A Study of Some Hydrological Aspects For Spillway Design of A Small Dam In The North of Iraq

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Abstract

This research is to evaluation and analyzing the main aspects of spillway design for Chaq-Chaq dam in north of Iraq in Suleimaniya governorate, with help of the hydraulic, hydrologic and climate data collecting. Four different distribution models are used in order to conduct the analysis required to find the different return periods of flood, based on the expected daily rainfall depth, also the result was compared with the study of Sogreah consulting company .Analysis of data shows that the length of the spillway of Chaq-Chaq dam should be increased by about 206% to accommodate the maximum flood discharge according to Extreme Value type I distribution with return period of 1000 year.

Keywords: Spillways**, flood discharge, return** period

دراسة لبعض العناصر الهيدرولوجية لتصميم مطفح لاحد السدود الصغيرة في شمال العراق

الخلاصة

في هذا البحث تم تقييم وتحليل السمات الاساسية لتصميم مطفح سد جقجق الصغير والواقع في شمال العراق في محافظة السليمانية من خلال جمع البيانات الهيدروليكية والهيدرولوجية والمناخية.تم استخدام اربعة توزيعات احصائية مختلفة بالاعتماد على العمق المطري اليومي المتوقع ولفترات عودة فيضانية مختلفة ، مع مقارنة النتائج مع الدراسة المقدمة من خلال شركة سوكريا.تحليل البيانات اظهرت ان طول مطفح السد يجب ان يزيد بنسبة 206% لاستيعاب التصريف الفيضاني الأقصى بالاعتماد على فترة عودة فيضانية مقدارها 1000سنة.

Introduction

Sources of water in Iraq are rivers, precipitation and ground water. Chaq-Chaq dam in AL-Suleimaniya gvernorate which its water resources come from precipitation and ground water. AL-Suleimaniya Governorate is located in the north eastern part of Iraq. It extends along the Iraqi-Iranian border.AL-Suleimaniya Governorate is located between 45^o and 46^o longitude and 34^{o}and 35.5^o latitude.

Rainwater however percolates into the ground water or evaporates into the atmosphere, while a large percentage of the total rainfall remaining as surface flow. The surface water flows in seasonal valleys after heavy rains.

The flood or draught frequency analysis of hydrologic data is an established method for determining

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critical design discharges for the spillway of any dam.

AL-Barzanji study the design floods for the Tigris river at the proposed Mkhool dam site using five distribution functions: Normal, log normal, Pearson typeIII, Log Pearson type III and Gumble . Pearson typeIII was found to be the best fitted probability distribution function with return period (1000year).[1]

Rainfall Data

In this study rainfall data has been obtained from Suleimaniya meteorological station for the period (1942-1989).From this data the daily rainfall depth expected for a 25,50, 100, 150, 200 and 1000 years of return period is calculated by mathematics extreme value analysis program called "EXTREME".

In order to find the daily rainfall depth a computer program was used to analyze the Normal, Extreme Value type I (Gumble), Log-Normal type II and Log-Person type III distributions.

The results of the daily rainfall depth expected for Normal, Log-Normal type II and Log-Pearson type III, Extreme vlue type I distributions are shown in table (1).

Maximum Flood Discharge(Chaq Chaq Dam)

The selection of the inflow design discharge is a matter of policy whereby the amount of tolerated risk is traded for the economy of the construction (height of the dam and spillway capacity).[3]

The maximum flood discharge into any reservoir of dam can be found using various return periods.The following equation may by used for this purpose: [4]

$$Q_{max}=P_{eff}*q_m*A \quad \ldots\ldots (1)$$

Where:

Q_{max} = Maximum flood discharge inflow to the reservoir (m^3/sec).

P_{eff} = Effective rainfall for a return period of x-years (cm).

q_m = Maximum ordinate for the unit hydrograph (m^3/sec.cm.km^2)

A = Catchment area (km^2).

The maximum inflow flood discharge of the dam reservoir was calculated from equation (1) for return period (100)years; as listed in table (2), and for return period (100) and(1000)years are listed in table (2) and table (3) respectively. Catchment area upstream of Chaq Chaq dam is (30.98 km^2) .[5] Maximum ordinate for unit hydrograph = 0.27 m^3/sec.cm.km^2. [5] Effective rainfall for a return period of 100 – year for normal distribution = 106.21 mm (Table (1))

Then:

$$Q_{max} = (10.621cm * 0.27 (m^3/sec.cm.km^2) * 30.98\ km^2) = 88.83\ m^3/sec.$$

Calculation Of The Maximum Flood Discharge According To A studying by Sogreah Consulting Company

A hydrological study for the area of Kirkuk and northern part of Iraq has been carried out by the Sogreah consulting company. Three empirical relations were derived between the maximum possible flood discharge that could occur every 100 – year and the catchment area.

The relation pertaining to the mountainan area takes the form.[6]

$$Q_{max}=17*A^{(0.63)} \quad \ldots\ldots(2)$$
$$= 17*(30.98)^{(0.63)}$$
$$= 147.85\ m^3/sec.$$

It is considered justifiable to select maximum flood discharge (147.85 m^3/sec) because the region is regarded an inhabited area and dam breaches may cause hazardous.

Rainfall Data Analysis

The parameters of distributions used in this study are estimation by method of moment; the parameters are given in Table (4). These parameters give an indication about which distribution should be accepted.

For a Normal distribution, the skewness and kurtosis that fit the Normal distribution for a given sample of data are (0) and (3), respectively. The sample estimates of the population skewness and kurtosis for daily rainfall depth are (2.64) and (2.60) respectively [see Table (4)]. Since the parameters are neither close to zero nor to 3, the Normal distribution could not be accepted. For Log-Normal type II distribution the skewness computed from the equation ($Cs = 3Cv + Cv^3 = 1.37$) is not close to ($Cs = 0.64$), [see Table (4)]. Furthermore, ($C_{sy} = -0.89$) is not close to zero and ($C_{ky} = 1.83$) is not close to (3.0) justify the not acceptance of Log-Normal type II distribution. The skewness coefficient of logarithm of data should be greater than zero for Log-Pearson type III distribution. Since the sample estimates of the population skewness ($C_{sy} = -0.89$), which is less than zero, then the Log-Pearson type III distribution could be not accepted. As for Extreme Value type I distribution the skewness and kurtosis are (0.56) and (2.94) respectively. The sample estimates of the population skewness and kurtosis are (0.64) and (2.60) respectively, [see Table (4)]. Since the parameters are close to the theoretical Extreme Value type I distribution parameters, then the Extreme Value type I distribution could be accepted.

Goodness of Fits

Mean and standard deviation are used to describe a set of data or observations. These statistics of parameters are estimated from samples. Sometimes the samples may be unrepresentative and may, therefore, lead to estimates that are too high or too low.[2]

The estimations will be of no use if they differ from expected values by more than certain prescribed limits. It is therefore necessary to test the statistics to see whether their difference is significant or not. Such tests are called the test of significance. When certain measures are used such as Standard Error (SE), Root Mean Square Error (RMSE) and bias (BIAS), the smallest values of these measures lead to the best fit. The results are given in Table (5).

From Table (5), it can be said that for these data sets, the Extreme Value type I distribution is one of the best models according to the Standard Error (SE), Root Mean Square Error (RMSE) and bias (BIAS).

With this resolution the return period (1000)years of Extreme Value type I distribution is the close to the Sogreah consulting company

study comparing between the results of two methods ,then the length of the spillway must increased to 30m.

Hydraulic Design Of Chaq Chaq Dam

To determine the spillway dimensions, this relation normally takes the form.[7,8]

$$Q = C * L * H_d^{3/2} \quad \ldots\ldots\ldots\ldots..(3)$$

Where:

Q = Discharge (m^3/sec)

$C = C_d\sqrt{2g}$ = Variable coefficient of discharge over the spillway, whose value varies from (1.6 $m^{1/2}$/sec) to (2.2 $m^{1/2}$/sec), depending on various factors such as relative depth of approach, relation of actual crest shape and slope of upstream face.[8]

L = length of spillway crest (m)
H_d = Design water head (m)
g = Acceleration (m/sec^2)
Figure (1) shows the variations mentioned above.
Chaq Chaq spillway parameters are:
Maximum water head over the spillway crest is equal to design water head over the spillway crest ($H_{max} = H_d$) = 1.75m.
Length of spillway crest (L) = 14.5m
Maximum flood discharge inflow (Q)for normal distribution with return period 100year = 88.83 m^3/sec

$Q = C * L * H_d^{3/2}$

$88.83\ m^3/sec = 2.2\ m^{1/2}/sec. * L * (1.75)^{3/2}$

L =17.44 m

Maximum flood discharge for return period 100years Substitute in equation (3) to determine the length of the spillway table (6)
Maximum flood discharge for return period(1000years)Substitute in equation (3) to determine the length of the spillway table (7)
Length of spillway according to study of Sogreah consulting company

$Q = C * L * H_d^{3/2}$

$147.85\ m^3/sec = 2.2\ m^{1/2}/sec. * L * (1.75)^{3/2}$

L = 29.03 m
= 29 m

Conclusions

The important conclusions of this study can be summarized as follows:

1. Analysis of the results has shown that the length of Chaq Chaq spillway should be increased by almost 206% to accommodate the maximum flood discharge ,which has been calculated for the period of flooding return of 1000 years.

2. The Extreme Value type I distribution is one of the best models according to the standard error (SE), Root Mean Square Error (RMSE) and bias (BIAS).

3. According to Extreme Value type I distribution model, the daily rainfall depth expected for 1000year-return period is about (182.05mm).

4. The maximum discharge over Chaq Chaq spillway is 152.28 m^3/sec.

Recommendations

More meteorological and rainfall stations in the region are needed to help enough data for the analyses and design of new water works.

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Table (1) Depth of daily rainfall (mm) for various return periods in AL-Suleimaniya meteorological station.

DISTRIBUTION	RETURN PERIOD (YEAR)					
	25	**50**	**100**	**150**	**200**	**1000**
Normal	93.77	100.32	106.21	109.42	111.60	122.72
Extreme Value type I	119.55	131.40	143.17	150.03	154.89	182.05
Log-Normal type II	150.97	209.50	281.29	330.23	368.35	642.27
Log-Person type III	101.34	115.00	129.17	143.97	148.97	155.60

Table (2)The Maximum Discharge With Return Period (100year)

Type of distribution	Maximum discharge m^3/sec
Normal	88.83
Extreme Value type I	119.76
Log-Normal type II	235.28
Log-Person type III	108.05

Table (3) The Maximum Discharge With Return Period (1000year)

Type of distribution	Maximum discharge m^3/sec
Normal	102.65
Extreme Value type I	152.28
Log-Normal type II	537.23
Log-Person type III	130.15

Table (4) Parameters estimation for the daily rainfall depth

PARAMETER	SYMBOL	DAILY RAINFALL DEPTH
Mean	$\overline{X}$	55.93
Standard deviation	S_d	21.61
Coefficient of variation	C_v	0.76
Skewness coefficient	C_s	2.64
Kurtosis coefficient	C_k	2.60
Mean of logarithm	$\overline{Y}$	1.71
Standard deviation of logarithm	S_{dy}	0.15
Skewness coefficient of logarithm	C_{sy}	-0.89
Kurtosis coefficient of logarithm	C_{ky}	1.83

Table (5) Standard Error (SE), Root Mean Square Error (RMSE) and bias (BIAS) of models for Daily Rainfall Depth.

TYPE OF DISTRIBUTION	SE	RMAE	BIAS
Normal	2.38	0.10	0.96
Log-Normal type II	2.29	0.12	0.90
Extreme Value type I	2.12	0.10	0.75
Log-Pearson type III	2.22	0.10	0.76

Table (6) Length of the spillway With Return Period (100year)

Type of distribution	Length of the spillway m
Normal	17.44
Extreme Value type I	23.51
Log-Normal type II	46.10
Log-Person type III	21.22

Table (7) Length of the spillway With Return Period (1000year)

Type of distribution	Length of the spillway m
Normal	20.15
Extreme Value type I	29.90
Log-Normal type II	105.48
Log-Person type III	25.55

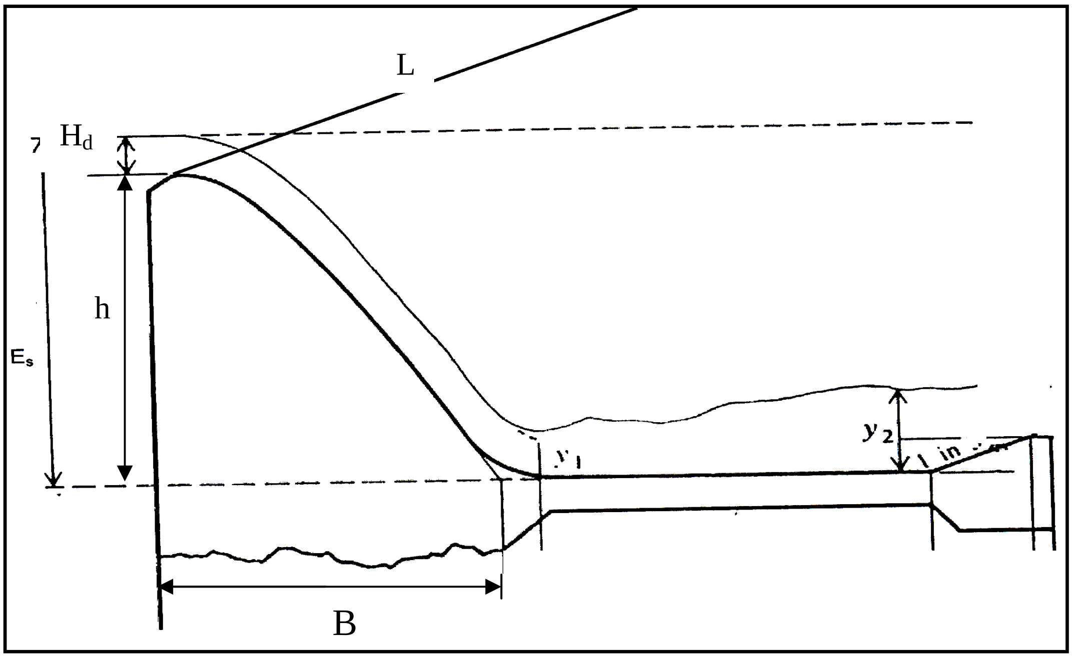

Figure (1) Hydraulic diagram of Chaq Chaq spillway flow