INTENSITY- DURATION -FREQUENCY ANALYSIS FOR RAINFALL IN BAIJI STATION

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ABSTRACT

In the present study, modified relations were obtained to relate rainfall intensity with frequency using Weibull method for 15, 30 and 60 minutes duration. This was done to estimate the designed value for rainfall intensity for any mentioned duration at any observation interval.

The obtained results show that the rainfall intensity increases with the increasing of return period. Also, for every duration rainfall, the intensity decreases with the increasing of duration.

Two types of probability distribution tests were applied for any duration, they are Gumble and Person (III) tests, also, statistical tests were applied to determine the optimum and suitable distribution for the studied data.

The obtained relations can be usefull as a design equation for small weirs, culverts and rain downsrtream systems in the case of construction of them in the studied area.

KEY WORDS

Duration, Frequency, Rainfall, Statistical analysis, Storm analysis.

NOTATIONS

No.	Symbol	Definition
1	Ci	Rainfall intensity for any return period
2	Cs	Skew coefficient
3	D	Duration of rainfall
4	I	Rainfall intensity
5	K	Return coefficient
6	k	Number of specified tools for the mentined distribution
7	M	Rank of the observation
8	MD	Absolute deviation
9	N	No. of reporting years
10	P	Probability in of the observation of the rank M
11	Ri	Rainfall for return period
12	SE	**Stanadared error**
13	T	Return period
14	σ	Standard deviation
15	$\overline{X}$	Average value of variables
16	$\overline{Y}$	Reduced variable

INTRODUCTION

Design of bridges, culverts, spillways and sewage systems of rainfall storms are based on value of peak discharge (flood) in a selected return period which is done by the designer [1].In some of design problems which is caused by management and treatment of water on catchment such as surface runoff discharge and controlling on and, its necessary to relate rainfall intensity for different durations and return periods, which is based on the value of rainfall intensity for the required duration for the same return period. Where the non effective performance of those structures was caused by the independency of the real value of rainfall intensity which is results from the unavailability of data for the required duration.

Rainfall intensity is defined as the ratio of the total amount of rain (rainfall depth) falling during a given period to the duration of the period. It is expressed in depth units per unit time, usually as mm per hour (mm/h) [2].

It can be obtain the designed value for the rainfall intensity for the mentioned duration via a logic relation relates rainfall intensity and frequency in the light of the rainfall data which was focused for the special station in the mentioned region [3].

For the purpose of obtaining a logic relation between rainfall intensity and rainfall frequency, data of durations 15, 30, 60 min. were used for the period of 1989-1999 for Baiji station which is located at the 44° 50′ latitude and length line 43° 29′ length line. Maximum rainfall intensity data were analyzed and tested for mentioned station by using Weible method. Also maximum rainfall intensity for special duration using two probable distributions (Gumble and Person (III)) to estimate the optimum probale distribution for any duration.

There were many studies and researches dealing with rainfall-duration frequency analysis.

Precipitation in arid and semi-arid zones results largely from convective cloud mechanisms producing storms typically of short duration, relatively high intensity and limited areal extent. However, low intensity frontal-type rains are also experienced, usually in the winter season.When most precipitation occurs during winter, as in Jordan and in the Negev,relatively low-intensity rainfall may represent the greater part of annual rainfall [2].

The statistical characteristics of high-intensity, short-duration, convective rainfall are essentially independent of locations within a region and are similar in many parts of the world. Analysis of short-term rainfall data suggests that there is a reasonably stable relationship governing the intensity characteristics of this type of rainfall. Studies carried out in Saudi Arabia (Raikes and Partners 1971) [2] suggest that, on average, around 50 percent of all rain occurs at intensities in excess of 20 mm/hour and 20-30 percent occurs at intensities in excess of 40 mm/hour. This relationship appears to be independent of the long-term average rainfall at a particular location.

Hosking and Wallis [4], describe regional frequency analysis using the method of L-moments. This general statistical methodology stems from work in the early 1970's. It only began seeing full implementation for rainfall frequency estimation in the 1990's but is now accepted as the state of the practice. The

National Weather Service is using Hosking and Wallis, 1997, as its primary reference for the statistical approach in its current studies. The method of L-moments (or linear combinations of probability weighted moments), provides great utility in choosing the most appropriate probability distribution function to describe the rainfall frequency distribution. It also provides tools for estimating the shape (higher order statistical moments) of the distribution and the uncertainty associated with the estimates.

Basel and Kaled[5] investigated rainfall intensity-duration-frequency relation for short duration for Mousl and Sulamaniya, they found the following relations enable to find rainfall intensity for any duration but for return period not exceeds observation period:

$$I = \frac{0.662T^{1.726}}{D^{0.202}}$$ …………………(1) Mousl Station

$$I = \frac{0.595T^{1.796}}{D^{0.0503}}$$ …………………(2) Sulamaniya station

Where :

I= Rainfall intensity, mm/hr

T= Return period, year

D= Duration of rainfall, minute

Eliberto [6] dealed with hydraulic analysis to estimate engineering design parameters of Venzuela, this study focused on storm advancement coefficient (r) (SAC) to establish storm pluviographs, intensity duration frequency (IDF) and area – depth- duration relations (ADD). Based on the analysis of 275 storm events, It can be calculated values of (r) and standard deviation for the rainfall data.

RESULTS AND DISCUSSION

Table (1) shows the data of rainfall intensity for different durations in Baiji station.

Analyzing of rainfall data using Weibel method

The available rainfall data for 15, 30 and 60 minutes duration were used for observation period of (1989-1999). By analyzing these data, maximum annual rainfall values for any duration were collected then converted to rainfall intensity data in mm/hr, then according to Weible method [7]: -

$$P = \frac{M}{N+1} \qquad \text{………………….(3)}$$

$$T = \frac{1}{P} \qquad \text{………………….(4)}$$

Where:-

P= Probability of the observation of the rank M

M= Rank of the observation inversely oreinted

N= No. of reporting years

T= Return period, year

Analyzing of data and modeling relations between rainfall intensity and frequency for studied duration period

Figures (1, 2 and 3) represent the relationship between the rainfall intensity and frequency for duration of 15,30 and 60 minutes respectively. The following relations are observed from these figures:-

I= 19.252Ln(T) + 9.3981 ... ………..(5) D= 15 minutes

I = 13.598Ln(T) + 4.979 ……… … (6) D= 30 minutes

I = 8.5739Ln(T) + 3.3765 ………… (7) D= 60 minutes

From the above figures it can be seen the following:-

1- Rainfall intensity increases with increasing of return period

2- At duration of 15 minutes the rainfall intensity values are obviously higher than those of 30 and 60 minutes for every calculated return period .

Duration-Rainfall Intensity Relationship for Various Return Periods

The previous equations (5,6 and 7) can be applied to obtain the rainfall intensity for every desired observation period and for durations 15,30 and 60 minutes respectively. Figure (4) shows the relations between the rainfall intensity and duration for the observation period of 10, 20, 30, 50 and 100 years. Referring to this figure it can be observe that the rainfall intensity decreases with increasing the duration for every observation return period , also, it can be seen that for a same duration, the rainfall intensity increases with increasing the return period.

Determination and selection of probability for optimum distribution of the station

Different types of probability distribution were applied on the rainfall intensity data for any duration, these types are:

1- Person distribution III

In case of using logarthmic Person distribution it is reccommended to convert data series to logarthmic form then calculating the quantites as followes[8]:

$$\overline{\log x} = \frac{\sum \log x}{n} \qquad \text{.................(8)}$$

$$\sigma_{\log x} = \sqrt{\frac{\sum (\log x - \overline{\log x})^2}{n-1}} \qquad \text{................(9)}$$

$$C_s = \frac{n\sum (\log x - \overline{\log x})^3}{(n-1)(n-2)(\sigma_{\log x})^3} \qquad \text{............(10)}$$

$$\log x = \overline{\log x} + K\sigma_{\log x} \qquad \text{............... (11)}$$

Where:

σ : Standard deviation

Cs: Skew coefficient

K : Return coefficient, depend on the return period and a skew coefficient and can be obtained from a certain type of table[8].

2- Gumble distribution

In case of using Gumble distribution it can be represent data by the following equations[8]:

$$x = \bar{x} + \left(\frac{y - y_n}{\sigma n}\right)\sigma_x \qquad \text{..............(12)}$$

$$y = -\left| lin.lin \frac{T}{T-1} \right| \qquad \text{..............(13)}$$

Where:

σ_x : standard deviation of sample

σn , y_n : functions of time length of observation can be obtain from certain type of tables[8].

$\bar{x}$: Average value of variables

y : Reduced variable, represents a function of return period (T).

For determination of optimum and more suitable distribution of the data for any duration of rainfall, the folowing tests were used:

a) Standard error : to obtain the strandared error of certain distribution the follwing relation is used[9]:

$$SE = \frac{\sum_{i=1}^{n}(R_i - C_i)^2}{n-k} \qquad \text{.................(14)}$$

Where:

SE: Standared error

Ri: Rainfall for return period i

Ci: Rainfall intensity for return period using a specified method for the mentioned distribution.

n: number of reporting years

k: Number of specified tools for the mentioned distribution

The lowest value of SE for each type of distribution will be an indicator for the optimum type of distribution.

b) Mean absolute deviation: to obtain the average of absolute values of deviation (MD) within the calculated and observed values of rainfall intensity for certain duration it can be used the following equation[10]:

$$MD = \frac{\sum_{i=1}^{n}(R_i - C_i)}{n} \qquad \text{...............(15)}$$

The lowest value of MD for each type of distribution will be an indicator for the optimum type of distribution.

c) Efficiency test: to obtain the distribution efficiency, the following equation is used [11]:

$$\text{EF}=\frac{A-B}{A} \qquad \text{................(16)}$$

$$A = \sum_{i=1}^{n}(R_i - \overline{R})^2 \qquad \text{..................(17)}$$

$$\text{B}=\sum_{i=1}^{n}(C_i - R_i)^2 \qquad \text{...........(18)}$$

Table (2) shows the results of the special test for the available data.

Determination of probable rainfall intensity for the studied rainfall duration

By applying the previous test on rainfall intensity data for 15, 30 and 60 minutes duration for every station it can observe that:

1- Person distribution represents the optimum distribution of the rainfall intensity data for a duration of 15 and 60 minutes.
2- Gumble distribution represents the optimum distribution of the rainfall intensity data for a duration of 30 minutes.

Figures (5, 6 and 7) represent Person distribution for durations (15, 30 and 60 minutes).

Figures (8, 9 and 10) represent Gumble distribution for durations (15, 30 and 60 minutes).

All of them show the relation between rainfall intensity and return period for the studied duration, they were plotted in the light of probability distribution results of Person and Gumble method.

CONCLUSIONS

For the present study and its limitations the following conclusions can be obtained:

1- Rainfall intensity increases with increasing the return period.
2- For every observation period, rainfall intensity decreases with the increasing of rainfall duration.

3- From the study and comparison of the results of optimum distribution tests for every duration, it can be realized that Person distribution represents the optimum type of distribution tests for rainfall intensity with durations of 15 and 60 minutes, whereas Gumble distribution represents the optimum type of distribution tests for rainfall intensity with duration of 30 minutes.

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Table (1) Data of rainfall intensity for different durations (Baiji station)

D= 15 minutes				D= 30 min				D= 60 min			
M	I, mm/hr	P= M/N+1	T= 1/P	M	I, mm/hr	P= M/N+1	T= 1/P	M	I, mm/hr	P= M/N+1	T= 1/P
1	64	0.0833	12	1	47	0.0833	12	1	28.5	0.0833	12
2	36	0.166	6	2	18.6	0.166	6	2	13	0.166	6
3	34	0.25	4	3	18.4	0.25	4	3	12.5	0.25	4
4	28	0.333	3	4	17	0.333	3	4	11.3	0.333	3
5	25.2	0.416	2.4	5	17	0.416	2.4	5	11.3	0.416	2.4
6	25.2	0.5	2	6	15.8	0.5	2	6	9.7	0.5	2
7	22	0.583	1.714	7	13.6	0.583	1.714	7	9.2	0.583	1.714
8	20	0.666	1.5	8	11	0.666	1.5	8	7.7	0.666	1.5
9	16.4	0.75	1.33	9	9.2	0.75	1.33	9	5.7	0.75	1.33
10	14	0.833	1.2	10	8.2	0.833	1.2	10	4.1	0.833	1.2
11	8	0.916	1.09	11	7.2	0.916	1.09	11	3.5	0.916	1.09

Table (2) Results of the special test of rainfall intensity in Baiji station

Duration Minutes	Type of distribution	SE	MD	EF
15	Gumble	10.688	23.9	0.997
	Person (III)	6.488	12.97	1.00
30	Gumble	10.74	24.03	0.9912
	Person (III)	14.086	28.17	0.962
60	Gumble	4.866	10.88	0.997
	Person (III)	1.965	3.93	0.998

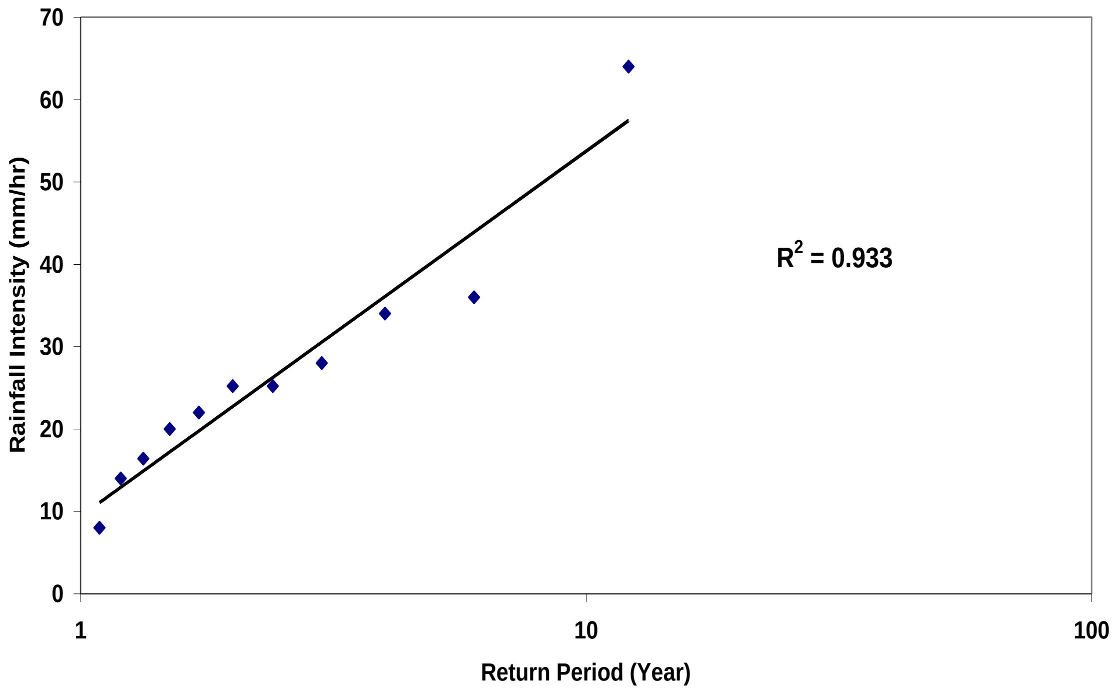

Figure (1)Rainfall intensity relates to return period (D= 15 min)

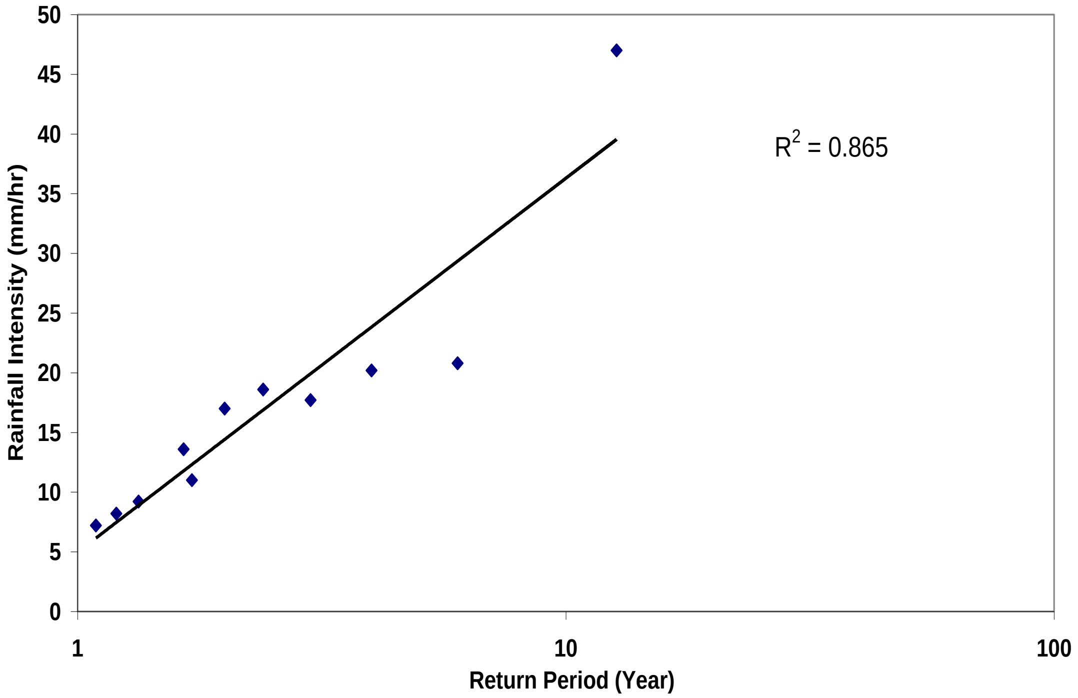

Figure (2) Rainfall intensity relates to return period (D= 30 min)

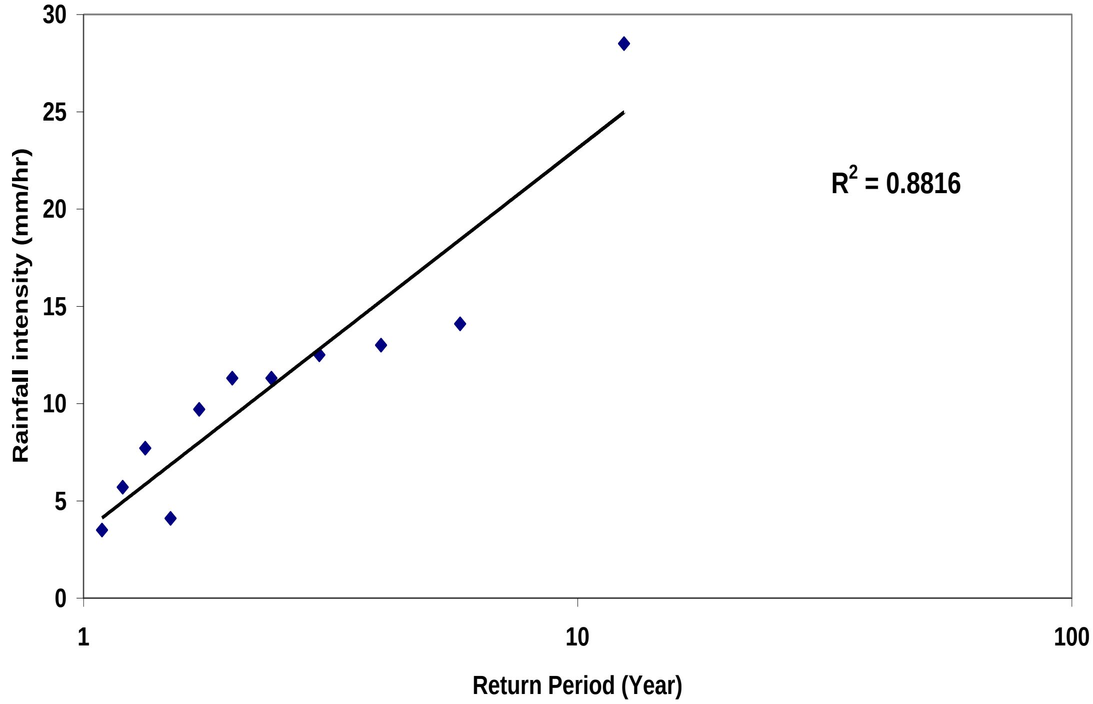

Figure (3) Rainfall intensity relates to return period (D= 30 min)

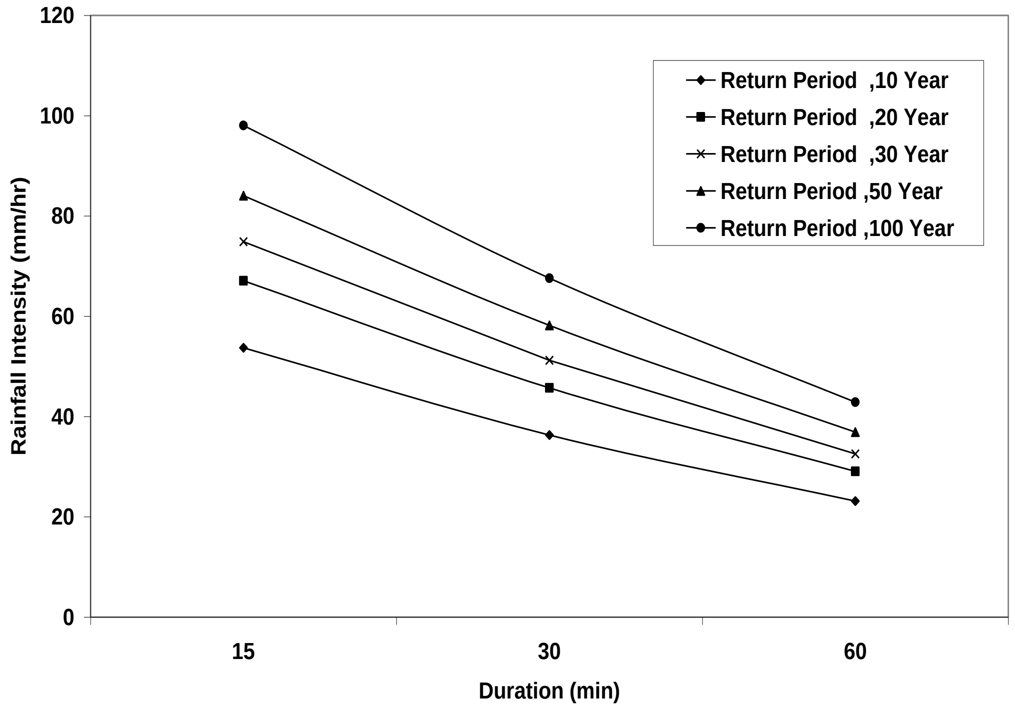

Figure (4) Rainfall Intensity- Duration- Frequency curve

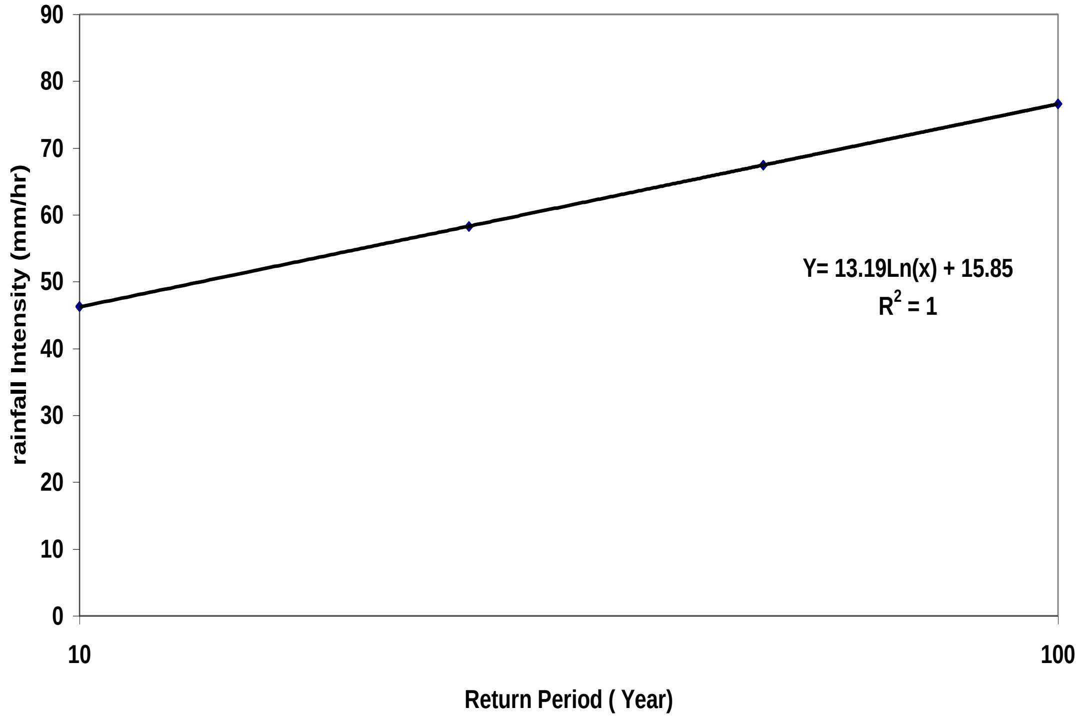

Figure (5) Rainfall intensity relates to return period of 15 min duration by Person distribution

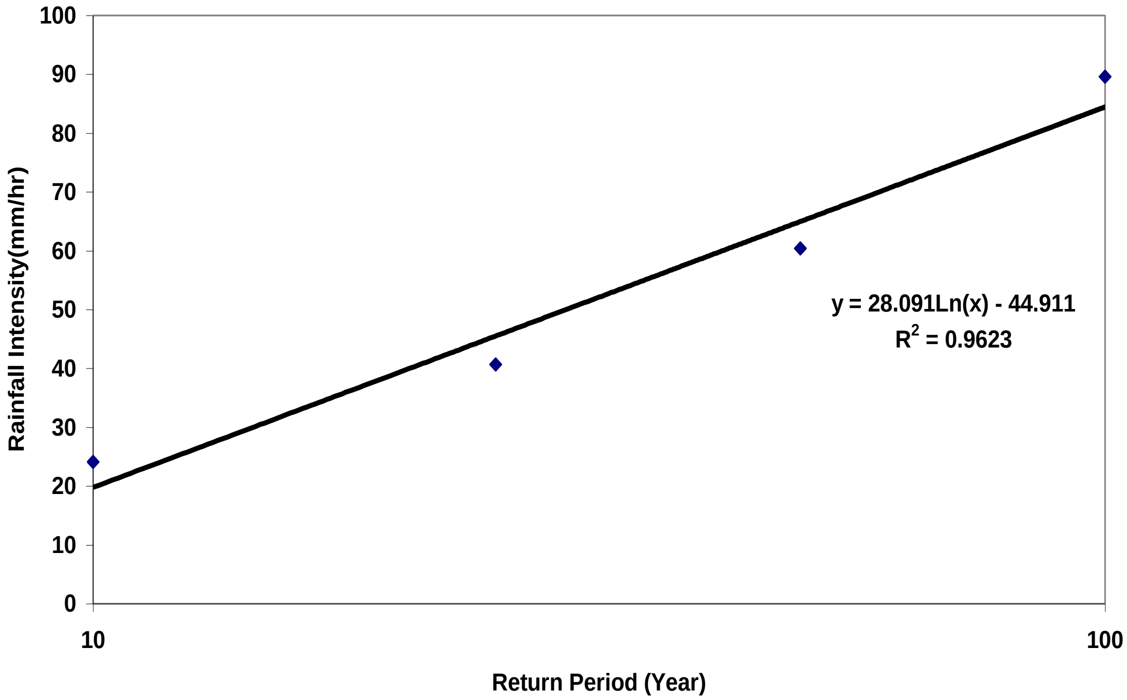

Figure (6) Rainfall intensity relates to return period of 30 min duration by Person distribution

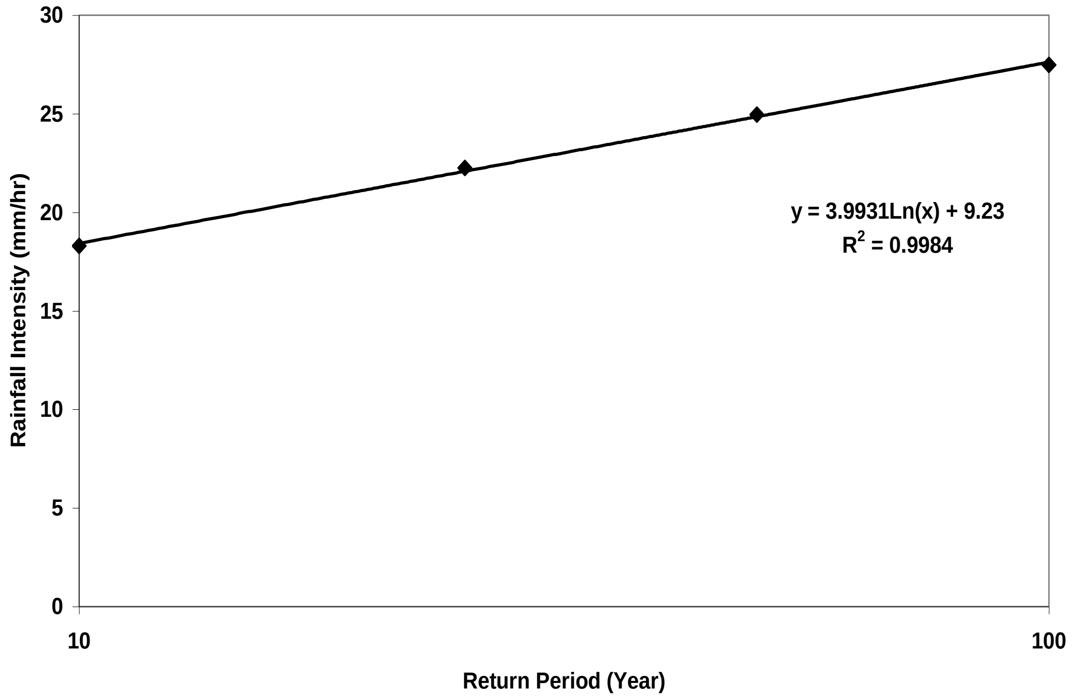

Figure (7) Rainfall intensity relates to return period of 60 min duration by Person distribution

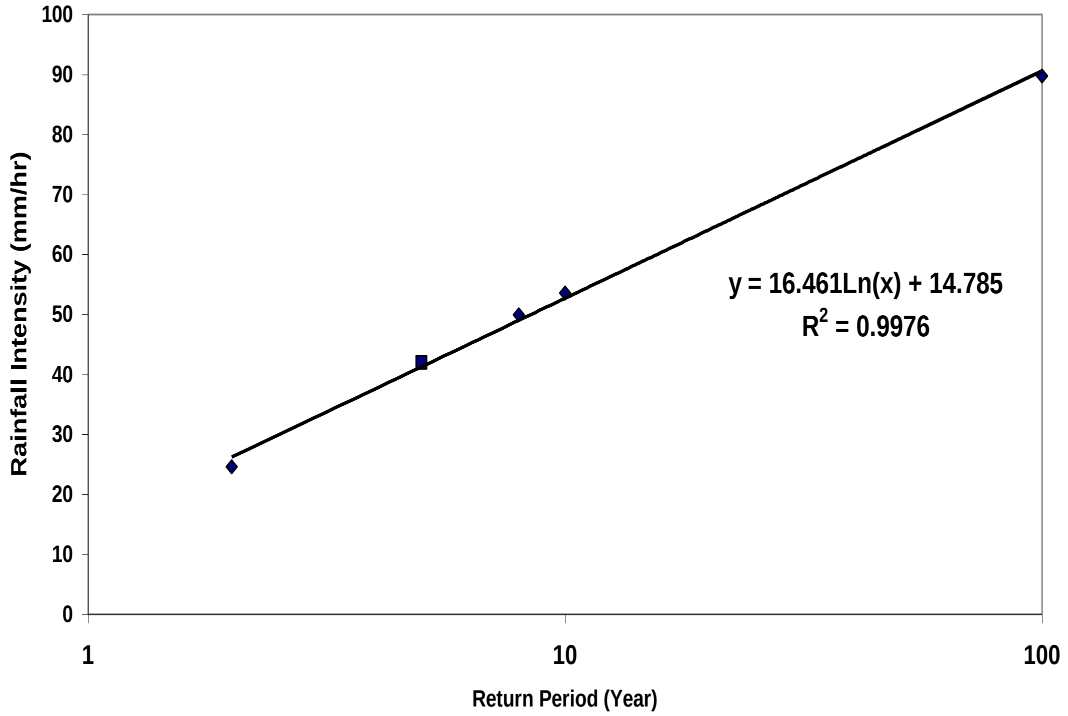

Figure (8) Rainfall intensity relates to return period of 15 min duration by Cumble Distribution

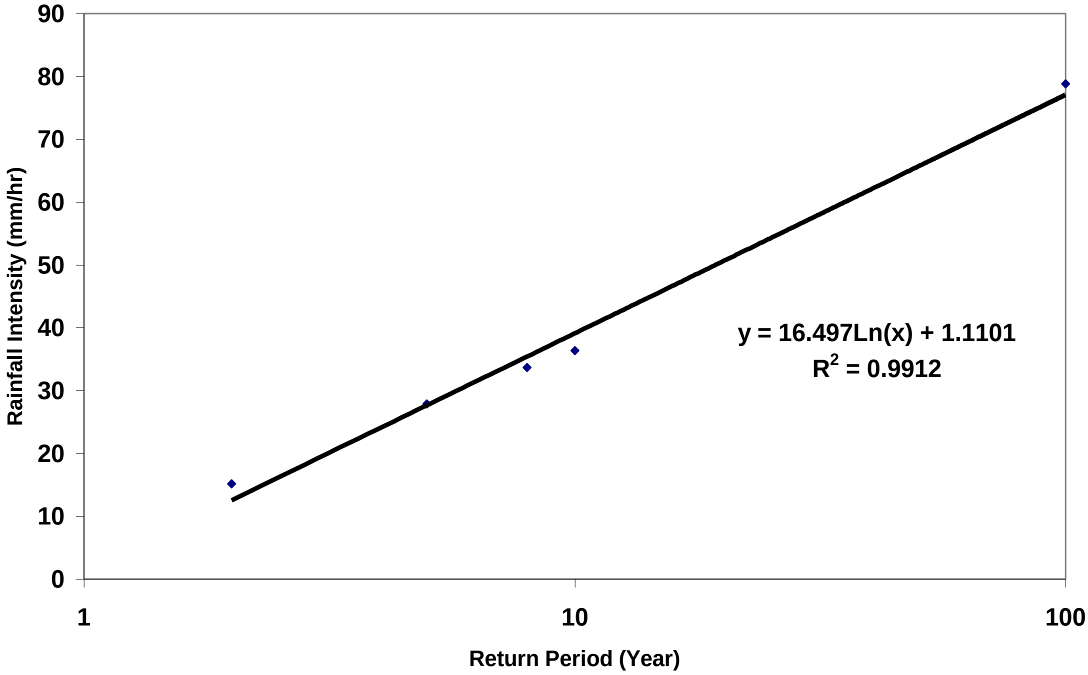

Figure (9) Rainfall intensity relates to return period of 30 min duration by Cumble Distribution

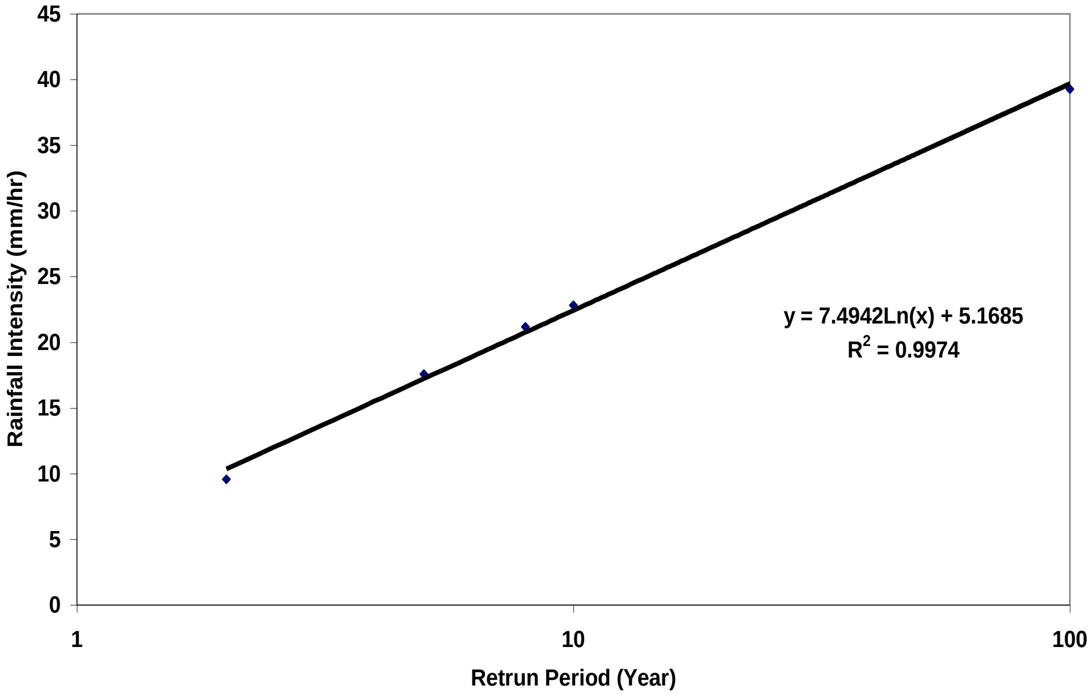

Figure (10) Rainfall intensity relates to return period of 60 min duration by Cumble Distribution

تحليل الشدة –الاستدامة-التردد للأمطار في محطة بيجي

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الخلاصة

في هذه الدراسة تم استنباط علاقات وضعية تربط الشدة المطرية بالتردد باستخدام طريقة وايبول و للاستدامات ١٥ ، ٣٠ ، ٦٠ دقيقة وذلك للتنبؤ بالقيمة التصميمية للشدة المطرية للاستدامة المعنية لأي فترة رصد مستقبلية.

بينت النتائج أن الشدة المطرية تزداد كلما زادت فترة الرصد كما أنه لأي فترة رصد معنية فإن الشدة المطرية تتناقص مع زيادة الاستدامة المطرية.

تم تطبيق توزيعان احتماليان على البيانات المطرية الخاصة بكل استدامة و هما توزيع كامبل و بيرسون النوع الثالث (III) مع استخدام اختبارات احصائية لتحديد التوزيع الأمثل و الأكثر ملاءمة للبيانات المرصودة.

يمكن الاستفادة من هذه العلاقات الوضعية في التصاميم الخاصة بالقناطر و السدود الصغيرة و منظومات صرف مياه الأمطار و غيرها من المنشآت المائية المطلوب إقامتها في منطقة الدراسة.

الكلمات الدالة

الاستدامة، التردد، المطر، التحليل الاحصائي، تحليل العاصفة المطرية.