Research Article

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Deriving rainfall intensity–duration–frequency (IDF) curves and testing the best distribution using EasyFit software 5.5 for Kut city, Iraq

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Abstract: The intensity of rainfall can be considered as an essential factor in designing and operating hydraulic structures. The intensity–duration–frequency (IDF) curve is used for designing hydraulic projects such as drainage networks, road culverts, bridges, and many other hydraulic structures. In the field of water resources engineering, IDF curve is dependent widely on the plan, designing, and operating the project. Additionally, it can be used for different flood engineering structures. The purpose of this research is to get the frequency of the intensity of rain duration for Al KUTcity, Iraq, and find curves. Three essential techniques of frequency analysis (Gumbel distribution, lognormal, and log Pearson Type III) were depended to formulate this relationship based on data of rainfall intensity during the period between 1992 and 2019. Distribution methods involving lognormal, Gumbel, and log Pearson Type III were applied by Indian Meteorological Department (IMD) for short periods of 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 6, 12, and 24 h with 2, 5, 10, 25, 50, and 100 years return periods. The results showed that rainfall intensity reduced as the duration of the storm increased, and if the return period of the rainfall was large, rainfall of any specific duration showed a higher intensity. Using EasyFit 5.5 software, for all durations, the lognormal probability distribution showed the best fit for the data group and estimated intensities of precipitation for return periods of 2, 5, 10, 25, 50, and 100 years. According to the obtained results, one can notice that the intensity of rainfall increased with the increment in return periods, but decreased with the increment in duration. The resulting IDF models could be used to improve accuracy and results.

Keywords: IDF curves, probability distributions, goodness of fit test, return period, EasyFit software 5.5, IDM reduction formula, Wasit, Iraq

1 Introduction

The curve that links the intensity of rainfall with its duration and occurrence frequency is called the intensity-duration-frequency (IDF) curve [1,2]. Urbanization, which occurred due to the high increase in population, and development of infrastructure have made several regions in Iraq vulnerable to severe flooding risks [3]. Economical and safe flood control structures can be designed using IDF curves. It represents a mathematical relationship that relates the return period, intensity, and duration of rainfall [4]. Studies on IDF relationship of rainfall have obtained special focus during the past few decades [5]. Hussein formulated IDF empirical relationship that can be used in the province of Karbala. Various statistical distributions were compared. It was concluded that the best method among the studied methods was log Pearson type III (LPT III) [6].The purpose of Zup and others was to create IDF precipitation curves for Mumbai under changing hydrologic conditions, and it was discovered that Colaba's precipitation intensity is 112.48 mm/h over the return period of 100 years. Even with the significant rainfall on July 26, 2005 in Mumbai, the curves of IDF that was created using the updated formula gave acceptable results in hydrological conditions shifting and were consistent [7]. Al-Awadi assessed curves of IDF and formulated a relationship for duration and intensities for a group of intervals of recurrence for Baghdad city. Log Pearson Type III, Gumbel method, and lognormal distribution were used, and based on the obtained results, small priority was given to LPT III distribution [8]. Wambua assessed IDF rainfall curves for Kenya's tropical river basin depending on empirical formulas to obtain rainfall of short durations, they ranged between 1 and 12 h, and empirical models for IDF curves

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were derived by regression analysis [9]. Muhammad and others presented a study in Kano State aiming at producing new IDF curves that might be used for safe and cost-effective hydraulic design. The maximum daily precipitation in Kano was divided by precipitation over shorter periods using the reduction equation (Indian Meteorological Department, IMD). The optimal dataset for all eras of use was discovered to be an unstable logarithmic probability distribution. Easy Fit 5.5 software is used to estimate the best intensities, first the most suitable for the area in question [10]. This research also adopted the IMD reduction equation to estimate the precipitation for shorter periods. However, several relationships are set up for IDF curves for different locations around the world. The primary aim of this work is to collect rainfall data for Kut city to develop IDF curves for different return periods. For this purpose, three different statistical distribution methods were applied, and the probability distribution function of the daily maximum precipitation data was verified by software of EasyFit 5.5. These equations and curves are very important in designing drainage systems in urban areas, for example, canals, storm sewers, and any different hydraulic projects.

Figure 1: The studied zone location.

2 Area of study and data collection

The study area is Wasit Province, which is located in eastern Iraq, southeast of Baghdad city. It is located along Tigris in the midway between Basra and Baghdad cities. The total area of Wasit Province is 17,153 km^2 (6,623 square miles). The topography of the area is approximately flat. The population of Wasit Province is approximately 1,450,000 inhabitants with about 3% annual growth rate (according to Wasit Statistic Department) (Figure 1).

2.1 Study area climate

The weather or climate of Wasit Province is hot as in a desert. Most rainfall occurs during the winter. The average annual temperature in Kut is 24.6°C (76.3°F). The mean speed of wind is approximately 2.0 m/s, the minimum value of total solar radiation is 7.7 MJ/M² in December, while the maximum value is 23.9 MJ/m²/m in June. The mean monthly temperature ranges from 37.6°C in August to 11.5°C in January, with variation in temperature. The monthly minimum and maximum relative humidity are about 14 and 62%, respectively. The humidity decreases in the summer due to high temperature, while increases in winter because of frequent rainfall, as shown in Figure 2 [11].

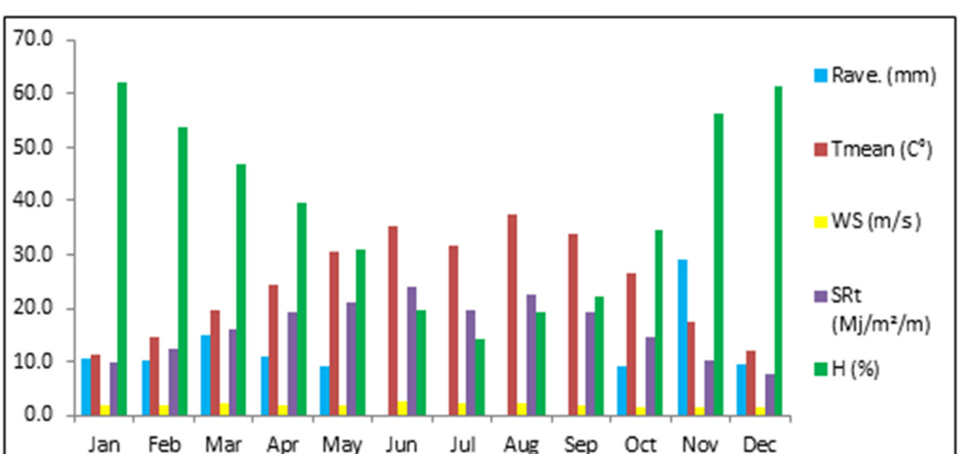

Figure 2: Summary of the climate data from 2013 to 2018 for Wasit Province.

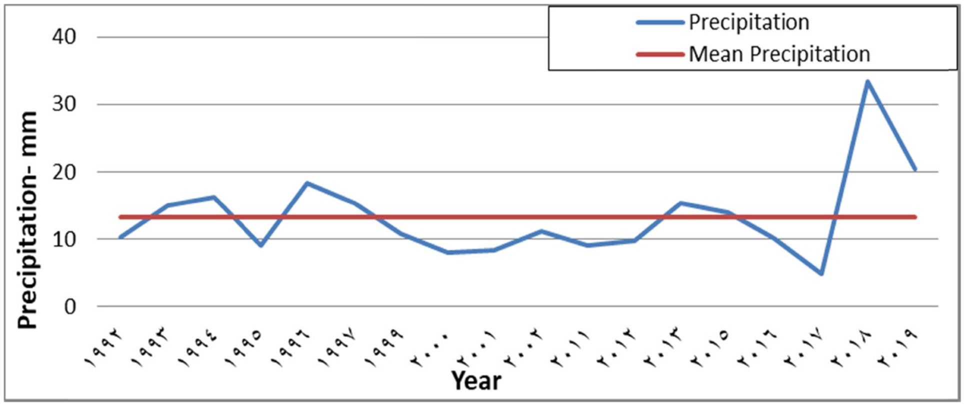

Figure 3: Annual precipitation of Wasit Province (1992–2019) · Disaggregation of daily rainfall data into shorter durations

2.2 Annual rainfall data

About 103.6 mm (4.08 in) of precipitation falls annually. Rainfall occurs during winter and spring seasons and differs from year to another. The watershed of Wasit Governorate experienced approximately the same amount of rainfall; however, it has some spatial differences in the distribution of other hydrological components such as runoff. Figure 3 shows that the average annual precipitation during 1992–2019 was 13.3 mm. The lowest value of precipitation was 4.8 mm in 2017. However, this value started to rise in recent years, reaching its highest value in 2018 (33.4 mm) and (20.5 mm) in 2019, the highest value of precipitation in Wasit Governorate.

The precipitation data involve the maximum values of daily precipitation from 1992 to 2019 [20]. The maximum daily precipitation was divided into small periods every half hour are 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 6, 12, and 24 h of precipitation. Values of precipitation are obtained depending on the empirical reduction formula prepared by IMD [10].

$$P(t) = P(24)\left(\frac{t}{24}\right)^{(1/3)}, \tag{1}$$

where $P(t)$ represents the required depth of precipitation at duration of t-hour (in mm), P (24) represents the value of daily precipitation (in mm), and t represents the rainfall duration (in h) for which the depth of precipitation is

Table 1: The required rainfall depth $P(t)$ for t-hour duration (in mm)

Year	P (mm)	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	6	12	24
1992	40.3	11.1	14.0	16.0	17.6	19	20.2	21.2	22.2	23.1	23.9	25.4	32.0	40.3
1993	49.0	13.5	17.0	19.5	21.4	23.1	24.5	25.8	27.0	28.1	29.1	30.9	38.9	49.0
1994	80.8	22.2	28.0	32.1	35.3	38.0	40.4	42.5	44.5	46.3	47.9	50.9	64.1	80.8
1995	53.2	14.6	18.4	21.1	23.2	25.0	26.6	28.0	29.3	30.5	31.5	33.5	42.2	53.2
1996	89.2	24.5	30.9	35.4	39.0	42.0	44.6	47.0	49.1	51.1	52.9	56.2	70.8	89.2
1997	68.8	18.9	23.9	27.3	30.1	32.4	34.4	36.2	37.9	39.4	40.8	43.3	54.6	68.8
1998	45.3	12.5	15.7	18.0	19.8	21.3	22.7	23.8	24.9	25.9	26.9	28.5	36.0	45.3
1999	47.6	13.1	16.5	18.9	20.8	22.4	23.8	25.1	26.2	27.2	28.2	30.0	37.8	47.6
2000	42.9	11.8	14.9	17.0	18.7	20.2	21.5	22.6	23.6	24.6	25.4	27.0	34.1	42.9
2001	28.3	7.8	9.8	11.2	12.4	13.3	14.2	14.9	15.6	16.2	16.8	17.8	22.5	28.3
2002	50.9	14.0	17.7	20.2	22.2	24.0	25.5	26.8	28.0	29.1	30.2	32.1	40.4	50.9
M*														
2011	51.3	14.1	17.8	20.4	22.4	24.1	25.7	27.0	28.2	29.4	30.4	32.3	40.7	51.3
2012	50.3	13.8	17.4	20.0	22.0	23.7	25.2	26.5	27.7	28.8	29.8	31.7	39.9	50.3
2013	87.5	24.1	30.3	34.7	38.2	41.2	43.8	46.1	48.2	50.1	51.8	55.1	69.5	87.5
2014	54.2	14.9	18.8	21.5	23.7	25.5	27.1	28.5	29.8	31.0	32.1	34.1	43.0	54.2
2015	61	16.8	21.2	24.2	26.6	28.7	30.5	32.1	33.6	34.9	36.2	38.4	48.4	61.0
2016	38.3	10.5	13.3	15.2	16.7	18.0	19.2	20.2	21.1	21.9	22.7	24.1	30.4	38.3
2017	29.3	8.1	10.2	11.6	12.8	13.8	14.7	15.4	16.1	16.8	17.4	18.5	23.3	29.3
2018	222	61.0	76.9	88.0	96.8	104	111	117	122	127	131	140	176	222
2019	103	28.3	35.7	40.8	45.0	48.4	51.5	54.2	56.6	58.9	61.0	64.8	81.7	103

M* – Missing or unknown data.

Table 2: Computed Gumbel frequency factor (K_t), rainfall (P_T) in (mm), and intensity (I_T) (in mm/hour) (using Gumbel method)

T_R (Year)	K_T	P_T (mm)	I_T (mm/h)									
			0.5 h	1 h	1.5 h	2 h	2.5 h	3 h	3.5 h	4 h	4.5 h	5 h
2	−0.16	12.3	24.6	12.3	8.2	6.15	4.92	4.10	3.52	3.08	2.73	2.46
5	0.72	17.8	35.5	17.9	11.9	8.89	7.11	5.92	5.08	4.44	3.95	3.55
10	1.3	21.4	42.8	21.7	14.3	11	8.55	7.12	6.11	5.34	4.75	4.27
25	2.04	26.0	51.9	26.4	17.3	13.0	10.4	8.66	7.42	6.49	5.77	5.19
50	2.59	29.4	58.8	30.0	19.6	14.7	11.8	9.79	8.40	7.35	6.53	5.88
100	3.14	32.8	65.6	33.5	21.9	16.4	13.1	10.9	9.37	8.20	7.29	6.56

required. Table 1 shows the rainfalls of shorter duration that were derived from maximum daily precipitation throughout year.

3 Methodology

In constructing the curves of IDF, the first step is to fit some theoretical frequency distribution to the maximum precipitation value of a group of certain periods [12]. Usually, local flood degradation data are not available with the accuracy required for cost-benefit analysis. The appropriate basis for decision-making is the threats and risks to the public safety of society. Risk assessment can be considered crucial to the selection of the recurrence period. In the current research, the maximum annual values of the available periods were statistically analyzed by three different methods of distribution, they are log-normal distribution, log Pearson III, and Gumbel distribution. The best fit was determined using EasyFit 5.5.

3.1 Gumbel distribution

In the theory of probability and statistics, distribution method of Gumbel (generalized extreme distribution value Type-I) can be applied for modeling the distribution of the highest value (or the lowest) for a set of samples of different distributions. The following equation gives the precipitation frequency P_T (in mm) for every duration with a certain return period T_R (in a year) [13].

$$P_T = P_{ave.} + K_T S, \tag{2}$$

where P_T represents the rainfall frequency (in mm) for each duration, S represents the standard deviation of precipitation data, P_{ave} is the average of annual precipitation data, and K_T is the Gumbel frequency factor given by equation (3).

$$K_T = \frac{\sqrt{6}}{\pi}\left\{0.5772 + \ln\left[\ln\left(\frac{T_R}{T_R - 1}\right)\right]\right\}, \tag{3}$$

where, T_R is the return period (2, 5, 10, 25, 50, and 100) years. Then, the rainfall intensity I_T (in mm/h) for return period T_R is obtained by equation (4).

$$I_T = \frac{P_T}{T_d}, \tag{4}$$

where T_d represents the time duration in hour.

3.2 The log Pearson type III

It is a statistical method that can be used for fitting data of frequency distribution to predict the design flood of a stream at a specific location [14]. The merit of this procedure is that the extrapolation is made for the events values with return periods well behind the recorded events of flood. Equation (5) gives the simple expression for the aforementioned distribution.

$$P^*_T = P^*_{ave.} + K_T S, \tag{5}$$

where, $P^*_{ave.}$ is the average of P^* values, P^* is the logarithm of precipitation, S^* is the standard deviation of P^* values, and parameter K_T is Pearson frequency factor which depends on return period (T_R) and skewness coefficient (G). Values of K_T factor can be obtained from tables in many hydrology references [28]. Skewness coefficient can be calculated by using equation (6).

$$G = \frac{N\sum(P^* - P^*_{ave.})^3}{(N-1)(N-2)S^*}, \tag{6}$$

where N is the sample size (number of years of record).

3.3 Lognormal method

It follows the same steps of LPT III (i.e., logarithm values of the statistical variables) but with normal K_T that was used in the method of Gumbel [12].

4 Results and discussion

4.1 Gumbel distribution method

It determines the return period intervals of 2, 5, 10, 25, 50, and 100 years for every duration, it needs many calculations. For every duration with a certain return period T_r (in a year), rainfall frequency P_t (in mm) can be determined depending on equation (2). After that, the intensity of rainfall I_T (in mm/h) for T_r return period can be achieved by equation (4).

The results obtained in Table 2 revealed that the rainfall intensity reduces as storm duration increases. Furthermore, rainfall of a certain duration has a higher intensity when it has a high return period.

Figure 4 shows the IDF curves for the Gumbel method. These curves are plotted on the normal scale for Gumbel methods (for T_r = 2, 5, 10, 25, 50, and 100 years).

4.2 LPT III distribution

The LPT III distribution model can be applied to determine the precipitation intensities for different return periods and precipitation durations from historical IDF curves. The LPT III distribution includes the logarithms of the computed values. The precipitation frequency was calculated by the LPT III procedure using equation (5), as shown in Table 3.

Table 3: Statistical variables calculated using LPT III

Year	P	P^* = Log P	$(P^* - P^*_{ave})^2$	$(P^* - P^*_{ave})^3$
1992	10.2	1.01	0.01	0.00
1993	15	1.18	0.01	0.00
1994	16.2	1.21	0.01	0.00
1995	9.1	0.96	0.02	0.00
1996	18.3	1.26	0.03	0.01
1997	15.3	1.18	0.01	0.00
1998	9.6	0.98	0.01	0.00
1999	10.8	1.03	0.00	0.00
2000	8	0.90	0.03	-0.01
2001	8.4	0.92	0.03	0.00
2002	11.2	1.05	0.00	0.00
M*				
2011	9.1	0.96	0.02	0.00
2012	9.8	0.99	0.01	0.00
2013	15.4	1.19	0.01	0.00
2014	17.2	1.24	0.02	0.00
2015	13.9	1.14	0.00	0.00
2016	10.1	1.00	0.01	0.00
2017	4.8	0.68	0.17	-0.07
2018	33.4	1.52	0.19	0.08
2019	20.5	1.31	0.05	0.01
Ave.	13.3	1.09	$\sum$ 0.64	$\sum$ 0.02

S^* = 0.18 G^* = 0.2. P^*_T (in mm) for every duration of precipitation applied in LPT III method.

Table 4: Calculated Pearson frequency factor (K_T) and precipitation (P_T) in (mm) using LPT distribution method

T_r	2	5	10	25	50	100
K^*_T	−0.033	0.83	1.301	1.818	2.159	2.472
P^*_T	1.08	1.24	1.32	1.42	1.48	1.53

Table 4 shows the computed values of K_T for T_r = 2, 5, 10, 25, 50, and 100 years that lead to calculate the frequency rainfall depth (Table 5).

To estimate floods in rural/urban basins, the resulted curves of IDF can be used. Using the resulted curves of IDF is recommended for the safe, efficient, and rigorous design of flood protection projects and hydraulic structures. Thus, the obtained IDF curves can be used, as displayed in Figure 5.

4.3 Lognormal method

It can be calculated by the IDF using Lognormal method for 30-min duration and return periods of 2, 5, 10, 25, 50, and 100 years, as shown in Table 6, and Figure 6 shows rainfall intensity IDF curves for lognormal method.

4.4 Goodness of fit test

For this study, LPT III, lognormal, and Gumbel distributions were applied for all series of data duration. Software of EasyFit 5.5 was used to fit the probability distributions for every rainfall duration data. For assessing the stability of every distribution of probability, the goodness of fit test, cumulative distribution graph, the least sum of statistic model identification criterion (LSSMIC), and probability density function (PDF) graph were applied. The probability distribution with lowest value of statistics showed higher fitting distribution according to the tests of fit goodness. Figures 7–10 show the PDFs, cumulative distribution functions (CDFs), probability difference, and probability–probability (P–P) plot of three selected distribution for 30 min.

Table 5: Computed intensity (I_T) in (mm/h) (LPT III method)

Duration (h)	Intensity (mm/h)					
	2 years	5 years	10 years	25 years	50 years	100 years
0.5	25.18	34.76	41.78	52.60	60.40	67.76
1	12.59	17.38	20.89	26.30	30.20	33.88
1.5	8.39	11.59	13.93	17.53	20.13	22.59
2	6.30	8.69	10.45	13.15	15.10	16.94
2.5	5.04	6.95	8.36	10.52	12.08	13.55
3	4.20	5.79	6.96	8.77	10.07	11.29
3.5	3.60	4.97	5.97	7.51	8.63	9.68
4	3.15	4.35	5.22	6.58	7.55	8.47
4.5	2.80	3.86	4.64	5.84	6.71	7.53
5	2.52	3.48	4.18	5.26	6.04	6.78

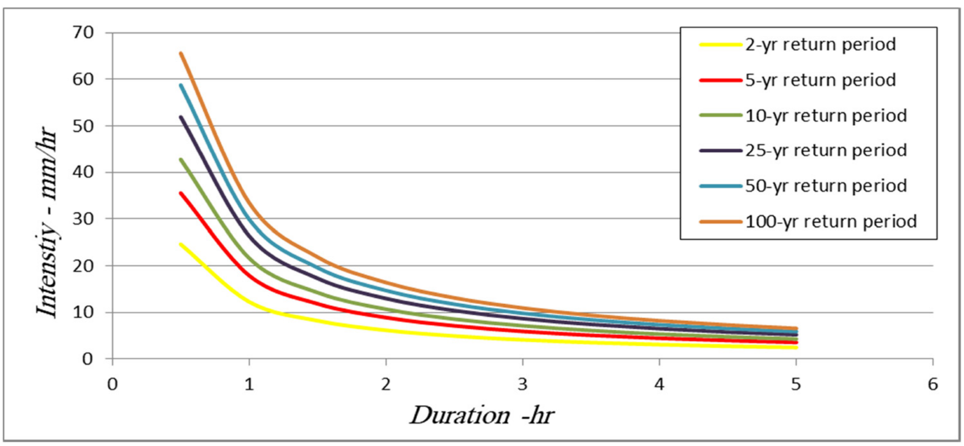

Figure 4: IDF curves for the study area (Gumbel method).

Figure 7 represents the PDF of three selected distribution for 0.5 h.The PDF is the function that represents any probability distribution by integration. The PDF is always positive, and its integral from ∞− to ∞+ is equal to one. The PDF can be described as an evaluation of the histogram continuum that represents the relative frequencies within the ranges of the graphed results. The PDF value of the Gumbel distribution is less than 0.06, the lognormal distribution is about 0.08, and finally, the LPT III distribution is about 0.12 as shown in the figure.

As shown in Figure 8, the CDF is a function that gives the probability distribution of a random variable with its value being a real number. the CDF of three selected distributions for 0.5 h, where the CDF value for the three

Table 6: Calculated intensity (I_T) in (mm/h) (lognormal method)

P_T	I_T									
	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
12.59	25.18	12.59	8.39	6.30	5.04	4.20	3.60	3.15	2.80	2.52
16.6	33.20	16.60	11.07	8.30	6.64	5.53	4.74	4.15	3.69	3.32
20.89	41.78	20.89	13.93	10.45	8.36	6.96	5.97	5.22	4.64	4.18
28.84	57.68	28.84	19.23	14.42	11.54	9.61	8.24	7.21	6.41	5.77
36.31	72.62	36.31	24.21	18.16	14.52	12.10	10.37	9.08	8.07	7.26
45.71	91.42	45.71	30.47	22.86	18.28	15.24	13.06	11.43	10.16	9.14

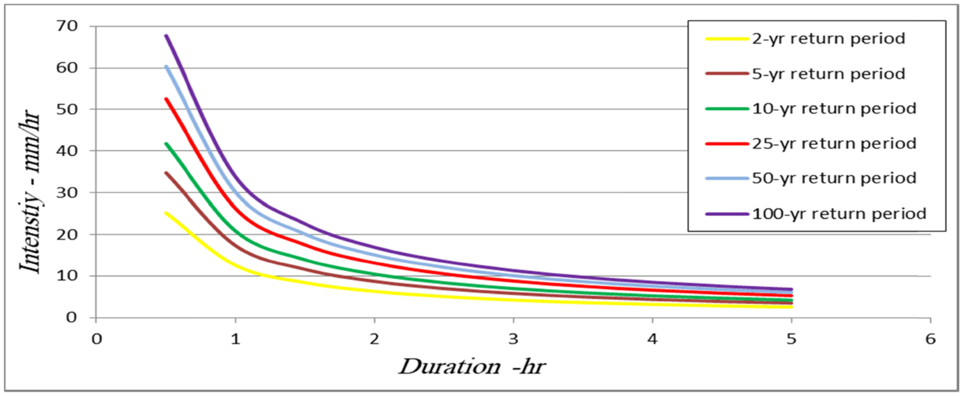

Figure 5: Rainfall intensity IDF curves of Wasit Province (LPT method).

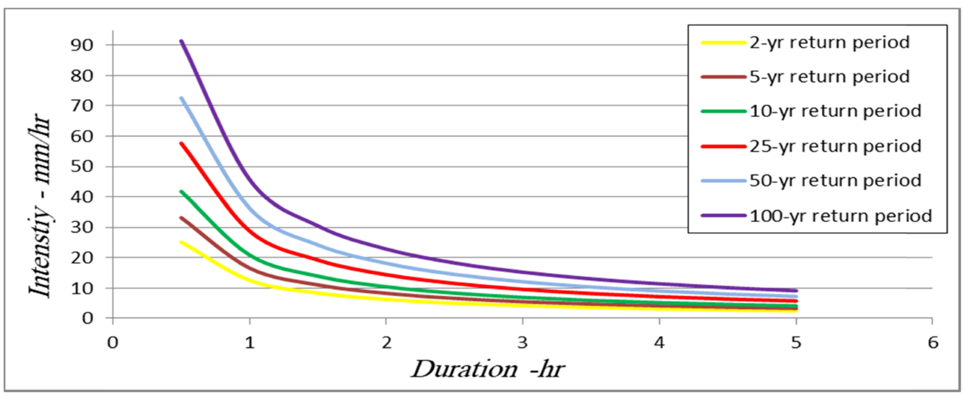

Figure 6: Rainfall intensity IDF curves of Wasit Province (lognormal method).

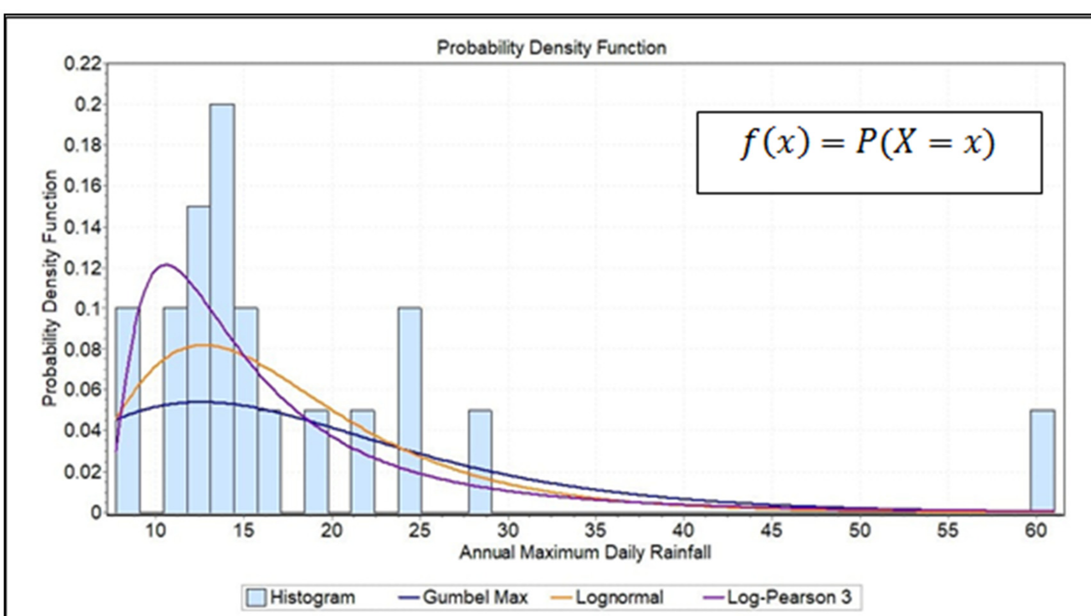

Figure 7: PDFs of three selected distributions for 0.5 h.

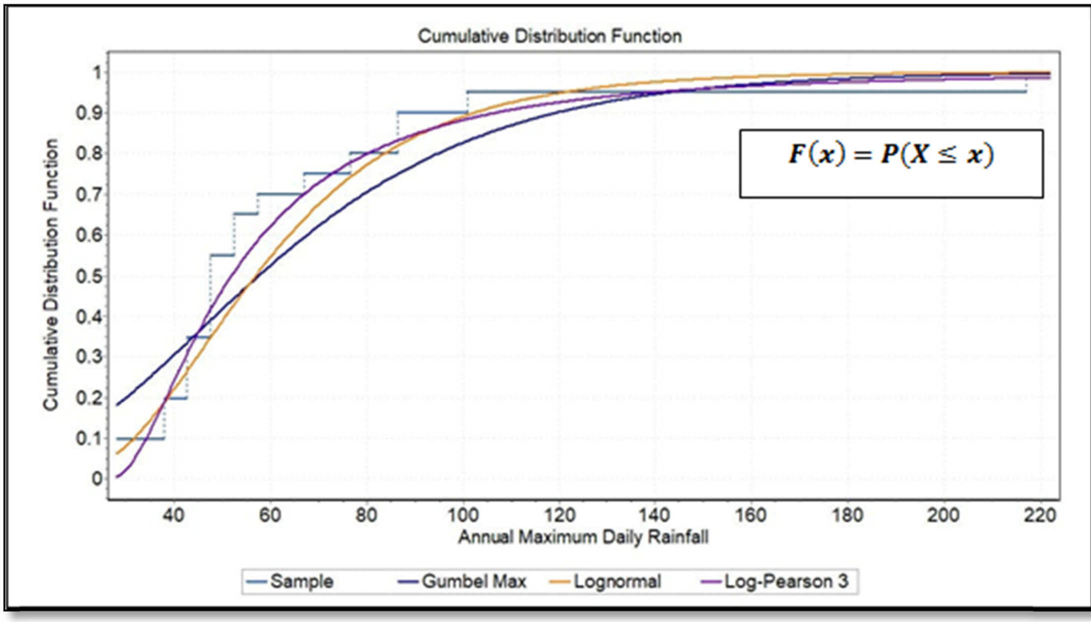

Figure 8: CDFs of three selected distributions for 0.5 h.

distributions was approximately between 0.9 and 1 as shown in the figure.

Figure 9 represents the plot of probability difference, which is a graph that shows the difference between the theoretical and empirical CDF values. It can be used for determining the degree of compatibility between the used theoretical distribution and the observed data, it also compares the fit goodness of various fitted distributions. It shows a scatterplot or a continuous curve for continuous distributions and a set of vertical lines for separated distributions (at every integer x).

Finally, Figure 10 shows the probability–probability (P–P) plot, which is a graph of the empirical CDF values plotted against the theoretical CDF values. It is used to determine how well a specific distribution fits the observed data. This plot will be approximately linear if the specified

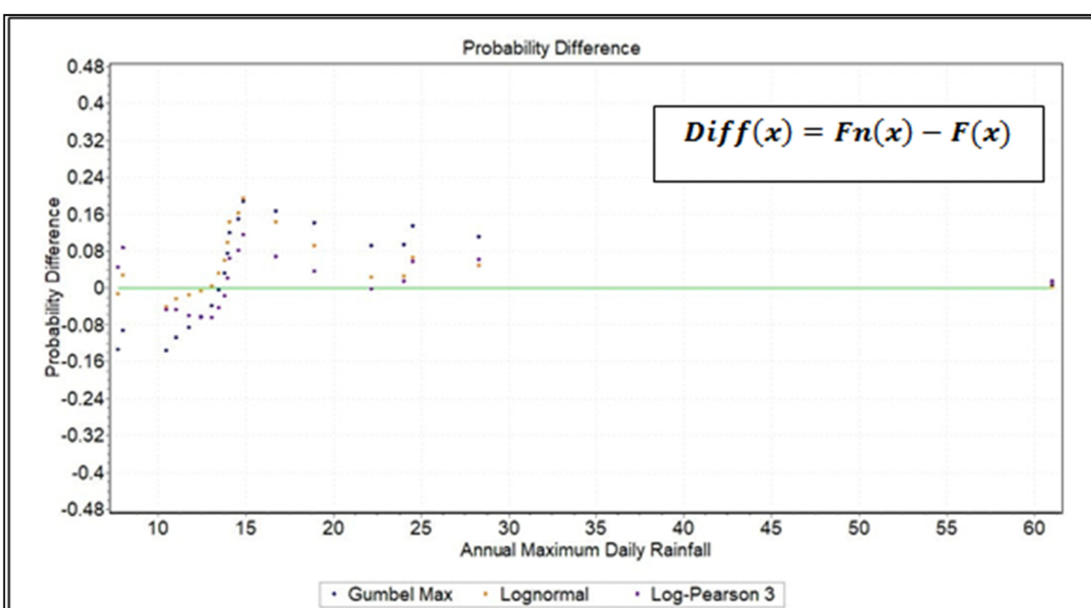

Figure 9: Probability difference of three selected distributions for 0.5 h.

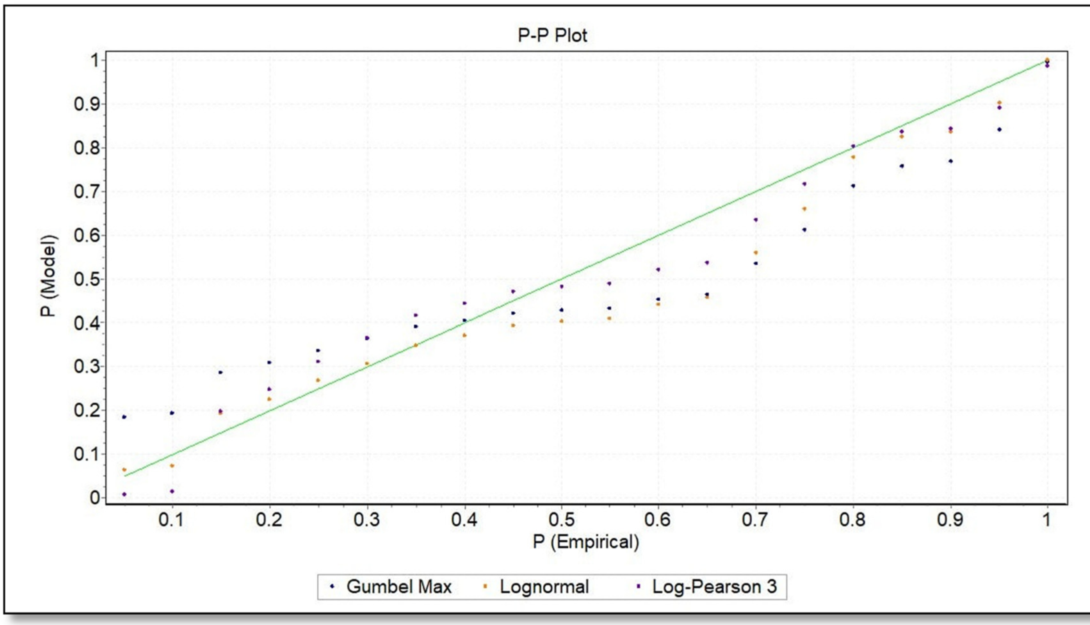

Figure 10: P–P plot of three selected distributions for 0.5 h.

theoretical distribution is the correct model. EasyFit displays the reference diagonal line along which the graph points should fall.

The results of descriptive statistics of each duration series are displayed by EasyFit 5.5 program (Table 7).

It is observed that the skewness values of all the data durations are approximately the same, with a value of 2.988. This means that the distribution of each data duration is approximately symmetrical. So is the coefficient of variance which is same for all periods, indicating the correctness of the work of the program and the accuracy of the results, the coefficient of variance is 0.650 for all periods. The best fit for each distribution was assessed using the Chi-square, Anderson–Darling, and Kolmogorov–Smirnov fit test for each period using EasyFit 5.5. With the help of a quality fit test and LSSMIC, the best appropriate distribution has been determined. The results showed that the best distribution is lognormal method as shown in Table (8), where LSSMIC is calculated from

$$\text{LSSMIC} = \text{Abs}\,(1 - \text{sum of statistic}). \tag{7}$$

Table 7: Results of descriptive statistics of rain data duration series

Statistic	0.5 h	1 h	6 h	12 h	24 h
Sample size	20	20	20	20	20
Range	53.21	67.05	121.83	153.5	193.4
Mean value	17.786	22.409	40.721	51.305	64.64
Variance	133.87	212.53	701.7	1113.9	1768.4
Std. deviation	11.57	14.578	26.49	33.376	42.052
Coef. of variation	0.650	0.650	0.650	0.650	0.650
Skewness	2.988	2.988	2.988	2.988	2.988

5 Conclusion and recommendations

5.1 Conclusion

1. Produced new IDF curves should be utilized to estimate the rainfall intensities for varied return times.

Table 8: Best fit model for 0.5 h

Distribution	Kolmogorov–Smirnov Statistic	Anderson–Darling Statistic	Chi-square Statistic	LSSMIC	Best fit
Gumbel	0.18802	1.3418	8.2854	8.81522	
Lognormal	0.19454	0.59911	1.0353	0.82895	Best
LPT III	0.11574	0.51631	3.0515	2.68355	

The revised IDF curve can be used to build and maintain urban water management systems such as culverts and bridges, among other things.
2. According to the obtained results of the current study about the precipitation data of Wasit, it is observed that no significant difference can be found in the rainfall analysis results of the curves of IDF between the applied methods. This can be attributed to the fact that a semi-arid climate and flat terrain are dominant in Wasit that cause slight differences in rainfall values.
3. Easy Fit 5.5 software was applied for determining the best results distribution, and one can notice that the lognormal was the best distribution, as the LSSMIC statistical model was used for assessing the fit of each probability distribution. The results showed that the lowest value of LSSMIC, which was 0.82895, was with lognormal distribution, and it was adopted as the best distribution for the data of Kut city.
4. It was also inferred that the maximum intensity occurred in the return period of 100 years and the minimum intensity occurred in the 2 year return period.

5.2 Recommendations

The new IDF curves developed should be used in estimating rainfall intensities for various return periods, and the derived IDF models could be used for better results and accuracy. The new IDF curve can be used to design drainage systems and maintain urban water management systems such as culverts, drains, sewers, bridges, etc. The existing IDF curve should no longer be used because it was developed using poor data records and developed for a long time. Disaggregated rainfall data of Kut City stations can be used for hydrological analysis. It is strongly recommended that the new IDF curves should be reviewed or updated every 4–5 years because of climate change and variability patterns of rainfall data.

Conflict of interest: The authors declare that they have no conflict of interest.

Data availability statement: Most datasets generated and analyzed in this study are comprised in this submitted manuscript. The other datasets are available on reasonable request from the corresponding author with the attached information.

References

[1] Akpen GD, Aho MI, Musa AA. Rainfall intensity-duration-frequency models for Lokoja Metropolis, Nigeria. Glob J Pure Appl Sci. 2018;24:81–90.
[2] Ewea HA, Elfeki AM, Bahrawi JA, Al-Amri NS. Modeling of IDF curves for stormwater design in Makkah Al Mukarramah region, The Kingdom of Saudi Arabia. Open Geosciences. 2018;10(1):954–69.
[3] Nile BK, Hassan WH, Esmaeel BA. An evaluation of flood mitigation using a storm water management model [SWMM] in a residential area in Kerbala, Iraq. IOP Conf Ser Mater Sci Eng. 2018;433(1):012001.
[4] Sane Y, Panthou G, Bodian A, Vischel T, Lebel T, Dacosta H, et al. Intensity-duration-frequency (IDF) rainfall curves in Senegal. Nat Hazards Earth Syst Sci. 2018;18(7):1849–66.
[5] Sun Y, Wendi D, Kim DE, Liong SY. Deriving intensity-duration-frequency (IDF) curves using downscaled *in situ* rainfall assimilated with remote sensing data. Geosci Lett. 2019;6(1):1–12.
[6] Hussein AK. Deriving rainfall intensity-duration-frequency relationships for Kerbala city. Al Muthana Journal for Engineering Sciences. 2014;3(1):25–37.
[7] Zope PE, Eldho TI, Jothiprakash V. Development of rainfall intensity duration frequency curves for Mumbai City, India. J Water Resour Prot. 2016;8(07):756–65.
[8] Al-Awadi AT. Assessment of intensity duration frequency (IDF) models for Baghdad city. Iraq J Appl Sci Res. 2016;12(2):7–11.
[9] Wambua RM. Estimating rainfall intensity-duration-frequency (IDF) curves for a tropical river basin. Int J Adv Res Publ. 2019;3(4):99–106.
[10] Mohammed A, Dan'Azumi S, Modibbo AA, Adamu AA. Development of rainfall intensity duration frequency (IDF) curves for design of hydraulic structures in Kano state. NIGER Platform A J Eng. 2021;5(2):10–22.
[11] Shamkhi MS, Tabark JA, Atyaf JM. Comparison between satellite rainfall data and rain gauge stations in the Al-Adhaim watershed, Iraq. Plant Arch. 2020;20(2):625–9.
[12] AlHassoun SA. Developing an empirical formulae to estimate rainfall intensity in Riyadh region. J King Saud Univ Eng Sci. 2011;23(2):81–8.
[13] Onen F, Bagatur T. Prediction of flood frequency factor for Gumbel distribution using regression and GEP model. Arabian J Sci Eng. 2017;42(9):3895–906.
[14] Bhat MS, Alam A, Ahmad B, Kotlia BS, Farooq H, Taloor AK, et al. Flood frequency analysis of river Jhelum in Kashmir basin. Quat Int. 2019;507:288–94.