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# Flood Peak Estimation at Hathnikund and Okhla Barrage

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**Abstract—***This paper describes the estimation of flood peak at the Hathnikund and Okhla Barrage sites in Yamuna River Basin. The flood peak has been estimated for Hathnikund and Okhla Barrage sites by using the frequency analysis and the empirical formula. Using the design flood values, the risk of failure of structure during various construction periods has been computed and presented in the paper. A comparison of design flood values at both the sites has also been made.*

**Keywords***: Flood peak, Hathnikund, Okhla, frequency, Yamuna*

## 1. INTRODUCTION

A flood is an unusually high stage in a river. It is an overflow of water outside its normal course. A flood results when a stream runs out of its confines and submerges surrounding areas. A flood from sea may be caused by a heavy storm, a high tide, a tsunami, or a combination thereof. As many urban communities are located near the coast this is a major threat around the world. The annual cycle of flood and farming was of great significance to many early farming cultures, most famously to the ancient Egyptians of the Nile River and to the Mesopotamians of the Tigris and Euphrates rivers.

For the design of hydraulic structures it is not practical from economic considerations to provide for the safety of the structure and the system at the maximum-possible flood in the catchments. Small structures such as culverts and storm drainage can be designed for less severe floods as the consequences of a higher-than design flood may not be very serious for such structures. On the other hand, storage structures such as dams demand greater attention to the magnitude of floods used in the design. The failure of these structures causes large loss of life and great property damage on the downstream of the structure. Therefore, it is clear that the type, importance of the structure and economic development of the surrounding area dictate the design criteria for choosing the flood magnitude.

Flood is defined as the instantaneous peak discharge adopted for the design of a river headwork or control structure after accounting for the economic and hydrological factors. It is a flood that the project can sustain without any substantial damage, either to the objects which it protects or its own structures. The design flood used for the specific purpose of designing the spillway of a storage structure is called spillway design flood. This term is frequently used to denote the maximum discharge that can be passed over a spillway without any damage or serious threat to the stability of the structure. The standard project flood (SPF) is the flood that would result from a severe combination of meteorological and hydrological factors reasonably applicable to the region. Extremely rare combinations of factors are excluded in computing the SPF. That probable maximum flood (PMF) is the extreme flood that is physically possible in a region as a result of most severe combinations including rare combinations of meteorological and hydrological factors. The PMF is used in situations where a failure of the structure would result in loss of life and catastrophic damage and as such complete security from potential floods is sought. On the other hand, SPF is often used where the failure of a structure is likely to cause less severe damages.

Standard techniques for flood estimation have been developed by most countries. These techniques generally include statistical methods based on the analysis of available gauged flood peaks, some kind of flood event modelling using rainfall-runoff techniques and, perhaps, the use of concepts such as the probable maximum flood. The frequency analysis approach for design flood estimation was first proposed by Eagleson (1972). It combines the probability density function of rainfall with a basin response function to obtain the flood frequency distribution. McKerchar and Macky (2001) compared design flood estimates from flood frequency analysis of six catchments to estimates from regional flood frequency analysis and a design storm approach. They concluded that design flood estimates generated by design storm methods often tend to be too large with differences of more than 100% compared to other estimates. Similarly Gutknecht et al. (2006) concluded in an Austrian case study that design floods from the design storm approach yield larger results than estimates from flood frequency statistics and regional methods for very low probability floods (return period of 5000-years). A review of flood frequency analysis is found in Bobe´e and Rasmussen (1995).

## 2. STUDY AREA (YAMUNA RIVER BASIN)

The main stream of Yamuna originates from Yamnotri Glacier at an elevation of 6387 m above mean sea level. After travelling through Himalayas, Yamuna enters the valley of Doon. Many tributaries join the river on its way to Tajewala Headworks in Haryana where a headwork exists for eastern and western Yamuna Canal which feed the states of Uttar Pradesh and Haryana respectively. A new barrage named Hathnikund has been constructed 3 km downstream of the Tajewala Barrage. The Yamuna enters in the National Capital Region (NCR) of Delhi approximately 1.65 Km north of Palla Village. It runs for about 45 kms in the southeast direction before leaving NCR of Delhi at a point to the east of Jaitpur downstream of Okhla Barrage. The entire reach of river Yamuna from origin to its end point can be broadly divided into the following reaches.

- Himalayan Segment–Origin to Hathnikund Barrage ( 172 km)
- Upper Segment - From Hathnikund to Wazirabad Barrage (224 km)
- Delhi Segment–Wazirabad Barrage to Okhla Barrage (22 km)
- Eutriphicated Segment–Okhla Barrage to Chambal Confluence ( 490 km)
- Diluted Segment–Chambal Confluence to Ganga Confluence (468 km).

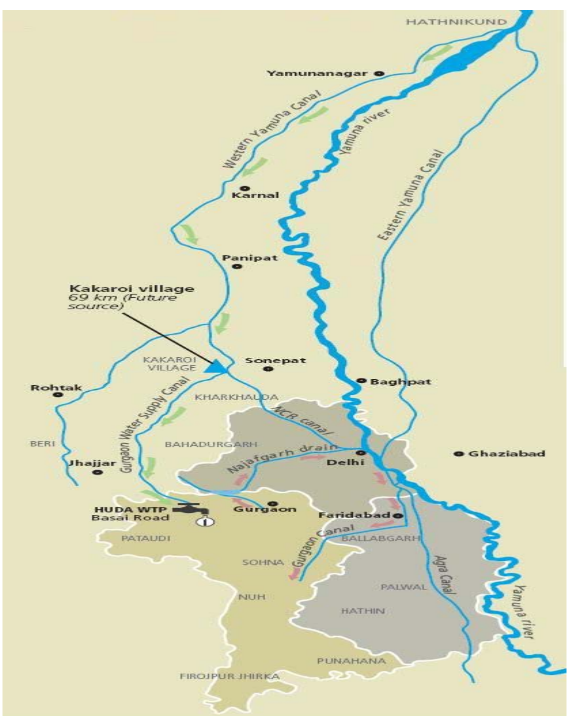


**Fig. 1: Reach of River Yamuna Downstream of Hathnikund Barrage.**

The reach of the River Yamuna downstream of Hathnikund Barrage is shown in **Error! Reference source not found.**. The Upper Segment and the Delhi segment of the Yamuna spanning from Hathnikund to Okhla/Kalindi Barrage are important for the assessment of vulnerability of the Delhi and NCR region to floods. There are mainly three barrages in the Delhi segment of the River Yamuna–Wazirabad, Indraprastha Barrage, and Kalindi Barrage. The length of the reach between Wazirabad and Kalindi Barrage is 22 km. The distance between Hathnikund and Kalindi barrage is approximately 245 Km.

There are following gauge points on the river in its reach from Palla to Jaitpur.

- Palla
- Wazirabad
- Old Railway Station
- Indraprastha Barrage
- Okhla Barrage

Monitoring of water levels is carried out at these stations during the flood season.


**Fig. 1: Course of River Yamuna in Delhi**

### 2.1. Main Causes of Floods in NCR of Delhi

The floods in NCR of Delhi are by and large influenced by discharges from Hathnikund headworks. In the event of heavy rain in areas upstream of Hathnikund, excess water is released downstream thereby causing floods in the NCR of Delhi. However, in the recent years even moderate rainfall has resulted in local floods in the region. A major reason for these local floods is high rate of runoff from urban areas which have been continuously growing at a very rapid rate. This problem of local floods is expected to aggravate in NCT of Delhi due to the reason that almost the whole of NCT of Delhi is likely to get urbanized by 2021 thus leaving very little scope for open and soft landscape surfaces. Another factor that is likely to aggravate the problem of floods is that by 2021 the demand of water supply is expected to rise to 1380 MGD which would generate approximately 1242 MGD of waste water which has to be drained by existing drainage system.

The valley storage in the Upper catchment areas has been lost over the recent years because embankments have been constructed on both banks upstream of Hathnikund Barrage. Consequently, for the same discharge higher flood levels are expected downstream of Hathnikund in the coming years as compared to flood levels in the past. In 1988, release of 5.775 lakh cusecs of water from Hathnikund caused a flood level of 206.920 m at the old railway station in Delhi. In 1995, discharge of 5.361 lakh cusecs from Hathnikund resulted in the flood level of 206.93 m at the old railway station. Thus, there is an accentuation of approximately 8% in water level as compared to 1988. The situation is further going to worsen as valley storage is likely to further decrease as Haryana may construct more embankments to save its agricultural areas from the impact of floods.

### 2.2 Major Floods in NCT of Delhi

Delhi has been experiencing floods of various magnitudes in the past due to floods in the Yamuna and the Najafgarh Drain system. The Yamuna crossed its danger level (fixed at 204.83m) twenty five times during the last 33 years. Since 1900, Delhi has experienced six major floods in the years 1924, 1947, 1976, 1978, 1988 and 1995 when peak level of Yamuna river was one meter or more above danger level of 204.49m at old rail bridge (2.66m above the danger level) occurred on sixth September 1978. The second record peak of 206.92m was on twenty seventh September 1988.

In the recent part, the city experienced high magnitude floods in 1977, 1978, 1988 and 1995, causing misery and loss of life and property to the residents of the city. A profile of these four floods indicated the extent of damage caused by these calamities. In Delhi Environment Status Report: WWF for Nature-India (1995), it has been pointed out that since 1978, the flood threat to Delhi has increased. In 1980, a discharge of 2.75 lakh causes at Tajewala resulted in flood level of 212.15 meters at the bund near Palla village in Delhi.

Flood of 1977: Najafgarh drain experienced heavy floods due to discharge from the Sahibi River. The drain breached at 6 places between Dhansa and Karkraula, marooning a number of villages in Najafgarh Block. 6 human lives were lost due to house collapse. 14 persons died in a boat mishap. Crop damage was estimated at Rs. 10 million.

Flood of 1978: (September) River Yamuna experienced a devastating flood. Widespread breaches occurred in rural embankments, submerging 43 sq km of agricultural land under 2 meters of water, causing total loss of the kharif crop. In addition to this, colonies of North Delhi, namely, Model Town, Mukherjee Nagar, Nirankari Colony etc. suffered heavy flood inundation, causing extensive damage to property. The total damage to crops, houses and public utilities was estimated at Rs. 176.1 million.

Flood of 1988: (September) River Yamuna experienced floods of very high magnitude, flooding many villages and localities Mukherjee Nagar, Geeta Colony, Shastry Park, Yamuna Bazaar and Red Fort area, affecting approximately 8,000 families.

Flood of 1995: (September) The Yamuna experienced high magnitude floods following heavy runs in the Upper catchment area and resultant release of water from Hathnikund water works. Slow release of water from Okhla barrages due to lack of coordination between cross state agencies further aggravated the problem. Fortunately, the flood did not coincide with heavy rains in Delhi, and could be contained within the embankments. Nonetheless, it badly affected the villages and unplanned settlements situated within the river-bed, rendering approximately 15,000 families homeless. These persons had to be evacuated and temporarily housed on roadsides for about two months, before they went back to living in the river-bed.

## 3. DATA ANALYSIS AND RESULT

Since, sufficiently long record of flood data is available at Okhla Barrage and Hathnikund Barrage; it was decided to use frequency analysis for the estimation of design flood for the Yamuna and the Hindon rivers.

It can be seen from Fig. 3 that the observed peak discharges in 1988 and in 1995 are higher than the 1978 discharge due to the reason that post 1978, the government of Haryana has undertaken construction of embankments downstream of Hathnikund Barrage. This has resulted in increased discharge in the reach of the river that lies in the NCT of Delhi.

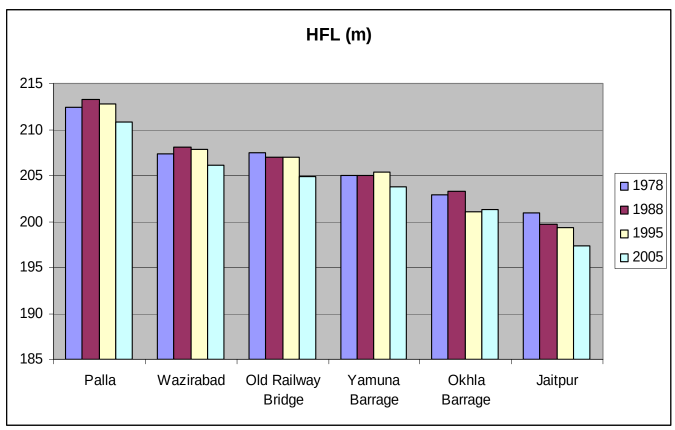


**Fig. 3: Comparison of HFL at different gauge points.**

### 3.1. Flood peak at Okhla and HathniKund Using Gumbel's and Log-Pearson method Method

Daily streamflow data at the Okhla and HathniKund barrage is available from 1960 to 2010. Based on the available data, peak flows have been extracted for the both the sites. The plots of peak discharge at Okhla and at HathniKund barrage are shown in Fig. 4 and Fig. 5 respectively.

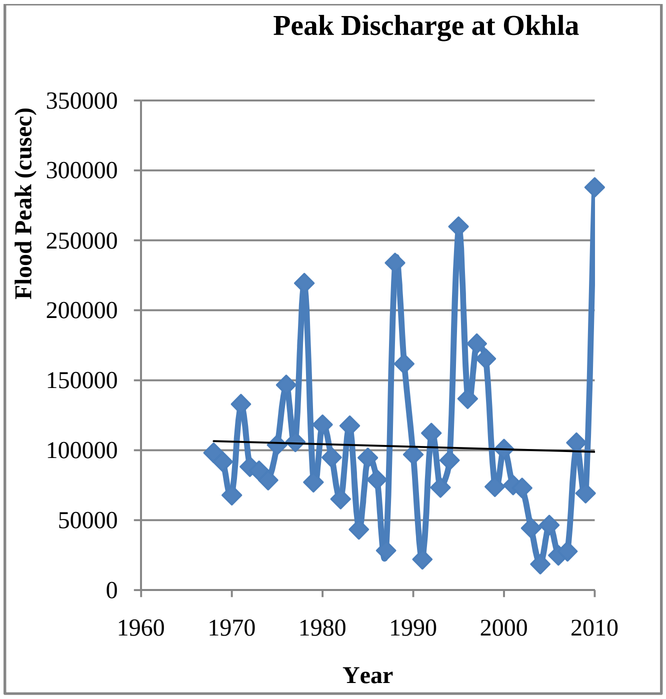


**Fig.** Error! No text of specified style in document.**: Flood Peak magnitudes at Okhla**

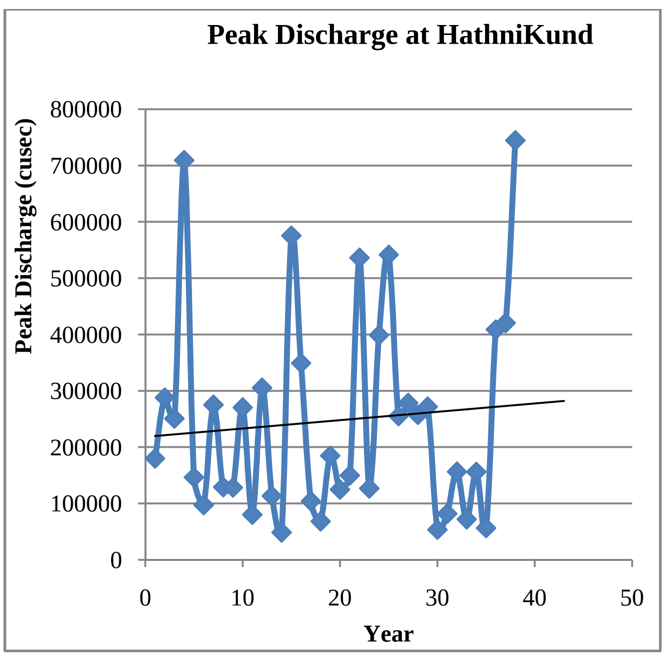


**Fig. 5: Flood Peak magnitudes at HathniKund**

## 4. METHODOLOGY

There are three basic approaches to the estimation of design flood: (1) Hydro-meteorological approach, (2) Frequency analysis, and (3) Use of empirical formulae. Application of hydro-meteorological approach is ruled out in the present case due to the non-availability of the required data. Many empirical formulae have been devised for the purpose of estimating peak flows. These formulae can be safely applied to the areas for which they have been specifically developed. However, these formulae must be used with great prudence, and must never be used unless their origin has been investigated. No particular formula will give precise results for all the sites. This is because of the fact that the magnitude of the flood of a given frequency depends upon several factors but these formulae are developed using a limited number of variables. Use of empirical formulae for estimation of design flood is, therefore, not recommended.

One of the primary objectives of the frequency analysis of hydrological data is to determine the recurrence interval of a hydrologic event of a given magnitude. The recurrence interval may be defined as the average interval of time within which the magnitude of a hydrologic event will be equaled or exceeded once, on the average. Hydrologic frequency analysis is the approach of using probability and statistical analysis to estimate future frequencies based upon information contained in hydrologic records. Through the use of statistical methods, observed data is analysed so as to provide not only a more accurate estimate of future frequencies than is indicated by the observed data.

The results of flood flow frequency analysis can be used for many engineering purposes: (i) for the design of dams, bridges, culverts, water supply systems, and flood control structures; (ii) to determine the economic value of flood control projects; (iii) to determine the effect of encroachments in the flood plain; (iv) to determine a reservoir stage for real estate acquisition and reservoir use purposes; (v) for the selection of runoff magnitudes for interior drainage, pumping plant, and local protection project design; and (vi) for flood plain zoning.

In the application of statistical methods to hydrologic frequency analysis, theoretical probability distributions are utilised. The hydrologic events that have occurred are assumed to constitute a random sample (observed set of events) and then are used to make inferences about the true population (all possible events) for the theoretical distribution considered. These inferences are subject to considerable uncertainty because a set of observed hydrologic events represent only a sample or small subset of the many sets of physical conditions that could represent the population described by the theoretical probability distribution. The existing methods of frequency analysis are numerous, with many diverse and confusing viewpoints and theories. Several types of probability distribution have been used in the past for hydrologic frequency determination. The most popular of these for flood flow frequency determination have been the log-normal, Gumbel's extreme value Type-I distribution, and log-Pearson Type-III distribution. The frequency analysis of the available peak discharge data at the Kol Dam and Rampur sites has been carried out using Gumbel's method (Gumbel, 1941) and log-Pearson method (Bobee, 1975). Gumbel's extreme value distribution is the most widely used distribution to predict extreme events such as flood peaks. The log-Pearson Type III distribution has little theoretical basis but it is being widely used as a tool to predict the future flood events by several western agencies.

## 5. RESULTS

The values of the flood peak at Okhla and HathniKund barrage site using Gumbel's and Log-Pearson method are shown in *Table 1 and Table 2*. It can be seen that for return periods upto 25 year, Gumbel's method produces higher values of flood peak when compared to the Log-Pearson method. For return periods greater than 25, Log-Pearson method produces higher values of design flood at Okhla barrage. For HathniKund barrage site It seen that for all return periods upto 1000 year, Gumbel's method produces lower values of flood peak when compared to the Log-Pearson method.

**Table 1: Floof Peak at Okhla Barrage**

| | **Flood Peak cusec** | |
|---|---|---|
| **Return Period (Year)** | **Gumbel's method** | **log- Pearson method** |
| 10 | 293550 | 254777 |
| 25 | 387027 | 377155 |
| 50 | 456378 | 488742 |
| 100 | 525216 | 619955 |
| 200 | 593808 | 773553 |
| 500 | 684298 | 923102 |
| 1000 | 752693 | 1238426 |

**Table 2: Floof Peak at Hathnikund Barrage**

| | **Flood Peak cusec** | |
|---|---|---|
| **Return Period (Year)** | **Gumbel's method** | **log- Pearson method** |
| 10 | 485212 | 495986 |
| 25 | 620031 | 702765 |
| 50 | 720053 | 879914 |
| 100 | 819336 | 1076762 |
| 200 | 918264 | 1295806 |
| 500 | 1048774 | 1494411 |
| 1000 | 1147417 | 1894872 |

Fig. 6 shows the comparison of design flood at Okhla barrage using different method. It can be seen from *Fig. 6* that the Log-Pearson method produces higher values of design flood at higher return periods.

Using the flood peak values, the risk of failure of a structure during various construction periods has been computed at Okhla barrage. In order to facilitate decision making the value of the flood for different return periods and the risk corresponding to the various assumed construction periods are presented in *Table 3.*

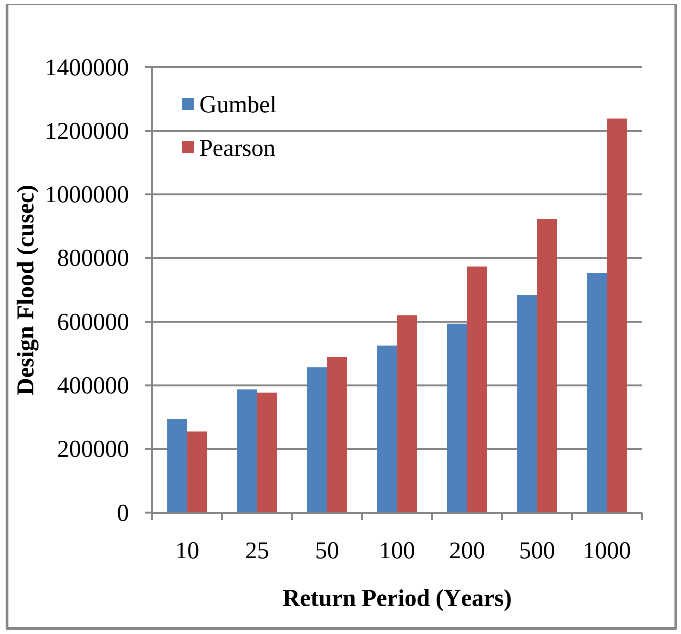


**Fig. 6: Comparison of flood peak Okhla Barrage using different methods**

**Table 3: Percentage Risk during various construction period at HathniKund Barrage**

| **Return Period (Years)** | **Flood Peak (Cusec)** | **Construction period, in years** | | | |
|---|---|---|---|---|---|
| | | **5** | **10** | **15** | **20** |
| 10 | 293550 | 67.2 | 89.2 | 96.4 | 98.8 |
| 25 | 387027 | 22.62 | 40.1 | 53.6 | 64.1 |
| 100 | 525216 | 4.9 | 9.5 | 14 | 18.2 |
| 1000 | 752693 | 0.49 | 0.996 | 1.589 | 1.48 |

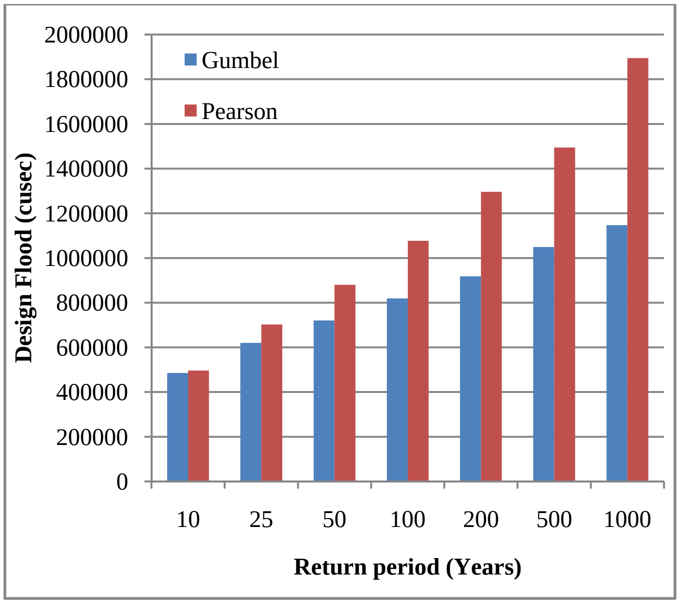


**Fig. 7: Comparison of flood peak HathniKund Barrage using different methods**

Fig. 7 shows the comparison of design flood at Hathnikund barrage using different method. It can be seen from Fig. 7 that the Log-Pearson method produces higher values of design flood at higher return periods.

Using the design flood values, the risk of failure of a structure during various construction periods has been computed at Hatinikund barrage . In order to facilitate decision making the value of the flood for different return periods and the risk corresponding to the various assumed construction periods are presented in Table 4

**Table 4: Percentage Risk during various construction period at HathniKund Barrage**

| Return Period (Years) | Flood Peak (Cusec) | Construction period, in years | | | |
|---|---|---|---|---|---|
| | | 5 | 10 | 15 | 20 |
| 10 | 485212 | 67.2 | 89.2 | 96.4 | 98.8 |
| 25 | 620031 | 22.62 | 40.1 | 53.6 | 64.1 |
| 100 | 819336 | 4.9 | 9.5 | 14 | 18.2 |
| 1000 | 1147417 | 0.49 | 0.996 | 1.589 | 1.48 |

## 6. CONCLUSIONS

Estimation of flood peak is extremely crucial for reservoir design and management. In the present paper, design floods for different return periods have been computed using Gumbel's and Log-Pearson method for Okhla and HathniKund barrage in yamunna river Basin. A comparison of design flood values obtained using the two methods indicated that for low return periods Gumbel's method produced higher values of design flood for Okhla barrage whereas Log-Perason method produced higher values for higher return periods. For HathniKund barrage, Gumbel's method consistently produced higher values of design floods. Based on Gumbel's and Log-Pearson method, the values of 1000-year return period flood for the Okhla barrage has been found to be 752693 cusec and 1238426 cusec respectively. For the HathniKund barrage site the 1000-year return period flood based on Gumbel's and Log-Pearson methods were found to be 1147417 and 1894872cusec respectively. The values of design flood corresponding to a return period of 10 00 years are critically important for the design of barrage. Using the design flood values, the risk of failure of structure during various construction periods has been computed and presented in the paper.

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