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ESTIMATION OF EXTREME FLOODS FOR THE DESIGN OF HYDRAULIC STRUCTURES-A CASE STUDY FOR AN UNGAUGED TOPCHI SITE ON THE BAMYAN RIVER IN AFGHANISTAN

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ABSTRACT

The extreme floods for the return periods of 10, 25, 50, 100 and 500 years at the ungauged Topchi site on the Bamyan River in Afghanistan were estimated by using the Gumbel extreme value distribution alongwith the envelope curve based on the flood data of 17 gauged sites for meteorologically and topographically similar areas in the Kunduz watershed. The envelope curves as the upper boundary of the extreme floods were developed taking into account the flood magnitudes at a particular return period and the area of the watershed on a log-log scale. These envelope curves were used to derive the extreme flood estimates for the ungauged site. The extreme floods for the return periods of 10, 25, 50, 100 and 500 years at the ungauged Topchi site were estimated as 295.52, 356.28, 400.61, 446.17 and 548.71 m^3/s, respectively. This analysis showed that there is hydrological potential of the ungauged Topchi site on the Bamyan River in Afghanistan

***Keywords**: Model of stress-strain state, Discrete fibers, Continuous fiber, Composite,The conditions of internal forces' equilibrium*

I. INTRODUCTION

The hydrological systems are impacted by the extreme events such as severe floods and so the estimation of the extreme flood flows is important for the design of different types of hydraulic structures. The magnitude of such floods is generally estimated based on the return period depending on the importance of these structures. The diversion structures such as barrages and weirs have usually small storage capacities and the risk of loss of life and property would be enhanced by the failure of comparatively large structures. Apart from the damage/loss of life and structures, the failure would also cause disruption of irrigation and other facilities that are dependent on these structures. The Indian Standard IS: 6966 (Part-I) -1989 "Hydraulic Design of Barrages and Weirs-Guidelines for Alluvial Reaches" describes the design procedures for the different hydraulic and hydrological components based on the return periods.

In some cases the observed hydrological data is not available for a particular site for the estimation of extreme floods and under such situation the hydrological data of the nearby stations which are meteorologically and topographically similar are investigated for the estimation of extreme floods for the ungauged site. At some sites in Afghanistan the measured hydrological data in terms of flood flows are either not available or are scarce for the estimation of extreme floods for an ungauged site. In this paper an ungauged Topchi site at the Bamyan River in the Bamyan province in Afghanistan has been identified for the estimation of extreme floods for the design and installation of different types of hydraulic structures for developing water resources and to study the hydrological potential of the ungauged site.

II. METHODOLOGY

The ungauged Topchi site (with watershed area of 1430 km^2) located on the Bamyan river was selected for this study which is a part of Kunduz watershed (also called Upper Kunduz River basin) and is near to the Bamyan city in Bamyan province, Afghanistan (Favre and Monowar,2004). Gumbel (1958) defined a flood as the largest value in the year and termed the annual series of flood flows a series of largest values of flood flows. For the estimation of the extreme floods for different return periods for this ungauged site, the daily flood data measured during the different durations for each of the 17 gauged sites as reported by Sether and Olson (2010) were used and from these data, the largest flood discharge for each year was selected for the probability analysis.

In this analysis, the Gumbel extreme value distribution (Gumble, 1958) was used. The Gumbel's distribution is one of the statistical approaches that is mostly used to analyze extreme flood data and also to predict other extreme hydrological events. Using these probability/frequency analyses for the different return periods, the envelope curves were developed for the different return periods. These envelope curves are used to assist the extreme flood estimations at the ungauged site of interest using the information on the flood characteristics of other comparable sites in the region as reported by Marshall and Bayliss (1994). Chow et al. (2010) reported that the extreme hydrological observations are located in the extreme tail of the probability distribution of all the observations and their probability distribution is different from that of the distribution from which it is derived.

The extreme value Type 1distribution function as reported by Chow et al. (2010) is expressed as :

$$F(X) = e^{-e^{-y}} \qquad -\infty \leq X \leq \infty \qquad (1)$$

According to Gumbel (1958), the probability of occurrence (P) of an event of magnitude X equal to or exceeding than the value X_0 is expressed as:

$$P(X \geq X_0) = 1-e^{-e^{-y}} \qquad (2)$$

Where y is a variable called the reduced variate and is given as;

$$y = \propto (X-\beta) \qquad (3)$$

Where the distribution parameter α is equal to $1.2825/\sigma_n$, the distribution parameter β which is the mode of the distribution is equal to $\bar{X} - 0.45005\,\sigma_n$ when the sample size is infinite. These parameters α and β have been related to the mean and the standard deviation of the variables X_i. σ_n is the standard deviation of the variable X_i and is expressed as:

$$\sigma_n = \sqrt{\frac{\sum_{i=1}^{n} (X_i-\bar{X})^2}{n}} \qquad (4)$$

The variables X_i and $\bar{X}$ are the observed magnitudes of the largest flood for each year under study and the mean of these magnitudes, respectively. Using the values of these parameters α and β, Eq. (3) can be written as:

$$y = (1.2825\,\sigma_n)(X-\bar{X}) + 0.577 \qquad (5)$$

For any given hydrological data of floods, the value of the reduced variate y_p (Eq. 2) is transposed as:

$$y_p = -\ln[-\ln(1-P)] \qquad (6)$$

Where y_p is the value of the reduced variate for a given probability P. The relationship between the probability (P) and the return period (T) is expressed as:

$$P = 1/T \qquad (7)$$

The return period (T) represents the average interval between the occurrence of a hydrological event of flood with magnitude equal to or greater than X. Inserting Eq. (7) in Eq. (6), the Eq. (6) can be written as:

$$y_T = -\left[\ln.\ln\frac{T}{T-1}\right] \qquad (8)$$

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Where y_T is the value of the reduced variate y for a given return period T. A general equation for the frequency analysis of the hydrological events is given as (Chow ,1964) :

$$X_T = \overline{X} + K.\ \sigma_n \qquad (9)$$

Where X_T is the value of the flood magnitude X for a return period of T and K is the frequency factor whose value depends on the return period T and the assumed frequency/probability distribution and is written as :

$$K = (\ y_T - \bar{y}_n\ )\ /\ \sigma_n \qquad (10)$$

Where $\bar{y}_n$ and σ_n are the reduced mean and the reduced standard deviation having the maximum constant values of 0.577 and 1.2825, respectively when the hydrological sample data size is infinite. But in this analysis, the sample size having the variable as flood discharge is finite and also the records of the flood flow measured data are of finite length. Das (2000) reported that under such conditions the reduced mean and the reduced standard deviation are a function of sample size. The values of these reduced parameters $\bar{y}_n$ and σ_n as a function of sample size reported by Das (2000) were used in this analysis. Under the condition of finite small sample size, the estimator of the standard deviation σ_{n-1} in place of standard deviation σ_n was used as:

$$\sigma_{n-1} = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \overline{X})^2}{n-1}}. \qquad (11)$$

Based on the estimator of the standard deviation σ_{n-1} and the frequency factor K, the value of the variable X at a particular return period T were used as:

$$X_T = \overline{X} + K\ \sigma_{n-1} \qquad (12)$$

For finding the magnitude of the flood X_T at a particular return period (Eq. 12), the value of y_T for a particular return period T was computed from Eq. (8) and using this value in Eq. (10) alongwith the values of $\bar{y}_n$ and σ_n for small samples, the value of the frequency factor K was estimated . Using this estimated value of K in Eq. (12) alongwith the values of $\overline{X}$ and σ_{n-1}, the value of X_T was computed which is the extreme flood magnitude for a particular return period T. In this analysis, the return periods of 10, 25, 50, 100 and 500 years were used.

Based on this statistical formulation, the extreme floods for the different return periods for 17 different gauged sites were estimated as the flood data at these sites from the corresponding watersheds do not significantly differ from each other in terms of meteorological and topographical characteristics. These extremes floods for the different return periods were used for the estimation of the extremes floods of the ungauged Topchi site for different return periods using the envelope curves as the watershed characteristics of the gauged sites and the ungauged site were similar. The envelope curves were developed by plotting the magnitudes of the extreme floods versus the area of the corresponding watersheds on the log-log paper . The envelope curve would encompass all the plotted flood data points which were used to obtain the extreme flood discharges for different return periods for any site for a given area of the watershed. Anne and Wilson (2013) reported that the envelope curves are useful in getting the quick estimation of the extreme values of a hydrological event for different return periods. The empirical linear relations were then fitted to the envelope curves which would provide the empirical flood estimates of the following type as reported by Castellarin et al. (2005).

$$Q_T = f\ (A) \qquad (13)$$

Where Q_T (m^3/s) is the extreme flood discharge at a particular return period T and A(km^2) is the area of the watershed. The 17 gauged sites alongwith the areas of the watersheds which are hydrologically and topographically similar to the ungauged site at Topchi were selected based on Sether and Oslon (2010) as reported under:

Kunduz River at Kolukh Tepa (37100 km^2), Kunduz River at Char Dara (24820 km^2), Kunduz River at Gerdab (22930 km^2) ,Kunduz River at Puli Konda Sang (12610 km^2) Bangi River at Puli Bangi (4200 km^2), Taloqan River at Puli Chugha (9760 km^2) , Farkhar River near Taloqan (4110 km^2) , Andarab River at Doshi (3705 km^2) ,Bamyan River at Doab (5005 km^2), Kokcha River at Khojaghar (20645 km^2), Kunduz River at Baghlan (19740 km^2), Kunduz River at Puli Khumri (17405 km^2), Kokcha River near Keshem (16765 km^2), Kokcha River near Jurm (7670 km^2), Keshem River (2145 km^2), Warduj River at Shashpul (4485 km^2) and Warduj River near Baharak (3350 km^2).

III. RESULTS & DISCUSSIONS

The extreme flood discharges for the different return periods of 10, 25, 50, 100 and 500 years at 17 different gauged sites are reported in Table 1.

Table 1. Extreme flood discharges for different return periods

Site name	Area, km^2	Extreme flood discharges for different return periods (m^3/s)				
		10 Yrs	25 Yrs	50 Yrs	100 Yrs	500 Yrs
Keshem River (Oct. 8,1968 to Sept. 30, 1978)*	2145	160.85	195.61	221.40	247.00	306.14
Warduj River near Baharak (April 22,1969 to Sept. 30, 1978)	3350	266.79	301.30	326.89	352.30	411.02
Andarab River at Doshi (Oct. 1, 1964 to Sept. 30, 1978)	3705	270.40	315.67	349.25	382.59	459.62
Farkhar River near Taloqan (Nov.22,1966 to Sept.30,1978)	4110	363.40	428.47	476.75	524.67	635.41
Bangi River at Puli Bangi (Aug.19, 1964 to Sept.30,1978)	4200	404.83	499.97	570.55	640.61	802.51
Warduj River at Shashpul (Oct. 1, 1969 to Sept.30,1978)	4485	433.11	506.71	561.30	615.50	740.73
Bamyan River at Doab (Oct. 1, 1964 to Sept.30,1978)	5005	244.07	353.93	435.43	516.34	703.29
Kokcha River near Jurm (Oct, 1, 1969 to Sept.30,1978)	7670	462.15	534.95	588.96	642.57	766.45
Taloqan River at Puli Chugha (Aug. 2, 1964 to Sept.30,1978)	9760	506.32	603.43	675.47	746.98	912.23

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Kunduz River at Puli Konda Sang (Oct. 1, 1967 to Sept.30,1978)	12610	194.47	221.83	242.13	262.28	308.84
Kokcha River near Keshem (oct. 1, 1969 to Sept.30,1978)	16765	862.75	976.43	1060.77	1144.48	1337.93
Kunduz River at Puli Khumri (Oct. 1, 1959 to March 26, 1968)	17405	504.17	586.46	647.51	708.11	848.14
Kunduz River at Baghlan (April 7,1968 to Sept.30,1978)	19740	409.09	470.80	516.57	562.01	667.02
Kokcha River at Khojaghar (April 26,1964 to Sept.30,1978)	20645	1206.41	1412.13	1564.75	1716.25	2066.32
Kunduz River at Gerdab (April 21,1964 to Sept.30,1978)	22930	415.54	472.92	515.49	557.74	655.37
Kunduz River at Char Dara (Aug. 5, 1964 to Sept.30,1978)	24820	398.17	465.38	515.23	564.72	679.07
Kunduz River at Kolukh Tepa (Oct. 1, 1965 to Sept.30,1978)	37100	760.74	889.04	984.23	1078.71	1297.03

* Duration of measured flood discharge data.

On the basis of above extreme flood data for different return periods, the envelope curves were drawn as the upper boundary of the plotted flood data points by plotting the flood discharge as a function of watershed area for each return periods of 10, 25, 50, 100, and 500 years on a log-log paper. The empirical relation of the linear nature were derived for each return period to estimate the extreme flood discharge at the ungauged site for the different return periods. The Figs. 1-5 represent the envelope curves for different return periods as developed from the flood data from 17 gauged sites.

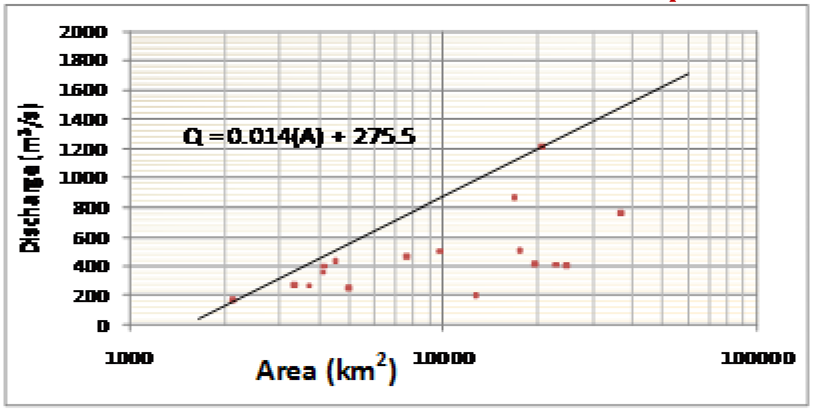

Fig.1. Envelope curve for 10 years return period

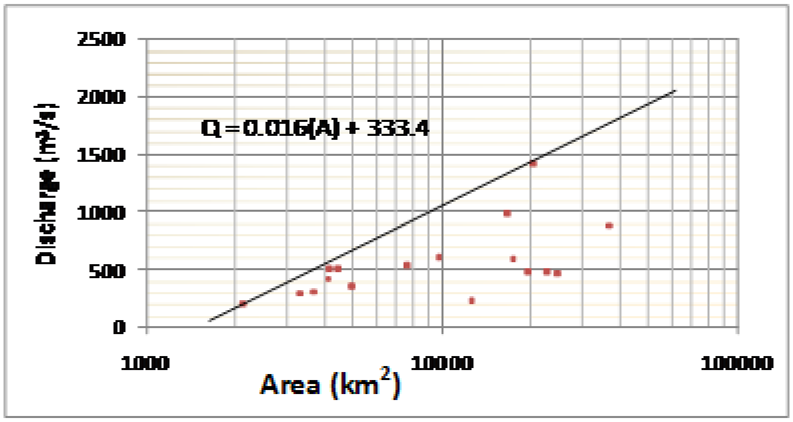

Fig.2. Envelope curve for 25 years return period

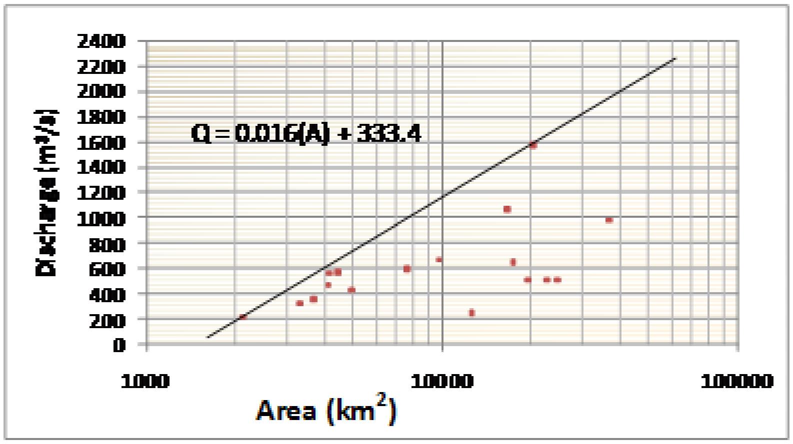

Fig.3. Envelope curve for 50 years return period

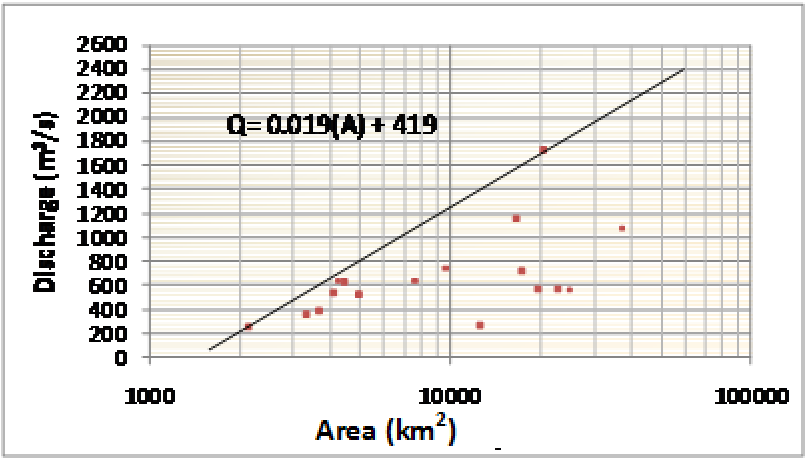

Fig.4. Envelope curve for 100 years return

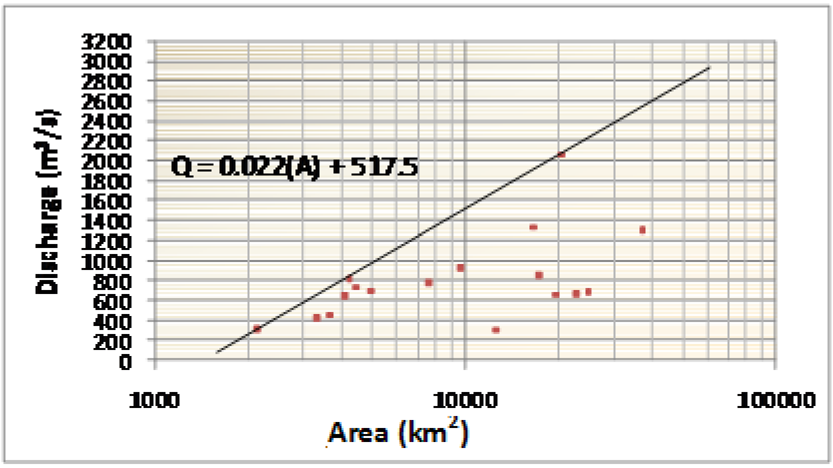

Fig.5. Envelope curve for 500 years return period

Table 2 gives the linear relation representing the envelope curves and the estimated extreme flood discharges for the ungauged Topchi site for different return periods.

Table 2: Envelope curves and estimated extreme flood discharges for different return periods at the ungauged Topchi site with watershed Area ($A = 1430\ km^2$)

Return Period, Yrs	Envelope Curve	Extreme flood Discharge (m^3/s)
10	$Q_{10} = 275.5 + 0.014 \times A$	295.52
25	$Q_{25} = 333.4 + 0.016 \times A$	356.28
50	$Q_{50} = 376.3 + 0.017 \times A$	400.61
100	$Q_{100} = 419.0 + 0.019 \times A$	446.17
500	$Q_{500} = 517.5 + 0.022 \times A$	548.71

The extreme floods for the return periods of 10, 25, 50, 100 and 500 years at the ungauged Topchi site were estimated as 295.52, 356.28, 400.61, 446.17 and 548.71 m^3/s, respectively. This analysis showed that there is good hydrological potential of the ungauged Topchi site on the Bamyan River in Afghanistan.

IV. CONCLUSION

The estimation of the extreme floods for different return periods is extremely crucial for the design and installation of hydraulic structures .The extreme flood magnitudes for the different return periods for 17 gauged sites in Kunduz watershed were estimated using Gumbel's method of extreme value distribution. The envelope curves of the linear form for the different return periods were developed for the ungauged site. Using these envelope curves , the extreme floods for the return periods of 10, 25, 50, 100 and 500 years at the ungauged Topchi site were estimated as 295.52, 356.28, 400.61, 446.17 and 548.71 m^3/s, respectively. This analysis elucidated the hydrological potential of the ungauged Topchi site on the Bamyan River in Afghanistan

REFERENCES

1. *Anne, K. and Wilson F. D. 2013. Flood estimation in small catchments. Directorate of Norwegian Resources and Energy.*
2. *Castellarin, A., Vogel, R.M. and Matalas, N.C. 2005. Probabilistic behavior of a regional envelope curve. Water Resources Research, 41. W06018, doi: 10.1029/2004WR003042.*
3. *Chow ,V.T. `1964. Handbook of Applied Hydrology, Section 8-1. McGraw Hill, New York.*
4. *Chow, V. T., Maidment, D. R. and Mays, L.W. 2010. Applied Hydrology. Tata McGraw Hill Edu. Pvt. Ltd. New Delhi.*
5. *Das, G. 2000. Hydrology and Soil Conservation Engineering. Prentice Hall of India Pvt. Ltd, New Delhi.*
6. *Favre, K. R. and Monowar, G. 2004. Watershed Atlas of Afghanistan. FAO/AIMS. Kabul.*
7. *Gumbel, E. J. 1958. Statistics of extreme values. Columbia Univ. Press. New York.*
8. *Marshall, D.C.W. and Bayliss, A.C. 1994. Flood estimation for small catchments, Report No. 124, Institute of Hydrology, Wallingford.*
9. *Sether, T.W. and Olson, S. A. 2010. Stream Flow Characteristics at Stream Gauges in Northern Afghanistan and Selected Locations. USGS Afghanistan Project Product No. 179. USGS Data Series 529, U.S. Geological Survey, Reston, Virginia. pp. 512. http://pubs.usgs.gov/ds/529/.*