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FLOOD ANALYSIS OF RESERVOIRS IN VISAKHAPATNAM DISTRICT BY USING PROBABILITY METHODS

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ABSTRACT

Visakhapatnam city located on the east coast of India with geographical co-ordinates 17^{O} – 15' and 18^{O} – 32' northern latitude and 18^{O} – 54' and 83^{O} – 30' in eastern longitudes (Figure 1) and witnessing a rapid expansion of residential and other built – up areas in both horizontal and vertical expanses. The district receives average annual rainfall of 1202 mm, of which south west monsoon accounts for 55.9% of the normal while north east monsoon contributes 6.8% of the normal rainfall. The Visakhapatnam region has been attacked by the number of floods during the past and present. To determine the magnitude and frequency of floods for Visakhapatnam district by gumbel distribution the water level readings of the reservoirs have been collected for 20 years (1993-2012).

The probability plot and flood – frequency curves by gumbel distribution of each reservoir are prepared using three different plotting position formulas which are weibull, gringorten and L-moments. It is found that L- Moments method is best fit for flood frequency curves, with some limitations which are good for small samples of data, when compare with gringorten and weibull methods. For the successful analysis of any probability method, data must be available for a minimum period of 20years.

KEYWORDS: Flood Frequency**,** Gringorten, Gumbel Distribution, L-Moments, Weibull

INTRODUCTION

Floods are one of the natural disasters that occur not only in India, but also in other parts of the world. Flood has been defined by various researchers in various ways. According to chow (1956), a flood is a relatively high flow, which overflows the natural channel provided for the run off. Flood frequency analysis is used to predict design floods for sites along a river. The technique involves using observed annual peak flow discharge data to calculate statistical information such as mean values, standard deviations, skew ness, and recurrence intervals. These statistical data are then used to construct frequency distributions, which are graphs and tables that tell the likelihood of various discharges as a function of recurrence interval or exceedence probability.

The main scope of the work is to determine the magnitude and flood frequency analysis, using the Gumbel distribution by Weibull formula, Gringorten formula and L-moments formula in the Visakhapatnam district.

OBJECTIVES OF THE STUDY

- The principal objective of the study is to assess the relative performance of the currently recommended flood frequency analysis method with some of the recently developed techniques.

- The parameters of the seasonal frequency distributions are fitted by maximizing an objective function that accounts for the likelihoods of both seasonal and annual peaks.
- To calculate the magnitude and flood frequency of the reservoirs in Visakhapatnam district
- Flood duration is found to be the most prominent indicator in determining flood hazard.
- The techniques, used in this study can help to provide a sound scientific basis for delineating maximum flows and protecting in stream values.

LITERATURE REVIEW

Jery Stedinger et. al. (2008) concluded that Estimates of the magnitude and frequency of flood flows are needed for the design and operation of water-use and water control projects. Determining flood flow frequency methods were developed to address the use of regional skew information and historical flood information. using the method of moments to fit pearson type 3 distribution to the logarithms of the flood series, there by yielding a log pearson type 3 distribution to model observed streamflow data.

Ladislav Gaal et. al. (2010) concluded that deals with at-site flood frequency estimation in the case when also information on hydrological events from the past with extraordinary magnitudes are available. A sensitivity analysis related to the choice of the most influential parameters of the statistical model was presented. The Bayesian MCMC methodology is presented on the example of the maximum discharges observed during the warm half year at the station Vltava-kamyk.

Neslihan Seckin et. al. (2012) concluded that Reliable estimates of maximum discharge are necessary to correctly size hydraulic structures, and accordingly to reduce the risk of their failures and minimize downstream environmental damage. Maximum discharge and its frequency are also required for flood risk assessment of the projects and determination of design flood discharge. In this gene-expression programming (GEP) and linear genetic programming (LGP) which are extensions to GP, in addition to logistic regression (LR) were employed in order to forecast peak flood discharges.

Never Mujere (2011) concluded that the flood forecasting of rainfall data to estimate return periods associated with flood peaks of different magnitudes from recorded historical floods using statistical methods. The selected method is Gumbel extreme distribution which is widely used for flood frequency analysis. Flood frequency analysis involves the fitting of a probability model to the sample of annual flood peaks recorded over a period of observations, for a catchment of a study region.

O. N. Dhar et. al. (2003) concluded that the study has shown that the flood problem in India is mostly confined to the states located in the indo-gangetic plains, north east India and occasionally in rivers of central India. As the bulk of summer monsoon rainfall occurs with in the period of four months, naturally majority of floods occur in Indian rivers during this season only. The ground conditions may also help in generating high percentage of run-off because of the antecedent wet conditions caused by rainy spells occurring with in the monsoon period itself.

S. Nadarajah et. al. (2005) concluded that the negative impacts of extreme hydrologic events, the characteristics of such events were used as a design criterion of hydraulic structures. Therefore, probabilistic assessment was developed and extreme value theory is one of the common methods to investigate the extreme phenomenon of interest. Extreme value theory deals with the stochastic behavior of the extreme value of a process by the using of extreme value distribution provides estimates of return period for flood peak and flood volume, which could be used as measures of flood protection.

STUDY AREA

The study has carried by collecting water levels and water discharge data from the five reservoirs namely Tandava, Raiwada, Meghadrigedda, konam, Gambhiramgedda reservoirs in the Visakhapatnam district shown in Figure 2.

- Thandava reservoir is most naturally formed reservoir due to its vowel shaped geological configuration as it is surrounded by hills around. Hence, construction of an earth dam for a length of 201m facilitated for formation of a reservoir of capacity 4960mcft. In Thandava reservoir, the maximum discharge is 34978m^3/sec is obtained in the month of January.
- Raiwada reservoir is having 2 head sluices both on right and left flanks the left head sluice is located at 3.30 km and the right head sluice is located at 4.050 km. The length of the earth dam is 5.75 km and it has one spillway regulator at the right flank of the earth dam. for Raiwada reservoir, the amount of discharge is obtained is 35746.50 m^3/sec in the months of January.
- Mehadrigedda is a typical shallow reservoir covering a large area, constructed in the hilly terrain. During the year 1989, the water withdrawal capacity of the reservoir was increased to 10.00 million gallons per day. Observed that for Meghadrigedda reservoir the maximum amount of discharge obtained in month of November which is about is 1329.58m^3/sec.
- Konam reservoir project is a medium irrigation project which was constructed across the river bodderu originates at Eastern Ghats and travels 15 km to reach konam village and merges in to Pedderu River (tributary of Sarada River) by travelling 16.50 kms in south east direction. For Konam reservoir, the amount of discharge is obtained is 30835.67 m^3/sec in the months of August.
- The Gambhiramgedda reservoir project was constructed across the river Peddagedda in the Anandhapuram mandal, Boyapalem. The total catchment area of the reservoir is 36.00 sq miles and the total yield per catchment is 387.00 mcft. For Gambhiramgedda reservoir, the maximum discharge obtained in the month of November which is about 5249.88m^3/sec.

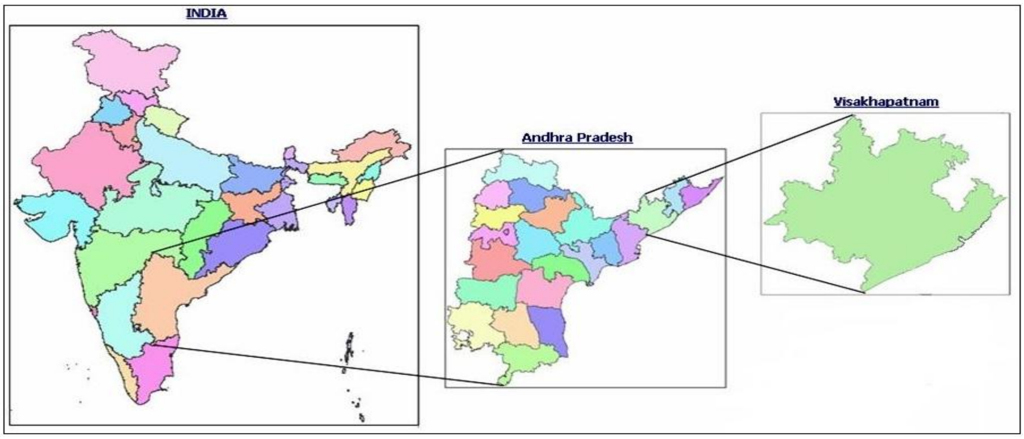

Figure 1: Location Map of Study Area

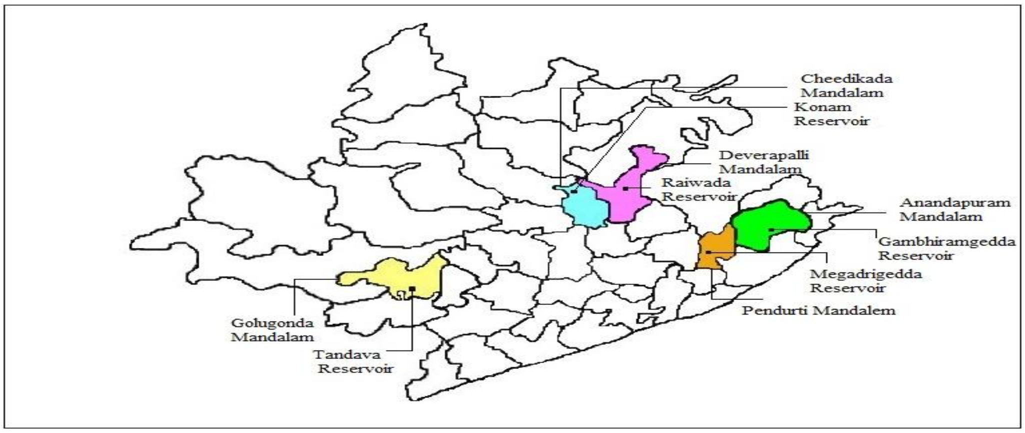

Figure 2: Showing Reservoir Map with Mandals

METHODOLOGY

The study has carried by collecting water levels and water discharge data from the five reservoirs namely meghadrigedda, gambhiramgedda, and tandava, raiwada, and konam reservoirs in the Visakhapatnam district (Figure 2). From the E.E, Dept of Irrigation of Visakhapatnam district. The estimation of flood frequency analysis in this region has done by using the application of gumbel distribution with weibull formula, gringorten formula and L-moment method. It is hoped that the findings from this study could contribute to the knowledge of the application of gumbel distribution in flood frequency study in Visakhapatnam region. For the analysis of flood frequency and magnitude, the water level readings about the reservoirs have taken. These water level values are then converted in to discharge 'Q' from by using the discharge rating curve for the reservoir.

$$\mathbf{Q = 7.44\ (H - 0.92)^{1.81}}$$

Where

'Q' = Discharge,

'H' = Maximum water level readings in meters.

After the conversion of water level readings in to discharge then the annual extreme series are arranged in descending order of magnitude. Then the arithmetic mean of annual flood is calculated (MAF). Then the plotting position of each sample is determined. In this study, mainly focus on the gumbel distribution with three plotting position formulas (**Weibull Distribution, Gringorten Method and L-moment Method**) which applied to data for analysis of flood frequency.

ANALYSIS AND RESULTS

The results of the flood frequency analysis (FFA) generated from the study gives information of likely values of discharge to be expected in the river at the various return periods based on the observed data which information is useful for many engineering purposes such as when designing structures in or near the river that may be affected by flood as well as in designing structures to protect against the largest expected events.

The magnitude and flood frequency analysis of the Meghadrigedda reservoir using Gumbel distribution by Weibull formula, Gringorten formula and L-moments formula, the results obtained from the calculations are shown in below (table-1) utilized to produce the probability plot and flood frequency curves.

Table 1: Results of Probability Methods Meghadrigedda Reservoir

Weibull (1939)			Gringorten (1963)			L-Moment (Hosking & Wallis 1997)				
Q_T/MAF	T_W	Y_W	Q_T/MAF	T_G	Y_G	Q_T/MAF	Discharge	Y_{LM}	F_X	T_{LM}
1.081	21	3.02	1.081	35.92	3.568	1.081	1329.58	1.56	0.8104	5.27
1.081	10.5	2.302	1.081	12.89	2.516	1.081	1329.58	1.56	0.8104	5.27
1.077	7	1.8703	1.077	7.85	1.993	1.077	1325.48	1.52	0.8035	5.089
1.077	5.25	1.554	1.077	5.65	1.636	1.077	1325.48	1.52	0.8035	5.089
1.073	4.2	1.3026	1.073	4.412	1.358	1.073	1319.99	1.47	0.794	4.854
1.073	3.5	1.089	1.073	3.618	1.128	1.073	1319.99	1.47	0.794	4.854
1.063	3	0.903	1.063	3.067	0.9302	1.063	1307.72	1.35	0.771	4.366
1.056	2.625	0.735	1.056	2.661	0.7526	1.056	1299.49	1.26	0.753	4.048
1.044	2.33	0.578	1.044	2.35	0.5903	1.044	1283.99	1.11	0.719	3.558
1.036	2.1	0.4362	1.036	2.104	0.438	1.036	1275.23	1.028	0.699	3.322
1.03	1.909	0.2986	1.03	1.905	0.295	1.03	1267.14	0.948	0.678	3.105
1.027	1.75	0.1659	1.027	1.74	0.156	1.027	1263.15	0.9	0.665	2.985
1.027	1.615	0.0353	1.027	1.601	0.0206	1.027	1263.15	0.9	0.665	2.985
1.014	1.5	-0.0938	1.014	1.483	-0.114	1.014	1247.11	0.74	0.62	2.631
1.007	1.4	-0.225	1.007	1.381	-0.252	1.007	1239.13	0.67	0.599	2.493
1.003	1.3125	-0.3611	1.003	1.293	-0.394	1.003	1233.82	0.61	0.58	2.38
0.848	1.235	-0.5062	0.848	1.214	-0.551	0.848	1043.34	-1.27	0.0284	1.029
0.845	1.166	-0.667	0.845	1.145	-0.725	0.845	1039.65	-1.31	0.0245	1.025
0.805	1.105	-0.855	0.805	1.084	-0.939	0.805	991.04	-1.79	0.0025	1.0025
0.724	1.05	-1.113	0.724	1.028	-1.281	0.724	891.22	-2.78	9.9E-08	1

Q_T/MAF= Annual Peak Discharge Over the Arthematic Mean of Annual Flood

Q_T=Peak Discharge of 'T' years Recurrence interval Y_G = Reduced Variate Gringorten T_W = Return Period Weibull

Y_{LM} = Reduced Variate L-moment Y_W = Reduced Variate Weibull F_X = Cumulative Density Function

T_G = Return Period Gringorten T_{LM} = Return Period L-moment

By the compression of the three plotting position methods we can observe the various differences in flood frequency curves of study reservoir when they are plotted together in one graph see figure: 3, 4, 5, 6, 7. From the figures of Gumbel distribution using the three plotting position formula/method in which few trends had been identified:

- Gumbel distribution with Weibull Formula is always the steepest followed by Gumbel distribution with Gringorten Formula and then Gumbel distribution by L-moment method, and
- Flood Frequency Curve of Gumbel distribution by L-moment always fit nicely to probability plot compared to the other two cases.

The steeper the slope of the flow duration curve the greater the variability in flow. In which L-moments are less sensitive to variability, less subjective to bias and they are robust in the presence of outliers, they give consistent results even if the extreme values contain measurement errors. And with L-moments it is the probabilities which were, it gives less weight to the very high or low data values, most probably this is the reason the probability plots by L-moments method fit nicely to the flood frequency curves.

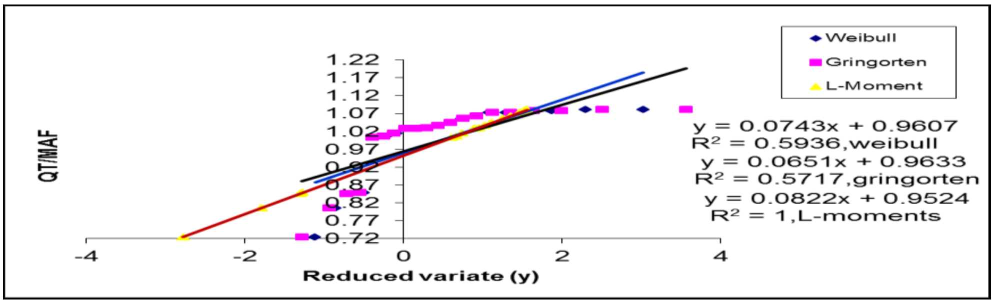

Figure 3: Combined Flood Frequency Curves, Meghadrigedda Reservoir

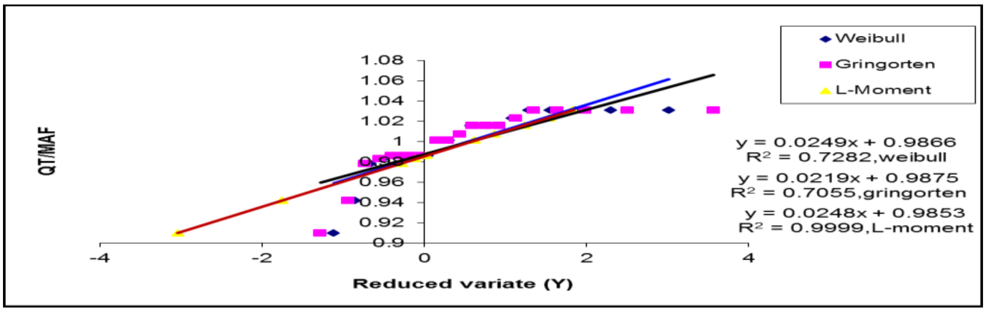

Figure 4: Combined Flood Frequency Curves, Gambhiramgedda Reservoir

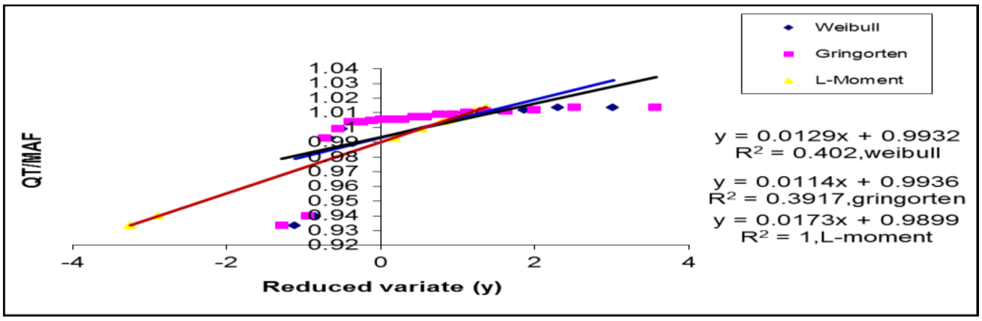

Figure 5: Combined Flood Frequency Curves, Raiwada Reservoir

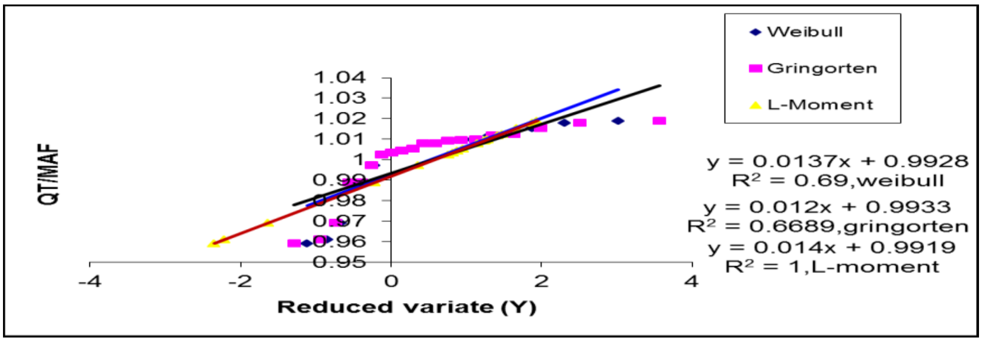

Figure 6: Combined Flood Frequency Curves, Konam Reservoir

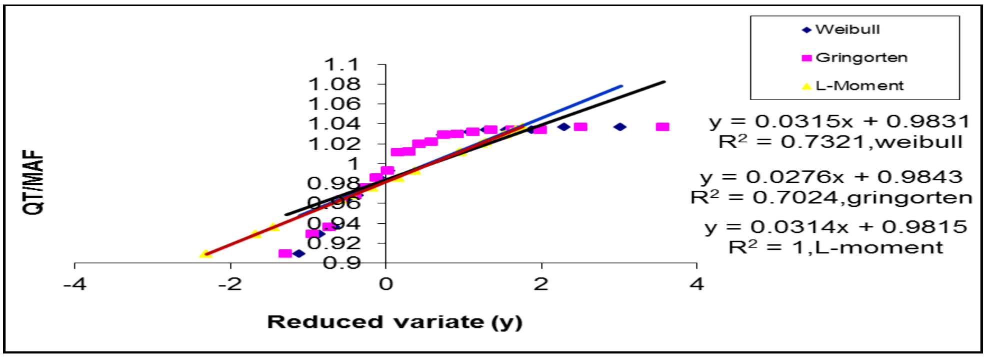

Figure 7: Combined Flood Frequency Curves, Thandava Reservoir

CONCLUSIONS

- Frequency of flood is analyzed using Gumbel distribution with three plotting position formulas, namely Weibull, Gringorten and L-moments. Also the L-moment method gives better plotting position but have some limitations so Gringorten formula is the best plotting position method with the Gumbel distribution.
- The flood frequency curve of Gumbel distribution by L-moment always fit nicely to probability plot, because the L-moment gives the less weight to the very high (or) low data values, when compared with other two cases.
- The probability methods are however, unable to give precise results, where lesser number of past records are available. For the success of any probability method, a minimum period of 20 years past records must be available.
- The using of extreme value distribution provides estimates of return period for flood peak and flood volume, which could be used as measures of flood protection.
- The flood frequency studies can be used as a guide in determining the capacity of a structure like, highway bridges, culverts, storm drains etc. When it is permissible to take a means of estimating the probable flood damage, prevented by a system of flood protection works over a period of years usually equal to the estimated economic life of the work.
- The flood frequency analysis is essentially a problem of information scarcity in arid and semi-arid regions, practically in these regions, the length of records is usually to short to insure reliable quintile estimates.

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