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FLOOD FREQUENCY ANALYSIS OF KUMAON REGION RIVERS UTTARAKHAND, INDIA

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ABSTRACT

Estimates of flood frequency quantiles are important in planning and design of hydraulic structures, Hence there is a need to seek for the most appropriate design estimator that would meet both safety and economic considerations of such structures. Flood frequency analysis is a tool used to estimate the frequencies of likely an occurrence of future floods. The objective of study is to estimate flood parameters of Kumaon Region Rivers of Uttarakhand, for different return period using statistical approaches, screening test using Anderson's Correlogram, Chow test for Outlier Detection and Kendall's Rank Correlation. Goodness of Fit tests Chi-square test, D-Index and K-S tests are applied to all the chosen, six probability distributions namely Normal, Log normal, Pearson type III, Log Pearson type III, Gumbel, Log Gumbel distributions using method of moments. By applying Model efficiency test, Coefficient of determination, root mean square errors for distributions and to suggest for best fitting distribution for Kumaon Region Rivers.In the present study, flood frequency analysis has been carried out for Kumaon Region Rivers namely Gola near Kathgodam barrage having Catchment area 600 km^2, Kosi near Ramnagar, Nainital district, 6753 km^2 and Sarda near Banbassa barrage of Champawat district 15100 km^2 catchment areas. The annual flood data's of all the river stations has been collected from the Irrigation departments. Goodness of fit tests shows that best probability distributions for all the three river stations are Log normal and Log Gumbel, but it is recommended form the literature review that to use Log Gumbel. Hence Log Gumbel is recommended for estimation of flood quantities. From model efficiency study it has been found that for river Kosi, Log Gumbel distribution, Log Pearson Type III distribution are best fitting for other two rivers.From trend line equation, maximum coefficient of determination (R^2) value and minimum root mean square error shown that for Kumaon Region Rivers for predicting expected flow Log Gumbel is the best distribution.

Keywords- *Flood Frequency Analysis, River Kosi, Gola & Sarda, Annual Peak Flood discharge, Return Period, Goodness of fit Test*

I. INTRODUCTION

Flood is the one which causes the natural disasters in India all most every year. It is commonly considered to be an unusually high stage of a river. It occurs generally during June to October. Generation of flood may be the random coincidence of several meteorological factors, and interventions of human in river catchments.For a river in its natural state, occurrence of a flood usually fills up the stream up to its banks and often spills over to the adjoining flood plains. Hydraulic structure planned within the river (like a dam or a barrage) or on an adjoining area (like flood control embankments), due consideration should be given to the design of the structure so as to prevent it from collapsing and causing further damage by the force of water released from behind the structure. Hence an estimate of extreme flood flow is required for the design of hydraulic structures, though the magnitude of such flood may be estimated in accordance with the importance of the structure. For example, the design flood of a large dam like the Tehrior the Hirakudwould be estimated to be more, than a medium sized dam like Chamera. Hence it is very much essential for proper selection of design flood value, higher would result in an increase in the cost of hydraulic structures, an under-estimated value is likely to place the structure and population involved in risk.Safe and economic design of various river engineering works, accurate estimation of flood is required using at site frequency analysis, like designing of small bridges, culverts etc. It is sufficient to estimates the maximum instantaneous discharge of the structure, has to pass during its economic life period. Commonly used probability distribution for

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flood frequency analysis include log normal two parameter, log normal three parameter, extreme value type I distribution, Pearson type III distribution and log Pearson type III distribution. Various methods for estimating the parameters of these distribution are available in flood frequency analysis literature. Flood frequency analysis uses historical records of peak flows to produce guidance about the expected behavior of future flooding. Primary applications of flood frequency analyses are to predict the possible flood magnitude over a certain time period and to estimate the frequency with which floods of a certain magnitude may occur.

II. MATERIALS & METHODS

Study Areafor the present study three rivers namely Gola, Kosi and Sarda Rivers of Kumaon region of Uttarakhand are taken up. The chosen catchment area is a sub basin of the Ganga River system. Geographically it is on the south east part of Nainital, Udham Singh Nagar and Champawat districts. It spreads from longitude 78° 07′ to 80° 29′ E and its latitude is 29° 16′ to 30° 05′ N. The Geographical catchment area of the three river is 21034 Sq.km.

Data AvailabilityGolariver discharge data are available from the year 1955 to 2014 with a record length of 60 years. The Catchment area of the basin is 600 square kilometers. Its minimum discharge of 144 m^3/s, maximum discharge of 3508 m^3/s and its average discharge 887 m^3/s. Kosi river discharge data are available from the year 1985 to 2014 with a record length of 30 years. The Catchment area of the basin is 6753 square kilometers. Its minimum discharge of 186 m^3/s, maximum discharge of 4534 m^3/s and its average discharge 1185 m^3/s. Sarda river discharge data are available from the year 1930 to 2014 with a record length of 85 years. The Catchment area of the basin is 15100 square kilometers. Its minimum discharge of 3284 m^3/s, maximum discharge of 15417 m^3/s and its average discharge 7903 m^3/s.

Method of Moments

The method of moments makes use of the fact that if all the moments of a distribution are known then everything about this distribution is known. For all the distribution in common usage four moments of fewer are sufficient all the moments. The method of moment's estimation is dependent on the assumption that the distribution of variate values in the sample is representative of the sample is representative of the population distribution. Therefore, a representation of the former provides an estimates of the later. Given that the form of the distribution is known or assumed, the distribution which the sample follows is specified by its first two or three moments calculated from the data.

$$X_T = \mu + K_T\sigma \qquad (2.1)$$

In which,

X_T = the magnitude of flood at required return period T

K_T = the frequency factor corresponding to T.

μ *and* σ = mean and standard deviation of the population

The following continuous distributions are used to fit the annual peak discharge series.

1. Normal distributions
2. Log normal distributions
3. Pearson type III distributions
4. Log Pearson type III distributions
5. Gumbel distributions

Log Gumbel distributions

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III. RESULTS & DISCUSSION

- **Anderson's Correlogram Test**

For checking the randomness of the annual flood series of individual are first undergone through Anderson's Correlogram test which shows the annual flood series data collected for the three river stations are if r_k upper is greater than r_k, then it is said to be random otherwise not random.

Table 3.1: Result for Anderson's Correlogram test

Station name	Station year	r_k	95% confidence limit		Remarks
			r_k Upper	r_k Lower	
Kosi	30	0.0157	0.3233	-0.3922	Random
Sarda	85	0.0350	0.2007	-0.2245	Random
Gola	60	0.5996	0.2361	-0.2699	Not Random

- **Chow Test for Outlier Detection**

Outlier test suggested by the Chow *et al.* (1988) and followed by water resource council at 10% significance level is applied for all the three river stations chosen, in order to find whether the maximum values of the computed series are less than the observed value or not.

Table 3.2: Result for outlier test

Station Name	Station Year	K_n	Observed series		Computed value		Remarks
			X_{Max}	X_{Min}	X_{Max}	X_{Min}	$Z_{comp}<Z_{obse}$
Sarda	85	2.961	15417.84	3284.75	22677.28	2403.49	No outliers
Gola	60	2.837	3508.45	144.41	4649.53	109.53	No outliers
Kosi	30	2.563	4534.82	186.89	5983.32	135.73	No outliers

- **Kendall's Rank Correlation Test**

Kendall's rank correlation test has been applied for all the three chosen river stations on the annual flow series. The Z values are calculated and it is checked for the 5% significance level. If Z computed less than Z tabulated value 1.96, it means that no trend has been observed. After the test it has been observed that from the Table. 3.3. No trend has been observed in all the three river stations.

Table 3.3: Kendell's rank correlation Test

Station Name	Station Year	E(P)	Test statistics P	Z computed	$Z_{comp}<Z_{Tabulated}$	Remarks
Sarda	85	1785	1557	1.7223	1.96	No trends
Gola	60	885	748	1.7528		No trends
Kosi	30	217.5	198	0.6959		No trends

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- **Prediction Discharge for Different Return Period**

From the suggested annual flood frequency analysis for any return period can be carried out with 95% confidence limit. The prediction for different return period is based on the statistical approach. These data are suitably predicated for estimation of extreme event of approximately 1000, 500, 200, 100, 75, 50, 25 and 10 years respectively for flood frequency analysis. For different range of gauged catchments area of different return period are calculated for all the river stations and presented in Table 3.4, 3.5 and 3.6 using various distribution. Computation of standard error of quantile estimates for the confidence limits at 95% significance level for the return period.

Table 3.4: Estimation of T-Year Flood and its Standard Error of Kosi River

Return Period	Computed Discharge (m^3/s)	Standard Error (m^3/s)	95% Significances Level	
			Upper Confidence Level (m^3/s)	Lower Confidence Level (m^3/s)
NORMAL DISTRIBUTION				
10	2502	254	3022	1982
25	3527	357	4255	2799
50	4317	446	5229	3406
100	5113	541	6219	4008
200	5919	640	7225	4612
500	6991	773	8569	5413
1000	10816	876	12603	9029
LOG NORMAL DISTRIBUTION				
10	2339	429	3216	1463
25	3425	755	4966	1884
50	4389	1085	6604	2174
100	5506	1503	8573	2438
200	6794	2023	10922	2666
500	8798	2897	14703	2882
1000	10573	3723	18170	2976
PEARSON TYPE III DISTRIBUTION				
10	2502	510	3544	1460
25	3527	898	5360	1694
50	4317	1132	6582	2052
100	5116	1334	7839	2394
200	5922	1614	9215	2628
500	6994	1946	10965	3022
1000	7809	2272	12352	3267
LOG PEARSON TYPE III DISTRIBUTION				
10	2351	479	3309	1392
25	3425	950	5364	1485
50	4389	1243	6925	1853
100	5506	1575	8721	2291
200	6794	2017	10910	2678
500	8798	2407	13710	3895
1000	10573	3055	16807	4339

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GUMBEL DISTRIBUTION				
10	2541	396	3350	1733
25	3310	534	4400	2220
50	3880	651	5209	2551
100	4446	744	5966	2926
200	5010	850	6745	3275
500	5754	990	7775	3733
1000	6316	1097	8555	4078
LOG GUMBEL DISTRIBUTION				
10	2362	396	3170	1553
25	4077	534	5167	2987
50	6114	629	7399	4829
100	9140	744	10660	7621
200	13648	850	15383	11912
500	23149	990	25710	21127
1000	34517	1097	36755	32278

Table 3.5: Estimation of T-Year Flood and its Standard Error of Gola River

Return Period	Computed Discharge (m^3/s)	Standard Error (m^3/s)	95% Significances Level	
			Upper Confidence Level (m^3/s)	Lower Confidence Level (m^3/s)
NORMAL DISTRIBUTION				
10	1750	116	1983	1517
25	2358	159	2676	2039
50	2817	195	3209	2425
100	3276	234	3745	2808
200	3736	273	4283	3188
500	4383	326	4997	3689
1000	4803	367	5538	4067
LOG NORMAL DISTRIBUTION				
10	1664	201	2067	1260
25	2268	320	2910	1626
50	2771	425	3622	1920
100	3318	540	4399	2237
200	3912	665	5244	2581
500	4777	845	6468	3087
1000	5496	991	7478	3514
PEARSON TYPE III DISTRIBUTION				
10	1748	116	1980	1515
25	2360	159	2679	2042
50	2825	196	3218	2432
100	3290	235	3760	2819
200	3755	275	4306	3204

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500	4371	329	5029	3712
1000	4837	370	5578	4096
LOG PEARSON TYPE III DISTRIBUTION				
10	1668	209	2086	1249
25	2287	342	2971	1602
50	2807	551	3909	1704
100	3370	770	4912	1829
200	4001	1047	6097	1905
500	4918	1490	7899	1937
1000	5686	1885	9458	1915
GUMBEL DISTRIBUTION				
10	1751	178	2109	1394
25	2241	240	2723	1760
50	2605	288	3181	2029
100	2966	335	3637	2294
200	3325	383	4092	2558
500	3800	444	4693	2906
1000	4158	494	5148	3169
LOG GUMBEL DISTRIBUTION				
10	1689	209	2046	1332
25	2753	342	3235	2271
50	3955	551	4532	3379
100	5668	770	6339	4996
200	8110	1047	8877	7343
500	13013	1450	13906	12119
1000	18602	1885	19591	17613

Table 3.6: Estimation of T-Year Flood and its Standard Error of Sarda River

Return Period	Computed Discharge (m^3/s)	Standard Error (m^3/s)	95% Significances Level	
			Upper Confidence Level (m^3/s)	Lower Confidence Level (m^3/s)
NORMAL DISTRIBUTION				
10	11670	424	12515	10826
25	13283	516	14312	12255
50	14373	585	15539	13207
100	15386	652	16686	14086
200	16341	717	17770	14911
500	17533	801	19129	15937
1000	18377	862	20095	16660
LOG NORMAL DISTRIBUTION				
10	11893	654	13197	10590
25	13955	891	15730	12180
50	15429	1079	17579	13279
100	16856	1273	19394	14319

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200	18250	1473	21186	15314
500	20054	1746	23534	16575
1000	21398	1957	25298	17498
PEARSON TYPE III DISTRIBUTION				
10	11672	502	12673	10670
25	13290	681	14648	11932
50	14373	832	16031	12716
100	15402	992	17379	13425
200	16362	1120	18593	14130
500	17561	1367	20285	14837
1000	18426	1518	21450	15401
LOG PEARSON TYPE III DISTRIBUTION				
10	11861	595	13048	10675
25	13848	908	15658	12038
50	15252	1265	17773	12732
100	16595	1724	20030	13160
200	17894	2263	22403	13384
500	19558	3101	25736	13379
1000	20783	3824	28402	13164
GUMBEL DISTRIBUTION				
10	11636	647	12926	10345
25	13751	873	15491	12010
50	15320	1045	17402	13238
100	16878	1217	19303	14452
200	18430	1390	21200	15659
500	20477	1620	23704	17250
1000	22055	1794	25599	18451
LOG GUMBEL DISTRIBUTION				
10	12104	647	13394	10813
25	16017	873	17758	14277
50	19718	1045	21800	17636
100	24236	1217	26662	21811
200	29768	1390	32538	26998
500	39042	1620	42270	35815
1000	47925	1794	51499	44351

- **Coefficient of Determination**

Flood frequency analysis has been carried out for Kumaon Region Rivers and results are shown in table 3.4 to 3.6. The coefficient of determination (R^2) for the best fitted lines in are summarized in Table 3.7. It has been found that for all the three river station. Log Gumbel distribution values for Kosi River the maximum (R^2) value is 0.9662, for Gola River (R^2) value is 0.9538 and for Sarda river (R^2) value is 0.8873. Hence for predicting expected flow in the Kumaon Region Rivers Log Gumbel is the best suitable distribution.

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Table 3.7: Coefficient of Determination

Coefficient of Determination (R^2)						
River	Distribution					
	Normal	Log Normal	Pearson Type III	Log Pearson Type III	Gumbel	Log Gumbel
Kosi	0.9339	0.8510	0.7553	0.8515	0.7444	0.9662
Gola	0.7485	0.8115	0.7493	0.8175	0.7444	0.9538
Sarda	0.6953	0.7276	0.6977	0.7192	0.7444	0.8873

IV. SUMMARY & CONCLUSIONS

- Flood frequency analysis is one of the simplest and widely used applications of statistics in the field of hydrology and hydraulic Structures. In the present study, an attempt has been made to apply annual flood series using method of moment's for estimation of flood parameters of Kumaon Region Rivers.
- •It has been found that statistical parameter for original Series of the Kosi river are mean 1185.1317 m3/s, standard deviation 1039.7593, coefficient of variance 0.8773, coefficient of skewness 2.3594 and kurtosis coefficient 8.9739. For Gola River mean 887.2692 m3/s, standard deviation 662.8295, coefficient of variance 0.7470, and coefficient of skewness 2.0393 and kurtosis coefficient 7.5730.Whereas for Sarda river mean 7903.4483 m3/s, standard deviation 2861.2137, coefficient of variance 0.3620, coefficient of skewness 0.4080 and kurtosis coefficient 2.6477.
- It has been found that statistical parameter for log transformed Series of the Kosi River are mean 6.5704 m3/s, standard deviation 0.6606, and coefficient of variance 0.1005, coefficient of skewness 0.0361 and kurtosis coefficient 3.5548. For Gola River mean 6.8037 m3/s, standard deviation 0.7386, coefficient of variance 0.1086, and coefficient of skewness 0.1700 and kurtosiscoefficient 3.5548. Whereas for Sarda river mean 8.9069 m3/s, standard deviation 0.3790, coefficient of variance 0.0426, coefficient of skewness -0.2556 and kurtosis coefficient 2.2695.
- Anderson's Correlogram test shows that both Kosi and Sarda's river stations annual flood series data's are random, whereas for Gola river station was not random. From Chow test for Outlier detection that all the three river station was free from outlier and fromKendall's rank correlation test shows that the Z values e calculated and it is checked for the 5% significance level for the three rivers, Z computed is less than Z tabulated value of 1.96, it means that no trend has been observed.
- In this study six distributions are considered and worked out the flood quantiles for different return period like 1000, 500, 200, 100, 75, 50, 25 and 10 years, here we are assumed that all the distributions are fittings for all three rivers stations.
- Tests of Goodness fit namely Chi squared test, K-S test and D-index test applied to the chosen probability distributions, it shows that for Gola and Sarda river stations Log Pearson Type III distribution are fitted and Kosi river stations Log Gumbel distributions are fitted.
- Model tests shows that for river Kosi, Log Gumbel distribution having maximum model efficiency 96.24 % and root mean square error 90.38 %, for river Gola having model efficiency 93.93 % and root mean square error 60.87 % whereas for river Sarda stations having model efficiency 98.37 % and root mean square error 240.97 %, Log Pearson Type III distribution are best fitting for both the rivers.

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- Discharge verses return period shows that flow pattern is of scattered and narrow,however the trend line equation gives the maximum value of Coefficient of determination ( ),for Kosi River is 0.9662, Gola River is 0.9538 and Sarda river is 0.8873for Log Gumbel distribution.
- Hence it is recommended to use the Log Gumbel distribution for predicting floods in Gola River, Kosi River and Sarda River stations of Kumaon Region

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