

International Journal Of

Recent Scientific Research

ISSN: 0976-3031 Volume: 7(2) February -2016

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THE OFFICIAL PUBLICATION OF INTERNATIONAL JOURNAL OF RECENT SCIENTIFIC RESEARCH (IJRSR) http://www.recentscientific.com/ recentscientific@gmail.com



Available Online at http://www.recentscientific.com

International Journal of Recent Scientific Research Vol. 7, Issue, 2, pp. 8670-8671, February, 2016 International Journal of Recent Scientific Research

RESEARCH ARTICLE

FLOOD FREQUENCY ANALYSIS: USING GUMBEL DISTRIBUTION

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ARTICLE INFO

ABSTRACT

Article History:

Received 11th February, 2016 Received in revised form 16th February, 2015 Accepted 17rd February, 2016 Published online 28th February, 2016

Key Words:

Flood Frequency analysis, peale discharge Gumbel distribution

In the case of small dams, diversion works & other hydraulic structures where structural failure or overtopping will not involve loss of life, it would be seldom economical to design them to withstand the probable maximum flood. A calculated risk is taken to design these structures for a flood lesser than the probable maximum flood.

The Frequency Analysis helps interpret a past record of events to predict the future probabilities of occurrence. Gumbel distribution helps to predict expected flood with different return periods. The present paper discusses one such case for construction of bridge so as to minimise the risk of any kind of problem that may arise in future.

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INTRODUCTION

In the case of small dams, diversion works & other hydraulic structures where structural failure or overtopping will not involve loss of life, it would be seldom economical to design them to withstand the probable maximum flood. A calculated risk is taken to design these structures for a flood lesser than the probable maximum flood.

The Frequency Analysis helps interpret a past record of events to predict the future probabilities of occurrence.

Data selection

For any frequency analysis, relevant, adequate & accurate data series is necessary.

Adequate data series refers to length of record. Data with sufficient length & reliability, can yield satisfactory estimates. For the estimation of flood flows of large return periods, it is necessary to extrapolate the magnitude outside the observed range.

The accuracy of the estimate reduces with degree of extrapolation. Some hydrologists set a limit of extrapolation of

about twice the length of record i.e. a 50 year data can be used to determine the magnitude of events up to 100 year flood, but not of floods of longer return period. If extrapolated to estimate 1000 year return flood, etc. then degrees of uncertainty involved in estimates have to be mentioned.

Flood Frequency Analysis: Using Gumbel Distribution

Hydrologic flood frequency analysis

Ven Te Chow has proposed the use of

 $x = x + K_{x}$, as the general equation for hydrologic frequency analysis.

where

- K = the frequency factor defined by a specific distribution. (Table values can be referred)
- \mathbf{x} = flood magnitude of given return period T

 \mathbf{x} = mean of observed / recorded floods

x = std. Deviation of observed / recorded floods

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Gumbel distribution

Gumbel was the first to realise that the annual maximum flood data are the observations of extreme values in different years. Hence they should follow extreme value distribution law viz. Double Exponential Probability Function .

F (x) = exp (-e^{-y}) where
$$y = x + a$$
, $a = c - \langle , c = 6$,

= 0.57721= Euler's constant

 \mathbf{y} = reduced variate , \mathbf{x} = magnitude of flood

$$c = 0.57721 * 6 = 0.45$$

$$. y = [x + 0.45]$$

$$= [x + 0.45]$$

$$= [x + 0.45]$$

$$*(0.7797)$$

Fitting of Double Exponential Distribution to the frequency distribution of observed data of floods can be checked by collecting records of floods of many rivers in the region & computing a set of skewness coefficients.

Cumulative Density Function (CDF) = $F(x) = \exp(-e^{-y})$, or y = lnln(F(x))

ln = natural log.

In Gumbel's Distribution CDF is $F(x) = P(X \le x) = \exp(-e^{-y})$

T= Return period of Flood, $P(X>x) = 1-F(x) = 1- \exp(-e^{-y})$

i.e. T = 1/P(X > x) or $1/T = 1 - exp(-e^{-y})$

or $\exp(-e^{-y}) = \frac{T-1}{T}$

i.e. $y = -\ln[-\ln F(x)]$

$$y = -\ln [\ln T - \ln(T - 1)]$$

$$\underline{\mathbf{x}}_{\mathbf{x}} = -\ln \left[\ln T \cdot \ln(T \cdot 1) \right]$$

$$\mathbf{x} = -\underline{\mathbf{6}} \left[+\ln \left(\ln \frac{T}{T \cdot 1} \right) \right]$$

The data of yearly values of maximum peak discharges for a bridge are given in Annex-I. Using above mentioned statistical method, one can estimate the discharge for return period of different magnitudes

RESULTS

Return period	K alue	K	$\mathbf{x} = \mathbf{x}$	+ K
1 in 100 years	K100	3.49	9613.323	m^3/sec
1 in 50 years	K50	2.89	8434.809	m^3/sec
1 in 10 years	K10	1.47	5645.659	m^3/sec

eak dischar (x) Rank. m ng 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	, 50, 100 yea ges for a briv Return period T=(n+1)/ m 51.00 25.50 17.00 12.75 10.20 8.50 7.29 6.38 5.67 5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68 2.55		discharges (x) m^3 / sec. in descending 2200 2175 2010 1925 1800 1775 1700 17700 17700 17700 1475 1375 1375 1375 1275 1225 1175 1100 1100	Rank m 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41	Return period T=(n+1)/ 1.96 1.89 1.76 1.70 1.65 1.59 1.55 1.50 1.46 1.42 1.38 1.34 1.31 1.28
(x) Rank m mg 1 2 3 4 5 6 6 7 8 9 10 11 11 12 13 14 15 16 17 17 18 19 20 20 21 22 23	Return period T=(n+1)/ m 51.00 25.50 17.00 12.75 10.20 8.50 7.29 6.38 5.67 5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	Year 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43	m ^{A3} / sec. in descending 2200 2175 2010 1925 1800 1775 1700 1770 1775 1375 1375 1375 1375 1275 1275 1225 1175 1100	m 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40	period T=(n+1)/ 1.96 1.89 1.82 1.76 1.70 1.65 1.59 1.55 1.50 1.46 1.42 1.38 1.34 1.31
m m ng 1 2 3 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 23	period T=(n+1) m 51.00 25.50 17.00 12.75 10.20 8.50 7.29 6.38 5.67 5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43	m ^{A3} / sec. in descending 2200 2175 2010 1925 1800 1775 1700 1770 1775 1375 1375 1375 1375 1275 1275 1225 1175 1100	m 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40	period T=(n+1)/ 1.96 1.89 1.82 1.76 1.70 1.65 1.59 1.55 1.50 1.46 1.42 1.38 1.34 1.31
m m ng 1 2 3 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 23	period T=(n+1) m 51.00 25.50 17.00 12.75 10.20 8.50 7.29 6.38 5.67 5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43	m ^{A3} / sec. in descending 2200 2175 2010 1925 1800 1775 1700 1770 1775 1375 1375 1375 1375 1275 1275 1225 1175 1100	m 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40	period T=(n+1)/ 1.96 1.89 1.82 1.76 1.70 1.65 1.59 1.55 1.50 1.46 1.42 1.38 1.34 1.31
ng 1 2 3 4 5 6 7 8 8 9 10 11 11 12 13 13 14 14 15 16 17 18 19 20 21 22	T=(n+1)/ m 51.00 25.50 17.00 12.75 10.20 8.50 7.29 6.38 5.67 5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43	in descending 2200 2175 2010 1925 1800 1775 1700 1770 1770 1770 1475 1375 1375 1275 1275 1275 1175 1100	27 28 29 30 31 32 33 34 35 36 37 38 39 40	T=(n+1)/ 1.96 1.89 1.82 1.76 1.70 1.65 1.59 1.55 1.50 1.46 1.42 1.38 1.34 1.34 1.31
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	51.00 25.50 17.00 12.75 10.20 8.50 7.29 6.38 5.67 5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43	2200 2175 2010 1925 1800 1775 1700 1770 1700 1475 1375 1375 1375 1275 1275 1225 1175 1100	27 28 29 30 31 32 33 34 35 36 37 38 39 40	1.96 1.89 1.82 1.76 1.70 1.65 1.59 1.55 1.50 1.46 1.42 1.38 1.34 1.34
2 3 4 5 6 7 8 9 10 11 1 12 13 14 15 16 6 7 7 8 9 9 10 11 1 12 13 14 15 16 7 20 20 22 22 23	25.50 17.00 12.75 10.20 8.50 7.29 6.38 5.67 5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43	2175 2010 1925 1800 1775 1700 1770 1475 1375 1375 1275 1275 1225 1175 1100	27 28 29 30 31 32 33 34 35 36 37 38 39 40	1.89 1.82 1.76 1.70 1.65 1.59 1.55 1.50 1.46 1.42 1.38 1.34 1.31
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	17.00 12.75 10.20 8.50 7.29 6.38 5.67 5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43	2010 1925 1800 1775 1700 1770 1475 1375 1375 1375 1375 1275 1225 1175 1100	28 29 30 31 32 33 34 35 36 37 38 39 40	1.82 1.76 1.70 1.65 1.59 1.55 1.50 1.46 1.42 1.38 1.34 1.31
4 5 6 7 8 9 10 11 12 13 13 14 15 16 17 18 19 20 21 22 23	12.75 10.20 8.50 7.29 6.38 5.67 5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	29 30 31 32 33 34 35 36 37 38 39 40 41 42 43	1925 1800 1775 1700 1770 1475 1375 1375 1375 1275 1275 1275 1275 1175 1100	29 30 31 32 33 34 35 36 37 38 39 40	1.76 1.70 1.65 1.59 1.55 1.50 1.46 1.42 1.38 1.34 1.31
6 7 8 9 100 111 12 13 14 15 16 16 17 18 19 20 21 1 22 23	10.20 8.50 7.29 6.38 5.67 5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	30 31 32 33 34 35 36 37 38 39 40 41 42 43	1800 1800 1775 1700 1700 1475 1375 1375 1375 1275 1275 1275 1175 1100	30 31 32 33 34 35 36 37 38 39 40	1.70 1.65 1.59 1.55 1.50 1.46 1.42 1.38 1.34 1.31
6 7 8 9 100 111 12 13 14 15 16 16 17 18 19 20 21 1 22 23	8.50 7.29 6.38 5.67 5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	31 32 33 34 35 36 37 38 39 40 41 42 43	1800 1775 1700 1475 1375 1375 1275 1225 1175 1100	31 32 33 34 35 36 37 38 39 40	1.65 1.59 1.55 1.50 1.46 1.42 1.38 1.34 1.31
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	7.29 6.38 5.67 5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	32 33 34 35 36 37 38 39 40 41 42 43	1775 1700 1700 1475 1375 1375 1275 1225 1175 1100	33 34 35 36 37 38 39 40	1.59 1.55 1.50 1.46 1.42 1.38 1.34 1.31
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	6.38 5.67 5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	33 34 35 36 37 38 39 40 41 42 43	1700 1700 1475 1375 1375 1275 1225 1175 1100	33 34 35 36 37 38 39 40	1.55 1.50 1.46 1.42 1.38 1.34 1.31
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	5.67 5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	34 35 36 37 38 39 40 41 42 43	1700 1475 1375 1375 1275 1225 1175 1100	34 35 36 37 38 39 40	1.50 1.46 1.42 1.38 1.34 1.31
10 11 12 13 14 15 16 17 18 19 20 21 22 23	5.10 4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	35 36 37 38 39 40 41 42 43	1475 1375 1375 1275 1225 1175 1100	35 36 37 38 39 40	1.46 1.42 1.38 1.34 1.31
11 12 13 14 15 16 17 18 19 20 21 22 23	4.64 4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	36 37 38 39 40 41 42 43	1375 1375 1275 1225 1175 1100	36 37 38 39 40	1.42 1.38 1.34 1.31
12 13 14 15 16 17 18 19 20 21 21 22 23	4.25 3.92 3.64 3.40 3.19 3.00 2.83 2.68	37 38 39 40 41 42 43	1375 1275 1225 1175 1100	37 38 39 40	1.38 1.34 1.31
13 14 15 16 17 18 19 20 21 22 23	3.92 3.64 3.40 3.19 3.00 2.83 2.68	38 39 40 41 42 43	1275 1225 1175 1100	38 39 40	1.34 1.31
14 15 16 17 18 19 20 21 21 22 23	3.64 3.40 3.19 3.00 2.83 2.68	39 40 41 42 43	1225 1175 1100	39 40	1.31
15 16 17 18 19 20 21 21 22 23	3.40 3.19 3.00 2.83 2.68	40 41 42 43	1175 1100	40	
16 17 18 19 20 21 22 23	3.19 3.00 2.83 2.68	41 42 43	1100	-	
17 18 19 20 21 22 23	3.00 2.83 2.68	42 43			1.24
18 19 20 21 22 23	2.83 2.68			42	1.21
19 20 21 22 23	2.68		1075	43	1.19
20 21 22 23			1075	44	1.16
21 22 23		45	1075	45	1.13
22 23	2.43	46	1000	46	1.11
23	2.32	47	725	47	1.09
-	2.22	48	625	48	1.06
24	2.13	49	400	49	1.04
25	2.04	50	325	50	1.02
K 'value is referred from the table			Mean =	4177.2	1
for Gumblel distribution			Std. Dev.	1848.10	
			Var.	3415465	
0.57721	+ ln (ln T)]			
Π			true for an infinite No. of observation		servation
d	istribution	istribution	0.57721 + In <u>(In T)</u>]	Std. Dev. Var. 0.57721 + ln (ln T)]	Std. Dev. 1848.10 Var. 3415465 0.57721 + ln (ln T)] 1

Annex-I

CONCLUSION

A risk is taken to design the structure (bridge) for a flood lesser than the probable maximum flood as mentioned above.

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