The Magnitude of the Hydrological Frequency Factor in Maximum Evaporation Estimation for Five Stations in Iraq

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Abstract

In this paper data of annual maximum evaporation and total annual evaporation (mm) from 1968 to 1993 years for Nasiriya, and Kirkuk stations, and from 1972 to 1993 years for Mosul, Amara, and Basra stations were analyzed by using frequency factor method for obtaining the magnitudes of extreme events. The Extreme value type I (Gumbel) and Extreme value type II distributions were fitted to the annual maximum evaporation, and the Normal and Log Normal distributions were fitted to the total annual evaporation. These distributions are used to fit evaporation data with 5, 10, 25, 50, 100 year return periods. Return period and frequency factor relationships are obtained for all these distributions. The study shows that Amara station had the maximum value of total evaporation (6634.24 mm) for 100 year return period by using Log Normal distribution, and there is an increase in evaporation amounts with the increase of return periods.
Keywords: Frequency factor, return periods, extreme events

الخلاصة

في هذا البحث تم تحليل بيانات التبخر السنوية العليا وبيانات التبخر السنوية الكلية (مليمتر) من سنة 1968 إلى سنة 1993 لمحطات الناصرية وكركوك ومن سنة 1972 الى سنة 1993 لمحطات الموصل، العمارة، والبصرة باستخدام طريقة معامل التردد للحصول على قيم الاحداث العظمى. تم مُلائَمَة توزيع القيمة العليا من النوع الاول (كمبل) وتوزيع القيمة العليا من النوع الثاني لبيانات التبخر السنوية العليا، التوزيع الطبيعي والتوزيع اللوغارتمي الطبيعي تم ملائمتها لبيانات التبخر السنوية الكلية. واخذت فترات العوده 5، 10، 25، 50، و100 سنة ولكل التوزيعات. وتم الحصول على العلاقة بين فترات العوده ومعاملات التردد ولكل التوزيعات المختاره. وتبين من هذه الدراسة بأنّ أقصى قيمةُ للتبخر الكليّ في محطة العمارة (6634.24 مليمتر) لفترة عودة 100 سَنَة وباستخدام التوزيع اللوغارتمي الطبيعي وبينت الدراسة بان هنالك زيادةً في كمياتِ التبخرِ بزيادة فترات العودة.
الكلمات المفتاحية: معامل التردد, فترات العوده , الأحداث المتطرّفة.

1. Introduction

Hydrologic systems are sometimes impacted by extreme events, such as severe storms, floods, and droughts. The magnitude of an extreme event is inversely related to frequency of occurrence, very severe events occurring less frequently than more moderate events. The objective of frequency analysis of hydrologic data is to relate the magnitude of extreme events to their frequency of occurrence through the use of probability distributions. The hydrologic data analyzed are assumed to be independent and identically distributed and the hydrologic system producing them is considered to be stochastic **(Chow *et al.*, 1988)**.

One of the major components of the hydrologic cycle is evaporation. Estimations of evaporation are very important in many civil engineering studies such as water balance calculations, irrigation management, and ecological modelling in studies of climatology, hydrology, agriculture, and ecology. Therefore, it becomes necessary to analyze and assess the amount of evaporation and examine methods for estimate the maximum values of evaporation for developing appropriate control strategies in the future. Evaporation, as the only loss away from the surface in the water balance equation, plays a large part in water quantity and quality. The influence of evaporation on water quality is mostly through the impurities left behind after water has evaporated (**Al-Riahi, 2012)**.

Variations in evaporation have a significant impact on the energy and water budgets of lakes. Understanding these variations and the role of climate is important for water resources management. Hydrologic frequency analysis is the method used for evaluation of the probability of the hydrologic events, which are averaged out in statistical viewpoints, either greater than or of a specific magnitude within a certain area, that will occur within a certain period. Common hydraulic engineering designs, such as dam height, embankment height, design discharge, etc., are all determined by the results of frequency analysis **(Lee, 2005).**

2. MATERIAL AND METHOD

2.1 Hydrological Data

Frequency analysis was performed on annual maximum evaporation and total annual evaporation data from five meteorological stations in Iraq (Nasiriya, Kirkuk, Mosul, Amara, and Basra). The data was obtained from Iraqi Meteorological Office, Baghdad. For annual maximum evaporation and total annual evaporation data, all the stations from 1972 to 1993 years, but for Nasiriya and Kirkuk stations from 1968 to 1993. Figures 1 and 2 showed the historical records of annual maximum evaporation (mm) for all stations adopted in this paper.

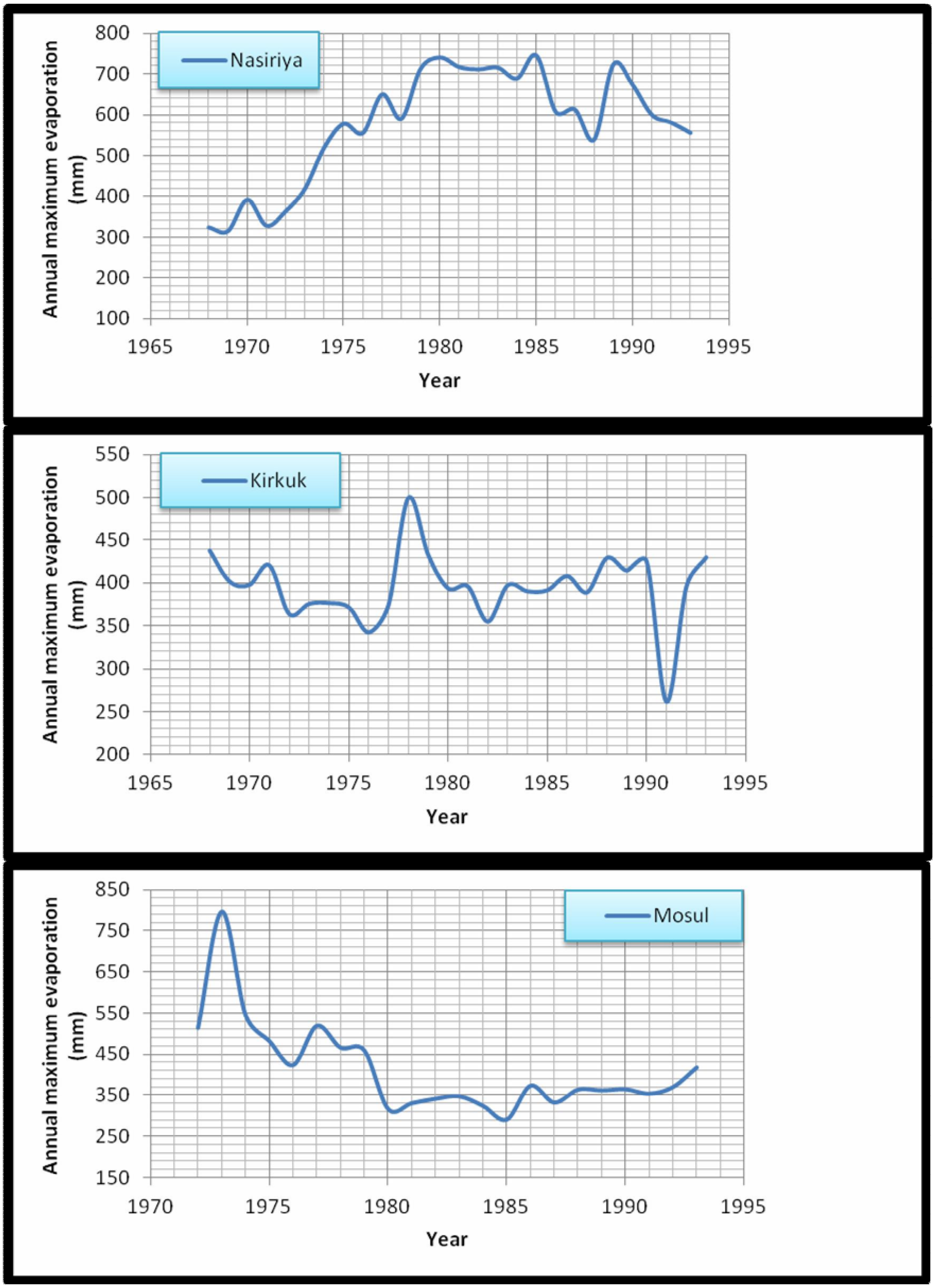

Figure 1: Historical records of annual maximum evaporation (mm) for Nasiriya, Kirkuk and Mosul stations.

Source: Iraqi Meteorological Office in Baghdad, Iraq.

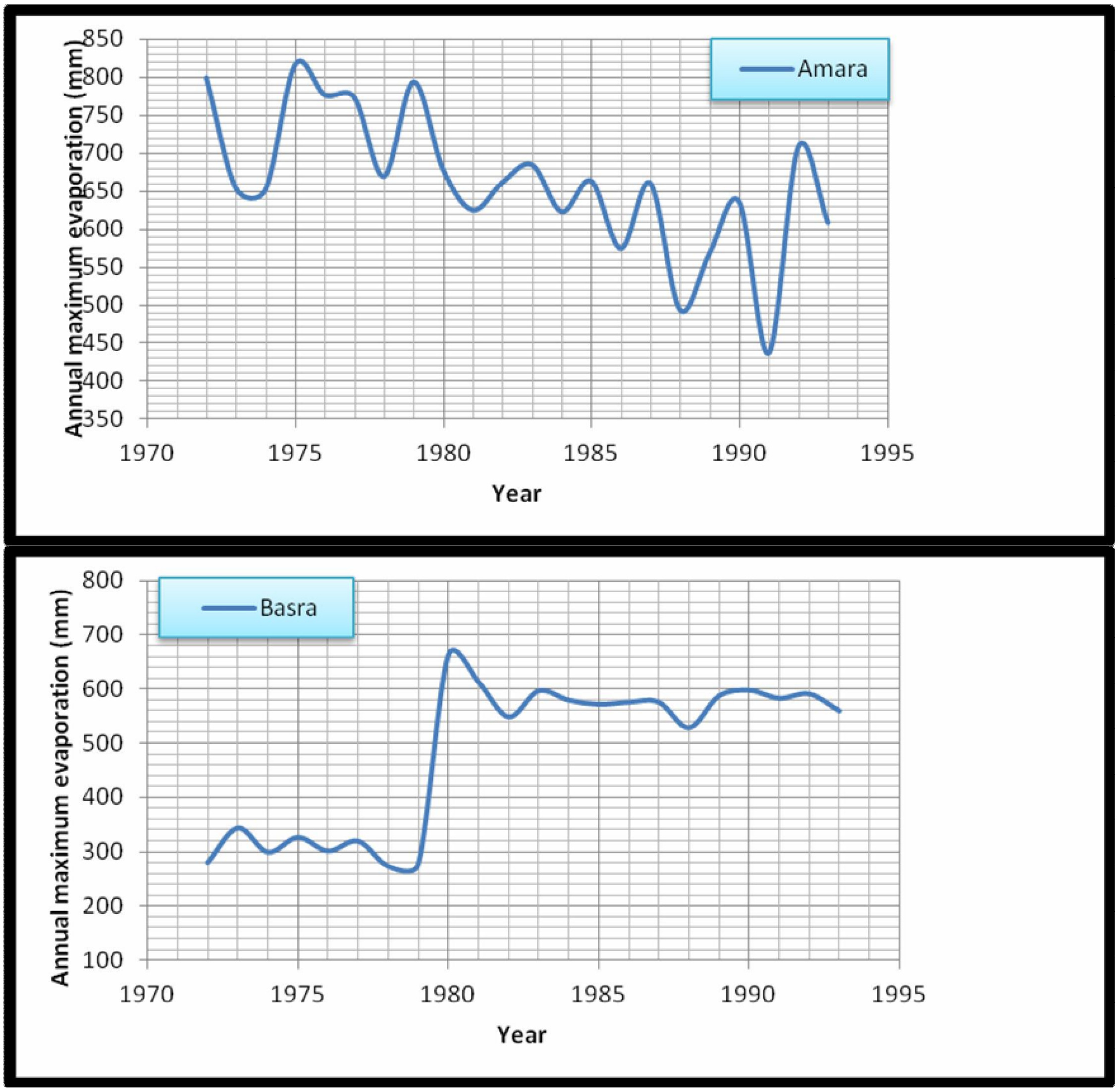

Figure 2: Historical records of annual maximum evaporation (mm) for Amara and Basra stations.

Source: Iraqi Meteorological Office in Baghdad, Iraq.

2.2 Hydrologic Frequency Analysis

2.2.1 *Frequency analysis using frequency factors*

The principle purpose of this paper is to compare and relate results from several sets of data; in terms of a frequency factor. For calculating the magnitudes of extreme events, the probability distribution function for any distribution must be invertible, that is given a value for *T* (return period, year) or **(Chow *et al.*, 1988):**

$[F(x_T) = T/(T-1)]$……………………………………………………………………..(1)

The corresponding value of x_T (the magnitudes of extreme events) can be determined. Some probability distribution functions are not readily invertible, and an alternative method of calculating the magnitudes of extreme events is required for these distributions. In this paper Frequency factors method is used for obtaining the magnitudes of extreme events. The magnitude x_T of a hydrologic event may be represented as the mean μ plus the departure Δ x_T of the variate from the mean

$x_T = \mu + \Delta x_T$ ……………………………………………………………………(2)

The departure may be taken as equal to the product of the standard deviation σ and a frequency factor K_T; that is, Δ x_T = K_T σ. The departure Δ x_T and the frequency factor K_T are functions of the return period *T* and the type of probability distribution to be used in the analysis. Equation of frequency analysis is

$x_T = \mu + K_T \sigma$……………………………………………………………(3)

This may be written by

$x_T = \bar{x} + K_T s$. ………………………………………………………….. (4)

Where:

x_T : Estimated event magnitude.
$\bar{x}$: Sample mean.
K_T: Frequency factor.
s : Sample standard deviation.

In the event that the variable analyzed is y=log x, then the same method is applied to the statistics for the logarithms of the data, using:

$y_T = \bar{y} + K_T s_y$ ………………………………………………………….. (5)

Where:

y_T: Estimated event magnitude for logarithm
$\bar{y}$: Sample mean for logarithm.
K_T : Frequency factor.
s_y : Sample standard deviation for logarithm

And the required value of x_T is found by taking the antilog of y_T. the frequency analysis method used in this study is as follows **(Chow *et al.*, 1988)**:

Normal distribution

One of the most important examples of a continuous probability distribution is the Normal distribution, sometimes called the Gaussian distribution. Theoretically, the Normal distribution has many fine characteristics, and many probability distributions can be approached by it. Moreover, some probability distributions are derived from it **(Lee, 2005).** For the Normal distribution, the frequency factor K_t equals a quantity called the *standard normal variable*, *z*, which can be approximated as **(Barkotulla *et al.*, 2009):**

$$K_t = z = w - \frac{2.515517 + 0.802853w + 0.010328w^2}{1 + 1.432788w + 0.189269w^2 + 0.001308w^3} \quad \text{……………………(6)}$$

Where $w = \left[ln\left(\frac{1}{p^2}\right)\right]^{1/2}$ [0< p≤ 0.5] ……………………………………..... (7)

P = Exceedance probability= 1/*T*

When p> 0.5; 1-p is substituted for p in Equation 7.

Alternatively the frequency factor (K_t) is computed by using tables **(Chow *et al.*, 1988)**, this tables gives the value of the frequency factor K_t depends on skew coefficient (Cs) with different return periods (*T*), and the values of return period (*T*) with different frequency factor are shown in Table 1. When the value of K_t is computed then it is substituted in Equation 4, the magnitudes of the extreme events for the Normal distribution are shown in Table 2.

Table 1: Relationship between K_t and T for the Normal and Log Normal dis.

Return period (T)	5	10	25	50	100
Frequency factor (K_t)	0.842	1.282	1.751	2.054	2.326

Table 2: Total annual evaporation for the Normal distribution.

Return period	Total annual evaporation (mm)				
	Nasiriya	Kirkuk	Mosul	Amara	Basra
5	4187.14	2521.75	2546.96	4123.00	3646.98
10	4538.37	2686.91	2747.67	4423.45	3975.67
25	4912.75	2862.96	2961.61	4743.70	4326.01
50	5154.62	2976.69	3099.82	4950.59	4552.36
100	5371.74	3078.79	3223.90	5136.32	4755.55

Log Normal Distribution

This method assumes the hydrologic quantity distribution presenting a Log Normal distribution. U.S Army, Corps of Engineers uses this method to transform the peak flow data with logarithm, and then employs the Normal distribution to analyze its flood frequency **(Lee, 2005)**. The value of frequency factor for the Log Normal distribution is computed by the same way as the Normal distribution, but the magnitudes of extreme events depend on the logarithm of the data. Then this value is used in Equation 5 to obtain the magnitudes of extreme events as shown in Table 3. The Relationship between the frequency factor and the return period the Log Normal distributions are shown in Table 1.

Table 3: Total annual evaporation for the Log Normal distribution.

Return period	Total annual evaporation (mm)									
	Nasiriya		Kirkuk		Mosul		Amara		Basra	
	y_T	x_T	y_T	x_T	y_T	x_T	y_T	x_T	y_T	x_T
5	8.35	4230.18	7.89	2670.44	7.82	2489.91	8.39	4402.82	8.21	3677.54
10	8.46	4722.06	8.00	2980.96	7.90	2697.28	8.51	4964.16	8.33	4146.42
25	8.58	5324.11	8.12	3361.02	7.99	2951.30	8.64	5653.33	8.45	4675.07
50	8.65	5710.15	8.19	3604.72	8.05	3133.79	8.73	6185.73	8.53	5064.45
100	8.72	6124.18	8.26	3866.09	8.10	3294.47	8.80	6634.24	8.61	5486.25

Extreme Value Type I Distribution (EVI)

This distribution was introduced by Gumbel (1941) who specifically estimated flood frequencies based on statistical theories. For its simplicity and credibility, it is used in the hydraulic engineering very often. U.S Weather Bureau has applied this method to analyze meteorological frequencies. The so-called extreme value distribution means the extreme distribution of statistics arranged in the ascending or descending order. The distribution characteristics may be used to estimate the recurrence period or probability of a certain hydrologic statistics. That is, a certain hydrologic statistics is considered as an appropriate distribution function. Then the mean, standard deviation, and skewness, etc., of this function distribution and parameters can be used to estimate the probability that a certain hydrologic statistics will occur. For the Gumbel distribution K_t is obtained from Equation 8 **(Prodanovic and Simonovic, 2007)**.

$$K_t = \frac{-\sqrt{6}}{\pi}\left[0.5772+ln\left(ln\left[\frac{T}{T-1}\right]\right)\right] \quad \ldots\ldots (8)$$

The relationship between the frequency factor and the return period for the EVI and EVII distributions are shown in Table 4. The magnitudes of extreme events for this distribution shown in Table 5.

Table 4: Relationship between K_t and *T* for the EVI and EVII distributions.

Return period (*T*)	5	10	25	50	100
Frequency factor (K_t)	0.719	1.305	2.045	2.592	3.137

Table 5: Annual maximum evaporation for the EVI distribution.

Return period	Annual maximum evaporation (mm)				
	Nasiriya	Kirkuk	Mosul	Amara	Basra
5	674.83	425.33	494.34	730.29	583.67
10	756.35	449.77	559.94	786.05	666.42
25	859.30	480.63	642.79	856.46	770.91
50	935.40	503.44	704.02	908.51	848.16
100	1011.22	526.16	765.04	960.37	925.12

Extreme Value Type II Distribution (EVII)

The value of frequency factor for this distribution is computed by the same way as Extreme value type I distribution, but the magnitudes of extreme events depends on the logarithm of the data. The magnitudes of annual maximum evaporation are shown in Table 6.

Table 6: Annual maximum evaporation for the EVII distribution.

Return period	Annual maximum evaporation (mm)									
	Nasiriya		Kirkuk		Mosul		Amara		Basra	
	y_T	x_T	y_T	x_T	y_T	x_T	y_T	x_T	y_T	x_T
5	6.52	678.58	6.05	424.11	6.17	478.19	6.59	727.78	6.37	584.06
10	6.69	804.32	6.11	450.34	6.30	544.57	6.68	796.32	6.56	706.27
25	6.89	982.40	6.19	487.85	6.47	645.48	6.79	888.91	6.80	897.85
50	7.05	1152.86	6.26	523.22	6.60	735.10	6.87	962.95	6.99	1085.72
100	7.20	1339.43	6.32	555.57	6.72	828.82	6.95	1043.15	7.17	1299.84

3. Conclusion

This paper is set out to investigate the maximum values of evaporation with different return periods in Iraqi regions. In order to clarifying the purpose of this study, five meteorological stations were considered, namely, (Mosul, Kirkuk, Amara, Nasiriya, and Basra stations). The available metrologic data from these stations, from Iraqi Meteorological Office, Baghdad, Iraq, have been analyzed using frequency factor method. Four probability distributions namely: The Normal, Log Normal, Extreme value type I, and Extreme value type II were used for these data. This study shows that Nasiriya station had the maximum values of annual evaporation (1011.22mm) and (1339.43 mm) and maximum value of total evaporation (5371.74 mm) for 100 year return period, by using Gumble, Extreme value type II and Normal distributions respectively, Amara station had the maximum value of total evaporation (6634.24 mm) for 100 year return period for Log Normal distribution, the values of the total annual evaporation for the Log Normal distribution is greater than for the Normal distribution, and the values of annual maximum evaporation for EVII distribution is greater than for EVI distribution see Tables 2,3,5,6 and Figures 3 and 4 for Nasiriya station, so the study shows that there is an increase in evaporation amounts with the increase of return periods.

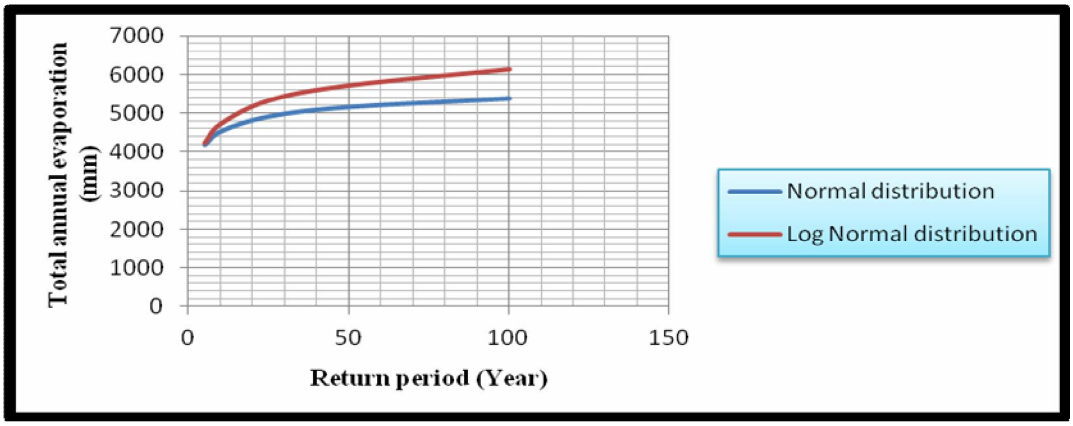

Figure 3: Total annual evaporation for Nasiriya station (Normal and Log Normal distributions).

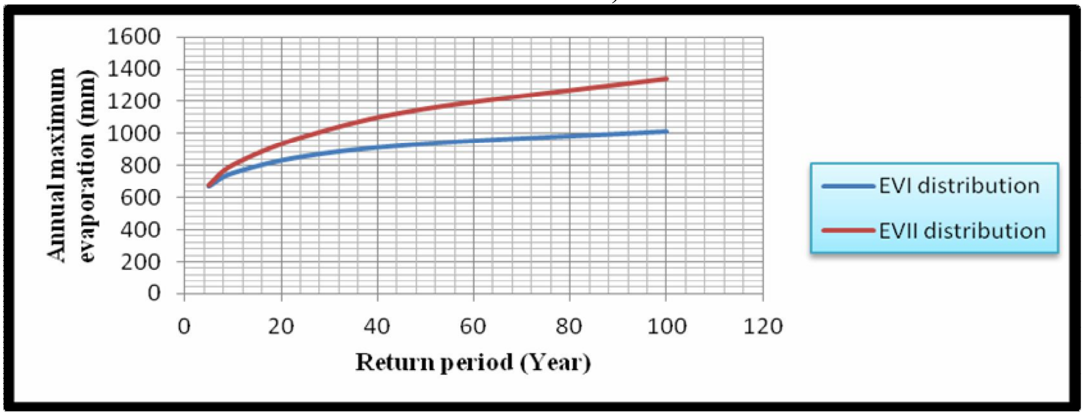

Figure 4: Annual maximum evaporation for Nasiriya station (EVI and EVII distributions).

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