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# Analysis of flood frequency using plotting position methods and Gumbel's method: Vaigai river basin, Southern India

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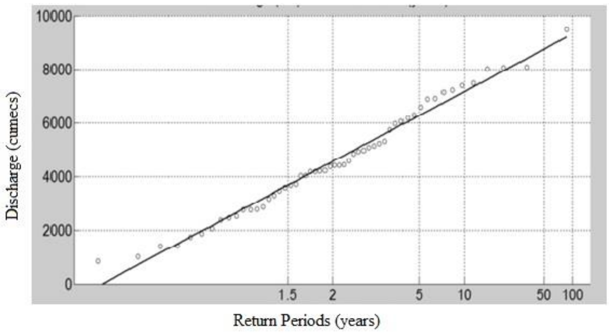
## Graphical abstract




## Abstract

Estimation of annual peak flood flow has considerable financial influence, as this can pave numerous ways for water resources planning, design of hydraulic structures, and sustainable management of these valuable resources at an optimum benefit. Six standard plotting position methods coupled with Linear Log-regression Model (LLM) are employed for the Return Period (RP) of 15, 20, 25, 30, 60, and 1000 years to forecast peak flood flow magnitudes and for this daily annual peak flood flow data for the periods of 24 years were used to illustrate the proposed methods. Another method, Gumbel's Analytical Approach (GAA), is also used to forecast the peak flood flow magnitude for the same RP, and it was taken as the benchmark to compare all the six methods of plotting position. The degree of accuracy of the plotting position is based on the coefficient of determination $R^2$. The $R^2$ values for Adamowski, Hazen, Beard, Chegodajev, Tukey, and Benard, are 0.9073, 0.9284, 0.9119, 0.9111, 0.9135, and 0.9111, respectively. Out of the six-plotting position methods, Hazen method predicted a very closer value in comparison with GAA. It is advantageous to have the additional method to forecast peak flood flow for longer RP. The achieved result assuredly facilitates effective planning, regulation, and maintenance of huge reservoirs across the frequent occurrence of floods in river basin areas, considering safety and particularly downstream inhabited areas to save loss of human life, animals, damages to properties, and an impair of cultivated crops.

**Keywords:** Hydraulic structures, peak flood flow, return period; cultivated crops.

## 1. Introduction

Floods are one of the most severe natural hazards in northern India, causing serious threats to inhabited areas, and it is also rarely occurring in southern India due to encroachment nearer and to the banks of river besides unusual hydrometeorological conditions leads to incessant rain pouring and thus causes floods. Floods are categorised based on causes into river floods, flash floods, dam breakage floods, coastal floods, and urban floods (Kundzewicz *et al.,* 2019; Sen, 2018). In the recent past, the areas that were not vulnerable to flood-prone earlier are becoming flood-prone due to various physical human activities on the land surface, leading to climate change and thus creating an uneven distribution of rainfall and pouring (Yadav *et al.,* 2021). Natural flood management by analytical and empirical concepts plays a vital role, especially in inaccessible areas of the river basin, in reducing flood risk, scope for improvements in societal benefits and environmental quality. The temporary creation of ponds considerably reduces the peak flood flow in the river (Nicholson *et al.,* 2020). Flood Frequency Analysis (FFA) is one of the prime movers for this development (Bloschl, 2006). In this domain, experiments were conducted in homogeneous regions with the aspects of flood regime, defined as geographically neighbouring regions (Merz *et al.,* 2005; Bowling *et al.,* 2000). According to the climatic and catchment physiographic characteristics, mostly these were delineated (Castellarin *et al.,* 2001; Gaal *et al.,* 2008; Kohnova *et al.,* 2006; Pfaundler, 2001; Solin, 2008). Flood seasonality has become more prevalent in recent years for identifying hydrologically homogeneous regions (Lecce, 2000; Ouarda *et al.,* 2006). The seasonality approach finds the way for analysis of mixed flood frequency distributions (Sivapalan *et al.,* 2005). The weather pattern is also linked with floods and has been used during floods (Bardossy *et al.,* 2005; Kysely *et al.,* 2006; Zehe *et al.,* 2006). The basin and climatic characteristics are based on regional flood flow data (Gaume *et al.,* 2010; Grimaldi *et al.,* 2006; Nezhad *et al.,* 2010; Noto *et al.,* 2009; Nyeko Ogiramoi *et al.,* 2012;

Reis Jr *et al.,* 2003). A flood quantile regression technique is more often adopted in regional FFA (Aziz *et al.,* 2015; Haddad and Rahman, 2012; Zaman *et al.,* 2012), another approach to the quantile regression technique parameter regression technique has been adopted in the past (Malekinezhad *et al.,* 2011; Micevski *et al.,* 2015). Comparative studies of both of them are also existing (Taylor, 2011). An acceptable homogeneous region generalized least squares techniques have been adopted in most FFA (Eng *et al.,* 2005; Griffis and Stedinger, 2007; Gruber and Stedinger, 2008). A special lagged model and spatial error model have been adopted to forecast daily or monthly steam flow prediction (Kokkonen *et al.,* 2003). The basin characteristics are realistic in nature of the floods (Bowling *et al.,* 2000; Brath *et al.,* 2006; Creutin and Borga, 2003). The catchment size has a few hundred square kilometres, usually, flood occurs (Norbiato *et al.,* 2008). Hydrological and meteorological frequency analysis have also mainly related to single characteristics value (Brunovsky *et al.,* 2009). The data of extreme events are inventories of extreme flood discharge values (Costa and Jarrett, 2008; Gaume *et al.,* 2009; Herschy, 2005; Pekarova, 2009). Severe floods are based on the sources of information of extraordinary events (Parent *et al.,* 2002).

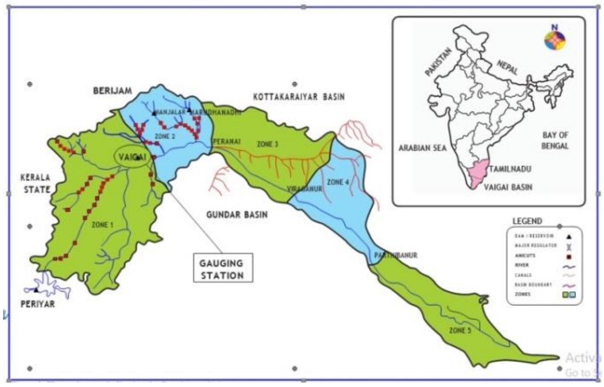



**Figure 1.** The study area (indicating the Gauging station).

Numerous approaches have been adopted in FFA to forecast peak flood flow magnitude (Basu and Srinivas, 2015; Shu and Ouarda, 2008). The variation of the data window certainly plays in assessing uncertainty by applying the ensemble simulation method (Obeysekera and Salas, 2014; Salas *et al.,* 2013). The simplest and easiest procedure is adapting plotting position methods in FFA (Zhang, 1982). Flood is also one natural disaster and causes the highest economic loss compared to another disaster (Baskar and Baskar, 2009). Estimation of return periods of regional floods plays a vital role in water resources management (Pandey and Nguyen, 1999). An accurate estimation of the largest flood event would depend on the use of traditional empirical, deterministic methods and statistical methods (England *et al.,* 2003). In FFA, numerous studies have been conducted to assess the uses of this statistical distribution (Baidya *et al.,* 2020). The RP of the flood is generated as that of the design storm event (Rogger *et al.,* 2012; Viglione *et al.,* 2009). The multivariate flood frequency analysis could also be used to estimate joint probabilities of flood characteristics (Gaal *et al.,* 2016; Grimaldi and Serinaldi, 2006). This article comprises four major sections. Following this introduction. Section 2 elaborately illustrates study area, Linear Log-regression Model and procedure adopted, GAA and concept adopted. Section 3 details the main research findings and comparative analysis of various empirical plotting position methods with GAA. Section 4 offers a conclusion to the study with discern of future research avenues.

## 2. Materials and methods

### *2.1. Study area*

Vaigai river basin is located between latitude 9$^{o}$ 15' to 10$^{o}$ 25'N and longitude 77o 15' to 79$^{o}$ E of southern Tamil Nadu, India, and the landscape of the basin is undulating with an arcuate shape covering 7393 square kilometres of the districts of Ramanathapuram, Sivagangai, Dindigul, Madurai, and Theni. The origin of the river starts at Gandamanaikan Zamin of Western Ghats. It is geographically located at an altitude of 1524 meters from mean sea level on the eastern slope of its origin. The total length of the river from its origin to its merging with the sea is about 258 kilometres. Cauvery and Pambar Kottakaraiyar basins cover the north, while the Gundar basin has southern parts and the Bay of Bengal has western parts of the basin. Figure 1 shows the study area indicating the shape of various hydraulic structures. The major tributary to the river Vaigai is Suriliar and other tributaries are Manjalar, Marudhandhi, Nagalar, Uppar, Varahanadhi, Theniar, Varatar, Sathiar, and Sirumalayar. The behaviour of the tributaries varies from semi-perennial to transient in nature. The rainy season usually starts in the second week of June and ends in December. The non-monsoon exists between the beginning of January and the second week of June. The storage level in the water bodies, as well as the groundwater table, rises during the monsoon season, and during that period, it is found to be hydrologically significant. However, during the non-monsoon season, the rainfall is scanty, and it is insignificant hydrologically during that period. The estimated average annual rainfall is 693.30mm, which consists of 58% contributed during monsoon and 42% from the non-monsoon period. The temperature fluctuates between 23.62$^{o}$C and 34.38$^{o}$C. The recorded relative humidity is 57.55%. The average wind speed and sunshine are estimated as 8.6km/h and 7.5h/day, respectively. The basin consists of deep red, red, black clayey, sandy, Laterite, and alluvial soils. In Cumbum valley and Uthamapalayam, good groundwater potential is available due to favourable soil types and geologically significant features. In the areas of Virattipathu, Achampatti, Alanganallur, Melakkal, and Palamedu, besides eastern parts and western parts up to Mandapam of Ramnad, reasonably good quality of groundwater persists. However, nearer to the coast, due to semi marine deposits, the quality of water is poor, fortunately, excellent quality groundwater is available in the eastern parts of Viraganur regulator, Southern parts of Bodinaickanur, and western parts of Melur.

*2.2. Linear log-regression model*

It can be expressed in the following form, and the various plotting position methods are given below:

$$Y_{p=C1*ln[T]+C2} \quad (1)$$

where: ln is the natural logarithm function, C1 and C2 are constants; $Y_p$-peak flood flow in $m^3/s$; T - Return period or Recurrence interval in years.

Plotting position methods are simple empirical technique and involves a relationship between the magnitude of peak flood flow versus its probability of exceedance, and it is pertaining to the probability value assigned to each of the data to be plotted. Six standard plotting position methods are chosen for the case study, and their relationships are summarised below from equations (2) to (7).

Adamowski method

$$T = \frac{[N+0.5]}{[m-0.25]} \quad (2)$$

Hazen method

$$T = \frac{[N]}{[m-0.5]} \quad (3)$$

Beard Method

$$T = \frac{[N+0.38]}{[m-0.31]} \quad (4)$$

Chegodajev method

$$T = \frac{[N+0.4]}{[m-0.3]} \quad (5)$$

Tukey method

$$T = \frac{\left[N+\frac{1}{3}\right]}{\left[m-\frac{1}{3}\right]} \quad (6)$$

Benard method

$$T = \frac{[N+0.2]}{[m-0.3]} \quad (7)$$

(m -rank of flow N -Number of total years of record)

C1= Co-efficient of slope (It is the ratio of an absolute variation in $Y_p$ and relative variation in T)

$$C1 = \frac{\sum_{i=0}^{n}\left(Yp_{i+1} - Ypi\right)}{\sum_{i=0}^{n}(\ln T_{i+1} - \ln T_i)} \quad (8)$$

C2 = Value of intercept;' Coefficient of determination.

$$R^2 = 1 - \left[\frac{\sum(Y_{pi} - c_1 {*} \ln T_i + c_2)}{\sum\left(Y_{pi} - \overline{Y}_p\right)^2}\right] \quad (9)$$

(n = 1, 2, 3,4…... 24; i = 1, 2, 3,4…...24)

*2.2.1. Linear log-regression model procedure adopted*

If it is plotted the dependent variable ($Y_p$) with actual scale and an independent variable (T) plotted in natural log values, it is termed a linear log-regression model. Whenever the effect of the T on the peak flood flows $Y_p$, the trend declines as the magnitude of the RP becomes rising exponentially, then this model is used. To forecast any given return period of peak flood flow, daily annual peak flood flow from $Y_{pl}$ to $Y_{p24}$ is used in various plotting position methods given in equations from (2) to (7). Figures 2 to 7 shows the plot of $Y_p$ Vs. T on semi-log paper, and from this best-fit average smooth straight line is drawn. The constant C1 is the ratio of summation of the difference of the second highest peak flood flow and the preceding highest peak flood flow, and the same procedure is followed till the last value and divided by the summation of the difference in the natural log of second highest and the preceding highest and continued up to the end. The C2 is the intercept const value obtained from the best fit line drawn. The degree of accuracy is found in equation (9). It is obtained from peak flood flow, separated by constant C1 multiplied by the exceedance probability and added with intercept value summation and divided by the summation of the difference between each peak flood flow value and mean of peak flood flow and its squared values and then obtained value is separated from 1, if this value is 1, then the statistical measure indicates the predicted magnitude likely to be 100% fit the data.

*2.3. Gumbel's analytical approach*

This method can be shown that extremely most frequency functions are applicable to hydrological frequency analysis and which can be following form:

$$Y_{T_r} = \overline{Y} + K\sigma \quad (10)$$

Where $\overline{Y}$ is the average peak flood flow value, and $\sigma$ is the standard deviation of the variable being analysed. The value $Y_{T_r}$ indicates the magnitude of the peak flood flow event reached or exceeded on an average once in $T_r$ years. K is the frequency factor. If Y is not normally distributed, the frequency factor depends on frequency and coefficient of skewness. A generally used distribution of extreme values is the double exponential distribution, and it is widely used by the Gumbel. The frequency factor is estimated by the following form:

$$K = \frac{X_{T_r} - \overline{X_n}}{S_n} \quad (11)$$

Where $\overline{X_n}$ is the reduced mean and $S_n$, the reduced standard deviation, are functions only of the size of the sample; and $X_{T_r}$, the reduced variate, is related to recurrence interval by the following form:

$$X_{T_r} = -\left(0.83405 + 2.30259 \log\log \frac{T_r}{T_r - 1}\right) \quad (12)$$

Table 1 gives the frequency factor K values, computed using equation (11) using the Gumbel's values for $\overline{X}_n$, $S_n$ and $X_{T_r}$.

**Table 1**. Values of (K) based on Equation (11)

| Sample size (N) in years | RP(T)in years | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 25 | 30 | 50 | 60 | 75 | 100 | 1000 |
| 15 | 0.967 | 1.703 | 2.117 | 2.410 | 2.632 | 2.823 | 3.321 | 3.501 | 3.721 | 4.005 | 6.265 |
| 20 | 0.919 | 1.625 | 2.023 | 2.302 | 2.517 | 2.690 | 3.179 | 3.352 | 3.563 | 3.836 | 6.006 |
| 25 | 0.888 | 1.575 | 1.963 | 2.235 | 2.444 | 2.614 | 3.088 | 3.257 | 3.463 | 3.729 | 5.848 |
| 30 | 0.866 | 1.541 | 1.922 | 2.188 | 2.393 | 2.560 | 3.026 | 3.191 | 3.393 | 3.653 | 5.727 |
| 35 | 0.851 | 1.516 | 1.891 | 2.152 | 2.354 | 2.520 | 2.979 | 3.142 | 3.341 | 3.598 | |
| 40 | 0.838 | 1.495 | 1.866 | 2.126 | 2.326 | 2.489 | 2.943 | 3.104 | 3.301 | 3.554 | 5.576 |
| 45 | 0.829 | 1.478 | 1.847 | 2.104 | 2.303 | 2.464 | 2.913 | 3.078 | 3.268 | 3.520 | |
| 50 | 0.820 | 1.466 | 1.831 | 2.086 | 2.283 | 2.443 | 2.889 | 3.048 | 3.241 | 3.491 | 5.478 |
| 55 | 0.813 | 1.455 | 1.818 | 2.071 | 2.267 | 2.426 | 2.869 | 3.027 | 3.219 | 3.467 | |
| 60 | 0.807 | 1.446 | 1.806 | 2.059 | 2.253 | 2.411 | 2.852 | 3.008 | 3.200 | 3.446 | |
| 65 | 0.801 | 1.437 | 1.796 | 2.048 | 2.243 | 2.398 | 2.837 | 2.992 | 3.183 | 3.429 | |
| 70 | 0.797 | 1.430 | 1.788 | 2.038 | 2.230 | 2.387 | 2.824 | 2.979 | 3.169 | 3.413 | 5.359 |
| 75 | 0.792 | 1.423 | 1.780 | 2.029 | 2.220 | 2.377 | 2.812 | 2.967 | 3.155 | 3.400 | |
| 80 | 0.788 | 1.417 | 1.773 | 2.020 | 2.212 | 2.368 | 2.802 | 2.956 | 3.145 | 3.387 | |
| 85 | 0.785 | 1.413 | 1.767 | 2.013 | 2.205 | 2.361 | 2.793 | 2.946 | 3.135 | 3.376 | |
| 90 | 0.782 | 1.409 | 1.762 | 2.007 | 2.198 | 2.353 | 2.785 | 2.938 | 3.125 | 3.367 | |
| 95 | 0.780 | 1.405 | 1.757 | 2.002 | 2.193 | 2.347 | 2.777 | 2.930 | 3.116 | 3.357 | |
| 100 | 0.779 | 1.401 | 1.752 | 1.993 | 2.187 | 2.341 | 2.770 | 2.922 | 3.109 | 3.349 | 2.61 |

**Table 2**. Daily annual peak flood flow and its squared values

| S. No. | Year | Peak flood flow $Y_p$ *100 ($m^3/s$) | Rank (m) | $Q_p^2$*10000 |
|---|---|---|---|---|
| 1 | 1998 | 8.75951891 | 1 | 76.72917153 |
| 2 | 2007 | 4.75184221 | 2 | 22.58000439 |
| 3 | 2009 | 4.5377672 | 3 | 20.59133116 |
| 4 | 2010 | 2.6767871 | 4 | 7.165189179 |
| 5 | 1997 | 2.4989576 | 5 | 6.244789087 |
| 6 | 2008 | 2.45421706 | 6 | 6.023181378 |
| 7 | 2011 | 2.37408051 | 7 | 5.636258268 |
| 8 | 2017 | 2.14641344 | 8 | 4.607090655 |
| 9 | 2018 | 1.83634448 | 9 | 3.372161049 |
| 10 | 1996 | 1.83606131 | 10 | 3.371121134 |
| 11 | 2005 | 1.82416826 | 11 | 3.327589841 |
| 12 | 2001 | 1.78735642 | 12 | 3.194642972 |
| 13 | 2006 | 1.7618713 | 13 | 3.104190478 |
| 14 | 2015 | 1.72789114 | 14 | 2.985607792 |
| 15 | 1999 | 1.35241037 | 15 | 1.829013809 |
| 16 | 2004 | 1.3158817 | 16 | 1.731544648 |
| 17 | 2014 | 1.19808381 | 17 | 1.435404816 |
| 18 | 2000 | 1.03044835 | 18 | 1.061823802 |
| 19 | 2013 | 0.784092192 | 19 | 0.614800566 |
| 20 | 1995 | 0.714716032 | 20 | 0.510819006 |
| 21 | 2012 | 0.67818736 | 21 | 0.459938095 |
| 22 | 2002 | 0.670541824 | 22 | 0.449626338 |
| 23 | 2003 | 0.587290432 | 23 | 0.344910052 |
| 24 | 2016 | 0.158007744 | 24 | 0.024966447 |
| | | Σ $Q_p$*100=49.46293675 | | Σ $Q_p^2$*10000=177.3951765 |

*2.3.1. GAA concept adopted*

From the daily annual peak flood flow data, the arithmetic mean peak flood flow is determined, and the standard deviation is determined by the statistical concept. The frequency factor is determined by the difference between reduced variate and reduced mean and divided by the reduced standard deviation, and equation (11) indicates K is suggested by the Gumblel's (Garg Santosh Kumar, 2015) considering RP and sample size N and $s_n$, for various values of K for T are presented in Table.1. The considered sample size of 24 years by using equation (11) the required K values is interpolated using Table.1; with the use of K values, the desired magnitude is determined for different T by using equation (10).

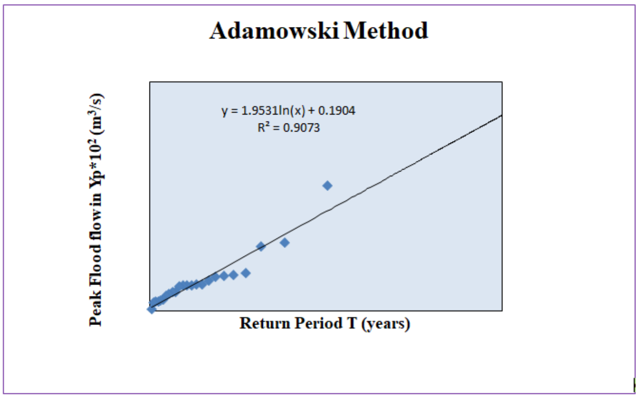



**Figure 2.** Peak flood flow for different RP by Adamowski method

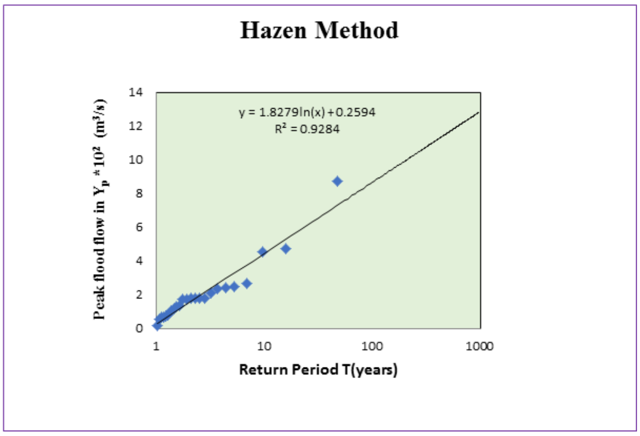



**Figure 3.** Peak flood flow for different RP by Hazen method.

## 3. Results and discussion

Table 1 gives the values of frequency factor K based on equation (11). The various RP values of 15, 20, 25, 30, 60, and 1000 and their corresponding values of K are 1.975, 2.2484, 2.4586, 2.6292,3.276, and 5.8796, respectively, and are obtained by the concept of interpolation from the Table 1. The mean peak flood flow value and standard deviation values are 206.095m$^3$/s and 181.124 m$^3$/s, respectively. The values of exceedance probability, mean of peak flood flow, and squared values of the mean of peak flood flow results are obtained by LLM with a coefficient of determination. The values of $R^2$ for Adamowski, Hazen, Beard, Chegodajev, Tukey, and Benard are 0.9073, 0.9284, 0.9119, 0.9111, 0.9135, and 0.9111. It is obtained by the best-fitted line drawn between peak flows and RP as presented in Figures 2 to 7. In Table 2, peak flood flow and mean square values are presented. In Table 3. to Table 5. an exceedance probability values, and it is based on the results obtained by LLM, the values of various T and its corresponding expected flood discharges are shown for all the chosen six plotting position methods. Out of the six methods in RP 15,20,25,30, all methods approximately predicted the more or less same peak flood flow magnitudes, and in the cases of RP of 60 and 1000 Hazen method produces a high variation compared with the remaining five methods. In the case of Hazen method of plotting position very closely matches with the GAA. The predicted flood discharge linearly increases as the values of RP increase. The incremental increase in the RP values of 15, 20, 25, 30, 60, and 1000 are steady with a uniform rate of increased values obtained in LLM. However, this is still shows that such forecast values are not possible in reality, and the predicted magnitude is certainly 100% veracious, if the $R^2$ value is equal to 1, and the GAA, the weightage of the frequency factor is introduced based on RP and N values. The added advantage of the frequency factor in GAA was taken as the benchmark for the comparison of all the six methods of plotting positions. The RP of 15, 20, 25, and 30, all the plotting position methods, produce approximately closer values than GAA. In the case of RP of 60, Adamowski, Beard, Tukey, and Benard have predicted almost closer values. Still, Hazen method alone is highly correlated with GAA, and it also consistently predicted the closer value for the longer RP of 1000 compared with GAA. Therefore, besides GAA, Hazen method of plotting position is concluded to be the best method for forecasting extreme values of peak flood flow in the future for the desired values of RP. The plotting with the highest $R^2$ value would predict the most accurate peak flood flow for larger return period values.

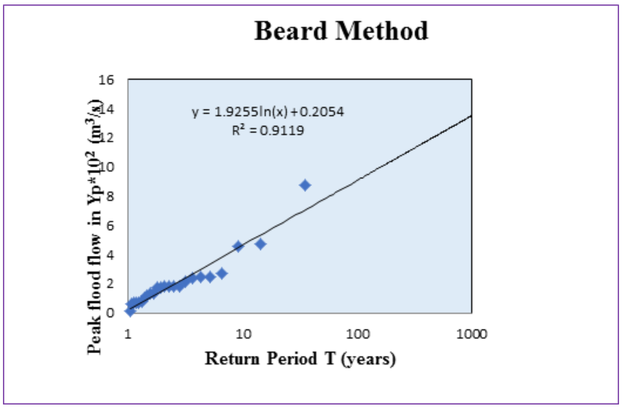



**Figure 4.** Peak flood flow for different RP by Beard method.

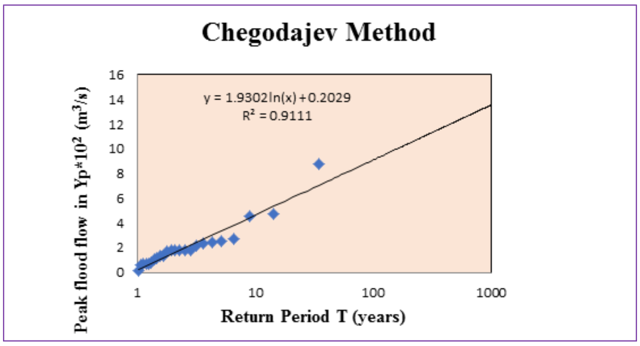



**Figure 5.** Peak flood flow for different RP by Chegodajev method.

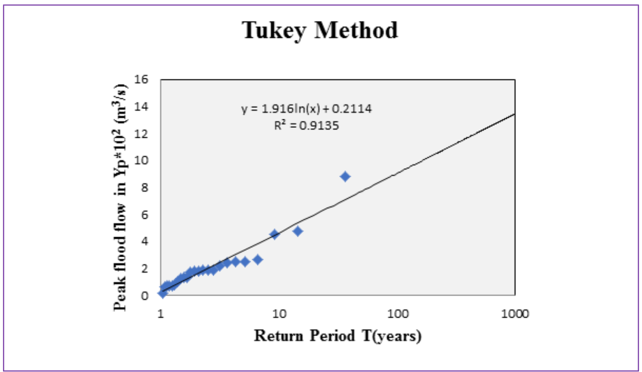



**Figure 6.** Peak flood flow for different RP by Tukey method.

All the six plotting positions derived relationship of frequency must be plotted graphically although results are altogether obtained graphically from Figures 2 to 7 as described in equation from (2) to (7). The paramount of this method can be widely used in any type of frequency study. The major advantages of this method, the derived relationship can be visualized easily and furthermore compared readily with the computed results. Another shortcoming angle of this method is not much reliable in estimation of larger RP. It plays a vital role where analytical methods are difficult for analysis of floods. GAA is limited to exclusively almost for annual maximum peak flood flow for a given duration. It is much reliable method besides it paves for frequency estimates. It is suitable for in areas the unusual combination of hydrometeorological besides geologically extreme topographic in the occurrence of extreme events and its analysis. In estimating flood peak flood flow for basin such as Vaigai in India, it is desirable.

**Table 3**. Exceedance probability values for Adamowski, and Hazen method

| Adamowski | | Hazen | |
|---|---|---|---|
| **Return Period (T)** | **Exceedance Probability (1/T) *100** | **Return Period (T)** | **Exceedance Probability (1/T) *100** |
| 32.66666667 | 3.06122449 | 48 | 2.083333333 |
| 14 | 7.142857143 | 16 | 6.25 |
| 8.909090909 | 11.2244898 | 9.6 | 10.41666667 |
| 6.533333333 | 15.30612245 | 6.857142857 | 14.58333333 |
| 5.157894737 | 19.3877551 | 5.333333333 | 18.75 |
| 4.260869565 | 23.46938776 | 4.363636364 | 22.91666667 |
| 3.62962963 | 27.55102041 | 3.692307692 | 27.08333333 |
| 3.161290323 | 31.63265306 | 3.2 | 31.25 |
| 2.8 | 35.71428571 | 2.823529412 | 35.41666667 |
| 2.512820513 | 39.79591837 | 2.526315789 | 39.58333333 |
| 2.279069767 | 39.79591837 | 2.285714286 | 43.75 |
| 2.085106383 | 43.87755102 | 2.086956522 | 47.91666667 |
| 1.921568627 | 47.95918367 | 1.92 | 52.08333333 |
| 1.781818182 | 52.04081633 | 1.777777778 | 56.25 |
| 1.661016949 | 56.12244898 | 1.655172414 | 60.41666667 |
| 1.555555556 | 60.20408163 | 1.548387097 | 64.58333333 |
| 1.462686567 | 64.28571429 | 1.454545455 | 68.75 |
| 1.38028169 | 68.36734694 | 1.371428571 | 72.91666667 |
| 1.306666667 | 72.53061224 | 1.297297297 | 77.08333333 |
| 1.240506329 | 80.6122449 | 1.230769231 | 81.25 |
| 1.180722892 | 84.69387755 | 1.170731707 | 85.41666667 |
| 1.126436782 | 88.7755102 | 1.11627907 | 89.58333333 |
| 1.076923077 | 92.85714286 | 1.066666667 | 93.75 |
| 1.031578947 | 96.93877551 | 1.021276596 | 97.91666667 |

**Table 4**. Exceedance probability values for Beard, and Chegodajev method

| Beard | | Chegodajev | |
|---|---|---|---|
| **Return Period (T)** | **Exceedance Probability (1/T) *100** | **Return Period (T)** | **Exceedance Probability (1/T) *100** |
| 35.33333333 | 2.830188679 | 34.85714286 | 2.868852459 |
| 14.4260355 | 6.931911403 | 14.35294118 | 6.967213115 |
| 9.063197026 | 11.03363413 | 9.037037037 | 11.06557377 |
| 6.60704607 | 15.13535685 | 6.594594595 | 15.16393443 |
| 5.198294243 | 19.23707957 | 5.191489362 | 19.26229508 |
| 4.284710018 | 23.3388023 | 4.280701754 | 23.36065574 |
| 3.644245142 | 27.44052502 | 3.641791045 | 27.45901639 |
| 3.170351105 | 31.54224774 | 3.168831169 | 31.55737705 |
| 2.80552359 | 35.64397047 | 2.804597701 | 35.6557377 |
| 2.515995872 | 39.74569319 | 2.515463918 | 39.75409836 |
| 2.280636109 | 43.84741591 | 2.280373832 | 43.85245902 |
| 2.085543199 | 47.94913864 | 2.085470085 | 47.95081967 |
| 1.921197794 | 52.05086136 | 1.921259843 | 52.04918033 |
| 1.780861943 | 56.15258409 | 1.781021898 | 56.14754098 |
| 1.659632403 | 60.25430681 | 1.659863946 | 60.24590164 |
| 1.553855959 | 64.35602953 | 1.554140127 | 64.3442623 |
| 1.460754943 | 68.45775226 | 1.461077844 | 68.44262295 |
| 1.378179763 | 72.55947498 | 1.378531073 | 72.54098361 |
| 1.304440877 | 76.6611977 | 1.304812834 | 76.63934426 |
| 1.238191976 | 80.76292043 | 1.23857868 | 80.73770492 |
| 1.178347028 | 84.86464315 | 1.178743961 | 84.83606557 |
| 1.124020286 | 88.96636587 | 1.124423963 | 88.93442623 |
| 1.074482151 | 93.0680886 | 1.074889868 | 93.03278689 |
| 1.029126214 | 97.16981132 | 1.029535865 | 97.13114754 |

**Table 5**. Exceedance probability values for Blom, Tukey and Benard method

| Tukey | | Benard | |
|---|---|---|---|
| **Return Period (T)** | **Exceedance Probability (1/T) *100** | **Return Period (T)** | **Exceedance Probability (1/T) *100** |
| 36.31343284 | 2.753801891 | 34.57142857 | 2.892561983 |
| 14.56886228 | 6.863953966 | 14.23529412 | 7.024793388 |
| 9.112359551 | 10.97410604 | 8.962962963 | 11.15702479 |
| 6.629427793 | 15.08425812 | 6.540540541 | 15.2892562 |
| 5.209850107 | 19.19441019 | 5.14893617 | 19.4214876 |
| 4.291005291 | 23.30456227 | 4.245614035 | 23.55371901 |
| 3.647676162 | 27.41471434 | 3.611940299 | 27.68595041 |
| 3.172099087 | 31.52486642 | 3.142857143 | 31.81818182 |
| 2.806228374 | 35.6350185 | 2.781609195 | 35.95041322 |
| 2.516028956 | 39.74517057 | 2.494845361 | 40.08264463 |
| 2.28022493 | 43.85532265 | 2.261682243 | 44.21487603 |
| 2.084832905 | 47.96547472 | 2.068376068 | 48.34710744 |
| 1.920284136 | 52.0756268 | 1.905511811 | 52.47933884 |
| 1.779809802 | 56.18577887 | 1.766423358 | 56.61157025 |
| 1.658486708 | 60.29593095 | 1.646258503 | 60.74380165 |
| 1.552648373 | 64.40608303 | 1.541401274 | 64.87603306 |
| 1.459508098 | 68.5162351 | 1.449101796 | 69.00826446 |
| 1.376910017 | 72.62638718 | 1.367231638 | 73.14049587 |
| 1.30316015 | 76.73653925 | 1.294117647 | 77.27272727 |
| 1.236908998 | 80.84669133 | 1.228426396 | 81.40495868 |
| 1.177068215 | 84.9568434 | 1.169082126 | 85.53719008 |
| 1.122750346 | 89.06699548 | 1.115207373 | 89.66942149 |
| 1.073224526 | 93.17714755 | 1.066079295 | 93.80165289 |
| 1.027883397 | 97.28729963 | 1.021097046 | 97.9338843 |

**Table**. 6 Peak flood flow computation for various RP

| Methods | Return periods and its peak flood flow Yp x10² (m³/s) | | | | | |
|---|---|---|---|---|---|---|
| | 15 | 20 | 25 | 30 | 60 | 1000 |
| Adamowski | 5.479 | 6.041 | 6.477 | 6.833 | 8.187 | 13.682 |
| Hazen | 5.209 | 5.735 | 6.143 | 6.476 | 7.743 | 12.886 |
| Beard | 5.419 | 5.973 | 6.403 | 6.754 | 8.089 | 13.506 |
| Chegodajev | 5.429 | 5.985 | 6.415 | 6.767 | 7.903 | 13.536 |
| Tukey | 5.400 | 5.951 | 6.378 | 6.728 | 8.056 | 13.447 |
| Benard | 5.445 | 6.001 | 6.432 | 6.783 | 8.122 | 13.552 |
| Gumbel's Analytical Approach | 5.638 | 6.133 | 6.514 | 6.823 | 7.995 | 12.710 |

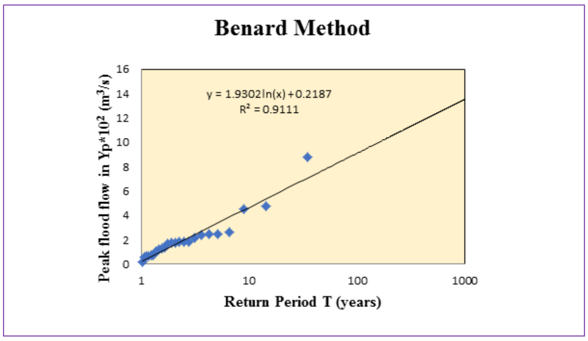



**Figure 7.** Peak flood flow for different RP by Benard method.

## 4. Conclusions

In this study, daily peak annual flood flow data for the periods of 24 years is used for the analysis. The LLM coupled with six plotting position methods are used and the same was compared with the GAA. It is observed that five methods of plotting position linearly proportional and it produces comparatively constant higher magnitude of peak flood flow as the values of RP is increases and in the case of natural event of occurrence of floods is certainly not possible. In the case of GAA, a frequency factor is introduced depending upon the length of data and RP and with this added advantage, it is being popularly used in FFA. It is firmly concluded that for low values of RP any one of the plotting position methods would be adopted conveniently to forecast future flood magnitude. Out of the six-plotting position method Hazen method could be adopted as easy and conveniently besides for an apropos angle to forecast larger RP on comparison with GAA and for the higher RP of 60 and 1000 GAA and Hazen method produces the magnitude of $7.995x10^2$, $12.710x10^2$ $m^3/s$ and $7.743x10^2$, $12.886x10^2$ $m^3/s$ respectively. The other methods of plotting position proved to be easy and convenient in forecasting the RP up to 30 years. The ultimate purpose of the research is to identify the extent to which various plotting position methods usage on comparison with popularly used GAA to forecast future peak flood flow magnitude and which would be certainly applicable to any region of the world. In inaccessible catchment areas rainfall data are usually obtained from recording rain gauges and it is very difficult to construct hydrograph for regulation of reservoirs existing in the forest catchment. In such cases, stream flow data would be obtained from unit hydrograph and applying all these methods in any given region of the world, reservoir constructed across the river for both gauged and ungauged locations could be regulated to achieve maximum benefits and thus eventually overall economy of the country is improved.

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