# Flood Frequency Analysis Using Gumbel Distribution Method at Garudeshwar Weir, Narmada Basin

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***Abstract*—** In this study, a flood frequency analysis of Narmada River basin in India was undertaken using Gumbel Distribution Method probability distribution method. The study was motivated by the need for safe and economic hydrologic design and assessments in the catchment area. Gumbel Distribution Method distribution was used to model the annual peak discharge for the river for the period 1984 to 2013 (30 years).The probability distribution function was applied to return periods (T) for 2yrs, 5yrs, 10yrs, 25yrs, 50yrs and 100yrs commonly used in for engineering design of hydraulic structures. The estimated discharges obtained are 22499.53$m^3$/s,37464.53 $m^3$/s, 47336.17 $m^3$/s ,59810.03 $m^3$/s,69062.28 $m^3$/s and 74442.23 $m^3$/s respectively. These values are useful for the hydraulic design of structures in the catchment area and for storm water management.

***Keywords—****Flood Frequency Analysis, Gumbel Distribution Method, Peak Discharge, Return Periods (T)*

## I. INTRODUCTION

Flood estimation is one of the major aspects of hydrologic design and is the first step in planning for flood regulation and protection measures. As estimate of probable maximum flood and the corresponding stage are necessary for the design of irrigation, hydro-power and flood control projects. Proper selection of the design flood is of utmost importance as it affects both the safety and cost of any structure. Too small a design flood for a major structure involves a high risk, not only of total failure of the structure and the services rendered by it but also to the safety of the persons and the property located downstream. An excessive design flood, on the other hand, will result in an unnecessarily costly structure which may adversely affect the economic feasibility of the project. Thus, in case where virtually no risk can be afforded, probable maximum flood is commonly adopted as the Design flood and in projects where the release of water due to structural failure or overtopping will not endanger life or cause disastrous damage downstream, design flood of lesser magnitude is adopted as it would be uneconomical to design such a structure to withstand the probable maximum flood.

Frequency based flood find their application in the estimation of design flood for almost all types of hydraulic structures and for the design of flood control structures, T- year design flood (T = 100 years, 50 years, 20 years, 10 years, or any desired year) is often required or calculated from the best fit distribution, hence probability distribution plays a vital role in designing and proper management of water resources. Flood Frequency Analysis (FFA) is used to predict design floods for sites along a river, the technique involves using observed annual peak flow discharge data to calculate statistical information such as mean value, standard deviation, skewness and recurrence interval. These statistical data are used to construct frequency distributions which are graphs and tables that tell the likelihood of various discharges as a function of recurrence interval or exceedence probability.

Flood frequency analyses commonly focus on the estimation of return periods associated with annual maximum flood peaks of various magnitudes. Based on an assumed distribution, it is possible to make a probability statement of future flows of various magnitudes. The estimated value of the random variable is also estimated for a given probability. Flood frequency analysis can take on many forms depending on the equation used in carrying out statistical analysis. Flood frequency analysis is a viable method of flood flow estimation in mostsituations and provides reliable prediction in regions of relatively uniform climatic condition from year to year and it is now an established method of determining critical design discharge for small to moderately sized hydraulic structures (Haktan, 1992). Therefore, flood frequency analysis of a river is vital. A random variable is a quantity that depends on chance the values or range of values can be predicted only with probability not with certainty. Examples of hydrologic random variables are mean monthly or annual stream discharge, precipitation etc. and a frequency relationship represents the likelihood of occurrence of values of a random variable. A distribution function provides a probabilistic model of phenomenon represented by a particular random variable.

This disadvantage is very important for the design of engineering structures. The stakes in the debate between the choice of the Gumbel distribution or any other distribution (Log-Normal and Log-Pearson III) is important because it is directly related to the reliability of hydraulic structures and roads. Also, is it considered necessary to verify, taking into account these new data, the validity of this distribution of probability (Gumbel) on the entire territory.

## II. LITERATURE REVIEW

The flood control planning and management of any water resources project requires the prediction of the future hydrologic events such as rainfall depth, flow depth, discharge and gauge level, and Surface water hydrology deals with movement of water along the watershedas a result of precipitation. However, flood is essentially a random phenomenon. It's, therefore, difficult to predict the exact maximum flood which can occur in future, (Arora, 2004).

Tha flood frequency studies can be used as a guide in determining the capacity of a structure e. g. Highway bridges, culverts, storm drains when it is permissible to take a means of estimating the probable flood dai7rage prevented by a system of flood protection works over a period of years usually equal to the estimated economic life of the works.( **Izinton** , et al., 2011)

The Log-Pearson Type III distribution tells you the likely values of discharges to expect in the river at various recurrence intervals based on the available historical record. This is helpful when designing structures in or near the river that may be affected by floods. It is also helpful when designing structures to protect against the largest expected event. For this reason, it is customary to perform the flood frequency analysis using the instantaneous peak discharge data. However, the Log-Pearson Type III distribution can be constructed using the maximum values for mean daily discharge data

## III. STUDY AERA

### *A. Narmada Basin: (Figure 1 )*

Narmada basin extends over states of Madhya Pradesh, Gujarat, Maharashtra and Chhattisgarh having an area of 98,796 Sq.km which is nearly 3% of the total geographical area of the country with maximum length and width of 923 & 161 km. It lies between 72°38' to 81°43' east longitudes and 21°27' to 23°37' north latitudes.

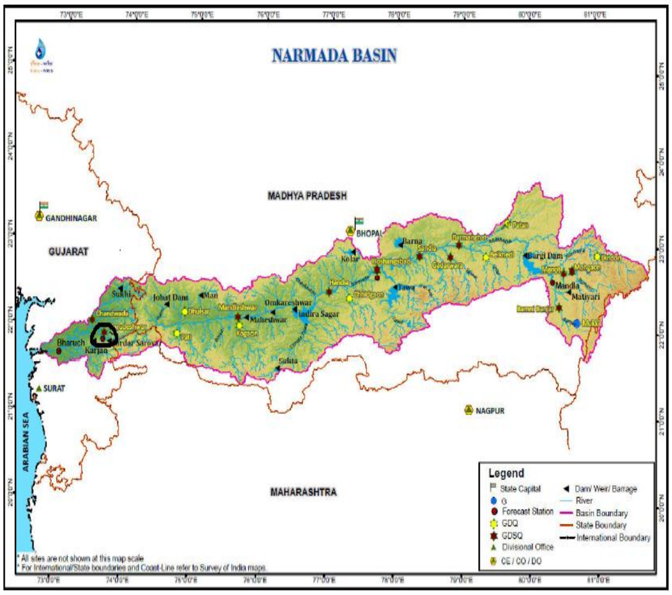


Figure 1: Narmada Basin (Source: www. India–Wris.Nrsc.Gov.In)

### *B. Garudeshwar Weir*

The Garudeshwar Weir is constructed across the Narmada River. Garudeshwar Weir (un gated)is located at 12.10 km d/s of Sardar Sarovar Dam near Garudeshwar village. (Table 1)

Table 1: Some Important Salient Featur of Garudeshwar Weir

| | |
|---|---|
| Type of weir | Major |
| River | Narmada |
| Village | Garudeshwar |
| Taluka | Nandod |
| State | Gujarat |
| Latitude | 21°52'57" |
| Longitude | 73°39'35" |
| Catchment Area | 89345 sq. km |

## IV. METHODOLOGY

### *A. Gumbel Distribution Method*

This extreme value distribution was introduced by Gumbel (1941) and is commonly known as Gumbel's distribution. It is one of the most widely used probability function for extreme values in hydrologic and meteorological studies for prediction of flood peak, maximum rainfalls, maximum wind speed, etc.

The following steps are necessary to apply the Gumbel Method:

1. Assemble the flood series ;
2. Calculate the mean $\bar{X}$ and standard deviations S of the flood series ;
3. Use Table and equation to determine the frequency factor and standard deviation S of the Gumbel a function of record length n ;
4. Select several return periods T and associated exceed probabilities P ; and (V) Calculate the Gumbel variant X and calculate the flood corresponding to the return periods T by using Equations discharge Q for each Gumbel variant (and associated return period).

The equation for fitting the Gumbel distribution to observed series of flood flows at different return periods T is

$$X = \bar{X} + KS$$

Where, X = the magnitude of the T-year event K = frequency factor and X = mean average

$$S = \text{standard deviation} = S = \frac{\sqrt{(x-\bar{x})^2}}{\sqrt{(N-1)}}$$

N = sample size-number of year 0 record

The flood frequency factor is expressed as or Using Table

$$K = -\left(\frac{\sqrt{6}}{\pi}\right)\left[0.57721 + in\left(in\left(\frac{T}{T-1}\right)\right)\right]$$

Where,

∏=3.14 In-natural logarithm, T = Return period

Table 2: Frequency Factors for Gumbel Distribution

| Sample Size N | Recurrence Interval | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 25 | 50 | 75 | 100 | 1000 |
| 15 | 0.967 | 1.703 | 2.117 | 2.410 | 2.632 | 3.321 | 3.721 | 4.005 | 6.265 |
| 20 | 0.919 | 1.625 | 2.023 | 2.302 | 2.517 | 3.179 | 3.563 | 3.836 | 6.006 |
| 25 | 0.888 | 1.575 | 1.963 | 2.235 | 2.444 | 3.088 | 3.463 | 3.729 | 5.842 |
| 30 | 0.866 | 1.541 | 1.922 | 2.188 | 2.393 | 3.026 | 3.393 | 3.653 | 5.727 |
| 35 | 0.851 | 1.516 | 1.891 | 2.152 | 2.354 | 2.979 | 3.341 | 3.554 | - |
| 40 | 0.838 | 1.895 | 1.866 | 2.126 | 2.326 | 2.943 | 3.301 | 3.491 | 5.478 |
| 45 | 0.829 | 1.478 | 1.847 | 2.104 | 2.303 | 2.913 | 3.268 | 3.520 | - |
| 50 | 0.820 | 1.466 | 1.831 | 2.086 | 2.283 | 2.889 | 3.241 | 3.491 | 5.478 |
| 55 | 0.813 | 1.455 | 1.818 | 2.071 | 2.267 | 2.869 | 3.219 | 3.467 | - |
| 60 | 0.807 | 1.446 | 1.806 | 2.059 | 2.253 | 2.852 | 3.200 | 3.446 | - |
| 65 | 0.801 | 1.437 | 1.796 | 2.048 | 2.241 | 2.837 | 3.183 | 3.429 | - |
| 70 | 0.797 | 1.430 | 1.788 | 2.038 | 2.230 | 2.824 | 3.169 | 3.413 | 5.359 |
| 75 | 0.792 | 1.423 | 1.780 | 2.029 | 2.220 | 2.812 | 3.155 | 3.400 | - |
| 80 | 0.788 | 1.417 | 1.773 | 2.020 | 2.212 | 2.082 | 3.145 | 3.387 | - |
| 85 | 0.785 | 1.413 | 1.767 | 2.013 | 2.205 | 2.793 | 2.135 | 3.376 | - |
| 90 | 0.782 | 1.409 | 1.762 | 2.007 | 2.198 | 2.785 | 3.125 | 3.367 | - |
| 95 | 0.780 | 1.405 | 1.757 | 2.002 | 2.193 | 2.777 | 3.116 | 3.357 | - |
| 100 | 0.779 | 1.401 | 1.752 | 1.998 | 2.187 | 2.770 | 3.109 | 3.349 | 5.261 |
| | 0.719 | 1.305 | 1.635 | 1.866 | 2.044 | 2.592 | 2.911 | 3.137 | 4.936 |

## V. ANALYSIS AND RESULT

The flood frequency analysis using annual peak discharge data of Narmada River at Garudeshwar Weir site for the period of record from 1984 to 2013 was carried out. The maximum flood discharge of 62297.06$m^3$/s was recorded in 1994 while lowest flood flow of 3567.92 $m^3/s$ was recorded in 2008. The30 year mean flood discharge is 25102.22$m^3/s$. The predicted discharge of different return period (2 yr., 5 yr., 25 yr., 50 yr. and 100yr.) is represented in Table 2 and as shown in Figure 2.

Table 3: Annual Maximum Discharge For Different Return Period Gumbel Distribution Method, Garudeshwar Weir

| Return Period | Frequency factor K | Flood Discharge |
|---|---|---|
| 2 | -0.164 | 22499.53 |
| 5 | 0.779 | 37464.99 |
| 10 | 1.401 | 47336.17 |
| 25 | 2.187 | 59810.03 |
| 50 | 2.770 | 69062.28 |
| 100 | 3.109 | 74442.23 |

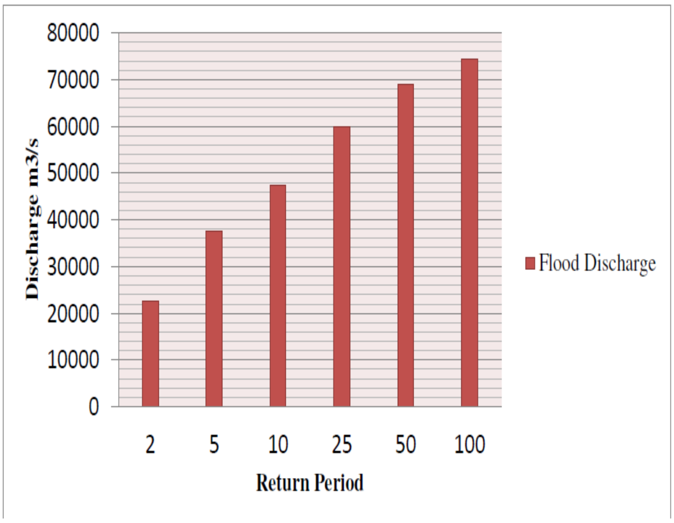


Figure 2: Annual Maximum Flood Discharge For Different Return Period Using Gumbel Distribution Method

The predicted annual flood discharge for 100 years return period using Gumbel Distribution Method is 74442.23$m^3/s$.

## CONCLUSION

Flood frequency analysis is one of the most challenging problems in hydrology. The hydrologic phenomena are often characterized by great variability and uncertainty precipitation, discharge. For this reason, a systematic approach to handling the problem is absolutely essential.

From the flood frequency study carried out on Narmada River basin catchment for 2 yrs, 5yrs, 10yrs, 25yrs, 50yrs and 100 yrs. The estimated discharges obtained. It has been observed that design floods for return period of 5 year were flood to be almost same as the observed data and verified with historical data. Garudeshwar Weir gauging station is having very high design flood as compare to other gauging station in the study area. These flood frequencies and design can be used as a guide in determining the capacity and design of structure like bridges, culverts.

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