Flood Frequency Analysis and the Canal Design for the Barnigad Region in the Yamuna River

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1 Introduction

In the arranging and plan of water assets ventures, designers and organizers are frequently intrigued to decide the extent and recurrence of floods that will happen at the undertaking territories. Flood frequency analysis is the assessment of how regularly a predefined occasion will happen. Before the assessment is done, investigation of the stream information assumes a vital part to acquire a likelihood dispersion of floods. Flood frequency analysis (FFA) is most usually utilized by designers and hydrologists worldwide and fundamentally comprises assessing flood top amounts for a bunch of non-exceedance probabilities [1].

Flood represents more human misfortunes than some other fiascos. To conquer these misfortunes, flood investigation is completed. It is for the most part utilized by engineers worldwide to gauge flood top amounts for a bunch of non-surpassing probabilities. The model boundaries setup is utilized to anticipate the limit occasions of enormous repeat stretch. Accurate information with respect to the recurrence interval of floods and their probability will serve as a potent tool for policymakers to make decisions regarding integrated water resources management.

Mean is the arithmetic average of a bunch of numbers or appropriation. It is the most usually utilized proportion of the focal inclination of a bunch of numbers. Mode is the number that shows up most often in an informational collection. A bunch of numbers might have one mode, more than one mode, or no mode by any means. Median is a better estimator as it is not biased towards the extreme values of a dataset. Variance captures the spread of the dataset. The amount of the squared distances of each term in the conveyance from the mean (μ), partitioned by the quantity of terms in

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the dispersion (N), is known as variance ($\sigma 2$). Standard deviation is the square root of the variance, and its symbol is σ. Kurtosis is defined as the measure of "tailedness" of the distribution. Skewness can be quantified as a representation of the extent to which a given distribution varies from a normal distribution. If the curve is shifted to the left or the right, it is said to be skewed.

Methods for estimation of missing data

Missing data is a typical issue looked at by researchers in ecological investigations. Environmental data information, especially precipitation information is profoundly powerless against be missed, which is because of a few reasons, for example, breakdown instrument, off base estimations, and movement of stations. Precipitation information is likewise influenced by the presence of exceptions because of the fleeting and spatial inconstancy of precipitation estimations. These issues may hurt the nature of precipitation information and in this manner, produce incorrectness in the results of the examination. Some of these methods are explained below.

The arithmetic-mean based method to fill the missing precipitation utilizes the concept that if the normal precipitation variation among all the stations is less than 10% of the concerned station, then this method can be chosen. The ordinary proportion strategy shows the typical precipitations fluctuate extensively then missing precipitation (P_x) is assessed by weighting the precipitation at different stations by the proportions of ordinary yearly precipitation. The typical proportion technique is changed to join the impact of distance in the assessment of missing precipitation. This strategy is known as the modified normal ratio method. The inverse distance strategy has been supported to be the most dependable technique as contrast with the other two techniques talked about above.

The average rainfall over a space might be considered as the principal contribution on watershed demonstrating measure, particularly of those which manage surface overflow, mostly because, as a rule, the downpour is the lone climatic variable that can clarify quick expanding stream. In any case, a few examinations show that spatial fluctuation of precipitation over the region and their conveyance design have a significant impact on the runoff reaction created. Here, some methods are shown below.

The arithmetical-mean method calculates areal precipitation using the arithmetic mean of all the point or areal measurements considered in the analysis. Thiessen-mean method calculates station weights based on the relative areas of each measurement station in the Thiessen polygon network. The individual loads are multiplied by the station perception and the qualities are added to acquire the areal normal precipitation. Isohyetal method includes drawing assessed lines of equivalent precipitation over an area based on point estimations. The magnitude and degree of the resultant precipitation spaces of inclusion are then considered versus the territory being referred to appraise the areal precipitation value.

Another very important parameter which is used for the design of hydraulic structures such as irrigation canal in the present case is **return period or recurrence interval**. It is a normal time or an expected normal time between occasions like quakes, floods, avalanches, or waterway release streams to happen. It is a factual

estimation normally founded on notable information over a drawn out period and is utilized typically for risk examination. Models incorporate concluding whether an undertaking ought to be permitted to go on in a zone of a particular gamble or planning constructions to endure occasions with a particular bring return period.

$$\text{Recurrence Interval} = \frac{n+1}{m} \tag{1}$$

where n is the number of years on record, and m is the position of observed occurrences when arranged in descending order. The formula is based on the Weibull distribution method. It is an extreme value of probability distribution that is frequently used to model the reliability, endurance, wind speeds, and different information. The main motivation to utilize Weibull distribution is a result of its adaptability. Weibull distribution reliability is estimated with the assistance of boundaries [2]. The main motivation to utilize Weibull distribution is a direct result of its adaptability. Weibull distribution reliability is estimated with the assistance of boundaries. The probability P of an event equalled to is given by Weibull Formula:

$$P = \frac{m}{n+1} \tag{2}$$

where m is rank, and n is no. of years of record.

For the design, we have considered the extreme value as given by the Gumbel distribution method. Gumbel's distribution is a measurable technique regularly utilized for anticipating outrageous hydrological occasions like floods. In this concentrate on it has been applied for flood recurrence investigation because of the space is less coordinated, subsequently, is not fundamentally impacted by repository activities, redirections, or urbanization. Stream information are homogeneous and free along these lines need long stretch examples, top stream information covers a moderately lengthy record (over 10 years) and is of satisfactory quality [3].

The equation for Gumbel's distribution as well as to the procedure with a return period T is given as,

$$X_T = \overline{X} + K.\sigma_x \tag{3}$$

where σ_x = Standard deviation of the sample size.

K = frequency factor, which is expressed as, $K = Yt - Y\overline{\overline{n}}/Snx$.

In which, Y_T = reduced variate, $Y_T = -[Ln\,Ln.\,(T/T - 1)]$.

For the design of the irrigation canal, two theories are used. In Kennedy's theory, there can be as many sections for the given discharge. Simply stated that CVR varied according to the silt grade but did not give any method to measure CVR. Adoption of Kutter's N and Chezy's equation to work out mean velocity incorporated the limitations of those relationships [4]. Kutter considered depth as variable and gave critical **velocity formula in terms D**,

$$V_0 = 0.55 \, my^{0.64} \tag{4}$$

Considered channel section trapezoidal. The section is tighter and deeper. Considered all channels in the regime when they neither silt nor scour. Did not consider the importance of bed width depth ratio, wood's B-D rations are not rigid. Applicable to irrigation channels only. In Lacey's theory, only one regime section for given discharge and silt factor. Lacey did not leave silt grade as guesswork but correlated silt factor f to the diameter of silt and rugosity coefficient. Lacey discarded arbitrary factors and gave general regime equation independent of rugosity coefficient [5].

$$V = 10.8 \, R^{2/3} S^{1/3} \tag{5}$$

Considered hydraulic mean depth R as relevant variable and derived velocity formula in terms of R:

$$V = 0.639(f * R)^{1/2} \tag{6}$$

Determined regime slope for the given release and silt factor. Silt is kept in suspension by vertical parts of Eddies brought about by grating against the wetted edge. Considered channel segment semi-circular. The part is more extensive and shallower. Thought about that diverts cannot be in the genuine system and arranged them into an underlying and last regime. Given the formula for the distinct wetted perimeter for the given discharge.

$$P = 4.75 \, Q^{1/2} \tag{7}$$

2 Study Area and Data Collection

The study area is the Banigrad which is the region in the stretch of the Yamuna river. The absolute length of the Yamuna River from its source up to its intersection with the Ganges at Allahabad is 1376 km. The length of the stream along its navigation from its source up to the proposed redirection weir site is about 69.58 kms. During this cross, the waterway dives from a rise of 6387 to 940.00 m msl—the bed level at the redirection site. The bowl of the stream is invested with thick blended wilderness and the waterway streams in its upper compasses through the rough territory and at lower comes to through genuinely thick blended wilderness mostly comprising pine trees. The catchment region caught at the proposed redirection site, which is roughly 400 m upstream of its intersection with Barnigad stream on the New Delhi-Yamunotri National Highway No. 123 at almost two km before Kuwa and almost 27 km before Barkot, is 1183.17 km^2 out of which 36.23 km^2 is under permanent snow. The climate of the Yamuna river basin at the project site is hilly monsoon type. The climate comprises a mild summer, severe cold in winter and moderate to heavy

rainfall during the monsoon (rainy) season. The cold season starts at about the start of October and continues up to the second week of April [6]. The summer begins from the second week of April and extends up to the end of June. The south-west monsoon covers the period from July through September and receives most of the rainfall due to tropical storms and depressions originating in the Bay of Bengal (Fig. 1).

The data for the present study is taken from the Uttarakhand Jal Vidyut Nigam Limited (UJVNL) [3]. The time period of the data is from 1981–2008 and the scale of the data is monthly.
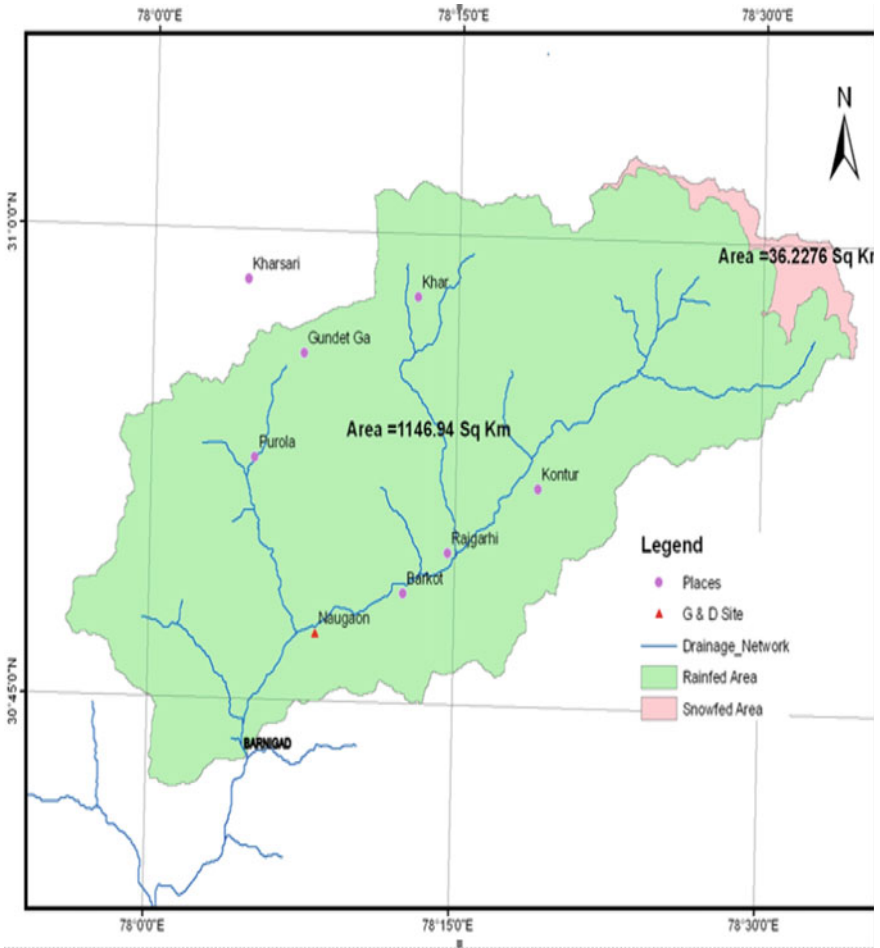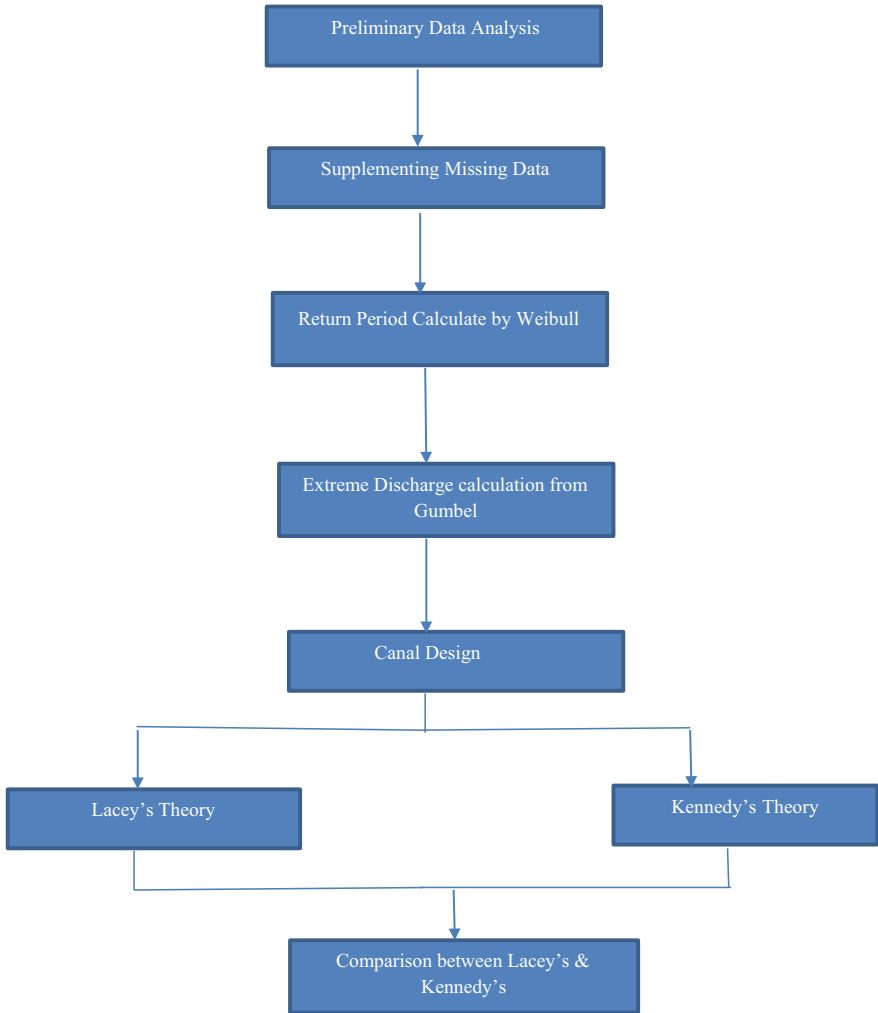

Fig. 1 Catchment area plan. *Source* I-WRIS: India Water Resources Information System [7]

3 Methodology

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│   Preliminary Data Analysis     │
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│   Supplementing Missing Data    │
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│ Return Period Calculate by Weibull │
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│  Extreme Discharge calculation from │
│              Gumbel             │
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│          Canal Design           │
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┌──────────────┐      ┌──────────────┐
│ Lacey's Theory │      │ Kennedy's Theory │
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      │ Comparison between Lacey's & │
      │        Kennedy's        │
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The calculations are shown below that are required for designing the channel section.

(i) **Using Kennedy's Theory**

$$\text{Discharge}(Q) = 276.7333, \ S = 1/6300, \ n = 0.023, \ m = 1$$

Now using critical velocity formula that is

$$V_0 = 0.55 \, my^{0.64}$$
$$V_0 = 0.857 \, m/s$$

Now Area, $A = Q/V_0$

$$A = 276.7333/0.857 = 322.90 \, m^2$$
$$A = y(b + y/2)$$
$$322.90 = 2(b + 1), \{y = 2\}$$
$$b = 160.45 \, m$$
$$P = 164.92 \, m$$
$$R = A/P = 1.95 \, m$$

Now calculation for V

$$V = 1/n \, (R^{2/3})(S^{1/2})$$
$$V = 1/0.023(1.95)^{2/3}(1/6300)^{1/2}$$
$$V = 0.8569 = 0.857$$
$$\text{So, } V_0 = V = 0.857$$

(ii)   **Using Lacey's Theory**

$$Q = 276.7333, \, f = 1$$
$$V = [Qf^2/140]^{1/6} = [276.7333 * 12/140]^{1/6} = 1.120$$

Now calculating the area and wetted perimeter

$$A = Q/V = 247.08 \, m^2$$
$$R = 2.5(V^2/f) = 3.136 \, m$$
$$P = 4.75(Q)^{1/2} = 79.01 \, m$$

$$P = b + (5)^{1/2}y \quad (i)$$
$$A = (b + y/2)y \quad (ii)$$

By solving the above equation, we get the values of y and b, so they are
So, $y = 3.38$ and the value of $b = 239.50$ m.
So now, using the formula for the value of S

$$S = (f^{5/3})/3340 * (Q)^{1/6}$$

$$S = 1/8523$$

4   Results

There are many missing values in the data, so first of all, the missing value has been filled with the help of the arithmetic mean, a method that is shown in Table 1. When all missing values find out then we calculated standard deviation, variance, skewness, and kurtosis to study the nature of the data. This is represented by Table 2. From this, Weibull distribution is found to be the most appropriate one to find out the return period.

When all the necessary parameter calculated then flood discharge, return period, and probability were calculated that shown in Table 3.

By using Gumbel and Weibull method's formulae for a particular return period (10 years, 15 years, and 20 years), the values of Y_T, K, and X_T are calculated and discharge (Q) also calculated. The values of Y_T, K, and X_T are shown below in Table 4.

By using Gumbel's and Weibull's discharge and the help of Kennedy's and Lacey's theory we design the channel section. So, all necessary data that relates to the channel section has been calculated and shown in Table 5.

Table 1 Missing data value treatment

Missing values in 1991–92	Missing values in 1994–95
34.9600	37.3000
105.6200	112.6000
146.6900	156.3900
88.6360	94.0800
35.5100	37.8100
20.4700	21.8000

Table 2 Preliminary statistical data analysis

Number of years	28
Standard deviation	44.7368
Variance	2001.38
Skewness	0.81546
Kurtosis	2.33233

Table 3 Weibull method analysis for return period calculation

m (Order No.)	Flood discharge	Tp (return period)	P (exceedance probability)
1	276.7333	29.0000	0.034483
2	208.5367	14.5000	0.068966
3	188.0068	9.6667	0.103448
4	177.16	7.2500	0.137931
5	173.7968	5.8000	0.172414
6	172.2733	4.8333	0.206897
7	166.5968	4.1429	0.241379
8	156.39	3.6250	0.275862
9	154.8533	3.222	0.310345
10	152.64	2.9000	0.344828
11	150.54	2.6364	0.379310
12	149.6933	2.4167	0.413793
13	146.69	2.2308	0.448276
14	142.75	2.0714	0.482759
15	140.6167	1.9333	0.517241
16	124.6333	1.8125	0.551724
17	121.2833	1.7059	0.586207
18	119.5933	1.6111	0.620690
19	117.0733	1.5263	0.655172
20	116.1333	1.4500	0.689655
21	109.8568	1.3810	0.724138
22	109.7167	1.3182	0.758621
23	108.0633	1.2609	0.793103
24	101.0333	1.2083	0.827586
25	100.8667	1.1600	0.862069
26	84.0833	1.1154	0.896552
27	82.7733	1.0741	0.931034
28	46.29	1.0357	0.965517

Table 4 Return period calculated from the Gumbel method

T (years)	Y_T	K	X_T
10	2.25037	1.5539	208.74
15	2.67375	1.9398	226.006
20	2.9702	2.2049	237.86

Table 5 Summary of the irrigation steps

	Q	1/S	n	m	Y	A	P	V₀	R	V
Kennedy's method										
Using discharge from Weibull's method	337.733	6300	0.023	1	2	394.87	200.516	0.857	1.97	0.86
Using discharge from Gumbel's method	276.7333	6300	0.023	1	2	322.90	164.92	0.857	1.95	0.856
Lacey's method	Q	1/S	n	f	y	A	P	b	R	V
Using discharge from Weibull's method	337.733	8814	6300	1	10	291.652	87.293	64.89	3.352	1.158
Using discharge from Gumbel's method	276.7333	2523	6300	1	3.38	247.8	79.01	71.43	3.136	1.12

5 Conclusion

In the whole process of channel design, we have used the arithmetic mean method for supplementing the missing data and for the return period, we used the Weibull distribution method. Along with for extreme value of discharge, we have used Gumbel's method and with the help of the discharge, we designed the channel section.

The advantage of using Lacey's theory over over Keneddy's theory is that-Due to the high amount of sediments, the true and final regime is followed. Kennedy's theory neglects eddies generated therefore the channels designed using it do not have silt supporting power. That's why we choose Lacey's theory. Lacey established a fixed relationship between bed width and depth while Kennedy's theory ignores them.

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