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Regional Flood Frequency Analysis For Godavari Basin Sub-Zone (3f)

NATIONAL INSTITUTE OF HYDROLOGY
JALVIGYAN BHAWAN
ROORKEE - 247 667 (U.P.)
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PREFACE

The Flood Frequency Analysis procedures provide the information on flood magnitudes and their frequencies, often needed for planning and design of various water resources Structures. The Flood Frequency Analysis for those gauging sites, where the historical peak discharges are available for sufficiently long period, may be carried using at site data. However, for the ungauged sites or sites with short record lengths, such analysis may not be able to estimate the floods with desired accuracy In such a situation the flood frequency analysis may be performed using regional approaches with 'regional and at site data' or 'regional data' alone.

There has been significant number of studies in the area of Regional Flood Frequency Analysis in India; wherein, the conventional method such as U.S.G.S. Method, Regression based Methods and Chow's Method etc. have been generally applied. Some attempts have already been made at National Institute of Hydrology and some Academic Institutions to study the applications of new approaches for regional flood frequency analysis for typical regions in India. Although a large number of application studies using conventional as well as advanced regionalisation techniques have been carried out, but no systematic efforts have been made so far in India to compare their relative performance.

In view of the above, a comparative study has been carried out by Sh. R.D. Singh, Dr. S. M. Seth and Sh. Rakesh Kumar, Scientists of NIH. Some of the important issues involved in regional flood frequency analysis procedures have been examined. It is expected that the study would definitely provide the solutions for some of problems which are currently being faced by the Hydrologists in the area of Regional Flood Frequency Analysis.

Satish Chandra
(SATISH CHANDRA)

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ABSTRACT

The most significant development in regional flood frequency analysis was the bringing out of a manual by U.S. Geological Survey in 1960, which was followed by a number of studies including U.K. Flood Studies and other typical studies covering general probability considerations, use of historical information, criteria for regional homogeneity etc. Some important developments during the last fifteen years include use of GEV (General Extreme Value) and Wakeby distributions, and use of PWM (Probability Weighted Moments) approach for parameter estimation. The application of PWM technique of parameter estimation provides efficient and reliable flood estimates even for situations where historical records are extremely short. Most of the regional flood frequency analaysis studies carried out for some typical regions in India are based on conventional methods such as U.S.G.S. Method, regression based methods and Chow's Method etc. In a few studies, conducted at National Institute of Hydrology and at some academic organisations, attempts have been made to study the applications of new approaches, such as Wakeby (PWM), GEV(PWM) and Power transformation techniques, etc for regional flood frequency analysis of some of the typical regions in India for which the conventional methods have been already applied.

In this study, flood frequency analysis using peak flood series data of hydrometeorologically homogeneous region of Godavari basin (Sub zone 3f) involving application of EV1 (PWM) and GEV (PWM) methods based on : i) at site data, ii) at site and regional data combined and iii) regional data alone is described and discussed. Homogeneity of the region has been tested using

U.S.G.S. Homogeneity test and co-efficient of variation based Homogeneity test. The annual peak flows for 16 to 26 years for twelve sites are considered in two parts. Ten sites data for parameter estimation and two sites data as independent test data. Descriptive ability of the various frequency methods considered for the study have been tested based on some goodness of fit criteria.

In order to evaluate the predictive ability criteria, synthetic flood series have been generated using the regional EV1 and GEV distributions parameters, derived from the historical records. Generated data sets have been considered for ten sites for a specific record length (same as the record lengths of historical data for respective gauging sites) and two independent sites, considering one at a time, of a variable record length (1,5,10,20,24,30 or 40). EV1 (PWM) method has been applied to the generated data of different sample sizes for an independent site considering. i) at site data, ii) at site and regional data, obtained from the generated data of the ten gauging sites, and iii) regional data alone involving the relationship between the mean annual peak flood and catchment area and the regional parameters for the concerned distribution. The computations have been repeated for second independent site on the same lines. Similarly, GEV (PWM) method was also applied to the generated data and computations have been made for the two independent gauging sites taking different sample sizes. The performance of different methods have been evaluated based on the predictive ability criteria, viz. bias, co-efficient of variation and root mean square error computed from the generated samples of different sizes by considering 1000 replications of the computation procedure for each sample length. The results obtained from EV1 (PWM) and GEV (PWM) with generated data of two different populations have been compared for the different methods.It is seen that the method based on GEV(PWM) approach using at site and regional data in a combined form, provides estimate of flood peaks for different recurrence intervals with computationally less bias and, comparable root mean square error and co-efficient of variation for the two independent catchments. The study, thus, establishes the applicability of GEV(PWM) approach for regional flood frequency analysis considering at site and regional data in the combinied form of the the Godavari Basin sub-zone (3f) region.

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1.0 INTRODUCTION

The information on flood magnitudes and their frequencies are often needed for planning and design of various water Resources structures. Flood Frequency analysis procedures provide such information from the available limited historical flood records. The peak flood data used for frequency analysis should satisfy the folloing assumptions in order to have the meaningful estimates:

i) the data should be random.

ii) the data should be homogeneous.

iii) the sample size should be such that the population parameters can be estimated from it.

iv) the data should be of good quality.

In the flood frequency analysis procrdures generally the following steps are involved:

i) Process the historical records from frequency analysis point of view.

ii) Choose various theoretical frequency distributions.

iii) Fit the chosen frequency distributions with the historical flood records. Estimate the parameters of the distributions using one or more parameter estimation techniques.

iv) Choose some goodness of fit criteria and select a best fit distribution based on those criteria.

v) Estimate the foods for different recurrence intervals using the estimated parameters of best fit distribution.

There are various distributions and methods of parameter estimation techniques available in the flood frequency analysis literature for fitting the peak flood data for the purpose of flood frequency analysis. Correct inference about the distributions which fit the peak flood series of a site is crucial in flood frequency analysis, as various distributions fitted to the same data result in different estimated values in the extrapolation range. There is no general agreement among the hydrologists as to which of the various theoretical distributions available should be used for modelling the peak flood series at a site. The reason being that the hydrologists try to infer about the population distribution from the sample data which is subjected to sampling variability. The conclusions arrived regarding the correct distribution based on the given sample data is influenced by the extent the data satisfied the basic assumptions needed for flood frequency analysis and the techniques employed like the adjustement of data, presence of outliers, historical information etc., method of parameter estimation, distribution model used and goodness of fit test adopted. As data arising from various situations form their own distributions, the procedure of transforming the data to a particular distribution has been suggested by some hydrologists without adopting a prior distribution for fitting the sample data.

The inference about the best fit distribution for a sample data observed at a site is made based on some goodness of fit criteria. Inspite of number of attempts it has not been possible to develop uniform goodness of fit criteria for selecting the best fit distribution. As a result recommendations about different, design flood estimates for the same site depend upon the goodness of fit criteria adopted. In order to avoid such subjectivity, hydrologosts are always in search of a robustfrequency distribution for fitting the peak flood series. A distribution or method of parameter estimation is termed as "robust" in flood frequency analysis context if it estimates medium and high return period floods with low bias, coefficient of varialtion and root mean square error. (Bias, co-efficient of variation and Root mean square error are explained in section 6.3.2).

The flood frequency analysis for those gauging sites, where the recorded peak discharges over number of years are available, are performed using the conventional procedure as given above. However, the reliability of such analysis is somewhat limited for the ungauged sites or sites with short record lengths. Such a situation can be overcome by adopting regionl approaches and performing flood frequency analysis with regional and at site data or regional data alone.

There has been significant developments and studies in the area of regional flood frequency analysis in India as well as abroad. Estimation of regional flood frequency parameters is preferred over the developed for a specific site for two reasons: i) Because of the sample variations present in the short hydrologic records, frequency estimates of rare events based on at site frequency analysis are subjected to large error and thus unreliable. This error can be reduced by combining data from many more sites.ii) there are many more sites in the same region where hydrologic data are not available but design flood estimates are needed for the design of small structures. In such a situation regional flood frequency analysis helps in transferring the knowledge arrived from gauged sites to ungauged sites.

Inspite of the large number of existing reginalisation techniques, very few studies have been carried out to test their comparative performances. However, in India no such systematic studies have been carried out.

In present study, probability weighted moment based EV1 and GEV distributions, which are simple and widely used distribtions available in recent flood frequency analysis literature, have been considered to fit the annual peak flood series data of hydrometeorologically homogeneous region of Godavari Basin Sub-zone (3f). The analysis has been carried out with : (i) at site data, (ii) at site and regional data, and (iii) regional data alone without considering at site data. Annual maximum flows for 16 to 26 years for twelve gauging sites in Godavari Basin Subzone 3f were available for the study. Out of tweleve gauging sites ten gauging sites data are used for the calibration of regional parameters while data for the remaining gauging sites are kept independent for the purpose of testing. Descriptive ability of various methods is tested based on the three numerical measures of goodness of fit described in section 6.3.1. The performance of different methods including modified U.S.G.S. method has been compared with each other.

In the second part of the study, Montecarlo experiments have been conducted, wherein the regional parameters of EV1 and GEV distributions are utilised for generating the respective populations at each gauging site includind thetwo independent gauging sites. The computations are made with the generated data for an independent gauging site taking samples of different sizes viz. 1, 5, 10, 20, 24, 30 and 40 respectively. Similar computations are also repeated for the second independent gauging site . The predictive ability of various methods has been testes based on the numerical criteria such as bias, co-efficient of variation and root mean square error computed from the generated samples of different sizes by considering 1000 replications .The results obtained from the two generated populations using the above mentioned procedures have been compared with an objective of selecting a robust method among various methods considered in the present study.

2.0 REVIEW

Statistical Flood Frequency Analysis has one of the most active areas of research since the last thirty to forty years. However, the questions such as (i) which parent distribution the data may follow ? (ii) what should be the most suitable parameter estimation techniques ? (iii) how to account for sampling variability while identifying the distributions ? (iv) what should be the suitable measures for selecting the best fit distribution? (v) what criteria one should adopt for testing the reginal homogeneity ? and many others remain unresolved. The scope of frequency analysis would have been widened if the parameters of the distribution could have been related with the physical process governing floods. Such relationships, if established ,would have been much useful for studying the effect of non stationarity and man made changes in the physical process on frequency analysis . Unfortunately, this has not been yet possible and the solution of identifying the parent distribution still remains empirical based on the principle of the best fit to the data. However, development of geomorphological Unit Hydrograph seems to be a good effort towards the physically based flood frequency analysis. Inspite of many drawbacks and limitations, the statistical flood frequency analysis remains the most important means of quantifying floods in systematic manner. Keeping this in view, various flood frequency analysis studies carried out in literature have been reviewed before taking up the present study .

Procedures for frequency analysis depends on (i) the amount and type of data used such as at site data, at site/regional data and regional data only without at site data, (ii) type of model, and (iii) form of distribution and estimating procedure used. For the sites having adequate length of records, frequency analysis may be performed either using at site data or at site/regional data . On the other hand , at site data togather with regional data can be utilized to provide most consistent and reliable flood estimates for the gauged sites with limited data records. For ungauged sites, however, only regional data can be used for flood frequency analysis.

As such there are essentially two types of models adopted in flood frequency analysis literature : (i) Annual flood series (AFS) models and (ii) Partial duration series models. Maximum amount of efforts have been made in modelling the annual flood series as compared to the partial duration series. The present study is also based on the annual flood series. Thus the literature review has been restricted to AFS studies only. A large number of peak flow distributions available in literature among them the Normal, Log Normal, Gumbel, Log Gumbel, General Extreme Value, Pearson Type III, Log Pearson Type III and Wakeby distributions have been commonly used in most of the flood frequency studies. For the estimation of the parameters of the various distributions, the method of moments, method of maximum likelihood, method of probability weighted moment, method based on principle of maximum entropy and method of least square are some of the methods which have been most commonly used by many investigators in frequency analysis literature. Once the parameters are estimated accurately for the assumed distrisbution, goodness of fit procedures then test whether or not the data do indeed fit the assumed distribution with a specified degrees of confidence. Different goodness of fit criteria have been adopted by many investigators while selecting the best fit distribution from the various distributions fitted with the historical data. However, most of the goodsness of fit criteria are conventional and found to be in appropriate for selecting a best fit deistribution
which may provide an accurate design flood estimate corresponding to the desired recurrence interval.

Although different forms of distributions estimation procedures and gosodness of fit criteria have been used by many investigators in their at site and regional flood frequency studies, but covering of the review of all the studies is beyond the scope of this report. However, a comprehensive review of various Flood Frequency Studies may be found else-where (Gries, 1983, Potter, 1987 and Seth, 1984-85). Here some of the regional and at site flood frequency studies, Carried out in India as well as abroad and relevant to the present study have been briefly reviewed.

2.1 Review of some Flood Frequency Studies Abroad

Dalrymple (1960) described an index flood technique to carry out regional flood frequency analysis. Benson (1962) pointed out the deficiencies in the U.S.G.S. index-flood method, proposed by Dalrymple (1960), and suggested many modifications in the U.S.G.S. index-flood method. NERC (1975) gave a method for regional flood frequency analysis based on order statistics.

Wallis(1980) recommended the method based on standardized probability weighted moments for regional flood frequency analysis. About General Extreme Value distribution recommended in the British Flood Studies Report, Wallis (1980) feels that its regional application is quite specific for U.K. conditions and therefore studies should be made for GEV distribution for other region also. He concluded that regionally derived flood estimate of the extreme quantiles are preferable to at site estimates. It is true for long records also. Gries and Wood (1981) investigated the use of probability weighted moments (PWM) for improving estimates of flood recurrence quantile events in both gauged and ungauged basins.

Several new regionalisation approaches have been introduced. The most extensive work has focussed on the application of the probability weighted moments in regional flood frequency studies for various distributional choices including the extreme value type 1, 2 and 3 distributions (EV1, EV2, EV3); The generalized extreme value distribution (GEV) and the Wakeby distribution. Various issues involved in regionalization have been investigated by Landwehr et al (1978, 1979a, 1979b, 1979c, 1984),Wallis (1980, 1981, 1982), Gries and Wood (1981, 1983), Kuczera (1983b), Hosking et al (1985a, 1985b), and Lettenmaier and Potter (1985).

Stendinger (1983) proposed an approach for regionalisation based on a log space transformation after taking into consideration some theoretical limitations of the standardization used in Index Foood methods. Kuczera (1983a) proposed regionalizing the parameters of the Box-Cox power transformation, using an empirical Bayes approach. The method accounts explicitly for unequal sample variances and inter site correlation. Rossi et al (1984) developed a regionalisation procedure for two components extreme value distribution in which annual floods are assumed to come from two distinct xtreme Value Type 1 distributions. Performance of these new regionalization techniques have not been tested syet properly.

Inspite of the large number of existing regionalisation techniques, very few studies have been carried out with some what limited scope in order to test their comparative performances. Some of the important comparative studies conducted by many investigators include Lettenmaier and potter (1985), Gries and Wood (1981, 1983), Kuczera (1982), Lettenmaier et al (1987) and Singh (1989).

2.2 Review of Some Flood Frequency Studies in India:

There has been significant number of studies in the area of Regional Flood Frequency Analysis in India. Goswami (1972), Thiru Vengadachari et al (1975), Seth and Goswami (1979), Jhakade et al (1984), Venkataraman and Gupta (1986), Venkataraman et al (1986), Thirumalai and Sinha (1986), Mehta and Sharma (1986), James et al.,Gupta(1987) and many others have conducted regional flood frequency analysis for some typical regions in India. In most of the regional flood frequency studies the conventional methods such as U.S.G.S. Method, regression based methods and Chow's method have been used. Some attempts have been made by Perumal and Seth (1985), Singh and Seth (1985), Huq et al (1986), Seth and Singh (1987) and others to study the applications of new approaches for regional flood frequency analysis of some of the typical regions in India for which the conventional methods have been already applied.

Although there has been large number of application studies using conventional as well as advanced regionalisation techniques, but as such no systematic efforts have been made by any investigator to compare their relative performances for any typical regions in India. In the light of this, a comparative study of some "at site", "at site and regional" and "regional" methods have been taken up in order to examine some of important aspects of at site and regional flood frequency analysis, with and without at site data, which require immediate attention in the Indian context.

3.0 STATEMENT OF THE PROBLEM

The review of literature on at site and regional frequency analysis reveals that the flood estimates obtained from flood frequency analysis using regional and at site data combined together are more consistent and reliable than the at site frequency analysis estimates specially for the short records. Inspite of considerable developments in the area of flood frequency analysis, there is still a lot of controvercy regarding choice of distribution, method of parameter estimation, goodness of fit criterion, regional homogeneity tests, method of regional frequency analysis with and without at site data, and many other aspects of frequency analysis. This study, therefore, has been taken up to examine some of the important issues related with at site and regional flood frequency analysis which require immediate attention. EV1 and GEV distributions, which are widely used in flood frequency analysis, have been considered for the study. Eight methods, involving the applications of EV1 and GEV distributions on (a) at site data, (b) at site and regional data and (c) regional data alone without considering at site data, have been used in the study in order to achieve the following objectives:

(i) to develop/derive regional flood frequency curves/regional parameters using different methods after conducting the regional homogeneity tests.

(ii) to estimate the floods corresponding to different recurrence intervals for twelve bridge catchments of Godavari Basin sub-zone (3f) using the eight different methods.

(iii) to compare the descriptive ability of different methods based on some performance criteria for each gauging site including some independent gauging sites not used in calibration.

(iv) to find out a robust regional frequency method among the methods considered in the study based on the predictive ability criteria given in the form of bias, root mean square error and co-efficient of variation, computed from 1000 samples of different sizes by conducting Monte Carlo Experiments on two different generated populations (Regional EV1 and GEV populations).

4.0 DESCRIPTION OF THE STUDY AREA

The lower Godavari sub-zone (3f) is essentially a sub-humid region having mean annual rainfall varying between 1000 mm to 1600 mm. The sub-zone (3f) covers parts of the areas in the States of Maharashtra, Madhya Pradesh, Andhra Pradesh and Orissa. The sub zone (3f) extends from longitude 76° to 83° east and lattitude 17° to 23° north, and is approximately L-shaped. Fig. 1 shows the location of Godavari basin sub zone (3f) in the map of India.

The extent of sub-zone (3f) showing river systems and bridge sites is illustrated in Fig. 2. The sub-zone (3f) covers an area of 1,74,200 sq.km. comprising of the sub-basins of Muneru, Pan Ganga, Wardha, Wain Ganga, Lower Godavari,Sabari and its tributaries. The Indravathi basin which forms a part of Godavari has not been included in the study. The lower Godavari sub-zone (3f) has a complex relief. Plains of medium heights upto 150 m exist near the main Godavari river in its lower reaches. Higher plains between heights of 150 m to 300 m cover most of the upper reaches. The western part of the sub-zone and north of Nagpur is the zone of the low plateau in the range of 300 m to 600 m. The south east and north west portions of the sub-zone cover high plateaus in the ranges of 600 to 900 m, and there are hills and higher plateaus ranges from 900 to 1350 m in the south eastern part of the sub-zone.

The sub-zone is having a continental type of climate cold in winter and very hot in summer. It receives most of the rainfall from the south west monsoon (June to September). A small portion of the sub-zone on the south east wind gets rain from north east monsoon (November-December) besides short duration thunder storms. The greater part of the sub-zone has an average annual temperature varying from 25°C to 27.5°C. The minimum temperature in the sub-zone varies from 2.5°C to

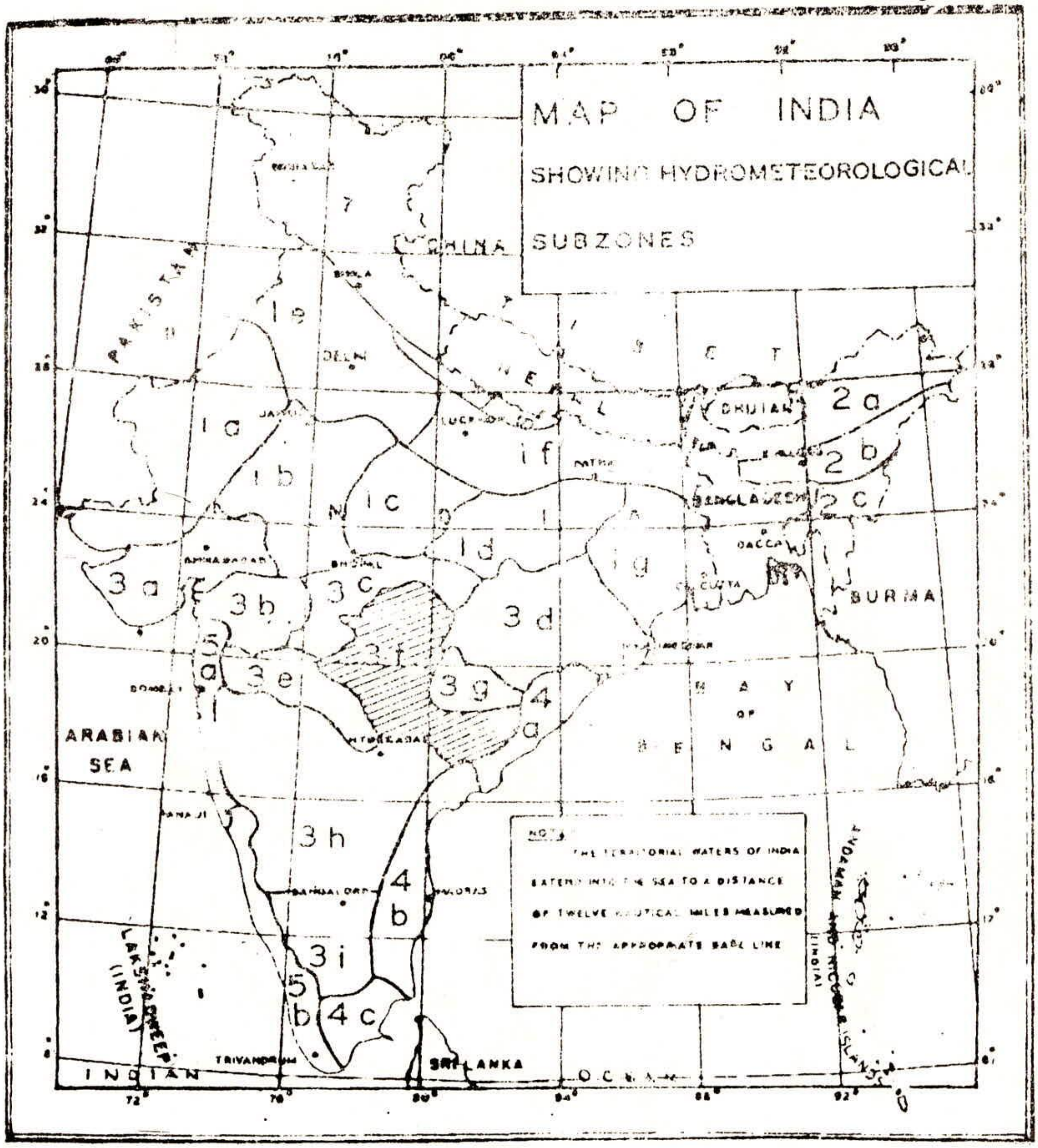

Fig. 1: Location of Godavari Basin Sub-Zone (3f)(CWC,1980)

Fig. 2 - Extent of Godavari Basin Sub-zone (3f)

$12.5^{\circ}C$. The maximum temperature recorded varies from $45^{\circ}C$ to $47.5^{\circ}C$. The minimum temperature is recorded in the month of December and the maximum temperature is recorded in April.

The broad soil groups in the sub-zone are red soils and black soils. The red soils are either classified into red sandy, red loamy and red yellow soils. Black soils are classified as deep black, medium black and shallow black soils. The black soils are clayey in texture and are derived from trap rocks. The texture of the red soils vary considerably from place to place and are derived from all types of rocks. Sandy textures predominates the red soil groups. The soil type may vary considerably from catchment to catchment. More than 50% of the area is covered by forest and only 25% of the area is arable land.

5.0 DATA AVAILABILITY FOR THE STUDY

The annual peak flood series data for 16 to 26 years varying over the period 1959 to 1984 for twelve gauging sites of this zone are available for the study. The drainage areas of these sites vary between 14.50 sq.km. to 824 sq.km. The available data of annual peak flood series of each of the twelve gauging sites have been extracted from Venkatraman et al. (1986). The description about the 12 gauging sites regarding catchment area, length of record, and period of record, for which data are available is given below:

Sl. No.	Bridge No.	Catchment Area (sq.km.)	Record Length	Record Period
1.	912/1	137.00	26	1959-1984
2.	973/1	341.00	26	1959-1984
3.	807/2	824.00	19	1966-1984
4.	214	35.00	18	1964-1966, 1968-1969 1972-1984
5.	801	233.00	16	1969-1984
6.	4	50.50	23	1962-1984
7.	59TT	65.40	24	1959-1964, 1967-1984
8.	57	162.26	22	1959, 1961-1964, 1968-1984
9.	20	60.00	24	1961-1984
10.	51	87.00	20	1965-1984
11.	149	14.50	24	1961-1984
12.	184	364.00	24	1959, 1961-1965, 1967-1969, 1971-1984

6.0 METHODOLOGY

6.1 Methods for flood frequency Analysis

Methods used in the study to carry out Flood Frequency Analysis involved the fitting of Extreme Value Type -I (EV1) and General Extreme Value Distributions (GEV).

6.1.1 Extreme Value Type-I Distribution (EV1)

This is a two parameter distribution and it is popularly known as Gumbel Distribution. The cummulative density function for EV1 distribution is given by:

$$F(x) = e^{-e^{\frac{-(x-u)}{\alpha}}} \tag{1}$$

where, F(x) is the probability of non exceedence and equal to $1-1/T$; T is the recurrence interval in years,u and α are the location and shape parameters respectively. These parameters can be estimated from the sample of annual maximum peak floods using the parameters estimation techiniques available in literature. Method of probability weighted moments (PWM) is one of the parameter estimation techniques which has been successfully applied by Landerwehr et al.(1979) for estimating the parametres of EV1 distribution more efficiently with less bias. The method of probability weighted moments which has been discussed in subsquent section was ,therefore, used for estimating the EV1 distribution parameters.

6.1.2 General Extreme Value Distribution(GEV)

GEV distribution is a generalised three parameter extreme value distribution proposed by Jenkinson (1955). Its theory and practical applications are reviewed in the Flood Studies (NERC,1975). The cummulative density function F(x) for GEV distribution is expressed as:

$$F(x) = e^{-\left(1-\kappa\left(\frac{x-u}{\alpha}\right)\right)^{1/\kappa}} \qquad (2)$$

where u, α and κ are location, scale and shape parameters of GEV distribution respectively. For estimating these parameters , a procedure based on method of probability weighted moments (Singh,1989) which has been described in the subsquent section, is used in the study.

6.1.3 Methods used

Depending upon the amount and type of data available, eight methods have been used for the study. These are classified in three groups: (i) At Site Flood Frequency Methods,(ii) At Site and regional Flood Frequency Methods, and (iii) Regional Flood Frequency Methods without using at site data.

(a) At Site EV1 PWM Method (EV1)

Methods based on probability weighted moments generally require expressing the distribution function in inverse from which is given below for EV1 distribution :

$$x = u - \alpha \ln(-\ln F) \qquad (3)$$

where, u and α as mentioned ealier are the parameters of the distribution.

Follwoing the Landwehr et al. (1979) the rth order probability weighted, M_{10r} is given by the equation:

$$M_{10r} = \frac{1}{n}\sum_{i=1}^{n} x_i\,(1-F_i)^r \qquad (4)$$

where, F_i the probability of non exceedence, is computed using the plotting position formulae :

$$F_i = \frac{i-0.35}{n} \qquad (5)$$

where, i is the rank in the arranged flood series, and n is the sample size.

Putting r =0,1,2,....etc. in equation (2), M_{100}, M_{101}, M_{102}... etc..are computed from the flood series.

The parameters u and α, of EV1 distribution and quantile Q_T are computed by this method following the steps given below:

i) Arrange the flood series and compute M_{100} and M_{101} using equations (4) and (5).

ii) Standardise the computed values of M_{100} and M_{101} obtained from step (i) dividing them by the at site mean, which is same as M_{100}. Hence :

$$m_o = \frac{M_{100}}{M_{100}} = 1.0 \qquad (6)$$

$$m_1 = \frac{M_{101}}{M_{100}} \qquad (7)$$

iii) Estimate the parameters, u and α , using the following equations(Landwehr 1979) :

$$u = m_o - 0.5772\ \alpha \qquad (8)$$

$$\alpha = \frac{m_o - 2\ m_1}{\ln 2} \qquad (9)$$

iv) Estimate the T-year recurrence interval flood using the relation :

$$x_T = u - \alpha\ (\ln - \ln\ (1 - \frac{1}{T})) \qquad (10)$$

v) Scale the quantiles x_T by at site mean in order to give an estimate for the site, Q :

$$Q_T = M_{100}\ x_T \qquad (11)$$

(b) At Site GEV PWM Method (GEV) :

The inverse form of the GEV distribution is :

$$x = u + \alpha\ (1 - (-\ln\ (\ F\ )^{\kappa}\ )/\ \kappa\ ) \qquad (12)$$

where u, α and κ are the location, scale and shape parameters of the distribution.

For κ=o, GEV distribution converges to the EV1 distribution. If $\kappa < 0$ or $\kappa > 0$, it represents the EV2 or EV3 distribution form respectively.

The parameters, u, α and κ, of the distribution and quantile Q_T are estimated using the method of probability weighted moment in the following steps :

i) Arrange the flood series and compute M_{100}, M_{101}, and M_{102} using equations (4) and (5).

ii) Standardise the computed values of M_{100}, M_{101}, and M_{102}, obtained from step (i) dividing them by the at site mean (same as M_{100}). Hence:

$$m_o = \frac{100}{M_{100}} = 1 \tag{13}$$

$$m_1 = \frac{M_{101}}{M_{100}} \tag{14}$$

$$m_2 = \frac{M_{102}}{M_{100}} \tag{15}$$

iii) From normalized values of m_o , m_1 , and m_2 obtain M_{110} and M_{120} using the equations :

$$M_{110} = m_o - m_1 \tag{16}$$

$$M_{120} = m_o - 2\ m_1 + m_2 \tag{17}$$

iv) Calculate a constant C :

$$C = (\ (2\ M_{110} - m_o\ )/\ (3\ M_{120} - m_o\ )\ ) - (\ ln_2/\ ln_3\ ) \tag{18}$$

v) Calculate the shape parameter κ using the relation :

$$\kappa = 7.8590\ C - 2.9554\ C^2 \tag{19}$$

vi) Calculate the scale parameter, α , using the relation:

$$\alpha = ((\ 2\ M_{110} - m_o\ ) * \kappa)\ /\ (\ \text{Gamma}(1+\kappa) * (1.\ -2^{-\kappa}\ )) \qquad (20)$$

vii) Calculate the location parameter, u using the relation :

$$u = m_o + (\alpha\ (\text{Gamma}\ (1+\kappa)\ -1)/\kappa) \qquad (21)$$

where, Gamma $(1+\kappa)$ is the value of Gamma of $(1+\kappa)$ computed from Gamma function subroutine.

viii) Estimate the quantile x_T using the relation:

$$x_T = u + \alpha\ (1 - (-\ln(\ 1 - \frac{1}{T})^{\kappa}\ )/\kappa \qquad (22)$$

ix) Scale the quantiles x_T by the at site mean for the at site estimates of quantiles Q_T for a site:

$$Q_T = x_T * M_{100} \qquad (23)$$

(c) Flood Frequency analysis (FFA) using Modified U.S.G.S. Method based on at site and regional data (SREV1-I) :

Following sequential steps are followed :

i) Test for regional homogeneity for the selected gauged catchments using the procedure described by Dalrymple (1960) and discard those catchments which are not homogenious.

ii) Compute the flood of 2.33, 5, 10, 20 and 50 years using the parameters u and α , estimated by the method of least square for different gauging sites after assigning the probbilites by Gringorton plottig position formula:

$$F_i = \frac{i-0.44}{n+0.12} \qquad (24)$$

iii) Compute the frequency ratios of floods of 5, 10, 20 and 50 years to mean annual flood (2.33 year flood) for each of the gauging sites and workout the median values of the frequency ratios corresponding to each recurrence interval.

iv) Draw the median values of the frequency ratios against the

EV1 reduced variate corresponding to different recurrence intervals. Such curves are known as the regional frequency curves.

v) Estimate the regional frequency ratio corresponding to a recurrence interval using the regional frequency curve for the catchments lying in the region.

vi) Estimate the quantiles Q_T for a particular catchment of the region after multiplying the regional frequency ratio by the at site mean computed from the sample.

(d) FFA Using Modified U.S.G.S. Method bsed on regional data (REV1)

Following sequential steps are followd:

i) Repeat step (i) to step (v) described for FFA using Modified U.S.G.S. Method based on at site and regional data.

ii) Establish the relationship between mean annual flood and catchment characteristics (usually catchment area) at each station.

iii) Estimate the mean annual peak floods for each gauging sites using the relationship established between mean annual peak flood and catchment area.

iv) Estimate the quantile Q_T multiplying the mean annual peak flood obtained from the previous step with the regional frequency ratio.

(e) FFA Using EV1 PWM Method based on at site and regional data SREV1-II):

The steps are:

i) Test for regional homogeneity of data for selected gauged catchments, using either U.S.G.S. homogeneity test or CV based homogeneity test.

ii) Rank the flood series of each gauging site and compute the at site values of PWM, $M_{100,j}$ and $M_{101,j}$ as:

$$M_{100,j} = \frac{1}{n(j)} \sum_{i=1}^{n(j)} x_{i,j} \qquad (25)$$

$$M_{101,j} = \frac{1}{n(j)} \sum_{i=1}^{n(j)} x_{i,j} \quad (1. - F_{i,j}) \tag{26}$$

where, $n(j)$ is the record length for the jth gauging site,

$M_{100,j}$ is the zeroth order probability weighted moment for the jth gauging site (same as the at site mean).

$M_{101,j}$, is the first order probability weighted moment for the jth gauging site.

$F_{i,j}$, is the probablity of non-exceedence and computed by the following plotting position formula:

$$F_{i,j} = \frac{(i - 0.35)}{n(j)} \tag{27}$$

$x_{i,j}$, is the ith rank value in the sample of annual maximum peak series for the jth gauging site.

iii) Standardize the at site values of PWM obtained from the previous step by the at site mean. Thus:

$$m_{o,j} = \frac{M_{100,j}}{M_{100,j}} = 1.0 \tag{28}$$

$$m_{1,j} = \frac{M_{101,j}}{M_{100,j}} \tag{29}$$

where, $m_{o,j}$ is the zeroth order standardized PWM, for jth gauging site , and

$m_{1,j}$ is the first order standardized PWM for jth gauging site.

iv) Compute the regional values of the standardized PWMs averaged across the ns sites in the region in the ratio of the record lengths. Hence:

$$\bar{m}_o = \frac{1}{L} \sum^{ns} m_{o,j} \quad n(j) = 1.0 \tag{30}$$

$$m_1 = \frac{1}{L} \sum_{i=1}^{ns} m_{1,j} \; n(j) \tag{31}$$

where,

$$L = \sum_{j=1}^{ns} n(j) = \text{Total record length} \tag{32}$$

$\bar{m}_o$, and $\bar{m}_1$ are the standardized regional PWMs.

v) Compute the regional EV1 parameters u and α using the relationships:

$$\alpha = \frac{\bar{m}_o - 2\,\bar{m}_1}{\ln 2} \tag{33}$$

$$u = \bar{m}_o - 0.5772\,\alpha \tag{34}$$

vi) Estimate the regional quantiles x_T using the relation:

$$x_T = u + \alpha\,(-\ln(-\ln(1.- \frac{1}{T}))) \tag{35}$$

vii) Scale the quantities x_T by at site mean (same as $M_{100,j}$) to estimate quantiles ($Q_{T,j}$) for each gauging site.Hence:

$$Q_{T,j} = M_{100,j}\; x_T \tag{36}$$

(f) FFA using EV1 PWM Method based on regional data (REV1-II) :

The steps are:

i) Repeat step (i) to (vi) described for FFA using EV1 PWM method based on at site and regional data.

ii) Estimate the mean annual peak floods ($\bar{Q}_j$) for each gauging site using the relationship between the mean annual peak floods and catchment area developed for the region.

iii) Scale the quantities x_T by the mean obtained from the previous step to estimate quantilies $Q_{T,j}$ for each gauging site. Hence:

$$Q_{T,j} = \bar{Q}_j\; x_T \tag{37}$$

(g) FFA Using GEV PWM Method based on at site and regional Data

(SRGEV):

The steps are:

i) Test for regional homogeneity of data for selected gauged catchments using CV based homogeneity test.

ii) Estimate at site values of PWM, $M_{100,j}$, $M_{101,j}$ and $M_{102,j}$, for each gauging site putting r = 0, 1, and 2 in the following equation , respectively :

$$M_{10r,j} = \frac{1}{n(j)} \sum_{i=1}^{n(j)} x_{i,j} \, (1 - F_{i,j})^{r} \tag{38}$$

iii) Standardise the at site values of PWMs obtained from step(ii) by the at site mean :

$$m_{r,j} = \frac{M_{10r,j}}{M_{100,j}} \tag{39}$$

where r = o, 1, and 2 respectively.

iv) Compute the regional values of standardized PWMs averaged across the ns sites in the region in the ratio of record lengths. Hence:

$$\bar{m}_r = \frac{1}{L} \sum_{j=1}^{ns} m_{r,j} \, n(j) \tag{40}$$

v) Estimate the regional parameters, κ, u and α of the GEV distribution using the procedure described for at site GEV PWM method where in place of at site standardized PWMs regional standardized PWMs are used. Thus in place of m_0, m_1, and m_2, $\bar{m}_0$, $\bar{m}_1$, and $\bar{m}_2$ are used in eq. (16) to (21).

vi) Estimate the regional quantiles x_T using the relation :

$$x_T = u + \alpha \left(1 - \left(-\ln\left(1 - \frac{1}{T}\right)\right)^{\kappa}\right)/\kappa \tag{41}$$

vii) Scale the quantiles x_T by at site mean for the estimation of quantiles $Q_{T,j}$ at any gauging site :

$$Q_{T,j} = M_{100,j} \; x_T \tag{42}$$

(h) **FFA Using GEV PWM Method based on regional Data (SRGEV):**

The steps are:-

i) Repeat step (i) to (vi) described for FFA using GEV PWM method based on at site and regional data.

ii) Estimate the mean annual peak floods ($\bar{Q}_j$) for each gauging site using the relationship between the mean annual peak floods and catchment area, developed for the region.

iii) Scale the quantiles x_T by the mean flood obtained from the previous step to estimate quantiles $Q_{T,j}$ for each gauging site. Hence :

$$Q_{T,j} = \bar{Q}_j \, x_T \tag{43}$$

6.2 Homogeneity Tests

In regional frequency analysis, available historical peak flood data of different sites which belong to a hydrologically homogeneous region are required to be grouped for estimating regional parameters. In this study the hydrologic homogeneity of the region was tested using (a) U.S.G.S. Homogeneity test and (b) Coefficient of variation based Homogeneity test. The procedures for the above tests are described below:

6.2.1 U.S.G.S. Homogeneity Test

This test has widely been used for testing homogeneity of a region. The steps involved in U.S.G.S. Homogeneity Test are:

(i) Compute the EV1 reduced variate corresponding to 10 year return period flood using the relation:

$$Y_T = -\ln\left(-\ln\left(1 - \frac{1}{T}\right)\right) \tag{44}$$

for example

$$Y_{10} = -\ln\left(-\ln\left(1 - \frac{1}{10}\right)\right) \tag{45}$$

$$= 2.25$$

(ii) Compute the 10 year flood putting $Y_{10} = 2.25$ in the following equation developed for the different catchments using least square approach :

$$X_{10} = u + \alpha Y_{10} \tag{46}$$

$$= u + 2.25 \alpha \tag{47}$$

(iii) Repeat step (i) and (ii) to compute 2.33 year flood, which is the annual mean flood for EV1 distribution, for the different catchments.

(iv) Compute the ratio of 10 year flood to annual mean flood ($Q_{2.33}$) at each gauging sites. The ratio is known as the 10 year frequency ratio.

(v) Average the 10 year frequency ratios of all the gauging sites to obtain the mean 10 year frequency ratio for the region as a whole.

(vi) Determine the EV1 reduced variate corresponding to the product of annual mean annual flood and the average 10 year frequency ratio from the linear regression equations developed for each catchment . Thus :

$$Y_T = (X_T - u)/\alpha \tag{48}$$

(vii) Plot the EV1 reduced variates obtained from step (vi) against the effective length of records for that station on a test graph where upper and lower regional limits of 95 % confidence are already plotted using the following co-ordinate pairs :

Sample size (n)	Lower Limit (Y)	Upper Limit (Y)
5	-0.59	5.09
10	0.25	4.25
20	0.83	3.67
50	1.35	3.15
100	1.52	2.88
200	1.80	2.70

(viii) If the plotted points for all the gauging sites lie between the 95 % confidence limits , then they are considered to be homogeneous.

6.2.2 Co- efficient of variation Based Homogeneity Test

The coefficient of variation based homogeneity test is performed in the following steps:

(i) Compute the coefficient of variation, CV_j, from sample of annual maximum flood peaks of each gauging site.

(ii) Compute the sampling variation of CV_j using the equation:

$$U_j = V/n_j \tag{49}$$

where U_j = the sampling variation of CV_j for each site

V = the regional variance of CV and is taken as 1/12, and

n_j = the record length at each site

(iii) Compute weighted regional average value of $\overline{CV}$ given by:

$$\overline{CV} = \frac{\sum_{j=1}^{ns} CV_j / U_j}{\sum_{j=1}^{ns} 1/U_j} \tag{50}$$

where, ns = no. of gauging sites.

(iv) Compute S -Statistic which expresses the total variation in CV within a region of ns sites using the equation :

$$S = \sum_{j=1}^{ns} \frac{(CV_j - \overline{CV})^2}{U_j} \tag{51}$$

(v) The statistic S has the form of a ψ^2 statistic and is expected to be distributed as ψ^2 with (ns-1) degrees of freedom. Note down the critical value of ψ^2 for (ns-1) degrees of freedom for a particular level of significance from Chi-square table.

(vi) Compare the computed statistic S with the critical value of chi-square obtained at step (v). If the value of S exceeds the critical value of chi-square then the hypothesis of a homogeneous region must be rejected otherwise if S is less, then the data is considered to be regionally homogeneous and applicable for analysis.

6.3 Evaluation Criteria for Selecting a Suitable Frequency Analysis Method

Evaluation criteria for selecting an appropriate frequency analysis procedure can be divided in to two categories: i) Descriptive ability, and ii) Predictive ability

6.3.1 Descriptive ability

Descriptive ability criteria relate to ability of a chosen model to describe/reproduce chosen aspects of observed flood peak hydrology. The descriptive ability criteria used in the study are :

a) Average of the relative deviations between computed and observed values of annual maximum discharge peak (ADF)

b) Efficiency (EFF)

c) Standard error (SE)

a) Computation of ADF Values:

For computation of ADF values the following relationship is used:

$$ADF = \frac{1}{n} \sum_{i=1}^{n} | QO_i - QC_i | / QO_i \tag{52}$$

b) Computation of EFF values:

EFF values are computed using the relations :

$$EFF = (IV - MV)/IV \tag{53}$$

$$\text{where, } IV = \sum_{i=1}^{n} (QO_i - \bar{Q})^2 \tag{54}$$

$$MV = \sum_{i=1}^{n} (QO_i - QC_i)^2 \tag{55}$$

$\bar{Q}$ = Mean of the observed peak discharge series, QO_i

QC_i = ith values of the computed peak discharge series

n = sample size

c) **Computation of SE values**

SE values are computed, in non dimensional form using the following relationships:

$$SE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (QRO_i - QRC_i)^2} \qquad (56)$$

where, $QRO_i = QO_i$

$QRC_i = QC_i / \overline{Q}$

ii) **Predictive ability criteria:**

Predictive ability criteria relate to statistical ability of procedure to achieve its assigned task, with minimum bias and maximum efficiency and robustness. In the study the following predictive ability criteria are used :

a) Bias
b) Root mean square Error (RMSE)
c) Co-efficient of variation (CV)

a) **Bias**

It is a meausre which indicates the tendency to over estimate or under estimate a given event level corresponding to the population estimate. A positive Bias indicates the over estimation and a negative bias indicates the under estimation. Mathematically, it is expressed as :

$$BIAS = \frac{E(\hat{x}_T) - x_T}{x_T} * 100 \qquad (57)$$

where, $E(\hat{x}_T)$ = mean of the estimates of x_T for a given sample size.

x_T = the population estimate of flood corresponding to

T-year recurrence interval.

b) Root mean square error (RMSE) :

RMSE is a common statistical measure which combines the effects of suggested methodology in fitting the population estimates. It is measured as:

$$\mathrm{RMSE} = \frac{[\{E\ (\hat{x}_T - x_T)\}^2]^{1/2}}{x_T} * 100 \tag{58}$$

c) Co-efficient of variation (CV)

The co-efficient of variation is a measure of the precision of estimation of scatter of the estimate derived from many samples of the same sample size. It is measured as:

$$\mathrm{CV} = \frac{[E\ \{x_T - E\ (\hat{x}_T)\}^2]^{1/2}}{x_T} * 100 \tag{59}$$

7.0 ANALYSIS

Analysis has been carried out with historical as well as generated data as follows:

7.1 Analysis Using Historical Data

The flood frequency analysis involving use of historical data has been performed in the following steps :

(i) Calculate the sample statistics such as mean, standard deviation, co-effiecient of variation and skewness from the available historical records of annual maximum peak flow records of annual maximum peak flood series for the twelve gauging sites.

(ii) Test for homogeneity of data from various gauging stations using the procedures described in Section 6.2.

(iii) Carryout flood frequency analysis using the eight different methods discussed in section 6.1. The regional parameters required for some of the methods are estimated using the historical data of flood peaks for ten gauging sites considered for calibration. The relationship between mean annual flood and catchment area (CA) developed for the region using least square method is: $\bar{Q} = 6.619\ (CA)^{0.76}$ and the correlation coefficient r = 0.85.

(iv) Estimate the floods for different return periods at the two independent gauging sites (the gauging sites not considered for calibration) using the eight different methods . The at site estimates for these two gauging sites are derived from the available annual maximum flood records of the respective gauging sites.

(v) Compute, ADF, EFF and SE values for each catchment by the eight different flood frequency analysis methods using eq.(52) to (56)

(vi) Compute mean values of ADF, EFF and SE values for different methods taking the weighted average of the respective values for each one of the twelve gauging sites .The weight for a gauging site is assigned as the ratio of catchment area for that gauging site with the catchment area for all the gauging sites.

7.2 Analysis Using Generated Data

Simulation study was carried out using the data generated from regional EV1 population and GEV populations through Monte Carlo Experiments.The regional EV1 and GEV population parameters were derived from historical records of the ten gauging sites using SREV1-II and SRGEV methods respectively. The steps followed in the analysis are as given below:

i) Generate NS = 10 (no. of gauging sites) random samples of size n(j), where j = 1...NS using regional EV1 population parameters, derived from historical records of ten gauging sites and at site means. Here no. of gauging sites ,NS,is equal to ten for the study and n(j) is the sample size of the available historical records at the j^{th} gauging sites.

ii) Generate random samples for each independent gauging sites of the size m(j), where j = 1.. NI, using the regional EV1 population parameters (Case-1) and at site means of each independent sites respectively. Initially m(j) =1. Here m(j) is the sample size for the j^{th} independent gauging site and NI= no. of independent gauging sites.

iii) Calculate the sample means:

$$\overline{Q}_j = \sum_{i=1}^{n(j)} x_{i,j} \,/\, n\,(j)\,, \qquad j = 1......NS \tag{60}$$

$$\overline{QI}_j = \sum_{i=1}^{m(j)} x_{i,j} \,/\, m\,(j), \qquad j = 1......NI \tag{61}$$

where, $\overline{Q}_j$ = at site mean for the j^{th} gauging site considered in calibration.

$\overline{QI}_j$ = at site mean for the j^{th} independent gauging site,and

$x_{i,j}$ = i^{th} observation at j^{th} independent gauging site.

iv) Estimate floods corresponding to T =2,10,20,50,100,200,500 and 1000-years recurrence intervals at each independent gauging site by :

a) EV1 method (except for sample size m(j)=1)

b) SREV1-I method

c) REV1-I method wherein the mean annual flood peaks, QI_j, at the j^{th} independent gauging site are obtained from the regional regression model estimate at the required independent site The regression Model generally used is in the following form:

$$\widehat{QI}_j = a\ (CA_j)^b \exp(z) \qquad (62)$$

where, z is an $N(0, Se^2)$ variate where Se^2 is the regression model variance. CA_j is the catchment area up to j^{th} gauging site, a and b are the coefficients to be estimated from the linear regression in the log domain. The noise term z is added in every simulation because individual values of Q, rather than mean values, are being simulated.

d) SREV1-II method

e) REV1-II method using the mean annual flood peaks obtained form eq. for the the respective independent gauging sites.

NOTE : Exclusion of the mean annual flood peaks for some gauging sites from the calibration of eq.(62) makes those gauging sites completely independent of the observed data as would be the case for a completely ungauged catchment.

f) GEV Method (except for sample size m(j)=1)

g) SRGEV method

h) RGEV method using the mean annual flood peaks obtained from the eq.(62) for the respective independent gaugingsites.

v) Store Quantiles ($\hat{Q}_T$, T = 2,10,20,50,100,200,500 and 1000 years) for each independent sites ,obtained from the applications of the eight methods except for EV1 method which is not applicable when sample size m(j)=1 , for subsequent calculation of bias, coefficient of variation and root mean square error estimates.

vi) Repeat steps (i) to (v), 1000 times.

vii) Calculate bias,root mean squareerror and coefficient of variation using the eq. (57) ,(58) and (59) respectively.

viii) Compute weighted mean values of Bias (WBIAS),CV (WCV) and

RMSE (WRMSE) using the following equations:

$$WBIAS = \sum_{i=1}^{nt} \tau_i \, Bias_i \, / \sum_{i=1}^{nt} \tau_i \qquad (63)$$

$$WCV = \sum_{i=1}^{nt} \tau_i \, CV_i \, / \sum_{i=1}^{nt} \tau_i \qquad (64)$$

$$WRMSE = \sum_{i=1}^{nt} \tau_i \, RMSE_i \, / \sum_{i=1}^{nt} \tau_i \qquad (65)$$

where, nt = No. of return periods (nt=8 for the study)

τ_i = i^{th} value of recurrence interval (τ_i =2, 10, 20, 50, 100, 200, 500 and 1000)

$Bias_i$, CV_i and $RMSE_i$ = Bias, Coefficient of variation and RMSE corresponding to τ_i- year recurrence interval.

ix) Repeat step (i) to (viii) using m(j) =5, 10, 20, 24, 30, and 40 respectively for the two independent gauging sites.

x) Repeat step (i) to (ix) with generated samples using regional GEV population parameters (Case-2) in place of the generated samples of the regional EV1 population (Case-1),and at site means for each gauging site.

8.0 DISCUSSION OF RESULTS

The sample statistics computed from the historical flood records of twelve gauging sites are given in Table 1 along with their catchment areas and sample sizes. It is observed from the table that the catchment area for the twelve gauging sites vary from 14.50 to 824 Sq.Km. The sample sizes of the historical flood record for the twelve gauging sites are between 16 to 26 years. The homogeneity of the region has been tested using :(i) U.S.G.S. Homogeneity Test and (ii) Co-efficient of variation based test. THese two tests are performed using the procedures described in Sections 6.2.1 and 6.2.2 respectively. Fig 3 illustrates the homogeneity test graph for U.S.G.S. Homogeneity test for the region. It can be observed from the figure that all twelve gauging sites are within the regional confidence band which indicates the data for all twelve gauging sites are regionally homogeneous. In order to perform the Homogeneity test using Co-efficient of variation based procedure , statistics has been computed and found to be less than the critical value of Ψ^2 at 5 % siginificance level for eleven degrees of freedom. Therefore, the hypothesis of a homogeneous region has been accepted and the data of these twelve gauging sites have been considered to be homogeneous and thus suitable for regional analysis.

The flood estimates for different recurrence intervals obtained by the eight different methods are given in Table 2 for the two test catchments. The table indicates wide range of variatios in flood estimates obtained by different methods specially for higher recurrence intervals. In order to evaluate the descriptive ability of different methods, ADF, EFF and SE values have been computed for each catchment using eq.(52) to (56) and those values are given in Tables 3 to 5 respectively. The mean values of ADF, EFF and SE are also computed for different methods and are given in Table 6. For a few sites the larger values of ADF, and SE ,and low values of EFF are observed from the tables

TABLE 1 :CATCHMENT AREA , SAMPLE STATISTICS AND SAMPLE SIZE

CATCHMENT NO.	CATCHMENT AREA	MEAN	SD	CV	SKEWNESS	SAMPLE SIZE
	(SQ.KM)	(CUMEC)	(CUMEC)			(YEARS)
912/1	137.000	552.769	391.386	0.708	0.854	26
973/1	341.000	462.423	273.028	0.590	0.363	26
807/2	824.000	1372.895	1014.728	0.739	1.149	19
214	35.000	68.889	33.354	0.484	0.994	18
801	233.000	306.875	165.704	0.540	0.285	16
4	50.500	236.522	118.493	0.501	0.481	23
59TTT	65.400	84.792	48.638	0.574	1.752	24
57	162.260	204.000	92.474	0.453	0.502	22
20	60.000	219.708	128.958	0.587	0.177	24
51	87.000	217.550	120.468	0.554	0.605	20
149	14.500	66.417	33.462	0.524	0.272	24
184	364.000	331.458	194.705	0.587	0.934	24

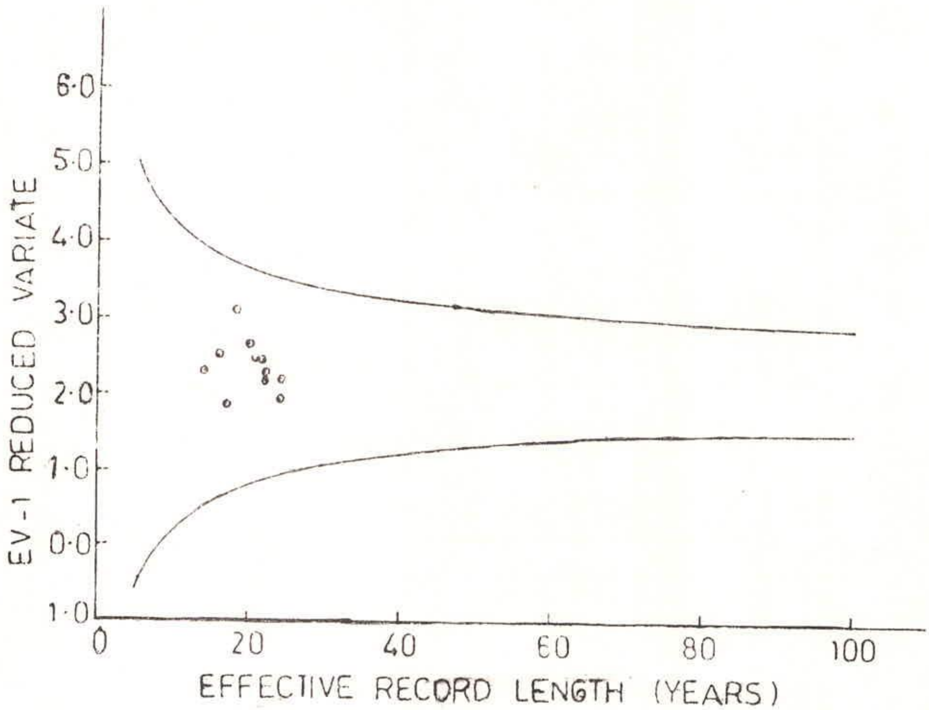

FIG. 3 - HOMOGENEITY TEST GRAPH

TABLE 2 : FLOOD ESTIMATES (CUMEC) FOR DIFFERENT RETURN PERIODS

RETURN PERIOD : (YEARS)	EV1	SREV1-I	SREV1-II	REV1-I	REV1-II	GEV	SRGEV	RGEV
TEST CATCHMENT NO.-1 (BR.NO 149)								
2	60.52	59.86	58.95	33.11	32.60	62.91	59.92	33.14
10	113.28	114.91	112.75	63.55	62.36	112.89	118.42	65.49
20	133.44	135.95	133.31	75.19	73.73	129.26	140.65	77.79
50	159.53	163.18	159.92	90.25	88.45	148.49	169.34	93.66
100	179.09	183.58	179.86	101.53	99.48	161.58	190.77	105.51
200	198.57	203.91	199.73	112.78	110.46	173.60	212.06	117.28
500	224.28	230.73	225.94	127.61	124.96	188.03	240.06	132.77
1000	243.71	251.00	245.75	138.82	135.92	197.95	261.15	144.44
TEST CATCHMENT NO.-2 (BR.NO 184)								
2	298.73	298.73	294.20	492.51	485.04	290.74	299.02	492.98
10	591.40	573.48	562.70	945.47	927.70	590.42	590.97	974.30
20	703.23	678.46	665.30	1118.54	1069.85	715.95	701.94	1157.26
50	847.99	814.34	798.09	1342.57	1315.79	888.26	845.11	1393.30
100	956.46	916.17	897.61	1510.45	1497.85	1025.07	952.05	1569.60
200	1064.54	1017.63	996.76	1677.72	1643.32	1168.30	1058.30	1744.77
500	1207.13	1151.48	1127.57	1898.40	1858.98	1368.44	1198.03	1975.13
1000	1314.89	1255.65	1226.44	2065.18	2021.97	1528.59	1303.29	2148.67

TABLE 3 : ADF VALUES FOR DIFFERENT CATCHMENTS

CATCHMENT NO.	(METHODS)							
	EV1	SREV1-I	SREV1-II	REV1-I	REV1-II	GEV	SRGEV	RGEV
912/1	0.17	0.37	0.31	0.36	0.38	0.17	0.31	0.30
973/1	0.14	0.16	0.15	0.16	0.16	0.15	0.14	0.14
807/2	0.18	0.29	0.25	0.28	0.30	0.16	0.25	0.24
214	0.08	0.10	0.13	0.11	0.10	0.08	0.13	0.13
801	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
4	0.06	0.06	0.08	0.06	0.06	0.05	0.08	0.09
59TTT	0.16	0.18	0.19	0.18	0.17	0.09	0.19	0.19
57	0.07	0.10	0.13	0.10	0.10	0.06	0.13	0.14
20	0.23	0.26	0.24	0.25	0.27	0.23	0.24	0.24
51	0.12	0.11	0.12	0.11	0.12	0.12	0.12	0.12
149	0.10	0.10	0.11	0.10	0.11	0.10	0.11	0.11
184	0.07	0.08	0.09	0.08	0.09	0.09	0.07	0.07

TABLE 4 : EFF VALUES FOR DIFFERENT CATCHMENTS

CATCHMENT NO.	(METHODS)							
	EV1	SREV1-I	SREV1-II	REV1-I	REV1-II	GEV	SRGEV	RGEV
912/1	0.98	0.94	0.96	0.93	0.94	0.98	0.96	0.96
973/1	0.99	0.95	0.93	0.95	0.94	0.95	0.94	0.94
807/2	0.97	0.90	0.94	0.89	0.92	0.96	0.94	0.94
214	0.96	0.94	0.89	0.94	0.93	0.96	0.89	0.89
801	0.92	0.96	0.92	0.96	0.94	0.95	0.92	0.92
4	0.95	0.97	0.91	0.97	0.94	0.97	0.91	0.91
59TTT	0.91	0.90	0.90	0.90	0.92	0.92	0.90	0.90
57	0.95	0.93	0.84	0.93	0.90	0.96	0.84	0.83
20	0.91	0.93	0.91	0.93	0.92	0.95	0.92	0.92
51	0.96	0.98	0.96	0.98	0.97	0.97	0.97	0.96
149	0.93	0.95	0.93	0.95	0.93	0.97	0.89	0.89
184	0.96	0.97	0.96	0.97	0.96	0.95	0.96	0.96

TABLE 5 : SE VALUES FOR DIFFERENT CATCHMENTS

CATCHMENT NO.	(METHODS)							
	EV1	SREV1-I	SREV1-II	REV1-I	REV1-II	GEV	SRGEV	RGEV
912/1	0.10	0.18	0.13	0.18	0.17	0.10	0.13	0.13
973/1	0.16	0.13	0.15	0.13	0.16	0.13	0.15	0.15
807/2	0.13	0.23	0.18	0.23	0.21	0.14	0.18	0.17
214	0.10	0.11	0.16	0.11	0.12	0.10	0.16	0.16
801	0.14	0.11	0.15	0.11	0.13	0.11	0.15	0.15
4	0.11	0.09	0.14	0.09	0.12	0.09	0.14	0.15
59TTT	0.17	0.18	0.17	0.18	0.16	0.16	0.17	0.17
57	0.10	0.12	0.18	0.12	0.11	0.08	0.18	0.18
20	0.17	0.15	0.17	0.15	0.16	0.13	0.17	0.17
51	0.10	0.08	0.11	0.08	0.09	0.09	0.11	0.11
149	0.13	0.11	0.13	0.11	0.13	0.09	0.16	0.16
184	0.11	0.10	0.11	0.10	0.11	0.13	0.11	0.11

TABLE: 6:MEAN VALUES OF ADF,EFF AND SE FOR DIFFERENT CATCHMENTS

S.NO.	METHOD	ADF	EFF	SE
1	EV1	0.126	0.950	0.127
2	SREV1-I	0.160	0.942	0.132
3	SREV1-II	0.159	0.922	0.148
4	REV1-I	0.160	0.942	0.133
5	REV1-II	0.164	0.934	0.140
6	GEV	0.118	0.956	0.113
7	SRGEV	0.158	0.920	0.150
8	RGEV	0.157	0.918	0.151

for some methods. This may be attributed to the assumption regarding the distribution, method of parameter estimation and the regional population as the data of those sites might have come from some other populations rather than the assumed one. It canalso be seen that the mean values of ADF, EFF and SE computed from different methods are quite comparable . It is, therefore, difficult to identify the suitable method for the region as whole based on the computed mean values of ADF, EFF and SE. Neverthless this comparative study may be useful for judging the relative performance of various methods. The flood frequency analysis is usually carried out with an objective of estimating the floods in the extrapolation range .Since the superiority of one method over others could not be established based on the descriptive ability tests, therefore one may not be able to decide which method or methods should be used for computing the floods in extrapolation range, out of the eight methods considered in the study. It leads to carryout the simulation study using all of them and test their predictive ability in order to choose the most robust method for the region. In light of this the simulation study has been conducted using the procedure described in section 7.2.

In the simulation study Monte Carlo Experiments have been performed using the generated data for two different populations. The generated data have been utilised to compute the performance criteria such as Bias,CV and RMSE using the eq.(57),(58) and (59) respectively corresponding to different recurrence intervals for the two test catchments. Tables 7 to 13 provide the estimates of Bias obtained from the different methods for sample sizes of 1, 5, 10, 20, 24, 30 and 40 respectively for Case-1 and Case-2 generated populations. Similar estimates for co-efficient of variation and root mean square errors were also obtained and these are given in Tables 14 to 20 and 21 to 27 respectively. The weighted mean values for Bias (WBIAS), CV (WCV) and RMSE (WRMSE) are also computed using the eq.(63) to (65) respectively . These values are given in Tables 28 to 30 for the different sample sizes.

TABLE 7 :PERCENTAGE BIAS OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT;-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
	(SAMPLE SIZE =1)															
EV1																
CASE-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CASE-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SREV1-I																
CASE-1	-1.0	-2.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
CASE-2	2.0	-2.0	-5.0	-8.0	-10.0	-13.0	-16.0	-19.0	4.0	0.0	-2.0	-6.0	-8.0	-11.0	-14.0	-16.0
SREV1-II																
CASE-1	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASE-2	2.0	-2.0	-5.0	-8.0	-11.0	-13.0	-16.0	-19.0	4.0	0.0	-2.0	-6.0	-8.0	-11.0	-14.0	-17.0
REV1-I																
CASE-1	-4.0	-5.0	-5.0	-6.0	-6.0	-6.0	-6.0	-6.0	122.0	120.0	119.0	119.0	119.0	119.0	118.0	118.0
CASE-2	-1.0	-5.0	-7.0	-10.0	-13.0	-15.0	-18.0	-21.0	130.0	120.0	115.0	108.0	102.0	96.0	89.0	84.0
REV1-II																
CASE-1	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0
CASE-2	-1.0	-5.0	-7.0	-11.0	-13.0	-15.0	-19.0	-21.0	130.0	120.0	115.0	107.0	102.0	96.0	89.0	83.0
GEV																
CASE-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CASE-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SRGEV																
CASE-1	-2.0	-2.0	-1.0	0.0	0.0	1.0	2.0	3.0	-1.0	0.0	1.0	2.0	2.0	3.0	4.0	5.0
CASE-2	-2.0	-3.0	-3.0	-2.0	-2.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	3.0	3.0
RGEV																
CASE-1	-5.0	-5.0	-4.0	-3.0	-3.0	-2.0	-1.0	0.0	120.0	121.0	122.0	124.0	126.0	127.0	130.0	132.0
CASE-2	-5.0	-5.0	-5.0	-5.0	-4.0	-4.0	-3.0	-2.0	120.0	119.0	120.0	121.0	122.0	123.0	125.0	126.0

TABLE 8 :PERCENTAGE BIAS OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
(SAMPLE SIZE =5)																
EV1																
CASE-1	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-2.0	-2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
CASE-2	-5.0	-3.0	-6.0	-9.0	-12.0	-15.0	-18.0	-21.0	6.0	-1.0	-4.0	-7.0	-10.0	-12.0	-16.0	-18.0
SREV1-I																
CASE-1	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASE-2	4.0	0.0	-3.0	-6.0	-8.0	-11.0	-14.0	-17.0	5.0	1.0	-1.0	-5.0	-7.0	-10.0	-13.0	-16.0
SREV1-II																
CASE-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
CASE-2	4.0	0.0	-3.0	-6.0	-9.0	-11.0	-15.0	-17.0	6.0	1.0	-1.0	-5.0	-7.0	-10.0	-13.0	-16.0
REV1-I																
CASE-1	-4.0	-5.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	122.0	120.0	119.0	119.0	119.0	119.0	118.0	118.0
CASE-2	-1.0	-5.0	-7.0	-11.0	-13.0	-15.0	-19.0	-21.0	130.0	121.0	115.0	108.0	102.0	97.0	89.0	84.0
REV1-II																
CASE-1	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0
CASE-2	-1.0	-5.0	-8.0	-11.0	-13.0	-16.0	-19.0	-21.0	130.0	120.0	115.0	107.0	102.0	96.0	89.0	83.0
GEV																
CASE-1	0.0	-3.0	-2.0	0.0	3.0	6.0	13.0	20.0	1.0	-1.0	0.0	2.0	5.0	9.0	17.0	25.0
CASE-2	-2.0	-5.0	-6.0	-4.0	-2.0	2.0	9.0	16.0	3.0	-3.0	-3.0	-2.0	1.0	5.0	13.0	21.0
SRGEV																
CASE-1	-1.0	0.0	0.0	1.0	1.0	2.0	4.0	5.0	0.0	1.0	1.0	2.0	3.0	4.0	5.0	6.0
CASE-2	0.0	-1.0	-1.0	0.0	0.0	1.0	2.0	3.0	1.0	1.0	1.0	1.0	2.0	2.0	3.0	4.0
RGEV																
CASE-1	-5.0	-5.0	-4.0	-4.0	-3.0	-2.0	-1.0	0.0	120.0	121.0	122.0	124.0	126.0	128.0	130.0	133.0
CASE-2	-5.0	-6.0	-5.0	-5.0	-5.0	-4.0	-3.0	-3.0	120.0	119.0	120.0	121.0	122.0	124.0	126.0	127.0

TABLE 9 :PERCENTAGE BIAS OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
	(SAMPLE SIZE =10)															
EV1																
CASE-1	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
CASE-2	4.0	-2.0	-4.0	-1.0	-10.0	-13.0	-16.0	-19.0	4.0	0.0	-3.0	-6.0	-9.0	-11.0	-15.0	-17.0
SREV1-I																
CASE-1	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
CASE-2	4.0	0.0	-3.0	-6.0	-9.0	-11.0	-15.0	-17.0	4.0	0.0	-3.0	-6.0	-8.0	-11.0	-14.0	-17.0
SREV1-II																
CASE-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASE-2	4.0	-1.0	-3.0	-6.0	-9.0	-12.0	-15.0	-17.0	4.0	0.0	-3.0	-6.0	-9.0	-11.0	-15.0	-17.0
REV1-I																
CASE-1	-4.0	-5.0	-5.0	-6.0	-6.0	-6.0	-6.0	-6.0	121.0	120.0	119.0	119.0	119.0	119.0	119.0	119.0
CASE-2	-1.0	-5.0	-7.0	-10.0	-13.0	-15.0	-18.0	-21.0	130.0	121.0	115.0	108.0	103.0	97.0	90.0	84.0
REV1-II																
CASE-1	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0
CASE-2	-1.0	-5.0	-7.0	-11.0	-13.0	-16.0	-19.0	-21.0	130.0	120.0	115.0	107.0	102.0	96.0	89.0	83.0
GEV																
CASE-1	-1.0	-2.0	-1.0	1.0	4.0	7.0	13.0	19.0	-1.0	-1.0	0.0	3.0	6.0	10.0	17.0	24.0
CASE-2	0.0	-4.0	-3.0	-1.0	1.0	5.0	11.0	17.0	0.0	-3.0	-2.0	1.0	4.0	8.0	16.0	24.0
SRGEV																
CASE-1	-1.0	0.0	0.0	1.0	2.0	3.0	4.0	5.0	-1.0	0.0	0.0	1.0	2.0	3.0	4.0	5.0
CASE-2	-1.0	-1.0	-1.0	0.0	0.0	1.0	2.0	2.0	0.0	-1.0	0.0	0.0	1.0	1.0	2.0	3.0
RGEV																
CASE-1	-5.0	-5.0	-4.0	-3.0	-3.0	-2.0	-1.0	0.0	120.0	121.0	122.0	124.0	126.0	128.0	130.0	132.0
CASE-2	-5.0	-5.0	-5.0	-5.0	-4.0	-4.0	-3.0	-3.0	120.0	119.0	120.0	121.0	122.0	123.0	125.0	127.0

TABLE 10: PERCENTAGE BIAS OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
	(SAMPLE SIZE =20)															
EV1																
CASE-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
CASE-2	4.0	0.0	-3.0	-6.0	-9.0	-11.0	-15.0	-17.0	5.0	1.0	-2.0	-5.0	-8.0	-10.0	-14.0	-16.0
SREV1-I																
CASE-1	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	1.0	0.0	0.0	0.0	0.0	0.0	-1.0	-1.0
CASE-2	4.0	0.0	-2.0	-6.0	-8.0	-11.0	-14.0	-17.0	5.0	1.0	-2.0	-5.0	-7.0	-10.0	-13.0	-16.0
SREV1-II																
CASE-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
CASE-2	4.0	0.0	-3.0	-6.0	-9.0	-11.0	-15.0	-17.0	5.0	-1.0	-2.0	-5.0	-8.0	-10.0	-14.0	-16.0
REV1-I																
CASE-1	-4.0	-5.0	-5.0	-6.0	-6.0	-6.0	-6.0	-6.0	122.0	120.0	119.0	119.0	119.0	119.0	119.0	118.0
CASE-2	-1.0	-5.0	-7.0	-10.0	-13.0	-15.0	-18.0	-21.0	130.0	121.0	115.0	108.0	102.0	97.0	89.0	84.0
REV1-II																
CASE-1	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0
CASE-2	-1.0	-5.0	-7.0	-11.0	-13.0	-16.0	-19.0	-21.0	130.0	120.0	115.0	107.0	102.0	96.0	89.0	83.0
GEV																
CASE-1	0.0	-1.0	0.0	1.0	3.0	5.0	9.0	12.0	0.0	0.0	1.0	3.0	5.0	7.0	11.0	15.0
CASE-2	0.0	-2.0	-1.0	0.0	2.0	4.0	8.0	12.0	0.0	-1.0	0.0	2.0	4.0	7.0	12.0	-16.0
SRGEV																
CASE-1	-1.0	0.0	0.0	1.0	2.0	3.0	4.0	5.0	0.0	1.0	1.0	2.0	3.0	4.0	5.0	6.0
CASE-2	0.0	-1.0	0.0	0.0	1.0	1.0	2.0	3.0	1.0	0.0	1.0	1.0	2.0	2.0	3.0	4.0
RGEV																
CASE-1	-5.0	-5.0	-4.0	-3.0	-3.0	-2.0	-1.0	0.0	120.0	121.0	122.0	124.0	126.0	128.0	131.0	133.0
CASE-2	-5.0	-5.0	-5.0	-5.0	-4.0	-4.0	3.0	2.0	120.0	119.0	120.0	121.0	122.0	124.0	126.0	128.0

TABLE 11:PERCENTAGE BIAS OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
(SAMPLE SIZE =24)																
EV1																
CASE-1	0.0	0.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0
CASE-2	4.0	-1.0	-3.0	-7.0	-9.0	-12.0	-15.0	-18.0	5.0	1.0	-2.0	-5.0	-8.0	-10.0	-14.0	-16.0
SREV1-I																
CASE-1	0.0	-1.0	-1.0	-1.0	-1.0	-2.0	-2.0	-2.0	1.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
CASE-2	4.0	0.0	-3.0	-6.0	-9.0	-11.0	-15.0	-17.0	5.0	0.0	-2.0	-5.0	-8.0	-10.0	-14.0	-16.0
SREV1-II																
CASE-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASE-2	4.0	-1.0	-3.0	-6.0	-9.0	-12.0	-15.0	-17.0	5.0	0.0	-2.0	-6.0	-8.0	-11.0	-14.0	-17.0
REV1-I																
CASE-1	-4.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	122.0	119.0	119.0	119.0	118.0	118.0	118.0	116.0
CASE-2	-1.0	-5.0	-11.0	-7.0	-13.0	-15.0	-19.0	-21.0	130.0	120.0	115.0	108.0	102.0	96.0	89.0	83.0
REV1-II																
CASE-1	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0
CASE-2	-1.0	-5.0	-8.0	-11.0	-13.0	-16.0	-19.0	-21.0	130.0	120.0	115.0	107.0	102.0	96.0	89.0	83.0
GEV																
CASE-1	-1.0	-1.0	0.0	1.0	3.0	4.0	7.0	10.0	0.0	0.0	1.0	3.0	4.0	7.0	11.0	14.0
CASE-2	-1.0	-2.0	-2.0	0.0	1.0	3.0	7.0	10.0	0.0	-1.0	0.0	2.0	4.0	6.0	11.0	15.0
SRGEV																
CASE-1	-1.0	0.0	0.0	1.0	2.0	3.0	4.0	5.0	0.0	0.0	1.0	2.0	3.0	3.0	4.0	5.0
CASE-2	-1.0	-1.0	-1.0	0.0	0.0	1.0	2.0	3.0	0.0	0.0	0.0	1.0	1.0	2.0	3.0	3.0
RGEV																
CASE-1	-5.0	-5.0	-4.0	-4.0	-3.0	-2.0	-1.0	0.0	120.0	121.0	122.0	124.0	126.0	127.0	130.0	132.0
CASE-2	-5.0	-6.0	-5.0	-5.0	-5.0	-4.0	-3.0	-3.0	120.0	119.0	120.0	121.0	122.0	123.0	125.0	127.0

TABLE 12:PERCENTAGE BIAS OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
	(SAMPLE SIZE =30)															
EV1																
CASE-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASE-2	-4.0	0.0	-3.0	-6.0	-9.0	-11.0	-14.0	-17.0	4.0	0.0	-2.0	-5.0	-8.0	-11.0	-14.0	-16.0
SREV1-I																
CASE-1	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
CASE-2	4.0	0.0	-2.0	-6.0	-8.0	-11.0	-14.0	-17.0	4.0	0.0	-2.0	-6.0	-8.0	-11.0	-14.0	-16.0
SREV1-II																
CASE-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASE-2	4.0	0.0	-2.0	-6.0	-8.0	-11.0	-14.0	-17.0	5.0	0.0	-2.0	-6.0	-8.0	-11.0	-14.0	-17.0
REV1-I																
CASE-1	-4.0	-5.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	122.0	119.0	119.0	119.0	119.0	118.0	118.0	118.0
CASE-2	-1.0	-5.0	-7.0	-11.0	-13.0	-15.0	-19.0	-21.0	130.0	120.0	115.0	108.0	102.0	96.0	89.0	83.0
REV1-II																
CASE-1	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0
CASE-2	-1.0	-5.0	-7.0	-11.0	-13.0	-16.0	-19.0	-21.0	130.0	120.0	115.0	107.0	102.0	96.0	89.0	83.0
GEV																
CASE-1	0.0	0.0	0.0	1.0	2.0	3.0	5.0	7.0	-1.0	0.0	1.0	2.0	4.0	6.0	9.0	12.0
CASE-2	1.0	-1.0	-1.0	0.0	1.0	2.0	5.0	8.0	0.0	-1.0	0.0	2.0	4.0	6.0	10.0	14.0
SRGEV																
CASE-1	-1.0	0.0	1.0	2.0	2.0	3.0	4.0	5.0	-1.0	0.0	1.0	2.0	2.0	3.0	5.0	5.0
CASE-2	0.0	0.0	0.0	1.0	1.0	2.0	3.0	3.0	0.0	0.0	0.0	1.0	1.0	2.0	3.0	3.0
RGEV																
CASE-1	-5.0	-5.0	-4.0	-4.0	-3.0	-2.0	-1.0	0.0	120.0	121.0	122.0	124.0	126.0	128.0	131.0	133.0
CASE-2	-5.0	-5.0	-5.0	-5.0	-5.0	-4.0	-3.0	-3.0	120.0	119.0	120.0	121.0	122.0	124.0	126.0	127.0

TABLE - 13 :PERCENTAGE BIAS OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
(SAMPLE SIZE =40)																
EV1																
CASE-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASE-2	4.0	0.0	-3.0	-6.0	-9.0	-11.0	-15.0	-17.0	4.0	0.0	-3.0	-6.0	-9.0	-11.0	-15.0	-17.0
SREV1-I																
CASE-1	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
CASE-2	4.0	0.0	-2.0	-6.0	-8.0	-11.0	-14.0	-17.0	4.0	0.0	-3.0	-6.0	-9.0	-11.0	-14.0	-17.0
SREV1-II																
CASE-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASE-2	4.0	0.0	-3.0	-6.0	-8.0	-11.0	-14.0	-17.0	4.0	0.0	-3.0	-6.0	-9.0	-11.0	-15.0	-17.0
REV1-I																
CASE-1	-5.0	-5.0	-5.0	-6.0	-6.0	-6.0	-6.0	-6.0	122.0	119.0	119.0	119.0	118.0	118.0	118.0	118.0
CASE-2	-1.0	-5.0	-7.0	-10.0	-13.0	-15.0	-18.0	-21.0	130.0	120.0	150.0	107.0	102.0	96.0	89.0	83.0
REV1-II																
CASE-1	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0
CASE-2	-1.0	-5.0	-7.0	-11.0	-13.0	-15.0	-19.0	-21.0	130.0	120.0	115.0	107.0	102.0	96.0	89.0	83.0
GEV																
CASE-1	0.0	-1.0	0.0	1.0	1.0	3.0	5.0	6.0	-1.0	-1.0	0.0	1.0	2.0	3.0	5.0	7.0
CASE-2	0.0	-1.0	-1.0	0.0	1.0	2.0	5.0	7.0	0.0	-1.0	-1.0	0.0	1.0	3.0	6.0	8.0
SRGEV																
CASE-1	-1.0	0.0	1.0	2.0	2.0	3.0	5.0	6.0	-1.0	0.0	0.0	1.0	2.0	3.0	4.0	5.0
CASE-2	0.0	0.0	0.0	0.0	1.0	2.0	3.0	4.0	-1.0	-1.0	-1.0	2.1	0.0	1.0	1.0	3.0
RGEV																
CASE-1	-5.0	-5.0	-4.0	-4.0	-3.0	-3.0	-2.0	-1.0	130.0	120.0	121.0	124.0	126.0	127.0	130.0	132.0
CASE-2	-5.0	-5.0	-5.0	-5.0	-4.0	-4.0	-3.0	-2.0	120.0	119.0	120.0	125.0	122.0	123.0	125.0	126.0

TABLE 14 :PERCENTAGE CV OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
	(SAMPLE SIZE =1)															
EV1																
CASE-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CASE-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SREV1-I																
CASE-1	57.9	57.5	57.4	57.4	57.4	57.4	57.3	57.3	59.1	58.9	58.9	58.9	58.9	58.9	58.9	58.9
CASE-2	77.9	74.9	73.1	70.6	68.7	66.8	64.3	62.5	80.4	78.1	76.3	73.8	71.9	69.9	67.4	65.5
SREV1-II																
CASE-1	57.9	57.8	57.8	57.8	57.8	57.8	57.9	57.9	59.0	59.2	59.2	59.3	59.3	59.3	59.3	59.3
CASE-2	78.0	74.7	72.9	70.4	68.5	66.6	64.1	62.2	80.6	77.6	75.7	73.1	71.1	69.2	66.6	64.7
REV1-I																
CASE-1	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	166.1	165.0	164.9	164.8	64.7	164.7	164.6	164.6
CASE-2	74.3	71.9	70.2	67.9	66.1	64.3	62.0	60.0	172.2	165.6	161.6	156.1	152.0	147.8	142.3	138.2
REV1-II																
CASE-1	71.7	71.8	71.8	71.8	71.8	71.9	71.9	71.9	165.9	166.3	166.4	166.5	166.5	166.6	166.6	166.7
CASE-2	74.5	71.5	67.4	69.8	65.5	63.7	61.4	59.6	172.4	165.5	161.4	155.9	151.7	147.5	142.0	137.9
GEV																
CASE-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CASE-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SRGEV																
CASE-1	57.5	57.8	58.8	58.1	59.4	60.0	61.1	62.0	58.5	59.1	59.6	60.5	61.3	62.2	63.6	64.7
CASE-2	74.7	74.4	75.3	74.9	75.9	76.7	77.9	79.0	76.9	77.2	77.7	78.7	79.6	80.7	82.5	84.1
RGEV																
CASE-1	71.1	71.1	72.3	73.2	74.0	74.9	76.2	77.4	165.1	166.2	167.1	168.5	169.9	171.4	173.8	175.8
CASE-2	71.2	71.2	71.6	72.3	73.0	73.9	75.3	76.5	165.5	164.8	165.2	166.3	167.4	168.8	171.2	173.5

TABLE 15:PERCENTAGE CV OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
	(SAMPLE SIZE =5)															
EV1																
CASE-1	26.9	28.5	29.5	30.6	31.2	31.8	32.4	32.7	27.4	29.2	30.3	31.4	32.1	32.7	33.3	33.7
CASE-2	37.1	36.2	36.1	35.6	35.1	34.5	33.6	32.8	37.9	37.4	37.4	36.9	36.4	35.8	34.9	34.1
SREV1-I																
CASE-1	26.5	26.7	26.8	26.9	26.9	26.9	27.0	27.0	27.1	27.0	27.1	27.1	27.1	27.2	27.2	27.2
CASE-2	36.3	35.4	34.6	33.6	32.7	31.9	30.7	29.9	37.2	36.0	35.2	34.1	33.2	32.3	31.2	30.3
SREV1-II																
CASE-1	26.5	26.8	26.8	26.9	26.9	27.0	27.0	27.0	27.0	27.1	27.2	27.2	27.2	27.3	27.3	27.3
CASE-2	36.3	35.2	34.4	33.2	32.4	31.5	30.3	29.5	37.3	35.8	35.0	33.8	32.9	32.0	30.8	29.4
REV1-I																
CASE-1	71.9	70.9	70.7	70.6	70.5	70.5	70.4	70.4	165.9	165.7	165.7	165.7	165.7	165.7	165.8	165.8
CASE-2	74.5	71.2	69.4	67.0	65.2	63.4	61.0	59.3	171.9	166.6	162.8	157.5	153.3	149.2	143.7	139.6
REV1-II																
CASE-1	71.8	71.5	71.4	71.4	71.4	71.4	71.4	71.4	165.8	166.5	166.6	166.8	166.8	166.9	167.0	167.0
CASE-2	74.6	71.1	69.3	66.9	65.1	63.3	60.9	59.1	172.3	165.9	161.9	156.4	152.2	148.0	142.5	138.4
GEV																
CASE-1	28.1	27.7	31.2	38.7	46.9	57.5	76.2	95.1	28.6	28.5	32.2	40.2	48.9	60.2	80.7	101.9
CASE-2	37.2	34.3	38.1	46.6	56.1	68.5	90.9	137.7	38.1	35.6	39.6	48.7	58.6	71.8	96.0	121.2
SRGEV																
CASE-1	26.4	26.7	27.0	27.6	28.2	28.9	30.1	31.1	27.0	27.1	27.3	27.7	28.1	28.7	29.6	30.4
CASE-2	34.8	35.0	35.3	36.0	36.6	37.5	38.9	40.3	36.0	35.7	35.8	36.2	36.6	37.2	38.3	39.3
RGEV																
CASE-1	71.4	71.4	71.7	72.3	72.9	73.6	74.7	75.7	164.3	166.4	167.8	169.9	171.8	173.9	177.1	179.7
CASE-2	71.7	71.8	71.0	71.4	71.9	72.5	73.7	74.8	164.5	165.1	166.1	167.9	169.5	171.5	174.6	177.3

TABLE 16 : PERCENTAGE CV OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
	(SAMPLE SIZE =10)															
EV1																
CASE-1	19.2	20.3	21.1	22.0	22.5	22.9	23.4	23.7	18.8	20.2	21.0	21.9	22.4	22.9	23.3	23.6
CASE-2	26.3	26.1	26.1	25.9	25.5	25.1	24.5	24.0	25.8	25.9	26.0	25.8	25.5	25.1	24.5	24.0
SREV1-I																
CASE-1	18.9	19.0	19.1	19.2	19.2	19.3	19.3	19.4	18.6	18.5	18.6	18.6	18.7	18.7	18.7	18.8
CASE-2	25.7	25.1	24.6	23.8	23.3	22.7	21.9	21.3	25.4	24.4	23.9	23.2	22.6	22.0	21.1	20.6
SREV1-II																
CASE-1	18.9	19.0	19.1	19.2	19.2	19.2	19.3	19.3	18.6	18.5	18.6	18.6	18.6	18.6	18.7	18.7
CASE-2	25.8	24.9	24.3	23.5	22.9	22.3	21.4	21.5	271.2	166.1	166.1	164.9	164.8	164.7	164.6	164.6
REV1-I																
CASE-1	71.8	71.3	71.3	71.2	71.2	71.2	71.2	71.2	166.1	164.9	164.8	164.7	164.6	164.6	164.6	164.5
CASE-2	74.5	71.7	70.0	67.6	65.8	64.0	61.7	59.9	172.0	166.2	162.3	156.9	152.8	148.6	143.2	139.1
REV1-II																
CASE-1	71.7	71.8	71.9	71.9	71.9	71.9	72.0	72.0	166.0	165.9	165.9	166.0	166.0	166.0	166.0	166.0
CASE-2	74.5	71.5	69.7	67.4	65.5	63.7	61.4	59.6	172.4	165.3	161.2	155.7	151.5	147.3	141.8	137.7
GEV																
CASE-1	20.2	19.9	22.9	29.1	35.5	43.6	57.4	70.9	20.5	19.7	22.7	29.5	36.7	45.8	61.8	77.6
CASE-2	26.5	24.7	28.3	35.8	43.7	53.8	71.4	88.9	26.9	24.4	28.0	36.2	45.1	56.8	77.4	98.5
SRGEV																
CASE-1	18.8	19.0	19.3	19.9	20.5	21.3	22.6	23.7	18.6	18.5	18.8	19.3	19.9	20.6	21.9	23.0
CASE-2	24.8	24.8	25.0	25.7	26.4	27.3	28.8	30.2	24.6	24.2	24.4	24.9	25.5	26.4	27.8	29.2
RGEV																
CASE-1	71.3	71.8	72.2	72.9	73.5	74.3	75.5	76.5	164.8	165.8	166.9	168.8	170.6	172.6	175.7	178.3
CASE-2	71.5	71.2	71.4	71.9	72.5	73.2	74.5	75.6	165.2	164.6	165.2	167.7	168.2	170.1	173.2	175.9

TABLE 17 :PERCENTAGE CV OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
(SAMPLE SIZE =20)																
EV1																
CASE-1	13.6	14.5	15.1	15.8	16.2	16.5	16.9	17.1	13.4	14.6	15.3	15.9	16.3	16.6	17.0	17.2
CASE-2	18.6	18.7	18.8	18.7	18.5	18.2	17.8	17.4	18.4	19.0	19.1	19.0	18.7	18.5	18.0	17.6
SREV1-I																
CASE-1	13.4	13.4	13.4	13.5	13.6	13.6	13.7	13.7	13.3	13.6	13.7	13.8	13.9	14.0	14.1	14.1
CASE-2	18.3	17.6	17.3	16.8	16.4	15.9	15.4	15.0	18.2	18.0	17.7	17.2	16.8	16.4	15.9	15.5
SREV1-II																
CASE-1	13.3	13.4	13.5	13.5	13.5	13.6	13.6	13.6	13.2	13.4	13.5	13.6	13.7	13.7	13.7	13.8
CASE-2	18.3	17.5	17.1	16.6	16.2	15.7	15.2	14.7	18.2	17.1	17.3	16.8	16.4	15.9	15.4	15.0
REV1-I																
CASE-1	71.8	71.1	71.1	71.0	70.9	70.9	70.9	70.9	166.1	165.0	164.9	164.8	164.7	164.7	164.7	164.7
CASE-2	74.4	71.5	69.8	67.4	65.6	63.8	61.5	59.7	172.1	166.0	162.1	156.7	152.6	148.4	143.0	138.9
REV1-II																
CASE-1	71.7	71.7	71.7	71.7	71.7	71.7	71.7	71.7	165.8	166.4	166.5	166.7	166.7	166.8	166.8	166.9
CASE-2	74.5	71.4	69.6	67.2	65.4	63.5	61.2	59.4	172.3	165.7	161.7	156.2	152.0	147.8	142.4	138.2
GEV																
CASE-1	14.4	14.3	16.7	21.6	26.5	32.3	41.6	50.2	14.2	14.4	16.8	21.6	26.6	32.6	42.4	51.5
CASE-2	18.8	17.8	20.9	27.2	33.4	41.1	53.7	65.8	18.6	18.0	21.1	27.4	33.8	41.8	51.1	67.9
SRGEV																
CASE-1	13.5	13.4	13.6	14.3	14.9	15.8	17.3	18.6	13.3	13.4	13.7	14.4	15.2	16.1	17.6	19.0
CASE-2	17.9	17.4	17.7	18.3	19.1	20.1	21.8	23.4	17.8	17.6	17.9	18.6	19.5	20.6	22.4	24.0
RGEV																
CASE-1	71.2	71.6	72.1	72.8	73.5	74.3	75.6	76.7	164.8	166.2	167.4	169.3	171.1	173.2	176.4	179.2
CASE-2	71.5	71.1	73.3	71.9	72.5	73.2	74.6	75.8	165.3	164.9	165.6	167.1	168.7	170.7	174.0	177.2

TABLE 18: PERCENTAGE CV OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -164)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
(SAMPLE SIZE =24)																
EV1																
CASE-1	12.3	13.0	13.5	14.1	14.4	14.7	15.0	15.1	12.4	13.5	14.5	14.8	15.1	15.5	15.8	16.0
CASE-2	16.8	16.8	16.8	16.7	16.5	16.2	15.8	15.5	16.9	17.5	17.7	17.6	17.4	17.2	16.8	16.5
SREV1-I																
CASE-1	12.1	12.4	12.6	12.7	12.8	12.9	13.0	13.0	12.2	12.5	12.7	12.8	12.9	13.0	13.1	13.1
CASE-2	16.5	16.3	16.1	15.7	15.3	15.0	14.5	14.1	16.7	16.6	16.3	15.9	15.6	15.2	14.7	14.3
SREV1-II																
CASE-1	12.1	12.3	12.4	12.5	12.6	12.6	12.7	12.7	12.2	12.4	12.5	12.5	12.6	12.6	12.7	12.7
CASE-2	16.5	16.1	15.8	15.3	15.0	14.6	14.1	13.7	16.7	16.3	15.9	15.4	15.1	14.7	14.2	13.8
REV1-I																
CASE-1	71.9	70.9	70.8	70.7	70.7	70.6	70.6	70.5	166.4	163.6	163.5	163.2	163.0	162.9	162.7	162.7
CASE-2	74.5	71.3	69.6	67.2	65.4	63.6	61.2	59.4	172.5	164.5	160.4	154.8	150.6	146.4	140.9	136.8
REV1-II																
CASE-1	71.8	71.5	71.4	71.4	71.4	71.4	71.4	71.4	166.1	165.2	165.3	165.2	165.1	165.1	165.0	165.0
CASE-2	74.6	71.1	66.9	69.3	65.1	63.3	60.9	59.1	172.7	164.5	160.3	154.7	150.5	146.2	140.7	136.6
GEV																
CASE-1	13.1	12.9	15.0	19.3	23.5	28.5	36.3	43.4	13.3	13.3	15.7	20.6	25.3	30.9	39.8	47.9
CASE-2	17.1	16.1	18.8	24.3	29.8	36.4	47.1	57.1	17.4	16.7	19.8	26.1	32.4	40.0	52.4	64.0
SRGEV																
CASE-1	12.1	12.3	12.7	13.4	14.2	15.2	16.7	18.0	12.2	12.4	12.7	13.5	14.2	15.2	16.7	18.0
CASE-2	16.0	16.0	16.4	17.2	18.1	19.2	21.0	22.6	16.2	16.2	16.5	17.3	18.2	19.3	21.1	22.8
RGEV																
CASE-1	71.4	71.4	71.7	72.4	73.1	73.9	75.2	76.3	165.2	166.1	165.0	167.7	169.3	171.1	173.9	176.3
CASE-2	71.7	70.8	71.0	71.5	72.1	72.9	74.2	75.5	165.7	163.8	165.2	164.2	166.4	168.0	170.7	173.1

TABLE 19 : PERCENTAGE CV OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN				PERIOD				IN		YEARS)					
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
							(SAMPLE SIZE =30)									
EV1																
CASE-1	11.1	12.0	12.4	12.9	13.2	13.5	13.7	13.9	10.8	11.9	12.4	12.9	13.3	13.5	13.8	14.0
CASE-2	15.3	15.5	15.6	15.4	15.2	15.0	14.6	14.3	14.8	14.6	15.7	15.6	15.5	15.2	14.9	14.6
SREV1-I																
CASE-1	11.0	11.3	11.4	11.5	11.6	11.7	11.8	11.8	10.7	11.0	11.1	11.3	11.4	11.5	11.5	11.6
CASE-2	15.1	14.9	14.7	14.3	14.0	13.7	13.3	12.9	14.7	14.5	14.3	14.0	13.7	13.4	12.9	12.6
SREV1-II																
CASE-1	11.0	11.3	11.4	11.5	11.5	11.6	11.7	11.7	10.7	10.9	11.0	11.1	11.1	11.2	11.2	11.3
CASE-2	15.1	14.8	14.4	14.1	13.8	13.4	12.9	12.6	14.7	14.3	14.1	13.7	13.3	13.0	12.5	12.2
REV1-I																
CASE-1	71.9	70.8	70.6	70.5	70.4	70.4	70.3	70.3	166.4	163.8	163.4	163.1	162.9	162.8	162.6	162.6
CASE-2	74.6	71.1	69.3	66.8	65.0	63.2	60.8	59.1	172.5	164.5	160.3	154.7	155.5	146.3	140.8	165.1
REV1-II																
CASE-1	71.8	71.4	71.4	71.3	71.3	71.3	71.3	71.3	166.1	165.4	165.3	165.2	165.2	165.2	165.2	165.1
CASE-2	74.6	71.1	69.3	66.8	65.0	63.2	60.8	59.0	172.6	164.7	160.5	154.9	150.7	146.4	140.9	136.8
GEV																
CASE-1	12.0	11.9	13.6	17.4	21.3	25.9	33.3	40.2	11.5	11.6	13.9	18.6	23.1	28.4	36.8	44.3
CASE-2	15.6	14.8	17.2	22.2	27.5	34.0	45.3	56.5	15.0	14.6	17.6	23.8	29.8	37.1	49.0	60.1
SRGEV																
CASE-1	11.1	11.3	11.6	12.3	13.1	14.1	15.7	17.1	10.8	10.9	11.3	12.1	13.0	14.0	15.7	17.2
CASE-2	14.8	14.7	15.0	15.8	16.8	17.9	19.8	21.6	14.4	14.2	14.6	15.5	16.5	17.7	19.7	21.5
RGEV																
CASE-1	71.7	71.4	71.5	71.8	72.1	72.5	73.1	73.7	164.7	165.3	166.4	168.3	170.0	171.9	174.8	177.3
CASE-2	72.1	70.9	70.7	70.7	70.8	71.0	71.6	72.1	165.2	164.0	164.6	165.9	167.3	169.0	171.8	174.3

TABLE 20:PERCENTAGE CV OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
	(SAMPLE SIZE =40)															
EV1																
CASE-1	9.6	10.2	10.6	11.1	11.3	11.6	11.8	12.0	9.4	10.2	10.7	11.2	11.5	11.7	12.0	12.2
CASE-2	13.1	13.3	13.4	13.3	13.1	12.9	12.6	12.4	12.8	13.4	13.5	13.5	13.3	13.2	12.9	12.6
SREV1-I																
CASE-1	9.5	9.7	9.8	10.0	10.1	10.2	10.3	10.3	9.3	9.5	9.7	9.9	10.0	10.1	10.2	10.2
CASE-2	13.0	12.7	12.5	12.2	12.0	11.7	11.4	11.1	12.7	12.6	12.4	12.2	11.9	11.7	11.3	11.0
SREV1-II																
CASE-1	9.4	9.7	9.8	9.9	10.0	10.0	10.1	10.1	9.2	9.4	9.5	9.7	9.7	9.8	9.8	9.9
CASE-2	12.9	12.6	12.4	12.0	11.8	11.5	11.1	10.8	12.7	12.4	12.2	11.8	11.5	11.3	10.9	10.6
REV1-I																
CASE-1	71.7	71.5	71.4	71.4	71.4	71.4	71.4	71.4	166.8	162.2	161.5	160.9	160.6	160.4	160.1	159.9
CASE-2	74.3	72.0	70.3	68.0	66.2	64.4	62.0	60.3	173.1	162.6	158.2	152.4	148.1	143.9	138.4	134.3
REV1-II																
CASE-1	71.7	71.8	71.9	71.9	71.9	71.9	72.0	72.0	166.3	164.6	164.3	164.1	164.0	163.9	163.8	163.8
CASE-2	74.5	71.6	69.8	67.4	65.6	63.8	61.4	59.7	172.9	163.6	159.3	153.6	149.3	145.1	139.5	135.5
GEV																
CASE-1	10.5	10.1	11.9	15.6	19.1	23.3	29.6	35.1	10.0	10.1	12.1	16.0	19.8	24.1	39.0	37.0
CASE-2	13.7	12.6	15.0	20.0	24.8	30.5	39.5	47.8	13.1	12.6	15.3	20.5	25.6	31.8	41.9	51.6
SRGEV																
CASE-1	9.6	9.7	10.0	10.8	11.6	12.6	14.3	15.7	9.4	9.4	9.8	10.6	11.5	12.6	14.3	15.8
CASE-2	12.9	12.5	12.6	13.6	14.6	15.7	17.7	19.4	12.5	12.3	12.7	13.6	14.6	15.8	17.8	19.6
RGEV																
CASE-1	71.3	71.8	72.2	72.8	73.3	74.1	75.1	76.1	166.5	166.4	164.3	164.5	165.0	165.7	167.0	168.3
CASE-2	71.5	71.3	71.4	71.9	72.3	72.9	73.9	74.9	168.4	163.4	162.5	161.9	161.8	162.1	163.0	164.2

TABLE - 21 : PERCENTAGE RMSE OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
	(SAMPLE SIZE =1)															
EV1																
CASE-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CASE-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SREV1-I																
CASE-1	58.0	58.0	57.0	57.0	57.0	57.0	57.0	57.0	59.0	59.0	59.0	59.0	59.0	59.0	59.0	59.0
CASE-2	78.0	75.0	73.0	71.0	70.0	68.0	66.0	65.0	81.0	78.0	76.0	74.0	72.0	71.0	69.0	67.0
SREV1-II																
CASE-1	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	59.0	59.0	59.0	59.0	59.0	59.0	59.0	59.0
CASE-2	78.0	75.0	73.0	71.0	70.0	68.0	66.0	65.0	81.0	78.0	76.0	74.0	72.0	71.0	69.0	67.0
REV1-I																
CASE-1	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	206.0	204.0	203.0	203.0	203.0	203.0	203.0	203.0
CASE-2	74.0	72.0	71.0	69.0	67.0	66.0	65.0	64.0	216.0	205.0	198.0	190.0	183.0	176.0	168.0	162.0
REV1-II																
CASE-1	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	205.0	206.0	206.0	206.0	206.0	206.0	206.0	206.0
CASE-2	74.0	72.0	70.0	68.0	67.0	66.0	64.0	63.0	216.0	205.0	198.0	189.0	183.0	176.0	167.0	161.0
GEV																
CASE-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CASE-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SRGEV																
CASE-1	58.0	58.0	58.0	59.0	59.0	60.0	61.0	62.0	59.0	59.0	60.0	61.0	61.0	62.0	64.0	65.0
CASE-2	75.0	74.0	75.0	75.0	76.0	77.0	78.0	79.0	77.0	77.0	78.0	79.0	80.0	81.0	83.0	84.0
RGEV																
CASE-1	71.0	72.0	72.0	73.0	74.0	75.0	76.0	77.0	204.0	206.0	207.0	209.0	211.0	213.0	217.0	220.0
CASE-2	71.0	71.0	72.0	72.0	73.0	74.0	75.0	77.0	205.0	203.0	204.0	206.0	207.0	209.0	212.0	215.0

TABLE 22:PERCENTAGE RMSE OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
(SAMPLE SIZE =5)																
EV1																
CASE-1	27.0	28.0	30.0	31.0	31.0	32.0	32.0	33.0	27.0	29.0	30.0	31.0	32.0	33.0	33.0	34.0
CASE-2	37.0	36.0	37.0	37.0	37.0	37.0	38.0	39.0	38.0	37.0	38.0	38.0	38.0	38.0	38.0	39.0
SREV1-I																
CASE-1	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0
CASE-2	36.0	35.0	35.0	34.0	34.0	34.0	34.0	34.0	38.0	36.0	35.0	34.0	34.0	34.0	34.0	34.0
SREV1-II																
CASE-1	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0
CASE-2	37.0	35.0	34.0	34.0	34.0	34.0	34.0	34.0	38.0	36.0	35.0	34.0	34.0	34.0	34.0	34.0
REV1-I																
CASE-1	72.0	71.0	71.0	71.0	71.0	71.0	71.0	71.0	206.0	204.0	204.0	204.0	204.0	204.0	204.0	204.0
CASE-2	75.0	71.0	70.0	68.0	67.0	65.0	64.0	63.0	215.0	206.0	199.0	191.0	184.0	178.0	169.0	163.0
REV1-II																
CASE-1	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	205.0	206.0	206.0	206.0	206.0	206.0	206.0	206.0
CASE-2	75.0	71.0	70.0	68.0	66.0	65.0	64.0	63.0	216.0	205.0	198.0	190.0	183.0	176.0	168.0	161.0
GEV																
CASE-1	28.0	28.0	31.0	39.0	47.0	58.0	77.0	97.0	29.0	29.0	32.0	40.0	49.0	61.0	82.0	105.0
CASE-2	37.0	35.0	39.0	47.0	56.0	69.0	91.0	115.0	38.0	36.0	40.0	49.0	59.0	72.0	97.0	123.0
SRGEV																
CASE-1	26.0	27.0	27.0	28.0	28.0	29.0	30.0	31.0	27.0	27.0	27.0	28.0	28.0	29.0	30.0	31.0
CASE-2	35.0	35.0	35.0	36.0	37.0	38.0	39.0	40.0	36.0	36.0	36.0	36.0	37.0	37.0	38.0	39.0
RGEV																
CASE-1	72.0	72.0	72.0	72.0	73.0	74.0	75.0	76.0	203.0	206.0	208.0	211.0	213.0	216.0	220.0	223.0
CASE-2	72.0	71.0	71.0	72.0	72.0	73.0	74.0	75.0	204.0	204.0	205.0	207.0	209.0	211.0	215.0	218.0

TABLE 23: PERCENTAGE RMSE OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN			PERIOD		IN			YEARS)							
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
(SAMPLE SIZE =10)																
EV1																
CASE-1	19.0	20.0	21.0	22.0	23.0	23.0	23.0	24.0	19.0	20.0	21.0	22.0	22.0	23.0	23.0	24.0
CASE-2	27.0	26.0	26.0	27.0	28.0	28.0	29.0	30.0	26.0	26.0	26.0	27.0	27.0	28.0	29.0	30.0
SREV1-I																
CASE-1	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
CASE-2	26.0	25.0	25.0	25.0	25.0	25.0	26.0	27.0	26.0	24.0	24.0	24.0	24.0	25.0	26.0	27.0
SREV1-II																
CASE-1	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
CASE-2	26.0	25.0	25.0	24.0	25.0	25.0	26.0	27.0	26.0	24.0	24.0	24.0	24.0	24.0	25.0	26.0
REV1-I																
CASE-1	72.0	72.0	71.0	71.0	71.0	71.0	71.0	71.0	206.0	204.0	204.0	203.0	203.0	203.0	203.0	203.0
CASE-2	74.0	72.0	70.0	68.0	67.0	66.0	64.0	63.0	215.0	205.0	199.0	191.0	184.0	177.0	169.0	163.0
REV1-II																
CASE-1	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	206.0	206.0	206.0	206.0	206.0	206.0	206.0	206.0
CASE-2	74.0	72.0	70.0	68.0	67.0	66.0	64.0	63.0	216.0	204.0	198.0	189.0	182.0	176.0	167.0	161.0
GEV																
CASE-1	20.0	20.0	23.0	29.0	36.0	44.0	59.0	73.0	21.0	20.0	23.0	30.0	37.0	47.0	64.0	81.0
CASE-2	27.0	25.0	28.0	36.0	44.0	54.0	72.0	91.0	27.0	25.0	28.0	36.0	45.0	57.0	79.0	101.0
SRGEV																
CASE-1	19.0	19.0	19.0	20.0	21.0	21.0	23.0	24.0	19.0	19.0	19.0	19.0	20.0	21.0	22.0	24.0
CASE-2	25.0	25.0	25.0	26.0	26.0	27.0	29.0	30.0	25.0	24.0	24.0	25.0	26.0	26.0	28.0	29.0
RGEV																
CASE-1	71.0	72.0	72.0	73.0	74.0	74.0	76.0	77.0	204.0	205.0	207.0	210.0	212.0	215.0	219.0	222.0
CASE-2	72.0	71.0	72.0	72.0	73.0	73.0	75.0	76.0	204.0	203.0	204.0	206.0	208.0	210.0	214.0	207.0

TABLE 24:PERCENTAGE RMSE OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
	(SAMPLE SIZE =20)															
EV1																
CASE-1	14.0	14.0	15.0	16.0	16.0	17.0	17.0	17.0	13.0	15.0	15.0	16.0	16.0	17.0	17.0	17.0
CASE-2	19.0	19.0	19.0	20.0	21.0	22.0	23.0	25.0	19.0	19.0	19.0	20.0	20.0	21.0	23.0	24.0
SREV1-I																
CASE-1	13.0	13.0	13.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
CASE-2	19.0	18.0	17.0	18.0	18.0	19.0	21.0	22.0	19.0	18.0	18.0	18.0	18.0	19.0	21.0	22.0
SREV1-II																
CASE-1	13.0	13.0	13.0	14.0	14.0	14.0	14.0	14.0	13.0	13.0	14.0	14.0	14.0	14.0	14.0	14.0
CASE-2	19.0	18.0	17.0	18.0	18.0	19.0	21.0	22.0	19.0	18.0	17.0	18.0	18.0	19.0	21.0	22.0
REV1-I																
CASE-1	72.0	71.0	71.0	71.0	71.0	71.0	71.0	71.0	206.0	204.0	203.0	203.0	203.0	203.0	203.0	203.0
CASE-2	74.0	72.0	70.0	68.0	67.0	66.0	64.0	63.0	215.0	205.0	199.0	190.0	184.0	177.0	169.0	162.0
REV1-II																
CASE-1	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	205.0	206.0	206.0	206.0	206.0	206.0	206.0	206.0
CASE-2	75.0	72.0	70.0	68.0	67.0	65.0	64.0	63.0	216.0	205.0	198.0	190.0	183.0	176.0	168.0	161.0
GEV																
CASE-1	14.0	14.0	17.0	22.0	27.0	33.0	43.0	52.0	14.0	14.0	17.0	22.0	27.0	33.0	44.0	54.0
CASE-2	19.0	18.0	21.0	27.0	33.0	41.0	54.0	67.0	19.0	18.0	21.0	27.0	34.0	42.0	56.0	70.0
SRGEV																
CASE-1	13.0	13.0	14.0	14.0	15.0	16.0	18.0	19.0	13.0	13.0	14.0	15.0	15.0	17.0	18.0	20.0
CASE-2	18.0	17.0	18.0	18.0	19.0	20.0	22.0	24.0	18.0	18.0	18.0	19.0	20.0	21.0	23.0	24.0
RGEV																
CASE-1	71.0	72.0	72.0	73.0	74.0	74.0	76.0	77.0	204.0	206.0	207.0	210.0	213.0	215.0	220.0	223.0
CASE-2	72.0	71.0	71.0	72.0	73.0	73.0	75.0	76.0	204.0	204.0	205.0	206.0	208.0	211.0	215.0	218.0

TABLE 25:PERCENTAGE RMSE OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
	(SAMPLE SIZE =24)															
EV1																
CASE-1	12.0	13.0	14.0	14.0	14.0	15.0	15.0	15.0	12.0	13.0	14.0	15.0	15.0	15.0	16.0	16.0
CASE-2	17.0	17.0	17.0	18.0	19.0	20.0	22.0	23.0	18.0	18.0	18.0	18.0	19.0	20.0	22.0	23.0
SREV1-I																
CASE-1	12.0	12.0	13.0	13.0	13.0	13.0	13.0	13.0	12.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
CASE-2	17.0	16.0	16.0	17.0	18.0	19.0	21.0	22.0	17.0	17.0	17.0	16.0	17.0	18.0	20.0	22.0
SREV1-II																
CASE-1	12.0	12.0	12.0	13.0	13.0	13.0	13.0	13.0	12.0	12.0	12.0	13.0	13.0	13.0	13.0	13.0
CASE-2	17.0	16.0	16.0	17.0	17.0	19.0	20.0	22.0	17.0	16.0	16.0	16.0	17.0	18.0	20.0	21.0
REV1-I																
CASE-1	72.0	71.0	71.0	71.0	71.0	71.0	71.0	71.0	206.0	203.0	202.0	202.0	201.0	201.0	201.0	201.0
CASE-2	75.0	72.0	70.0	68.0	67.0	65.0	64.0	63.0	216.0	204.0	197.0	189.0	182.0	175.0	167.0	160.0
REV1-II																
CASE-1	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	206.0	205.0	205.0	205.0	205.0	205.0	205.0	205.0
CASE-2	75.0	71.0	70.0	68.0	66.0	65.0	64.0	63.0	216.0	204.0	197.0	188.0	182.0	175.0	166.0	160.0
GEV																
CASE-1	13.0	13.0	15.0	19.0	24.0	29.0	37.0	45.0	13.0	13.0	16.0	21.0	26.0	32.0	41.0	50.0
CASE-2	17.0	16.0	19.0	24.0	30.0	37.0	48.0	58.0	17.0	17.0	20.0	26.0	33.0	40.0	54.0	66.0
SRGEV																
CASE-1	12.0	12.0	13.0	13.0	14.0	15.0	17.0	19.0	12.0	12.0	13.0	14.0	14.0	16.0	17.0	19.0
CASE-2	16.0	16.0	16.0	17.0	18.0	19.0	21.0	23.0	16.0	16.0	17.0	17.0	18.0	19.0	21.0	23.0
RGEV																
CASE-1	72.0	72.0	72.0	73.0	73.0	74.0	75.0	76.0	204.0	205.0	206.0	209.0	211.0	213.0	217.0	220.0
CASE-2	72.0	71.0	71.0	72.0	72.0	72.0	74.0	76.0	205.0	203.0	203.0	205.0	206.0	208.0	212.0	214.0

TABLE 26:PERCENTAGE RMSE OF FLOOD ESTIMATES

METHOD	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
(SAMPLE SIZE =30)																
EV1																
CASE-1	11.0	12.0	12.0	13.0	13.0	13.0	14.0	14.0	11.0	12.0	12.0	13.0	13.0	14.0	14.0	14.0
CASE-2	16.0	16.0	16.0	17.0	18.0	19.0	21.0	22.0	15.0	16.0	16.0	17.0	17.0	19.0	20.0	22.0
SREV1-I																
CASE-1	11.0	11.0	11.0	12.0	12.0	12.0	12.0	12.0	11.0	11.0	11.0	11.0	11.0	11.0	12.0	12.0
CASE-2	16.0	15.0	15.0	15.0	16.0	17.0	19.0	21.0	15.0	15.0	15.0	15.0	16.0	17.0	19.0	21.0
SREV1-II																
CASE-1	11.0	11.0	11.0	11.0	12.0	12.0	12.0	12.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
CASE-2	16.0	15.0	15.0	15.0	16.0	17.0	19.0	21.0	15.0	14.0	14.0	15.0	16.0	17.0	19.0	21.0
REV1-I																
CASE-1	72.0	71.0	71.0	71.0	71.0	71.0	71.0	71.0	206.0	203.0	202.0	202.0	201.0	201.0	201.0	201.0
CASE-2	75.0	71.0	70.0	68.0	66.0	65.0	64.0	63.0	216.0	204.0	197.0	188.0	182.0	175.0	167.0	160.0
REV1-II																
CASE-1	72.0	72.0	72.0	71.0	71.0	71.0	71.0	71.0	206.0	205.0	205.0	205.0	205.0	205.0	205.0	205.0
CASE-2	75.0	71.0	70.0	68.0	66.0	65.0	64.0	63.0	216.0	204.0	197.0	188.0	182.0	175.0	166.0	160.0
GEV																
CASE-1	12.0	12.0	14.0	17.0	21.0	26.0	34.0	41.0	11.0	12.0	14.0	19.0	23.0	29.0	38.0	46.0
CASE-2	16.0	15.0	17.0	22.0	27.0	34.0	46.0	57.0	15.0	15.0	18.0	24.0	30.0	38.0	50.0	62.0
SRGEV																
CASE-1	11.0	11.0	12.0	12.0	13.0	15.0	16.0	18.0	11.0	11.0	11.0	12.0	13.0	14.0	16.0	18.0
CASE-2	15.0	15.0	15.0	16.0	17.0	18.0	20.0	22.0	14.0	14.0	15.0	16.0	17.0	18.0	20.0	22.0
RGEV																
CASE-1	72.0	72.0	72.0	72.0	72.0	73.0	73.0	74.0	204.0	205.0	207.0	209.0	212.0	214.0	210.0	221.0
CASE-2	72.0	71.0	71.0	71.0	71.0	71.0	72.0	72.0	204.0	203.0	204.0	205.0	207.0	209.0	213.0	216.0

TABLE - 27 : PERCENTAGE RMSE OF FLOOD ESTIMATES

	TEST CATCHMENT -1 (BRIDGE NO.149)								TEST CATCHMENT:-2 (BRIDGE NO. -184)							
	(RETURN PERIOD IN YEARS)															
METHOD	2	10	20	50	100	200	500	1000	2	10	20	50	100	200	500	1000
(SAMPLE SIZE =40)																
EV1																
CASE-1	10.0	10.0	11.0	11.0	11.0	12.0	12.0	12.0	9.0	10.0	11.0	11.0	11.0	12.0	12.0	12.0
CASE-2	14.0	13.0	14.0	15.0	16.0	17.0	19.0	21.0	13.0	13.0	14.0	15.0	16.0	17.0	19.0	21.0
SREV1-I																
CASE-1	9.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	9.0	10.0	10.0	10.0	10.0	10.0	10.0
CASE-2	14.0	13.0	13.0	13.0	15.0	16.0	18.0	20.0	13.0	13.0	13.0	14.0	15.0	16.0	18.0	20.0
SREV1-II																
CASE-1	9.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	9.0	9.0	10.0	10.0	10.0	10.0	10.0	10.0
CASE-2	14.0	13.0	13.0	13.0	15.0	16.0	18.0	20.0	13.0	12.0	13.0	13.0	15.0	16.0	18.0	20.0
REV1-I																
CASE-1	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	206.0	201.0	201.0	200.0	200.0	199.0	199.0	199.0
CASE-2	74.0	72.0	71.0	69.0	67.0	66.0	65.0	64.0	216.0	202.0	195.0	186.0	180.0	173.0	164.0	158.0
REV1-II																
CASE-1	72.0	72.0	72.0	72.0	72.0	72.0	72.0	72.0	206.0	204.0	204.0	204.0	204.0	204.0	204.0	204.0
CASE-2	74.0	72.0	70.0	68.0	67.0	66.0	64.0	63.0	216.0	203.0	196.0	187.0	181.0	174.0	165.0	159.0
GEV																
CASE-1	11.0	10.0	12.0	16.0	19.0	23.0	30.0	36.0	10.0	10.0	12.0	16.0	20.0	24.0	31.0	38.0
CASE-2	14.0	13.0	15.0	20.0	25.0	31.0	40.0	48.0	13.0	13.0	15.0	21.0	26.0	32.0	42.0	52.0
SRGEV																
CASE-1	10.0	10.0	10.0	11.0	12.0	13.0	15.0	17.0	9.0	9.0	10.0	11.0	12.0	13.0	15.0	16.0
CASE-2	13.0	13.0	13.0	14.0	15.0	16.0	18.0	20.0	13.0	12.0	13.0	14.0	15.0	16.0	18.0	20.0
RGEV																
CASE-1	72.0	72.0	72.0	73.0	73.0	74.0	75.0	76.0	205.0	204.0	205.0	206.0	207.0	209.0	211.0	214.0
CASE-2	72.0	71.0	72.0	72.0	72.0	73.0	74.0	75.0	207.0	202.0	202.0	202.0	203.0	203.0	205.0	207.0

Table 28 WEIGHTED MEAN VALUES OF BIAS OF FLOOD ESTIMATES

		TEST CATCHM.1(BR.149)		TEST CATCHM.2(BR.184)	
S.NO	METHOD	CASE-1	CASE-2	CASE-1	CASE-2
		(SAMPLE SIZE = 1)			
1.	EV1	-	-	-	-
2.	SREV1-I	-3.0	-16.5	-1.0	-14.0
3.	SREV1-II	-2.0	-16.6	0.0	-14.5
4.	REV1-I	-6.0	-18.6	118.2	88.8
5.	REV1-II	-5.0	-18.9	121.0	88.2
6.	GEV	-	-	-	-
7.	SRGEV	2.2	-0.3	4.2	2.7
8.	RGEV	-0.8	-2.7	130.2	125.0
		(SAMPLE SIZE = 5)			
1.	EV1	-1.8	-18.5	1.0	-15.8
2.	SREV1-I	-1.0	-14.5	0.0	-13.5
3.	SREV1-II	0.0	-14.9	1.0	-13.5
4.	REV1-1	-6.0	-18.9	118.0	88.9
5.	REV1-II	-5.0	-19.0	121.0	88.2
6.	GEV	14.8	10.8	19.1	15.1
7.	SRGEV	4.0	2.2	5.2	3.3
8.	RGEV	-0.8	-3.3	130.9	125.9
		(SAMPLE SIZE = 10)			
1.	EV1	-1	-16.3	0.5	-14.9
2.	SREV1-I	-1.0	-14.9	-1.0	-14.5
3.	SREV1-II	0.0	-15.0	0.0	-14.9
4.	REV1-I	-6.0	-18.6	119.0	89.2
5.	REV1-II	-5.0	-19.0	121.0	88.2
6.	GEV	14.5	12.5	18.7	18.1
7.	SRGEV	4.2	1.7	4.2	2.3
8.	RGEV	-0.8	-3.2	130.3	125.5

(SAMPLE SIZE = 20)

1.	EV1	0.0	-14.9	1.0	-13.9
2.	SREV1-I	-1.0	-14.5	0.8	-13.5
3.	SREV1-II	0.0	-14.9	1.0	-13.9
4.	REV1-1	-6.0	-18.6	118.5	88.9
5.	REV1-II	-5.0	-19.0	121.0	88.2
6.	GEV	9.5	9.0	12.0	12.7
7.	SRGEV	4.2	2.3	5.2	3.3
8.	RGEV	-0.8	1.0	131.8	126.4

(SAMPLE SIZE = 24)

1.	EV1	-1.0	-15.5	1.0	-13.9
2.	SREV1-I	-1.9	-14.9	-1.0	-13.9
3.	SREV1-II	0.0	-15.0	0.0	-14.5
4.	REV1-I	-6.0	-18.8	118.0	88.2
5.	REV1-II	-5.0	-19.0	121.0	88.2
6.	GEV	7.8	7.5	11.4	11.8
7.	SRGEV	4.2	2.2	4.3	2.7
8.	RGEV	-0.8	-3.3	130.2	125.5

(SAMPLE SIZE = 30)

1.	EV1	0.0	-14.6	0.0	-14.0
2.	SREV1-I	-1.0	-14.5	-1.0	-14.0
3.	SREV1-II	0.0	-14.5	0.0	-14.5
4.	REV1-I	-6.0	-18.9	118.1	88.2
5.	REV1-II	-5.0	-19.0	121.0	88.2
6.	GEV	5.5	5.8	9.7	11.0
7.	SRGEV	4.2	2.7	4.5	2.7
8.	RGEV	-0.8	-3.3	131.8	125.9

(SAMPLE SIZE = 40)

1.	EV1	0.0	-14.9	0.0	-14.9
2.	SREV1-I	-1.0	-14.5	-1.0	-14.6
3.	SREV1-II	0.0	-14.5	0.0	-14.9
4.	REV1-1	-6.0	-18.6	118.0	88.6
5.	REV1-II	-5.0	-18.9	121.0	88.2
6.	GEV	4.9	5.3	5.5	6.2
7.	SRGEV	5.0	2.2	4.2	2.1
8.	RGEV	-3.2	-3.5	130.0	125.0

TABLE - 29 : WEIGHTED MEAN VALUES OF CV OF FLOOD ESTIMATES

		TEST CATCHM.1(BR.149)		TEST CATCHM.2(BR.184)	
S.NO	METHOD	CASE-1	CASE-2	CASE-1	CASE-2
		(SAMPLE SIZE = 1)			
1.	EV1	-	-	-	-
2.	SREV1-I	57.3	64.2	58.9	67.2
3.	SREV1-II	57.9	63.9	59.3	66.4
4.	REV1-I	71.5	61.7	159.3	141.9
5.	REV1-II	71.9	61.3	166.6	141.7
6.	GEV	-	-	-	-
7.	SRGEV	61.2	78.1	63.8	82.8
8.	RGEV	76.4	75.5	174.1	171.7
		(SAMPLE SIZE = 5)			
1.	EV1	32.3	33.4	33.3	34.7
2.	SREV1-I	27.0	30.7	27.2	31.1
3.	SREV1-II	27.0	30.3	27.3	30.5
4.	REV1-I	70.4	60.9	165.8	143.3
5.	REV1-II	71.4	60.7	167.0	142.2
6.	GEV	80.9	109.4	86.2	102.6
7.	SRGEV	30.3	39.2	29.8	38.5
8.	RGEV	74.9	74.0	177.5	175.1
		(SAMPLE SIZE = 10)			
1.	EV1	23.4	24.4	23.3	24.4
2.	SREV1-I	19.3	21.8	18.7	21.1
3.	SREV1-II	19.3	21.7	18.7	25.2
4.	REV1-I	71.2	61.5	164.6	142.8
5.	REV1-II	72.0	61.2	166.0	141.5
6.	GEV	60.6	75.7	65.6	82.8
7.	SRGEV	22.8	29.1	22.1	28.1
8.	RGEV	75.7	74.7	176.1	173.8
		(SAMPLE SIZE = 20)			
1.	EV1	16.9	17.7	17.0	17.9
2.	SREV1-I	13.7	15.4	14.1	15.9
3.	SREV1-II	13.6	15.1	13.7	15.4
4.	REV1-I	70.9	61.3	164.7	142.6
5.	REV1-II	71.7	61.0	166.8	142.0
6.	GEV	43.4	56.4	44.4	57.0
7.	SRGEV	17.6	22.2	17.9	22.7
8.	RGEV	75.8	74.9	176.9	174.7

Table 29 (contd.)

(SAMPLE SIZE = 24)

1.	EV1	14.9	15.8	15.8	16.7
2.	SREV1-I	13.0	14.4	13.1	14.6
3.	SREV1-II	12.7	14.1	12.7	14.2
4.	REV1-I	70.6	61.0	162.8	140.6
5.	REV1-II	71.4	60.8	165.0	140.4
6.	GEV	37.7	49.3	41.5	54.9
7.	SRGEV	16.9	21.3	16.9	21.5
8.	RGEV	75.4	74.5	174.3	171.2

(SAMPLE SIZE = 30)

1.	EV1	13.7	14.6	13.8	14.8
2.	SREV1-I	11.8	13.2	11.5	12.9
3.	SREV1-II	11.7	12.9	11.2	12.5
4.	REV1-I	70.3	60.7	162.7	155.8
5.	REV1-II	71.3	60.6	165.1	140.6
6.	GEV	34.8	48.0	38.3	51.4
7.	SRGEV	16.0	20.2	16.0	20.1
8.	RGEV	73.2	71.7	175.2	172.3

(SAMPLE SIZE = 40)

1.	EV1	11.8	12.6	12.0	12.8
2.	SREV1-I	10.3	11.3	10.2	11.3
3.	SREV1-II	10.1	11.1	9.8	10.9
4.	REV1-I	71.4	61.9	160.1	138.1
5.	REV1-II	72.0	61.3	163.8	139.2
6.	GEV	30.6	41.2	34.3	44.1
7.	SRGEV	14.6	18.0	14.6	18.2
8.	RGEV	75.3	74.1	167.3	163.5

TABLE - 30 : WEIGHTED MEAN VALUES OF RMSE OF FLOOD ESTIMATES

		TEST CATCH.1(BR.149)		TEST CATCHM.2(BR.184)	
S.NO.	METHOD	CASE-1	CASE-2	CASE-1	CASE-2
		(SAMPLE SIZE = 1)			
1.	EV1	-	-	-	-
2.	SREV1-I	57.0	66.2	59.0	68.6
3.	SREV1-II	58.0	66.2	59.0	68.8
4.	REV1-I	72.0	64.9	203.0	167.6
5.	REV1-II	72.0	64.1	206.0	166.8
6.	GEV	-	-	-	-
7.	SRGEV	61.2	78.2	64.0	83.0
8.	RGEV	76.2	75.7	217.5	212.7
		(SAMPLE SIZE = 5)			
1.	EV1	32.4	38.3	33.4	38.5
2.	SREV1-I	27.0	34.0	27.0	34.0
3.	SREV1-II	27.0	34.4	27.0	34.0
4	REV1-1	71.0	64.0	204.0	168.7
5	REV1-II	72.0	63.9	206.0	167.1
6.	GEV	82.2	97.5	88.3	103.9
7	SRGEV	30.2	39.2	30.2	38.3
8.	RGEV	75.2	74.2	220.3	215.5
		(SAMPLE SIZE = 10)			
1.	EV1	23.5	29.3	23.4	29.2
2.	SREV1-I	19.0	26.3	19.0	26.2
3.	SREV1-II	19.0	26.3	19.0	25.3
4	REV1-1	71.0	64.1	203.0	168.6
5	REV1-II	72.0	64.1	206.0	166.7
6.	GEV	62.2	77.0	68.2	84.5
7	SRGEV	23.1	29.0	22.7	28.1
8.	RGEV	76.1	75.1	219.3	209.1
		(SAMPLE SIZE = 20)			
1.	EV1	16.9	23.7	16.9	23.0
2.	SREV1-I	14.0	21.0	14.0	21.0
3.	SREV1-II	14.0	21.0	14.0	21.0
4	REV1-1	71.0	64.1	203.0	168.0
5	REV1-II	72.0	64.0	206.0	167.1
6.	GEV	44.9	57.1	46.2	59.4
7	SRGEV	18.0	22.5	18.6	23.0
8.	RGEV	76.1	75.1	220.2	215.4

(SAMPLE SIZE = 24)					
1.	EV1	14.9	22.0	15.8	22.0
2.	SREV1-I	13.0	21.0	13.0	20.5
3.	SREV1-II	13.0	20.7	13.0	20.0
4	REV1-1	71.0	64.0	201.1	166.1
5	REV1-II	72.0	63.9	205.0	165.8
6.	GEV	38.8	50.0	43.1	56.4
7	SRGEV	17.5	21.5	17.6	21.5
8.	RGEV	75.2	74.6	217.4	212.0
(SAMPLE SIZE = 30)					
1.	EV1	13.8	21.0	13.9	20.6
2.	SREV1-I	12.0	19.5	11.8	19.5
3.	SREV1-II	12.0	19.5	11.0	19.5
4	REV1-1	71.0	63.9	201.1	166.1
5	REV1-II	71.0	63.9	205.0	165.8
6.	GEV	35.4	48.4	39.6	52.8
7	SRGEV	16.6	20.5	16.6	20.5
8.	RGEV	73.4	71.8	216.3	213.5
(SAMPLE SIZE = 40)					
1.	EV1	11.9	19.5	11.9	19.5
2.	SREV1-I	10.0	18.5	10.0	18.5
3.	SREV1-II	10.0	18.5	10.0	18.5
4	REV1-1	72.0	64.9	199.1	163.8
5	REV1-II	72.0	64.1	204.0	164.8
6.	GEV	31.2	41.5	32.7	51.5
7	SRGEV	15.5	18.5	15.0	18.5
8.	RGEV	75.2	74.2	208.4	204.3

It is seen that all methods in general underestimate the floods (negative values of biasness) for test catchment no.1 (Br.no. 149) taking sample size equal to one. It is also observed that the methos REV1-I and REV1-II have generally larger bias as compared to the other methods. For test catchment no.2 (Br. No. 184), the computed values of Bias using REV1-I, REV1-II and RGEV methods are unusually high. On the other hand ,at site EV1 method estimates the floods for the higher recurrence intervals with larger Bias as compared to the " at site and regional methods (SREV1-I, SREV1-II, and SRGEV)." for the population of Case-2. At site GEV method , however, results in larger bias for both ,Case-1 and Case-2 ,populations. Whenever small generated samples are used to estimate higher recurrence interval floods, the computed bias values are quite high using the at site methods. It indicates that at site flood frequency methods are not capable of providing the reliable estimates of floods in the extraploation range from the samples of the size generally available for the historical flood records in our country. The regional methods without using at site data are rejected as the computed Bias values are unusually high even for the larger sample sizes. Thus the regional methods together with at site data may be preferred for flood frequency analysis. Out of three regional and at site methods(SREV1-I,SREV1-II, and SRGEV), SRGEV method estimates floods with relatively less bias using generated samples for both the populations. The computed values of Biasness using SRGEV method are much lower than that of the other methods even when the samples of size equal to one have been considered. Similar conlusions are also drawn from analysing other samples of different sizes for the two test catchments,except that the minor dicrease in the computed values of Bias are evident with increase in sample size.

The computed values of CV and RMSE are also much higher for "the regional methods without considering at site data "specially for test catchment no.2 in comparison to the other methods. It is seen from the tables 14 to 20 and 29 that the other methods have comparable CV values. Similar observations are also made from the Tables 21 to 27 and 30 regarding the RMSE values. Further it is also observed that the computed values of CV and RMSE by different methods have been considerably reduced with increase in sample sizes except for the regional methods without using at site data,wherein such patterns are missing.

9.0 CONCLUSIONS

The regional flood frequency analysis has been carried out for Godavari Basin Sub Zone (3f) using the eight different methods considering (i) at site data, (ii) at site and regional data together , and (iii) regional data alone without using at site data. From the study the following conclusions are drawn:

(a) The superiority of one method over others could not be established based on the computed values of ADF, EFF and SE .

(b) All eight methods have been considered for simulation study wherein flood frequency analysis were carried out with the samples of different sizes generated using the regional EV1 (PWM) (Case-1) and GEV (PWM) (Case-2) parameters derived from the historical data.

(c) At-site EV1 (pwm) and GEV (PWM) are not applicable for analysing the samples of size one.

(d) All regional methods without considering at site data (REV1-I, REV1-II and RGEV) estimate the floods with larger Bias, CV and RMSE values for both the gauging sites. The values are very much high for Test catchment no. 2. It indicates the unreliability associated with the regional methods without considering the at site data whlie estimating the floods for different recurrence interval. Efforts, therefore, should be made to collect the historical flood records even from indirect sources in order to provide some at site data for regional frequency analysis.

(v) At-site methods generally estimate the floods for higher recurrence intervals with larger Bias from the samples of the size of the historical records generally available in india. Thus at-site methods may not always be able to provide reliable and consistent flood estimates in the extrapolation range which are usually needed for design of medium and majorwater resources structures.

(vi) PWM based at-site and regional GEV method (SRGEV) in general estimates the floods with less bias, and comparable coefficent of variation and root mean square errors for the two test catchments. Thus, out of the eight methods studied SRGEV method may be considered as a robust method for this region. Further more the versatility of SRGEV method is also established for dealing with limited data situations prevalling in India.

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DIRECTOR	....	DR. SATISH CHANDRA
SCIENTISTS	....	R D SINGH RAKESH KUMAR S M SETH
TECHNICAL STAFF	....	P K GARG DIGAMBAR SINGH
OFFICE STAFF	....	T P PANICKER SANDEEP KUMAR