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Development of Intensity Duration Frequency Curves for Precipitation in North Lakhimpur (ASSAM)

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ABSTRACT

An Intensity- Duration- Frequency (IDF) curves is the graphical representation of the probability that a given average rainfall intensity will occur in a particular region for a given duration of storm having desired frequency of occurrence. The intensity of rainfall is the rate of precipitation, i.e., depth of precipitation per unit time. This can be either instantaneous intensity or average intensity over the duration of rainfall. Here, in this project we have considered average intensity of rainfall. The Intensity Duration Frequency (IDF) relationship of rainfall amounts is considered as one of the most commonly used tools in water resource engineering for planning, design and operation of water resources project, or for various engineering projects against design floods. The objective of this research is to derive IDF relationship of rainfall for watershed of North Lakhimpur, Assam. These relationships are useful in design of urban drainage works, for example storm sewer, culverts and other hydraulic structure. In this study, rainfall depth for 11 years viz. 2006 to 2016 has been collected from the Regional Meteorological centre, Guwahati. Gumble's frequency analysis technique has been used to calculate the return periods for a period of 2yrs, 5yrs, 10yrs, 50yrs and 100yrs from the maximum intensity. Finally, regression analysis has been to develop the Intensity Duration Frequency (IDF) curve.

KEYWORDS: IDF, Return Period, Regression Analysis, North Lakhimpur

I. INTRODUCTION

In many parts of the world, flooding is probably the most severe hazard among the natural hazards occurring due to change in rainfall pattern. Development of rainfall Intensity-Duration-Frequency (IDF) relationship is a primary basic input for the design of the storm water drainage system for cities. Intensity-Duration-Frequency (IDF) relationship of rainfall amounts is one of the most commonly used tools in water resources engineering for planning, design, and operation of water resources projects. Rainfall Intensity-Duration-Frequency IDF curves are graphical representations of the amount of water that falls within a given period of time in catchment areas. IDF curves are used to aid the engineers while designing urban drainage works. A design flood is the flood magnitude selected for the use as a criterion in designing flood control works. The objective of the rainfall IDF curves is to estimate the maximum intensity of rainfall for any duration and return period. This frequency analysis uses annual or seasonal maximum intensity of rainfall for any duration and return period. This frequency analysis uses annual or seasonal maximum series, or independent values above a high threshold selected for different durations. IDF analysis takes into account the different durations in a single study, and prevents curves intersecting.

II. STUDY AREA

Lakhimpur is an administrative district in the state of Assam in India. It is situated at 27°13'60 N and 94°7'0 E.The district headquarters are located at North Lakhimpur. The district is bounded on the north by Siang and Papump are District of Arunachal and on the east by Dhemaji District and Subansiri River. Majuli Sub Division of Jorhat District stands on the southern side and Gohpur sub division of Sonitpur District is on the West. The Brahmaputra is navigable for steamers in all seasons as far as Dibrugarh, in the rainy season as far as Sadiya; its navigable tributaries within the district are the Subansiri, Ranganadi and Dikrong. Lakhimpur's climate is classified as warm and temperate. The summers here have a good deal of rainfall, while the winters have very little. In Lakhimpur, the average annual temperature is 25.0 °C. The rainfall here averages 1200 mm.

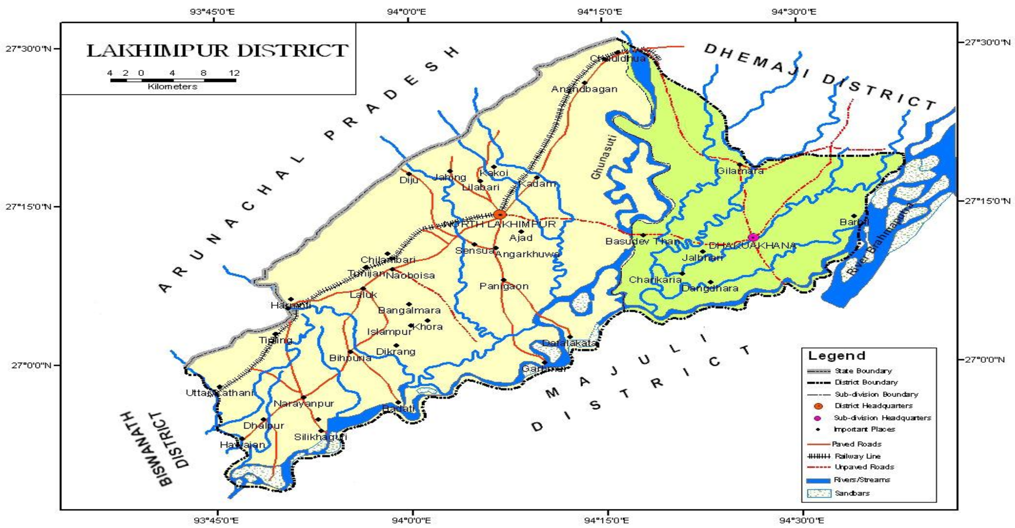

Fig 1.1: Study Area Map of North Lakhimpur district (Source: Ground water booklet of Lakhimpur district)

2.1 Objectives of the study

. To collect the data of rainfall depth of North Lakhimpur for 11 years from Regional Meteorological centre, Guwahati. The data of 24 hours rainfall was obtained from the year 2006-2016.

a. To calculate the return period for the period of 2yr, 5yr, 10yr, 50yr and 100yr from the maximum intensity using Gumbel's distribution.

b. To establishment of Intensity-Duration-Frequency curves for several purpose :

- The estimation of extreme rainfall for design purposes.
- The assessment of the rarity of observed rainfalls.
- Comparison of methods to estimate design rainfall.

III. METHODOLOGY

The classical approach for building IDF curves has three steps. In the first step, a probability distribution function is fitted to each duration sample. In a second step, the quantities of several return periods T are calculated using the estimated distribution function from step1. Lastly, the parameters of the IDF equations and coefficient of different return periods are calculated by using non-linear multiple regression method. The results obtained showed that in all the cases the correlation coefficient is very high indicating the goodness of fit of the formulae to estimate IDF curves in the region of interest.

3.1 Intensity-Duration-Analysis

It is observed that the most intense storms last for every short durations. As the duration of storm increases, the maximum average intensity of storm decreases. If the observed maximum rainfall intensities at a place for various durations such as 10min, 15min, 1hr, 3hr, 5hr, 7hr, etc are plotted against respective durations, a graph known as intensity-duration graph is obtained.

3.1.1 Empirical IDF Equations

The IDF formulae are the empirical equations representing a relationship among maximum rainfall intensity (as dependent variable) and other parameters of interest such as rainfall duration and frequency (as independent variable). There are several commonly used functions found in the literature of hydrology applications, four basic forms of equations used to describe the rainfall intensity duration relationship are summarized as follows:

Talbot equations I= ………. (3.1)

Bernard equations:

I= ………. (3.2)

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Kimijima equation:

I=

………. (3.3)

Sherman equation:

I=

………. (3.4)

Where I is the rainfall intensity (mm/hr); d is the duration (minutes); a, b and c are the constant parameters related to the meteorological conditions. These empirical equations show rainfall intensity decreases with rainfall duration for a given return period. All functions have been widely used for hydrology practical applications.

3.1.2 Calculation of Recurrence Period by Gumbel's method

The extreme value distribution was introduced by Gumbel and is commonly known as Gumbel's distribution. The estimate of rainfall intensity of given duration for different return period is obtained by this method. It is one of the most widely used probability-distribution functions for extreme values in hydrologic and meteorological studies for protection of flood peaks, maximum rainfalls, maximum wind speeds, etc. It was confirmed that the Gumbel distribution well describes the variation of annual series of maximum rainfall intensity. According to this theory of extreme events, the probability of occurrence of an event equal to or larger than a value of X_o is,

$P(Xx_o)$ =1- ……….(3.5)

In which y is a dimensionless variable given by

y=(x-a)

a=x-0.45005$_X$

=1.2825/$_X$

Thus, y= ………. (3.6)

Where, =mean and =standard deviation of the variable X

In practice it is the value of X for a given P that is required and as such equation 3.5 is transposed as,

Y_p=-ln[-ln(1-P)] ………. (3.7)

Noting that the return period T=1/Pand designating y_1= the value of y, commonly called the reduced variable, for a given T

Y_1 = -[ln.ln] ………. (3.8) Or

Y_1= -[0.834 + 2.303log log ………. (3.8 a)

Now by rearranging equation 3.6, the variable X with a return period T is,

X_t=x+k

Where, K= …………… (3.9)

Gumbel's Equation For Practical Use are as follows Equation 3.9 gives the value of the variable X with a recurrence interval T is used as

X_T = + Kσ_{n-1}

Where, σ_{n-1} =standard deviation of the sample of size N

K = frequency factor expressed as K=

In which y=2 reduced variable, a function of T and is given by,

$Y_{T=}$ .Or

$Y_{T=}$ -

= reduced mean,a function of sample size N

S_n = reduced standard deviation, a function of the sample size

3.1.3 Intensity-Duration Frequency Analysis

Every storm in a year is analyzed to find the maximum intensities for various duration. Thus each storm gives one value of maximum intensity for duration. The largest of all such values is taken to be the maximum intensity in that year for that duration. Likewise the annual maximum intensity is obtained for all the duration. Similar analysis yields the annual maximum intensities for various durations in different years. It will then be observed that the annual maximum intensity for any given duration is not the same every year but varies from year to year. In other words it behaves as a random variable.

3.1.4 Regression Analysis

Regression analysis tries find out the average relationship between the variables. It refers to the methods by which estimates are made of the values of one variable from the knowledge of the values of one or more other variables. In regression analysis however one variable is taken as the dependent variable and the other taken as the independent variables, thus making it possible to study the cause and effect relationship. However, the maximum intensity varies inversely with the duration and generally an equation of the for,

I= …….(3.10)

IV. RESULTS AND CALCULATIONS

4.1 Calculation of Return Period:

The calculation of return period is done according to Gumbel's distribution method. The return period for 2 years, 5 years, 10 years, 50 years, 100 years are found out.

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Table 4.1 : For 1 day, the return period of 2yr, 5yr, 10yr, 50yr, and 100yr :

Order No.	INTENSITY (X) mm/day	SUM	AVERAGE (X_{avg})	$X-X_{avg}$	$(X-X_{avg})^2$	$S=\sum(X-X_{avg})^2$	S/(N-1)	$б_{n-1}=\sqrt{S/(n-1)}$
1	103.8	436.7	39.7	64.1	4108.81	8354.87	835.48	28.9
2	67.6		39.7	27.9	778.41			
3	66		39.7	26.8	718.24			
4	40		39.7	0.3	0.09			
5	38.9		39.7	-0.8	0.64			
6	34.1		39.7	-5.6	31.36			
7	28.6		39.7	-11.9	141.61			
8	17.7		39.7	-22	484			
9	14.8		39.7	-24.9	620.01			
10	13.8		39.7	-25.9	670.81			
11	11.4		39.7	-28.3	800.89			

For N= 11, Yn= 0.4996, Sn= 0.967

T	T-1	T/T-1	ln(T/T-1)	ln(ln(T/T-1))	Y= -ln(ln(T/T-1))
2	1	2	0.6931	-0.3666	0.3666
5	4	1.25	0.2231	-1.5001	1.5001
10	9	1.1111	0.1053	-2.2509	2.2509
50	49	1.0204	0.0202	-3.9021	3.9021
100	99	1.0101	0.01	-4.6052	4.6052

Y	Yn	Y-Yn	Sn	K=(Y-Yn)/Sn
0.3666	0.4996	-0.1333	0.9676	-0.137
1.5001	0.4996	1.0005	0.9676	1.034
2.2509	0.4996	1.7513	0.9676	1.809
3.9021	0.4996	3.4025	0.9676	3.516
4.6052	0.4996	4.1056	0.9676	4.243

Return Period	Xavg	K	бn-1	K*бn-1	$X_t=X_{avg}+K*б_{n-1}$
2	39.7	-0.137	28.9	-3.959	35.741
5	39.7	1.034	28.9	29.882	69.582
10	39.7	1.809	28.9	52.28	91.98
50	39.7	3.516	28.9	101.612	141.312
100	39.7	4.243	28.9	122.622	162.322

Table 4.2 : For 3 day, the return period of 2yr, 5yr, 10yr, 50yr, and 100yr :

Order No.	INTENSITY (X) mm/day	SUM	AVERAGE (X_{avg})	$X-X_{avg}$	$(X-X_{avg})^2$	$S=\sum(X-X_{avg})^2$	S/(N-1)	$б_{n-1}=\sqrt{S/(n-1)}$
1	164.4	1003.96	91.27	73.13	5347.99	21753.1	2175.3	14.75
2	138.7		91.27	47.43	2249.6			
3	136.1		91.27	44.83	2009.72			
4	112.6		91.27	21.33	454.96			
5	109.8		91.27	18.53	343.36			
6	85.1		91.27	-6.17	33.06			
7	74.8		91.27	-16.47	271.26			

8	74.8		91.27	-16.47	271.26			
9	68.2		91.27	-23.07	532.22			
10	21.1		91.27	-70.17	4923.83			
11	18.36		91.27	-72.91	5315.86			

For N= 11 ,Y_n= 0.4996,
S_n=0.9676

T	T-1	T/T-1	ln(T/T-1)	ln(ln(T/T-1))	Y= - ln(ln(T/T-1))
2	1	2	0.6931	-0.3666	0.3666
5	4	1.25	0.2231	-1.5001	1.5001
10	9	1.1111	0.1053	-2.2509	2.2509
50	49	1.0204	0.0202	-3.9021	3.9021
100	99	1.0101	0.01	-4.6052	4.6052

Y	Yn	Y-Yn	Sn	K=(Y-Yn)/Sn
0.3666	0.4996	-0.1333	0.9676	-0.137
1.5001	0.4996	1.0005	0.9676	1.034
2.2509	0.4996	1.7513	0.9676	1.809
3.9021	0.4996	3.4025	0.9676	3.516
4.6052	0.4996	4.1056	0.9676	4.243

Table 4.3 : For 5 day, the return period of 2yr, 5yr, 10yr, 50yr, and 100yr :

Order No.	INTENSITY (X) mm/day	SUM	AVERAGE (X_{avg})	$X-X_{avg}$	$(X-X_{avg})^2$	$S=\sum(X-X_{avg})^2$	S/(N-1)	$\sigma_{n-1}=\sqrt{S/(n-1)}$
1	341.7		140.15	201.55	40622.4			
2	219.4		140.15	79.25	6280.56			
3	194.4		140.15	54.25	2943.06			
4	185.3		140.15	45.15	2038.52			
5	161.9		140.15	21.75	473.06			
6	120.8	1541.7	140.15	-19.35	374.42	85608.13	8560.81	92.52
7	102.1		140.15	-20.05	402			
8	96.6		140.15	-43.55	1896.61			
9	55.9		140.15	-84.25	7098.06			
10	31.8		140.15	-108.35	11739.72			
11	31.8		140.15	-108.35	11739.72			

For N= 11 ,Yn= 0.4996,
Sn= 0.9676

T	T-1	T/T-1	ln(T/T-1)	ln(ln(T/T-1))	Y= - ln(ln(T/T-1))
2	1	2	0.6931	-0.3666	0.3666
5	4	1.25	0.2231	-1.5001	1.5001
10	9	1.1111	0.1053	-2.2509	2.2509
50	49	1.0204	0.0202	-3.9021	3.9021

100	99	1.0101	0.01	-4.6052	4.6052

Y	Yn	Y-Yn	Sn	K=(Y-Yn)/Sn
0.3666	0.4996	-0.1333	0.9676	-0.137
1.5001	0.4996	1.0005	0.9676	1.034
2.2509	0.4996	1.7513	0.9676	1.809
3.9021	0.4996	3.4025	0.9676	3.516
4.6052	0.4996	4.1056	0.9676	4.243

Return Period	X_{avg}	K	$б_n$-1	K*$б_n$-1	$X_t=X_{avg}+K*б_{n-1}$
2	140.15	-0.137	92.52	-12.67	127.48
5	140.15	1.034	92.52	95.66	235.81
10	140.15	1.809	92.52	167.37	307.52
50	140.15	3.516	92.52	325.3	465.45
100	140.15	4.243	92.52	392.56	532.71

Table 4.4 : For 6 day, the return period of 2yr, 5yr, 10yr, 50yr, and 100yr :

Order No.	INTENSITY (X) mm/day	SUM	AVERAGE	$X-X_{avg}$	$(X-X_{avg})^2$	$S=\sum(X-X_{avg})^2$	S/(N-1)	$б_{n-1}=\sqrt{S/(n-1)}$
1	294.3	1976.5	179.68	114.62	13137.74	89135.91	8913.59	94.41
2	256.8		179.68	77.12	5947.49			
3	256.8		179.68	77.12	5947.49			
4	241.7		179.68	62.02	3846.48			
5	225.7		179.68	46.02	2117.84			
6	199		179.68	19.32	373.26			
7	167.9		179.68	-11.78	138.76			
8	158.8		179.68	-20.88	435.97			
9	151.1		179.68	-28.18	794.11			
10	24.4		179.68	-155.28	24111.87			
11	0		179.68	-179.68	32284.9			

For N= 11 ,Yn= 0.4996,
Sn= 0.9676

T	T-1	T/T-1	ln(T/T-1)	ln(ln(T/T-1))	Y= -ln(ln(T/T-1))
2	1	2	0.6931	-0.3666	0.3666
5	4	1.25	0.2231	-1.5001	1.5001
10	9	1.1111	0.1053	-2.2509	2.2509
50	49	1.0204	0.0202	-3.9021	3.9021
100	99	1.0101	0.01	-4.6052	4.6052

Y	Yn	Y-Yn	Sn	K=(Y-Yn)/Sn
0.3666	0.4996	-0.1333	0.9676	-0.137
1.5001	0.4996	1.0005	0.9676	1.034
2.2509	0.4996	1.7513	0.9676	1.809
3.9021	0.4996	3.4025	0.9676	3.516
4.6052	0.4996	4.1056	0.9676	4.243

Return Period	Xavg	K	бn-1	K*бn-1	$X_t=X_{avg}+K*б_{n-1}$
2	179.68	-0.137	94.41	-12.93	166.75

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5	179.68	1.034	94.41	97.61	277.29
10	179.68	1.809	94.41	170.78	350.46
50	179.68	3.516	94.41	331.94	511.62
100	179.68	4.243	94.41	400.58	580.26

B. Construction of Intensity-Duration-Frequency Curves:

A) Intensity frequency curve

The frequency analysis and the maximum intensity of rainfall for various return period can be obtained. Then from the result of these analysis graphsof maximum rainfall intensity against the return period for various durations are plotted.

Table 45 : For 1 day Maximum Intensity

Return Period	X_{avg}	K	Ϭn-1	K*Ϭn-1	$X_t=X_{avg}+K*Ϭ_{n-1}$
2	39.7	-0.137	28.9	-3.959	35.741
5	39.7	1.034	28.9	29.882	69.582
10	39.7	1.809	28.9	52.28	91.98
50	39.7	3.516	28.9	101.612	141.312
100	39.7	4.243	28.9	122.622	162.322

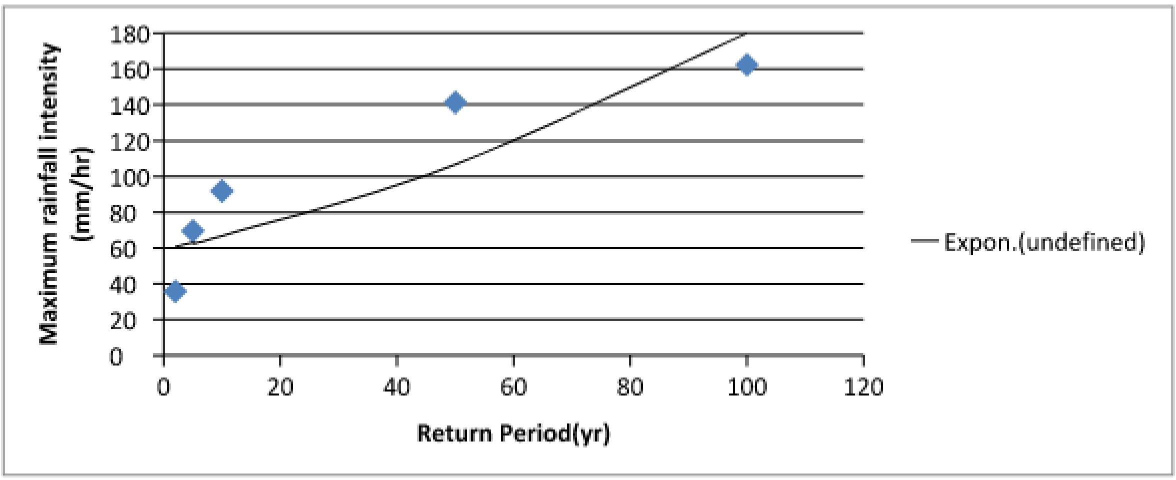

Fig 4.1 Intensity frequency curve for 1 day

Table 4.6: For 3 day Maximum Intensity

Return Period	X_{avg}	K	Ϭn-1	K*Ϭn-1	$X_t=X_{avg}+K*Ϭ_{n-1}$
2	91.27	-0.137	14.75	-2.02	89.25
5	91.27	1.034	14.75	15.25	106.52
10	91.27	1.809	14.75	26.68	117.95
50	91.27	3.516	14.75	51.86	143.13
100	91.27	4.243	14.75	62.58	153.85

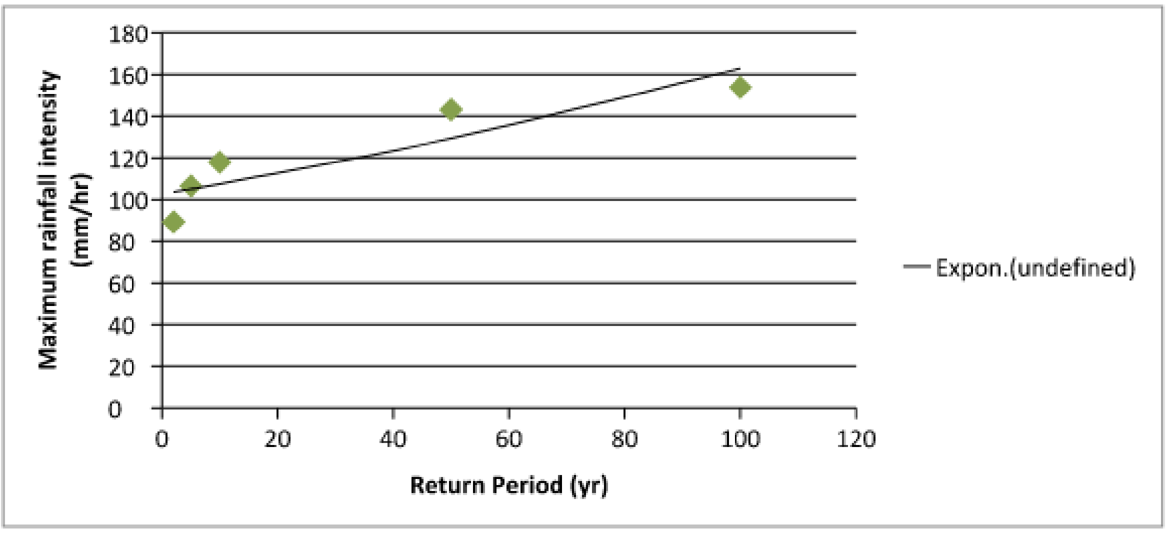

Fig 4.2 Intensity frequency curve for 3 day

Table 4.7 : For 5 day Maximum Intensity

Return Period	Xavg	K	Ϭn-1	K*Ϭn-1	$X_t=X_{avg}+K*Ϭ_{n-1}$
2	140.15	-0.137	92.52	-12.67	127.48
5	140.15	1.034	92.52	95.66	235.81
10	140.15	1.809	92.52	167.37	307.52
50	140.15	3.516	92.52	325.3	465.45
100	140.15	4.243	92.52	392.56	532.71

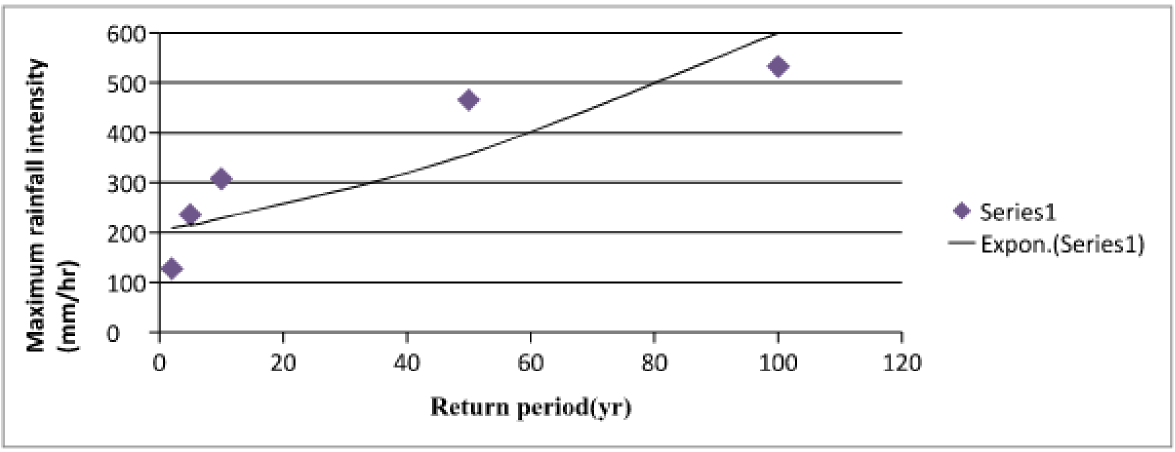

Fig 4.3 Intensity frequency curve for 5 day

Table 4.8: For 6 day Maixmum Intensity

Return Period	Xavg	K	Ϭn-1	K*Ϭn-1	$X_t=X_{avg}+K*Ϭ_{n-1}$
2	179.68	-0.137	94.41	-12.93	166.75

5	179.68	1.034	94.41	97.61	277.29
10	179.68	1.809	94.41	170.78	350.46
50	179.68	3.516	94.41	331.94	511.62
100	179.68	4.243	94.41	400.58	580.26

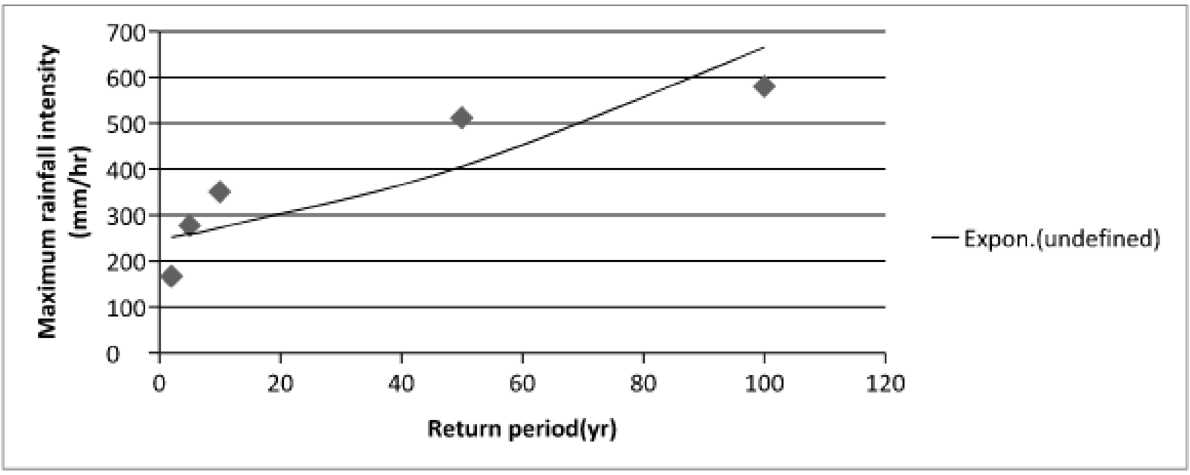

Fig 4.4 Intensity frequency curve for 6 day

B) Intensity frequency duration curve

Table 4.9: Return period 2, 5, 10, 50,100 years maximum Intensity duration

Return Period years	Intensity for duration (mm/hr)			
	1day	3day	5day	6day
2	35.741	89.25	127.48	166.75
5	69.582	106.52	235.81	277.29
10	91.98	117.95	117.95	350.46
50	141.312	143.13	143.13	511.62
100	162.332	153.85	153.85	580.26

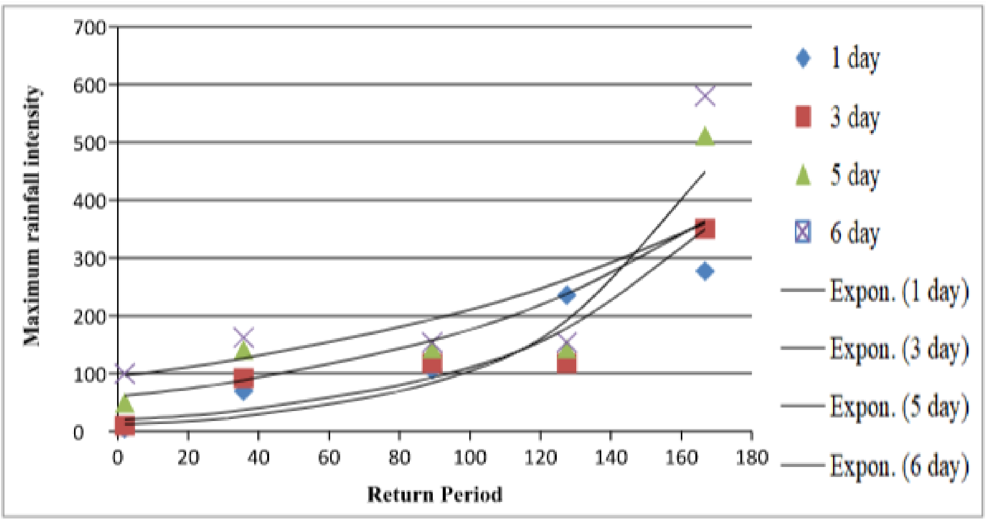

Fig 4.5 Return period 2, 5, 10, 50,100 years Intensity

V. CONCLUSION

This study had been conducted for the formulation and construction of IDF curves using rainfall data for the year 2006 to 2016 for North Lakhimpur area, Assam. The rainfall intensity is found to be non-uniform throughout the area. The actual method to construct IDF curves involves three main steps. The first step is to obtain the annual maximum intensity for each interval length. Then for each time interval, a statistical analysis has to be done to compute the quantiles for different return periods. In the third step, the IDF curves are usually determined by fitting a specified parametric equation for each return period to the quantiles estimates, using regression techniques. Using this method the same can be found out for other cities as well as by collecting the rainfall data for the respective day. From this study, the following conclusions are made:

- The gradual exponential decrease of IDF curves for different return periods reveal that the conclusion of maximum intensity for all the years is satisfactory.
- The value of 'a' for which the sum of the squared deviation is minimum is found out and when the corresponding value of 'c' and 'b' for the maximum squared deviation of 'a' is put in the equation (3.10) and is back calculated, the values of intensity for the corresponding time interval is found out to be approximately same.
- The values of 'a', 'b' and 'c' are found to be 34, 0.97, and 12.133 respectively.

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REFERENCES

[1]. Parthasarathy, K. & Singh G., (1961) - Rainfall intensity-duration-frequency for India forlocal drainage design - Indian Journal of Meteorology & Geophysics, Vol.-12(2), 231-242.

[2]. Raiford, J. P., Aziz, N. M., Khanand, A. A., Powell, D. N. (2007). Rainfall Depth-Duration-Frequency Relationships for South Carolina, North Carolina, and Georgia, AmericanJournal of Environmental Sciences, 3 (2), 78-84.

[3]. Nhat, Le M., Tachikawa,Y. , Takara, K. (2006). Establishment of Intensity-Duration-Frequency Curves for Precipitation in the Monsoon Area of Vietnam. Annuals of Disas.Prev. Res. Inst., Kyoto Univ., No. 49 B, 93-103.

[4]. Ram Babu, Tejwani, K. K., Agrawal, M. C. & Bhusan, L. S. (1979) - Rainfall intensity duration-return period equations & nomographs of India, CSWCRTI, ICAR, Dehradun,India.

[5]. Kothyari, U.C., and Garde, R. J. (1992), - Rainfall intensity - duration-frequency formula forIndia, Journal of Hydraulics Engineering, ASCE, 118(2).

[6]. Trevor M. Daniell and Guillermo Q. Tabios III (2008), Rainfall Intensity-Duration-Frequency (IDF) Analysis for the Asia Pacific Region, Technical documents in Hydrology, No.2. International Hydrological Programme.