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Analysis of Hydrological Aspects for Spillway Design - A Case study, Bawashaswar Dam, North Iraq)"

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Abstract Estimation of the peak discharge for the design of spillway and other outlet structure of dam in ungagged catchments is the always a challenge in the hydraulic and hydrological studies. The limitation of insufficient data is also another challenge. This paper is to evaluate and analyze the main aspect of the spillway design for the Bawashaswar Dam in North of Iraq. The studies are conducted with help of the limited hydraulic, hydrologic and climatic data available in the basin and neighboring catchment to the dam. Using the data, a relation between maximum daily rainfalls and monthly rainfall was evolved. Two different distribution models were used to conduct the analysis. Different return periods of the flood, based on the maximum daily rainfall data were estimated. The design discharge was estimated and compared with final design report of the Bawashaswar dam, by using different methods for extrapolation. The estimated design discharge with a return period of 100 years and 500 years was found higher by about 40% to 100%. Further computations showed that the length of the spillway may have to be increased between 25% and 100 % to accommodate the newly estimated maximum flood discharge according to Log person type III distribution.

Index Terms— rainfall–runoff, flood discharge, return period, Spillways

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1 INTRODUCTION

TA dam is a wall of solid material built across a river valley or catchment to block the flow of the river. The stored water is used for multi-purpose uses such as irrigation, hydropower and water supply, etc. The principle safety valve of the dam is spillway, therefore has maximum importance in the design. The hydrological data for the catchment must be known for a long period to determine the design discharge for the spillway. Unfortunately, many times lack of both hydraulic and hydrological data is observed, which affects dependability of the final results.

In this connection, the literature survey indicates that Olascoaga [1] made a rainfall—rain day study of 10 regions in Argentina utilizing daily rainfall data for 5 years. His studies found that a single normalized rainfall curve gave a satisfactory representation of the rainfall distribution of all the rainfall regions.

R. Singh [2] adopted another approach to estimate the daily stream flow time series at ungagged catchments. He transferred a set of model parameters resulting from the calibration of a rainfall-runoff model at a gauged catchment (or set of gauged catchments) to an ungagged site of interest. Central idea to this approach is the selection of a gauged donor catchment that is considered hydrological similar to the ungagged catchment.

Similar concept was followed for a study for a Dam in Iraq. This paper discusses the problem of determination of design discharge for proposed at Bawashaswar dam in north of Iraq.

MATERIALS AND METHODS

Study area

The three Governorates Erbil, Dohuk, and Sulaymaniyah are located on the northern part of the Republic of Iraq and known as Kurdistan region. The region lies between latitudes 34° 42' N and 37° 22' N and between longitudes 42° 25' and 46° 15' east and lowest point in the region is Kifri. Study area and dam catchment are shown in figure (1). The study area , lies between East longitude of 44°58' to 45°11' and North latitude of 34°43' to 34°56'. The Bawashaswar dam site is located on (N: 34° 43′ 12″), (E: 44° 58′ 27″) and with elevation Z = 250 m above mean sea level. The dam is located in Kifri district, about 2 km to the northeast of the city and collects stores water from two main valleys Bkir shal and Omer bla. Both valleys receive water from the surrounding mountains.

The catchment of dam is about 35km length. The near rainfall gauged station are Kalar and Darbandikhan station which are located it about (30) km and (120) km from Kifri. Kifri, kalar and darbandikhan city are shown in figure (2). The dam is located in the semi-arid zone, with hot summer and cold winter. The area have eight month of rainfall, start from October and end in May and other month have dry season

Figure (1) shown dam site on Iraq Map

ISSN 2229-5518

Figure (2) Shown three catchment

Precipitation increases from southwest to northeast. The averages annual rainfall various from 350 mm in the Erbil area to more than 1100 mm at Sherwan - Mazen in the high mountains bordering Iran.

Data Used

There were two rainfall gauge station in the near of dam. Kalar and Darbandikhan rainfall gauge station. The Kalar station is away from dam site about 30 km and Darbandikhan station away about 120 km. For Kalar station, there were four years daily rainfall data from (2009-2012) and annual rainfall from (2001-2012).For Darbandikhan stations, there were annual rainfall data only from (1962-2010).

There were some other rainfall gauge stations, but they far away from the dam catchment. They had different hydrological characteristics; therefore they were neglected.

Methodology

Maximum daily and monthly rainfall relations for Kalar catchment

The rainfall data for the Bawashaswar dam site was not available for this study. Therefore, the nearest catchment was selected to transfer the data from it as a donor. The nearest catchment was Kalar catchment and it is in same isohyet line with Kifri catchment.

Daily rainfall data for kalar catchment was available from (2009 till 2012).The monthly rainfall shows variation in every year. Therefore, relation between maximum daily (24 hour) rainfall and monthly rainfall from (2009-2012) for Kalar catchment it was evolved.

The best fit relations were found to be the linear relations for the eight rainfall months form October till May. The evolved equations from each month from October till May, were applied on the monthly rainfall data from (2001-2012) and maximum daily rainfall for each month was determined. These data set was known as (Short data).

Transferred Data from Darbandikhan Catchment

Darbandikhan Dam had rainfall gauge station and records data from (1962-2010). It is located on isohyet line 675 mm and Bawashaswar and Kalar city are on isohyet line 275 mm.

Depending on monthly rainfall data from (2001till 2010) for Darbandikhan and Kalar Catchment, the monthly relation was evolved between two catchment.

The best fit relation was linear relation for each month (i.e. October 2001 till 2010).Apply these relation on the Darbandikhan rainfall data from (1962 till 2010), the data transfer to Kalar catchment.

The transferred data convert to maximum daily rainfall depended on Kalar daily and monthly rainfall relation that was used to find maximum daily rainfall for Kalar catchment from (2001-2012).

By add maximum daily rainfall from Kalar catchment for (2011 and 2012) to convert data, we got maximum rainfall data from (1962-2012) for Kalar catchment. These data was known as (Long data).

Rainfall frequency analysis

Estimation of the basin's flood peak is an important part of the hydrological studies of dam and hydro power projects. The peak discharge and the hydrograph of flood should be specified for the considered return periods.

Two methods of frequency analysis distribution were used for prediction of maximum daily rainfall values. Gumbel and Log-Pearson Type III distribution with helping of computer program were used. The result of the rainfall for different return period for Gumbel and log Pearson type III distribution were shown in figure (3)

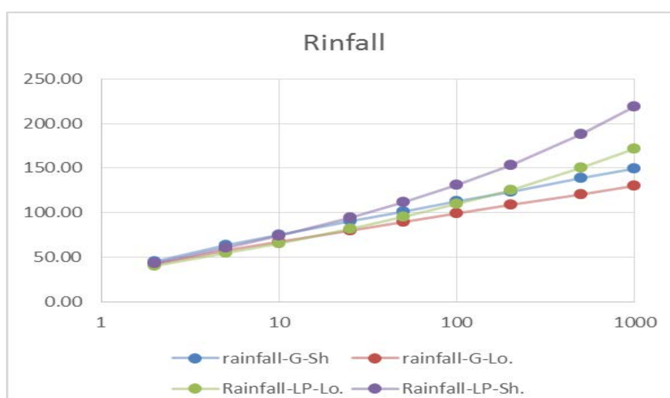

Figure (3) shows rainfall for different return period for Gumbel (G) and log Pearson (LP) type III distribution for short (Sh.) and long (Lo.) data.

Rainfall –runoff relation and CN value

Because no stream flow measurement is available, SCS model (Soil conservation service); can be considered the most suitable in this case.

$$P_e = \frac{(P-0.2S)^2}{(P-0.8S)} \quad (1)$$

$$S = \frac{25400-254CN}{CN} \quad (2)$$

Where P_e accumulated precipitation excess is at time t (equivalent to direct runoff) in mm, P is depth of precipitation in mm, S is potential maximum retention of the watershed and CN is curve number.
CN for the dam catchment calculated from CN tables. Depending on hydrologic soil groups and the nature of the antecedent moisture condition for AMCII group (weighted mean). The total catchment area had (284 km^2). Catchment divided to two parts according to the topography and the characteristics of the area as shown in the table (1) below.

Table (1): Calculation of CN for AMC II group for all months

Area (Km^2)	Land Use and Cover	Hydrologic Condition	Infiltration rate	Area type	Partial Area(Km^2)	Area %	CN from SCS tables	average CN
284	Fallow Straight row	Poor	Moderate	Type B	190	67	86	85
	Fallow, Contoured	Poor	Low	Type C	93	33	84	

Maximum Flood Discharge

The design discharge for different return period has great effect on the dam height and spillway capacity.
Estimation of maximum flood discharge (Peak flood is based on equation:

$$Q_p = \frac{0.208\,A\,Q}{T_{peak}} \quad (3)$$

Where, A is area of catchment in km^2, Q is cumulative rainfall for different return period and T_{peak} is time of concentration which can be calculated by Bransby-Williams formula:

$$T_c = \frac{22.7\,L}{A^{-0.1}\,S^{-0.2}} \quad (4)$$

Where, T_c = time of concentration (min), L = length of catchment (km), S = slope from the furthest point of the catchment area to the dam (m/m), A= area of catchment (hectare).

Rainfall Data Analysis

Figure (4) Shows the Peak Design discharge (PQ) for different return period by Gumbel (G) and Log Pearson(LP) type III for Short (Sh.) and Long data(Lo.).
As shown in figure (4), were gotten four lines for Gumbel and Log Pearson type III distribution for different return period.

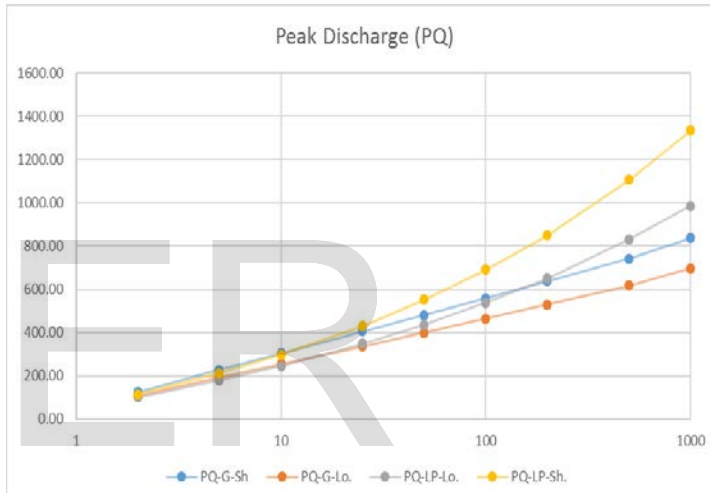

Figure (4) Shows PQ for Gumbel and LP type III for different return period.

To decide type of the distribution must be used in the design of dam spillway, the Moment ratio diagrams (MRD), were used MRD depended on coefficient of skewness (β_1=C_s^2) and the coefficient of Kurtosis (β_2=C_k) of the distributions. The Value of the Skewness and Kurtosis for data are shown in table (4).

Table (4).Value of Skewness and Kurtosis for short and long data		
Value	Short Data	Long Data
Skewness	(1.82, β1=3.31)	(1.70, β1= 2.9)
Kurtosis	(β2=7.60)	(β2=6.00)

From the MRD, Gumbel distribution had only one single point. It was not easy to find exactly this point. The skewness and Kurtosis of both short and long data were nowhere near Gumbel point (viz. β1=0, β2 = 3) in MRD. Therefore, the Gumbel distributions cannot be used in design of spillway. On the

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other hand, the log Pearson type III had wide range of flexibility, since both β1, β2 for data are lie in log Pearson type III region in MRD.

To select one data of log Pearson type III, Anderson Darling test was used. With help of excel program and special program used in some department India for statistical analysis and hydrology project.

After calculation, two values of (A^2) were got. For log Pearson type III, short data (A^2=1.115) and for long data (A^2=3.9).

By using table (4.21) page 155 in reference (7), the value of A^2 range from 0.752 to 0.786.But the value was got are out of the range of this range.

An element of judgment inevitably enters into the process of frequency analysis and any amount of mathematical analysis will not necessary yield a true answer to any given problem. Statistical testes, in particular, can only indicate probabilities of satisfying criteria and are unlikely to give. Therefore, the nearest value to the A^2 range was took. The value of log Pearson type III- short data which equal to (1.115) was used in calculation. The other value for A^2 is too high and didn't used in calculation.

Hydraulic Design of Bawashaswar Dam

To determine the spillway dimensions, this relation normally takes the form

$$Q = C * L * H^{3/2} \quad (5)$$

Where: Q = Discharge (m^3/sec).

$$C = C_d * \sqrt{2g} \quad (6)$$

C is 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.[3]

L = length of spillway crest (m).

H^d = Design water head (m).

g = Acceleration (m/sec^2).

The design discharge for 100 years and 500 years with the design length of the spillway are shown in table (5)

Table (5).Shown the spillway length for different design discharge

No	Return Period(years)	Peak Discharge (m3/sec)	Head (Hi)(m)	C_d	Length of spillway(m)	Peak Discharge (m3/sec) for spillway length
1	100	692	1.5	0.493	173	694
2	100	692	1.5	0.493	175	702
3	200	850	1.5	0.493	212	851
4	200	850	1.5	0.493	215	862
5	500	1108	1.5	0.493	277	1111
6	500	1108	1.5	0.493	280	1123

Conclusion

From case study analysis and result, the important conclusions of this study can be summarized as follows:

1. The Best fit relation between maximum daily rainfall and monthly rainfall was linear relation.
2. The best relation between Darbandikhan rainfall gauge station and Kalar rainfall gauge station was linear relation depending on monthly rainfall data relation.
3. Data from catchment can't be transformed to another catchment by only taking the average of the monthly rainfall. The rainfall data has relation (linear or nonlinear) depend on the rainfall in the catchment.
4. In the analysis of the frequency distribution, log Pearson type III distribution was more flexible than Gumbel distribution.
5. It is not necessary to depend on the result come from frequency analysis, but must also depend on experience judgment.
6. The actual design of spillway was 140 m. Length of the dam's spillway must be increased more than (25%) for return period 100 years. For 200 design years, spillway length must increase more than 50%. For 500 design years, the spillway must increase about 100% of the actual length.

Recommendation

1. More rainfall stations are needed in the region for more data collection for further analysis in the future.
2. Because there is a small town in the downstream of the dam with about 2 km. it's necessary to construct another spillway in suitable site of catchment to reduce the hazard of the dam failure.

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