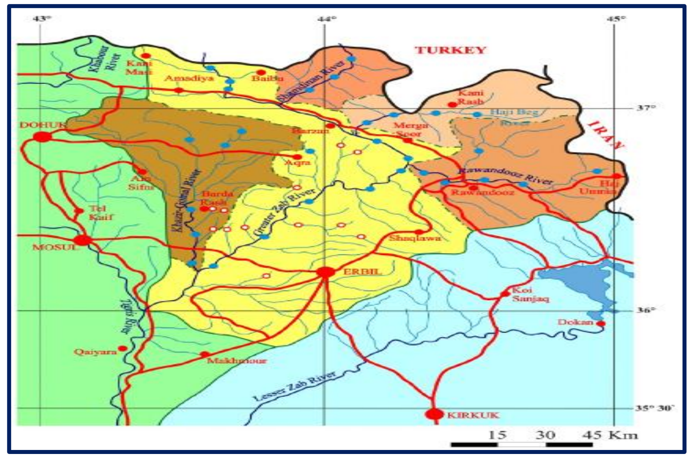

Fig. 1. The map of the researched area

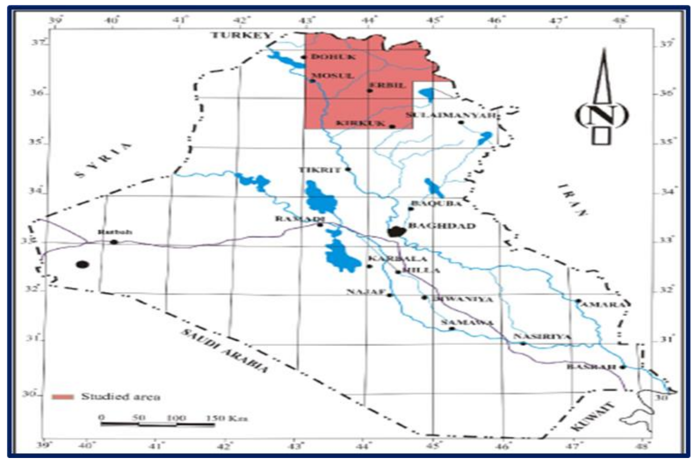

Fig. 2. Location of the study area comparing to the whole map of the country

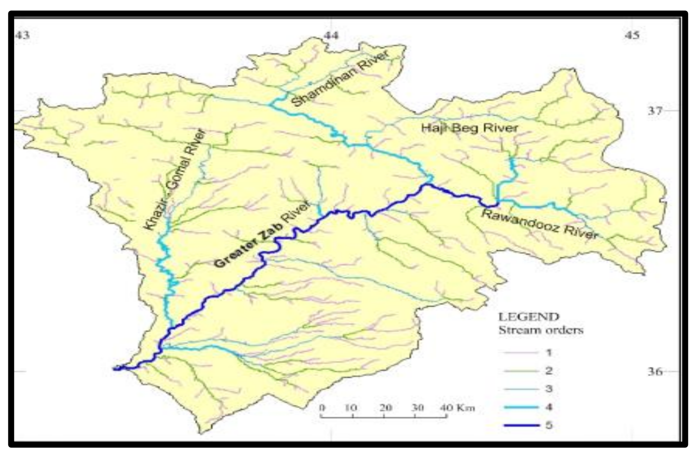

Fig. 3. The tributaries of Greater Zabb river

B. Statistics and Calculations

Generally, the flood frequency may depends on distributions functions of hydrological studies. In this study many distributions have been used to analyze the field data.

1. Gumble Distribution

The general equation of Gumble distribution is as below, [17]

$$X_T = \overline{X} + k\,\sigma_{n-1} \tag{1}$$

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Where X_T is the value of maximum discharge at frequency period, T (years), $\bar{X}$ is the arithmetic mean of variables, K is the frequency factor on frequency period T, and σn-1 is the standard deviation of variables.

$$Y_T = -\left[\, Ln\left(Ln\left(\frac{T}{T-1}\right)\right)\right] \quad (2)$$

$$k = \frac{Y_T - \bar{Y}}{S_n} \quad (3)$$

Both of $\bar{Y}$ and Sn are the reduction mean value, and the reduction value of standard deviation respectively, [17].

2. *Log Person Type III Distribution*

In this distribution, the values of the X variable will convert to logarithmic terms, then the data will be analyzed depending on the way used by [17].

$$Z = Log\ X \quad (4)$$

$$\bar{Z}_T = \bar{Z} + k_z \sigma_Z \quad (5)$$

Where X is the annual maximum discharge (m3/s), $\bar{Z}T$ is the logarithmic arithmetic mean at The frequency period, (years), $\bar{Z}$ is the logarithmic arithmetic mean, kz is the repetition coefficient which is a function depends on frequency period (T), and the skew coefficient is Cs [17].

The standard deviation of Z variable, σz can be obtained by:

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

$$\bar{Z} = \frac{\sum Z}{N} \quad (7)$$

N is the number of values.

3. *The Normal Distribution*

The normal distribution depends on the following equation which is use to estimate the flood flow rate, [18]

$$Q_T = \bar{x} + K_T * S_x \quad (8)$$

Where $\bar{x}$ is the mean of the original, Sx is the standard deviation of the original, and K_T is the frequency factor of the period of the return flood in years.

4. *Log Normal Distribution*

The log normal distribution depends on the following equation which is use to estimate the flood flow rate, [18]

$$Q_T = Exp(\bar{y} + K_T * S_y) \quad (9)$$

Where $\bar{y}$ is the mean of log transformed, Sy is the standard deviation of log transformed, K_T is the frequency factor of the period of the return flood in years.

5. *General Extreme Value using Power Weighted Method*

The general extreme value, GEV, by using of the power weighted method, PWM, may depends on the following equation, [18]

$$M_{100} = \bar{x} \quad (a)$$

$$M_{101} = \sum x_i(1-F_i)/N \quad (b)$$

$$\alpha = (M_{100} - 2*M_{101})/Ln(2) \quad (10)$$

$$u = M_{100} - 0.5772 * \alpha \quad (11)$$

$$Y_T = -\left[\, Ln\left(Ln\left(\frac{T}{T-1}\right)\right)\right] \quad (2)$$

$$X_T = u + \alpha * Y_T \quad (13)$$

$$b_0 = M_{100} = \sum x_i/N \quad (14)$$

$$b_1 = M_{110} = E(XF) = \sum x_i F_i/N \quad (15)$$

$$b_2 = M_{120} = \sum x_i F_i^2/N \quad (16)$$

$$c = ((2b_1-b_0)/(3b_2-b_0) - \ln 2/\ln 3) \quad (17)$$

$$\alpha = ((2b1-b0)*k/\Gamma(1+k)*(1-(2)^{\wedge}-k)) \quad (18)$$

$$u = M100-0.5772*\alpha \quad (19)$$

$$X_T = u + \alpha*[1-\{-\ln(1-1/T)\}^k]/k \quad (20)$$

6. *Gumble Distribution with General Extreme Value*

Using of Gumble distribution with the general extreme value depends on the equations (a), (b), (2), (10), and (11), and the maximum discharge value at the frequency period can be calculated by

$$X_T = u + \alpha * Y_T \quad (21)$$

7. *Weibull Distribution*

This method works the same as Gumble distribution except it does not using equation but use curve log x axis and log equation of curve as shown figure 4, [18]. Equation (22) represents the direct relationship of figure 4.

$$Discharge = 1917 * Ln(RPF) + 727.4 \qquad R^2 = 0.976 \quad (22)$$

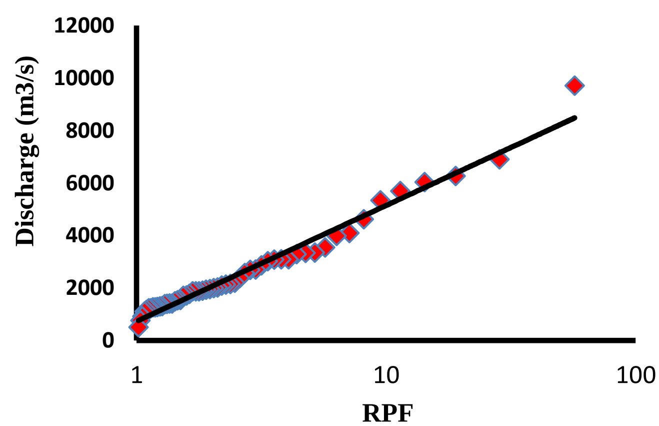

Fig.4. The log curve and log equation of Weibull distribution

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III. Result and Discussion

A series of maximum discharge of the Greater Zabb river at Eski-Kelek station were collected and the relationship that obtain the yearly peak discharges was drawn as shown in figures 5 and 6. The horizontal red line in figure 6 refers to the average value of maximum discharge during the study area.

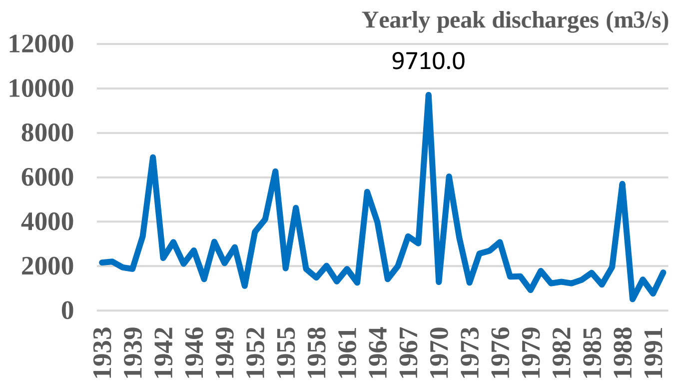

Fig.5. The maximum discharge of the Greater Zabb river at Eski-Kelek station

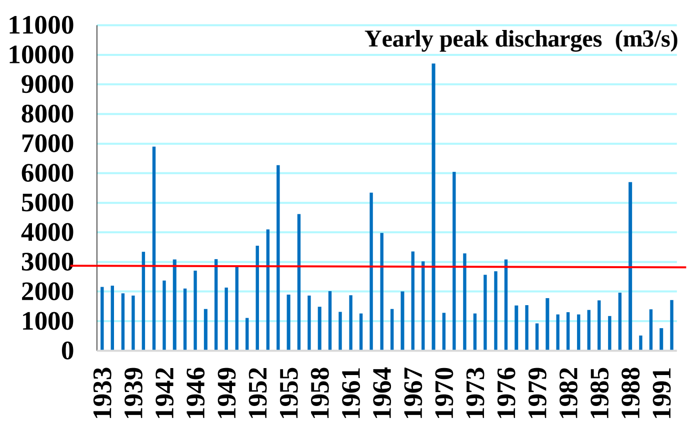

Fig.6. The maximum discharge of the Greater Zabb river at Eski Kelek station

Statistically, table I views the values of the arithmetic mean, the standard deviation, the skewness, the kurtosis, the logarithmic mean, the logarithmic standard deviation, and the logarithmic skewness for the collected data respectively. From this table it's clear that the values of these terms during the study period refer to higher flood discharge values than that illustrated by [16].

TABLE I
Values of statistical terms for the Greater Zabb river for the period 1933-1992

$\bar{X}$	σ_{n-1}	C_s	C_k	$\bar{Z}$	σ_z	C_s	$\bar{Y}$	S_y
2578	1740	1.96	4.6	3.316	0.27	0.334	7.68	0.58

Tables II, III, IV, V, VI, VII, and VIII represent the application of multi statistical distributions on the recorded data. The data in table II was listed by applying of Log person type III distribution in equation (5) using the Excel program as in [16].

TABLE II
The higher maximum discharge for the period 1933- 1992 predicted by Log person type III distribution equation for the studied return period

Return period (T) of years	2	10	25	50	100	200	500	1000	10000	10^5
Maximum discharge (m^3/s)	2142	4493	5733	6660	7589	8514	9772	11340	15279	28656

The data in table III was listed by applying of Gumble distribution in equation (1) using the Excel program as in [17].

TABLE III
The higher maximum discharge for the period 1933- 1992 predicted by Gumble distribution equation for the studied return period

Return period (T) of years	2	10	25	50	100	200	500	1000	10000	10^5
Maximum discharge (m^3/s)	2246	5224	6723	7835	8938	10038	11013	15306	19564	23820

The data in table IV was listed by applying of Weibull distribution using the Excel program.

TABLE IV
The higher maximum discharge for the period 1933- 1992 predicted by Weibull distribution for the studied return period

Return period (T) of years	2	10	25	50	100	200	500	1000	10000	10^5
Maximum discharge (m^3/s)	2057	5143	6900	8229	9558	10888	12645	13974	18389	22805

The data in table V was listed by applying of the normal distribution in equation (8) using the Excel program.

TABLE V
The higher maximum discharge for the period 1933- 1992 predicted by the normal distribution equation for the studied return period

Return period (T) of years	2	10	25	50	100	200	500	1000	10000
Maximum discharge (m^3/s)	0	4907	5774	6334	6838	7300	7955	8251	9414

The data in table VI was listed by applying of the Logarithmic normal distribution in equation (9) using the Excel program.

TABLE VI
The higher maximum discharge for the period 1933- 1992 predicted by the logarithmic normal distribution equation for the studied return period

Return period (T) of years	2	10	25	50	100	200	500	1000	10000
Maximum discharge (m^3/s)	2163	4552	5978	7128	8350	9652	11513	13021	18762

The data in table VII was listed by applying of the GEV-PWM in the equations (10-20) using the Excel program.

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TABLE VII
THE HIGHER MAXIMUM DISCHARGE FOR THE PERIOD 1933- 1992 PREDICTED BY GEV-PWM EQUATIONS FOR THE STUDIED RETURN PERIOD

Return period (T) of years	2	10	25	50	100	200	500	1000	10000
Maximum discharge (m^3/s)	2410	4854	6677	8385	10452	12963	17818	21089	41513

The data in table VIII was listed by applying of the Gumble-GEV mixed distribution in the equation (21) using the Excel program.

TABLE VIII
THE HIGHER MAXIMUM DISCHARGE FOR THE PERIOD 1933- 1992 PREDICTED BY GUMBLE-GEV EQUATION FOR THE STUDIED RETURN PERIOD

Return period (T) of years	2	10	25	50	100	200	500	1000	10000	10^5
Maximum discharge (m^3/s)	2316	4662	5842	7089	8036	8453	9595	11165	14289	17412

Figure 7 represents the relationship between the maximum discharge and the log frequency period of the study, and this (linear) relationship can easy understood by Equation (23).

$$\text{Discharge} = 4415.0 * \text{Log}(T) + 727.4 \qquad R^2 = 0.976 \qquad (23)$$

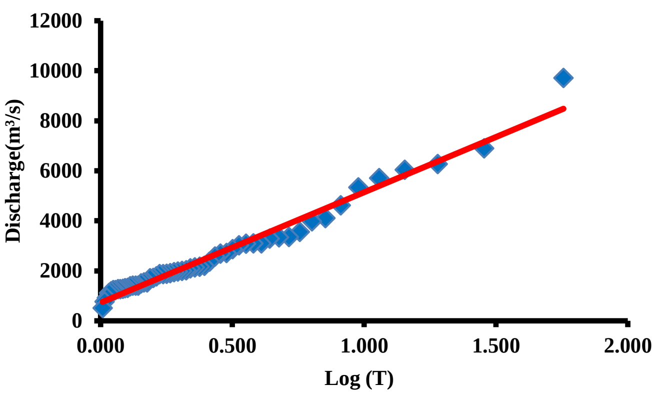

Fig.7. Maximum discharge with log frequency period (log T) during 1933-1992

Figure 8 shows the anomaly percentage of reading discharge from average through years of study.

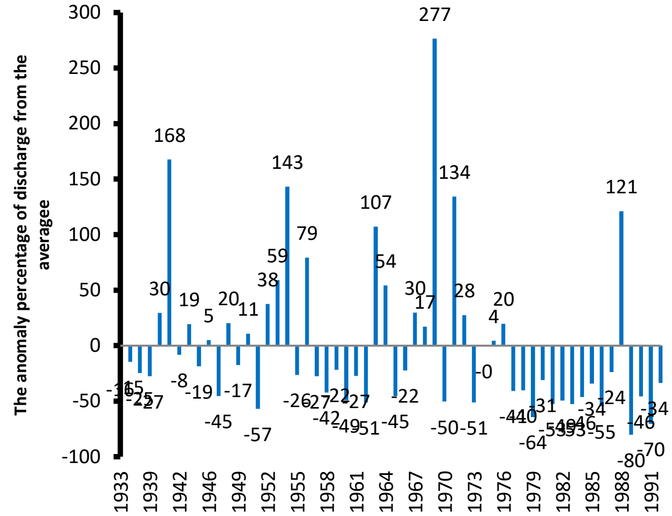

Fig.8. the percent of anomaly of reading discharge from average through years of study

Table IX shows the average discharge that incomes to Aski-kulak station through the months and years from 1932-2019.

TABLE IX
THE AVERAGE DISCHARGE BY M3/S AND BCM THROUGH MONTHS AND YEARS FROM 1932-2019

Month	AV.Q(m^3/s)	AV.(BCM)*
Oct	126	0.34
Nov	176	0.46
Dec	231	0.62
Jan	282	0.75
Feb	399	0.96
Mar	603	1.62
Apr	945	2.45
May	923	2.47
Jun	540	1.4
Jul	270	0.72
Aug	158	0.42
Sep	121	0.31
Av.Year	397.3	12.55

*BCM = Billion cubic meter, water year began from start of October and finish in end of April

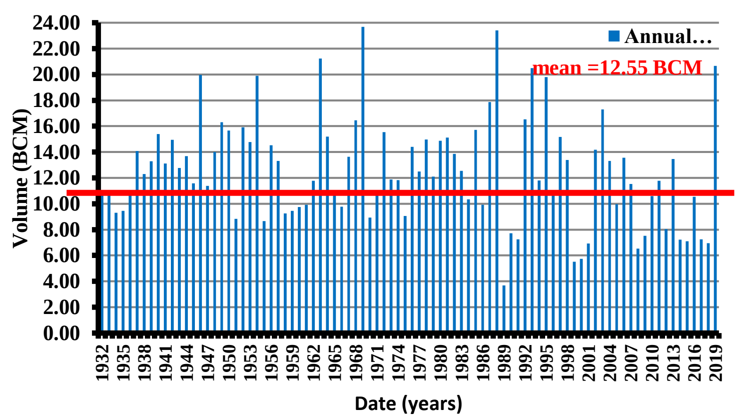

Figure 9 shows the annual volume of average discharge by billion cubic meter from 1932 to 2019 with mean income of Aski-kulak station.

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Fig.9. The annual volume of average discharge by (BCM) through 1932 – 2019 with mean incomes

A. *Check of Goodness of fit for various distributions*

1. *Chi-square goodness of fit (χ^2)test*

This test can be done by using of the following equation [19] and [20],

$$\chi^2 = \sum_{j=1}^{m} (Oj - Ej)/Ej \quad (24)$$

Where m is the number of class (5 - 20), Oi is the observed frequency, Ei is the expected frequency and its equal to (number of observations / Number of class), (N/m),

If the computed χ^2 is less than the critical χ^2, then the distribution can be assumed to be fit well as shown of table X which represent the Chi-square goodness of fit (χ^2) for maximum discharge data.

TABLE X
THE CHI-SQUARE GOODNESS OF FIT (X^2) FOR MAXIMUM DISCHARGE DATA

No.	Type of distribution	(χ^2) computed	The decision
1	Normal	32.75	Rejected
2	Log normal	0.6	Accepted
3	Gumbel	5.61	Accepted
4	Log person	0.6	Accepted
5	Weibull	0.61	Accepted
6	GEV	9.12	Rejected
7	Gumbel with GEV	1.5	Accepted

But the GEV is Accepted when using Klomogrove - Simrnov test.

2. *Kolmogorov-Smirnov Test*

This test is based on the high vertical variation between the computing and the empirical distributions [21]. The main aim of testing is done by comparing the empirical cumulative frequency Sn(x) with assuming dis.(FX(x)). The large variation between Sn(x) and FX(x) is called the Kolmogorov-Smirnov statistic test. For a sample size n, the data is rearranged in raising order, X1 < X2 < . . . < Xn and the Kolmogorov-Smirnov statistic is evaluated for each commanded value:

Sn(x)= 0; if X < X1

= k/n; if Xk ≤ X < Xk+1 = 1; if X > Xn

Dn = max |Fx(x)- Sn(x) |

P(Dn ≤D_n^α n) = 1 - α

where D_n^αis named a critical value which is equal to 0.199, α is an importance level and the k simple to the data rank order as shown in table XI.

TABLE XI
KOLMOGOROV-SMIRNOV STATISTIC TEST FOR MAXIMUM DISCHARGE DATA

No.	Type of distribution	Dn	The decision
1	Normal	0.22	Rejected
2	Log normal	0.017	Accepted
3	Gumble	0.12	Accepted
4	Log person III	0.018	Accepted
5	Weibull	0.02	Accepted
6	GEV	0.168	Accepted
7	Gumble with GEV	0.129	Accepted

From table 11 it's obvious that the normal distribution is rejected and excluded while in table 10 two distributions were rejected, the normal and GEV distributions.

CONCLUSION

From the analysis of the return period (T) of flood, and comparing of equations and distributions of Gumble, Log person type III, Normal distribution, Log normal distribution, Weibull distribution, General Extreme Value, GEV, used via Power Weighted Method distribution, and Gumble with GEV distribution obtained result values were convergent among distributions through Tequals 1000 year except in log normal distribution and general extreme value was higher than other. The Bakhma dam which designed by EPDC Japanese report1979 on the Greater Zabb using period equal to 100, 1000, 10000 years and the obtained discharges were 10700, 15000, 19300 m3/s, respectively. While The Swiss consultants study during 1985 used forecasting flood in Greater Zabb and probability of flood were T =100,1000,10000 years and peak maximum flood (PMF) were 10900, 15400, 19800, and 25400 m3/s respectively. The spillway of Bakhma Dam has designed with maximum probable flood capacity of 25850 m3/s as shown in the Ministry of Water Resource report of 2005. These results are very close from concluded values of research which mentioned except the normal distribution. Fluctuation of discharge may cause damage in river side and flood neighbor towns in downstream. Therefore it is necessary to construct dams to control flood in the Greater Zabb river which belongs to Tigris river, because there's no dam to control floods. Checking the study outcomes was done by using the best fit test which include Chi-square goodness of fit (χ^2) for maximum discharge data and Kolmogorov-Smirnov statistic test. Best fit tests show the distributions are accepted except the Normal distribution and GEV are rejected.

RECOMMENDATION

1- Suggesting the construction of a dam on the Greater Zabb river to control flood and saving water to utilize from it during the scarcity season.

2- Forecasting of flood by probability theory method of main and branch river of Iraq to check the highest discharge in rivers and highest flood waves to take the caution in case of flood risk and its effect on the towns near or next to the rivers.

3- Forecasting of flood by probability theory method of rivers to design dams, barrages, and regulators on maximum flood discharge during 100, 500, 1000, 10000 and 105 years.

4- In addition to this research, study the peak of water with peak of flood of Mosul dam and the Lower Zabb to explain the role of the Tharthaar and downstream of Samarra barrage in passing flood waves as well showing the need to construct new dams north of Samarra and expanding the Tharthaar regulators.

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