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DEVELOPING RAINFALL INTENSITY-DURATION-FREQEQNCY RELATIONSHIP FOR BASRAH CITY

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Abstract

The rainfall Intensity-Duration-Frequency (IDF) relationship is one of the most commonly used tools in water resources engineering, either for planning, designing and operating of water resource projects, or for various engineering projects against floods. The purpose of this paper is to develop an empirical formula to estimate design rainfall intensity based on intensity–duration–frequency (IDF) curves for Basrah City. These curves have been generated from a 31-year recorded rainfall data. The study showed maximum intensities occur at shout duration large variations with return period, Furthermore ,it also notice ; at long duration there is no much difference in intensities with return period**.**

Keywords: Rainfall,Frequency, Duration, Intensities

تطوير علاقات الشدة المطرية - التكرار - الاستدامة لمدينة البصرة

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الخلاصة

العلاقة بين الشدة المطرية وتكرار الشدة المطرية والاستدامة هي إحدى أكثر الأدواتِ المستعملةً في هندسة مصادرِ المياه، سواء في التخطيط والتَصميم او في تشغيل مصادرِ المياه . الغرضَ من هذا البحث َهو ايجاد علاقة وضعية لتَخمين شدة مطرِ التصميمِ اعتمادا على تكرار الشدة المطريَة و مدّةِ الاستدامة لمدينة البصرة . وقد تم ايجاد هذه العلاقة بالاعتماد على بيانات مطرِية يومية مسجّلةِ ل 31 سَنَة لمدينةِ البصرة وتم رسم هذه المنحنيات من هذه العلاقة. وقد اظهرت هذه الدراسةُ ان الشدة المطرية العظمى تحصل خلال مدة استدامة قصيرة مع تباين شديد بالاعتماد على فترات التكرار،بينما خلال الاتدامة الطويلة للشدة المطرية لا يوجد تباين واضح بالاعتماد على فترات التكرار.

1.Introduction

The rainfall Intensity-Duration-Frequency (IDF) relationship is one of the most commonly used tools in for various engineering projects against floods. IDF curves express the relation between the intensity, duration and return period of the rainfall. In order to construct of IDF curves, a historical series of the maximum rainfall intensities at a higher time resolution (with a one-minute interval) is required. Such rainfall data are available only from a limited number of rain-gauging stations; the most accessible rainfall data are 1-day precipitation totals from a denser network of non-recording rain gauge(Nhat et al, 2006).

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The establishment of IDF relationships was done as early as in(Bernard (1932). Since then, many sets of relationships have been constructed for several parts of the globe:Hershfiled (1961) developed various rainfall contour maps to provide the design rain depths for various return periods and durations. Bell(1969) proposed a generalized IDF formula using the one hour, 10 years rainfall depths; P_1^{10}, as an index. Chen (1983) further developed a generalized IDF formula for any location in the united States using three base rainfall depths]P_1^{10} P_{24}^{10} P_1^{100} which describe the geographical variation of rainfall .

Kouthyari and Garde (1992) presented a relationship between rainfall intensity and P_{24}^{2} for India. Koutsoyiannis et al.(1998) cited that IDF relationship is a mathematical relationship between the rainfall intensity 'i,' the duration 'd' and the return period 'T' (or equivalently, the annual frequency of exceedance, typically referred to as 'frequency' only).

1. Empirical IDF Formulas

The IDF formulas are the empirical equations representing a relationship among maximum rainfall intensity (as dependant variable) and other parameters of interest such as rainfall duration and frequency (as independent variables). There are several commonly used functions found in the literature of hydrology applications, four basic forms of equations used to describe the rainfall intensity duration relationship are summarized as follows(Chowetal, 1988):

Talbot Equation $i = \frac{cT^m}{d+b}$……………………………………….eq.(1)

Bernard Equation $i = \frac{cT^m}{d^e}$……………………………………….eq.(2)

Kimijima Equation $i = \frac{cT^m}{d^e+b}$…………………………………….eq.(3)

Sherman Equation $i = \frac{cT^m}{(d+b)^e}$…………………………………….eq.(4)

Where 'i' is the rainfall intensity (mm/hour); d is the duration (minutes); T return period in years c, b, e and m are the constant parameters related to the metrological conditions.

These empirical equations show rainfall intensity decreases with increase in rainfall duration for a given return period. All functions have been widely used for hydrology practical applications.

2.Generalized IDF Formula

When local rainfall data is available, IDF curves can be developed using frequency analysis. From daily maximum rainfall ,corresponding values hourly values can be obtained using Indian Meteorological Department(IMD) empirical reduction formula, Commonly distributions for rainfall frequency analysis which is the Extreme Value Type I(Gumble distribution) is used. We estimate the equation parameters using least square method , Bernard Equation eq.(2)

3.Empirical Reduction Formula

Daily rainfall data for the study area were available for a period of 31 years . From this data base, the maximum values were extracted for each year and were converted into shorter duration (1-, 2-, 3-, 6- and 12-hr) values using the reduction formula suggested by the Indian Meteorological Department (Rathnam 2000), which is:

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$P_t = P_{24} \left({}^{t}/_{24}\right)^{1/3}$……………………………………………….eq.(5)

Where:

Pt is required precipitation depth for the duration t-hour in mm.

P24 is daily precipitation in mm.

and t is the time duration in hours for which precipitation depth is required in hours.

4.Gumble Distribution

Gumbel distribution methodology (EV-1) was selected to perform the flood probability analysis. The Gumbel theory of distribution is the most widely used distribution for IDF analysis owing to its suitability for modeling maxima. It is relatively simple and uses only extreme events (maximum values or peak rainfalls). The Gumbel method calculates the 2, 5, 10, 25, 50 and 100-year return intervals for each duration period and requires several calculations. Frequency precipitation P_T (in mm) for each duration with a specified return period T (in year) is given by the following equation.

$P_T = P_{av} + K_T * S$…………………………………………...….eq.(6)

where:

P_T= frequency precipitation for each duration with a specified return period T.

P_{av} = average of the maximum precipitation corresponding to a specific duration.

S = standard deviation of the series.

$S = \sqrt{\frac{(Pt - P_{av})^2}{n-1}}$ ……………………………………………..eq.(7)

Where:

pt= Maximum Precipitation Depth corresponding to a specific duration.

n = number of years of record .

K_T = the frequency factor

$K_T = -\sqrt{6}\left\{0.5772 + \ln\left(-\ln\left(1 - \frac{1}{T}\right)\right)\right\}/\pi$……………………..eq.(8)

6.Curve Fitting

The lest square method is followed in order to estimate IDF equation parameters.IDF equation is

$i = \frac{cT^m}{d^e} = \frac{K}{d^e}$ ……………………………………..……………….eq.(9)

$K=c\,T^m$ ………………………..……………….……………….eq.(10)

By applying the logarithmic function to get:

log i=log K+e log d……………………………………………….eq.(11)

Now making the following substitution into eq. (11):

Ǐ=log i………………………………………………………….……….eq.(12)

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Ǩ=logK……………………………………………………………eq.(13)
Ď=log d……………………………………………………………eq.(14)

Yield the equivalent linear function relation to that given by eq,(9):
Ǐ= Ǩ +e T * Ď…………………….………………………………….eq.(15)
For each return period we obtain e- value:

$$e\,T = \frac{N\sum \check{I}_i * \check{D}_i - \sum \check{D}_i \sum \check{I}_i}{N\sum(\check{D}_i)^2 - (\sum \check{D}_i)^2}$$ ………………………………………..eq.(16)

i = 1,2,3……N=12

Then the parameter (e) for IDF equation is

$$e = \frac{eT}{L}$$ …………………………………..…………………..eq.(17)

Where L=6
For each return period 6 value for K were obtained:

$$\check{K} = \frac{\sum \check{I}_i \sum(\check{D}_i)^2 - \sum \check{D}_i \sum(\check{I}_i * \check{D}_i)}{N\sum(\check{D}_i)^2 - (\sum \check{D}_i)^2}$$ …………..……………………………eq.(18)

Now applying the logarithmic function to eq(10) we get:

log K=log c+m log T…….….……………………………………eq.(19)

Also we have:

Č=log c……………………………………………………..….eq.(20)

Ť= log T…………………………………….……………………eq.(21)

$$\check{C} = \frac{\sum \check{K}_j \sum(\check{T}_j)^2 - \sum \check{T}_j \sum(\check{K}_j * \check{T}_j)}{L\sum(\check{T}_j)^2 - (\sum \check{T}_j)^2}$$ ………………………………………eq.(22)

$$m = \frac{L\sum \check{K}_j * \check{T}_j - \sum \check{K}_j \sum \check{T}_j}{L\sum(\check{T}_j)^2 - (\sum \check{T}_j)^2}$$ ……….………………………………….eq.(23)

j= 1,2,3….L, L =6

7.Data Available

In order to estimate the empirical formula for intensity–duration–frequency relationship in Basrah city, the available data acquired from Iraqi Meteorological Organization and Seismology includes 24-hour Rainfall data basis from 1980-2010 for Bsarah city were consider as presented in Table 1.

8.IDF Program

The development of IDF equation and curves program is done using maple language ,the entire rainfall data in Table 1 is used to carry out frequency analyses to determine the maximum intensities for known return periods and various durations. The flowchart of the

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program is shown in Figure1, the methodology which is used for development the program is:

1. The hourly maximum Precipitation (i.e. 1 hr, 2 hr …. 12 hr) is evaluated using the IMD reduction formula.
2. From the evaluated maximum hourly Precipitation data, the mean and standard deviation are evaluated.
3. The hourly Precipitation depth analysis is carried out for various return periods using the Gumble Distribution Function for EV-1.
4. Maximum Precipitation depths (1 hr, 2 hr …. 12 hr) are converted nto hourly intensities .
5. Estimation of the equation parameters by curve fitting.
6. The generalized Intensity-Duration-Frequency equation (24) is developed .

$$i = \frac{7.95\, T^{0.298}}{d^{0.667}} \quad \text{……………………………..…………………….eq.(24)}$$

7. Maximum intensities for various durations and return periods are evaluated using eq.(24) .
8. Intensity for different return period and duration are plotted as shown in Figure 2.

Table 1 Maximum Daily Rainfall Recorded in Basrah City During 1980-2010.

N0	Year	daily rainfall mm	N0	Year	daily rainfall mm
1	1980	28.1	17	1996	29.4
2	1981	21.3	18	1997	30.8
3	1982	15.1	19	1998	22.1
4	1983	18.3	20	1999	73.6
5	1984	45.4	21	2000	33.0
6	1985	73.2	22	2001	26.6
7	1986	58.5	23	2002	15.7
8	1987	9.6	24	2003	17.5
9	1988	M	25	2004	17.0
10	1989	17.5	26	2005	26.0
11	1990	11.6	27	2006	27.5
12	1991	57.0	28	2007	37.0
13	1992	21.9	29	2008	18.0
14	1993	22.9	30	2009	20.0
15	1994	28.5	31	2010	6.5

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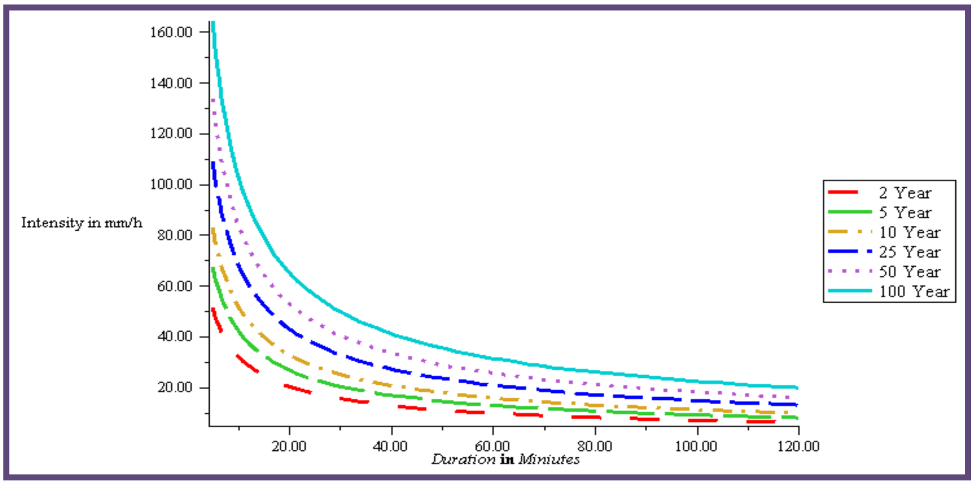

Fig. 1 Intensity - Frequency - Duration Curves For Basrah City.

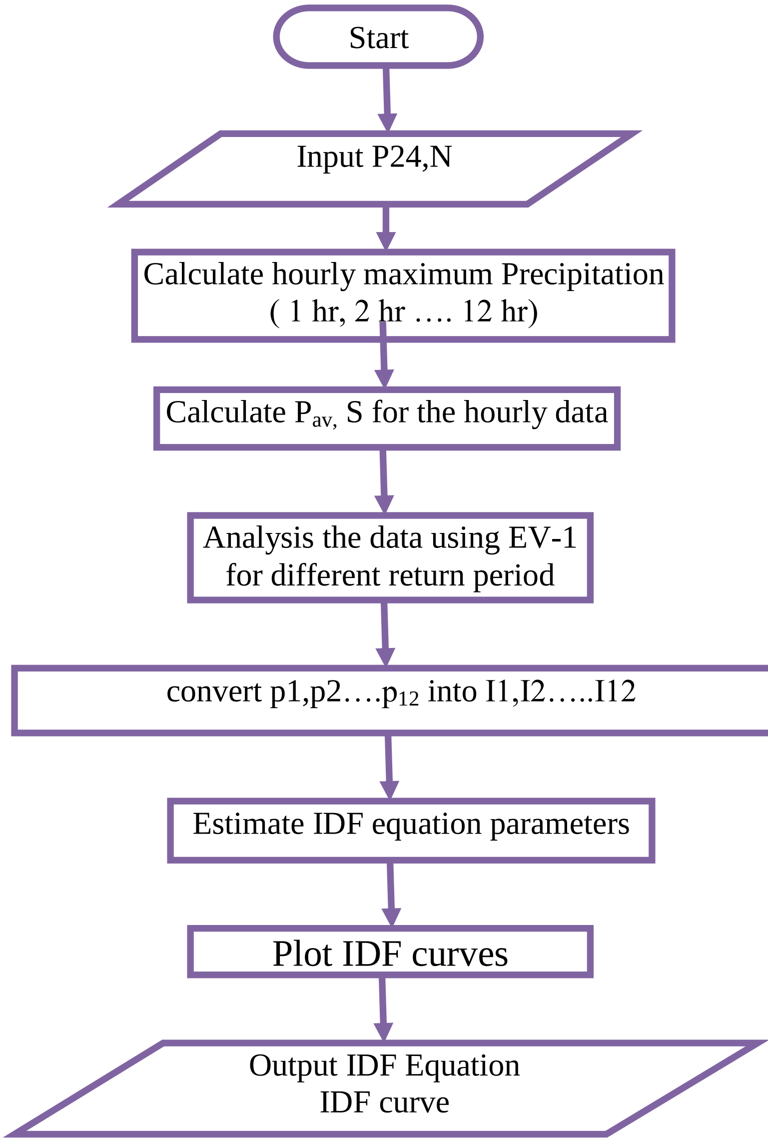

Fig.1 Program Flow Chart.

9. Results and Discussion

Most hydrological studies require short duration rainfall-runoff data and generally in developing countries, such short duration data are not available. However, daily data are collected and are available; hence efforts have been made to develop short duration data from daily data to aid in hydrological studies in general, and urban stormwater management in particular. This study has been conducted to the formulation and construction of IDF curves using daily rainfall data by using empirical equations.

From Table 1 it can be noticed one missing daily rainfall value in 1988.In addition there is no much difference in rainfall amount in the recorded years This might be because that Basrah City has flat topography where variations of precipitation is not large and maximum daily rainfall amount recur every ten year . In last decade minimum amount of daily rainfall is recorded which is 6.5 mm.

10. Conclusions

1. The study showed maximum intensities occur at shout duration with large variations with return period, while with long duration there is no much difference in intensities with return period.
2. Maximum intensity occur at return period 100 years with duration of 5 minute.
3. Minimum intensity occur at return period 2 years with duration of 120 minute.

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LIST OF SYMBOLS	
Symbol	Definition
i	Rainfall intensity
T	Return period
Pt	precipitation depth for the duration t
P24	daily precipitation
PT	frequency precipitation for each duration with a specified return period T
Pav	average of the maximum precipitation corresponding to a specific duration
S	standard deviation of the series
K_T	the frequency factor
d	Duration
c, m, e	regional coefficients