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Generation of Intensity Duration Frequency curve using short duration rainfall data for different Return Period for Guwahati city.

Ruby Das, Diganta Goswami, Biswajit Sarma

Abstract— Estimation of Peak Flood Discharge for the desired return period is a pre-requisite for planning, design, and management of hydraulic structures like stormwater drains, barrages, dams, spillways, bridges,etc. The purpose of the present study is to develop an Intensity Duration Curve (IDF) Curve for the Guwahati city by using Gumbel's Extreme Value distribution and to develop an IDF empirical formula to estimate the rainfall intensity for any duration and any return period with minimum effort. Short duration rainfall data for the year 1990 to 2014 was collected. This model is developed to predict precipitation depth for various return period storms. The derived precipitation depth is utilized for generation of intensity duration frequency curve having different return periods.

Index Terms—Gumbel's Extreme Value Distribution, Guwahati City, IDF Curve, Return Period, Rainfall Duration., Rainfall Intensity, Short Duration Rainfall.

1 Introduction

Guwahati is said to be the legendary Pragjyotishpur, the City of Eastern Light.Guwahati is situated on the southern bank of river Brahmaputra with its cardinal points as $26^0 10'$ north latitude and $91^0 49'$ east longitude. The city is situated on undulating plain with varying altitudes ranging from 49.5 m to 55.5 m above mean sea level (MSL).

The Brahmaputra river bank in Guwahati is higher than most of the city areas. The average ground level (GL) of the river bank is 51.3m whereas the average GL of the rest of the city, except hill and wetlands (Beel), is around 49m. However, the High Flood Level (HFL) of Brahmaputra at the DC court is 51.37m as recorded in 1988. The water level of river Brahmaputra remains above 49m every year for a number of days during the seasons of heavy rain. Therefore, gravity flow of surface runoff of the cityinto the river cannot take place in those days and pumping is to be resorted to during the rainy season.

In the past, many researchers have developed IDF curves for different regions of the world. Bell (1969) generated IDF curves for certain areas of U.S.S.R; Al-Sheikh (1985) has developed IDF relations for Saudi Arabia. Al-Khalaf (1997) hasconducted a study for generating short duration, high-intensity rainfall in Saudi Arabia using IDF studies. Koutsoyiannis (1998) has suggested the construction ofIDF curves using data from recording as well as non-recording stations. Elsebaie (2012)generated IDF relationship for two regions in Saudi Arabia. Ogarekpe (2014) has generated IDF relationships for Calabar Metropolis, South-Nigeria. The present study focuses on the development of IDF curves and hence IDF relationships for Guwahati city using the Gumbel Extreme Value distributions.

- *Ruby Das is currently working as Assistant Engineer (Civil) in Assam Public Works Department, ARRTI, Fatashil Ambari, Guwahati, Assam India. E-mail: rdborah@gmail.com*
- *Diganta Goswami is currently working as Associate Professor, Department of Civil Engineering, Assam Engineering College, Guwahati, Assam, India E-mail: digantagoswami2@gmail.com*
- *Biswajit Sarma is currently working as Director, College Development Council, Gauhati University., Guwahati, Assam India. E-mail:cdcdirector@gauhati.ac.in*

2 Rainfall Regime of the Study Area

Guwahati city which comprises northern and north-eastern India as well as adjoining parts of Nepal, Bhutan, Bangladesh, and North Myanmar. In this zone, rainfall generally occurs in the monsoon months from June to September while the months from November to February are generally dry with occasional winter rains. It is seenthat, four meteorological conditions are mainly responsible for heavy rainfall and subsequent floods:

a) Movement of a monsoon trough to the northeast,from the Bay of Bengal to the sub-basin
b) Shifts of the monsoon trough to the north from its normal position.
c) Formation and movement of lowlands or land depressions over North-East India.
d) Circulation of cyclonic upper air over North-East India.

The annual rainfall in Guwahati was on average 1,681 mm from 2008 to 2012 (*Source: IMD Monthly Rainfall data from 2008 to 2012*). Of this amount, 63% of the rain fell during the monsoon months (June to September), 31% during the pre-monsoon months (March to May), 5% during the post-monsoon months (October to November), and 1% during winter (December to February). Hence, approximately 94% of total annual rainfall occurred during the wettest seven months

(March to September).

3 Objective & Data Collection

The objective of this research is to establish the relationship between the intensity, duration, and frequency of rainfall and to use it to assess the probability of intensity of the rainfall in the future for a given duration, for Guwahati city

For this study, hourly daily rainfall data for the period 1990 to 2014 has been collected from IMD, Guwahati and Intensity duration frequency curve is generated using these data.

The rainfall Intensity Duration Frequency (IDF) relationship is one of the most commonly used tools in water resources engineering, either for planning, designing and operating of water resource projects, or the protection of various engineering projects (e.g. highways, etc.) against floods. They describe the relationship between mean precipitation intensity and frequency of occurrence (the inverse of the return period) for different time intervals of a given duration. These intervals over which the precipitation intensity is averaged are called durations. The intensity is time rate of precipitation, that is, depth per unit time (mm/hr). The average intensity is commonly used and can be expressed as shown in (1)

$$i = P/D \tag{1}$$

Where P is the rainfall depth (mm or in) and D is the duration, usually in hours. The frequency is usually expressed in terms ofreturn period, T, which is the average length of time between precipitation events that equal or exceed the design magnitude

4 Approach

The first step of constructing the IDF curve for a given region is to assess the local rainfall data and determine the maximum rainfall depth associated with each year. The maximum rainfall depth has been foundfor different duration of rainfall,and descriptive statistical analysis is done for each duration. The mean and standard deviation are determined as functions of duration. Thus one for the mean depth of rainfall, μ,as a function of the duration of the rainfall and the other one is the standard deviation (σ).of the depth of rainfall. Then, a Probability Distribution Function (PDF) or a Cumulative Distribution Function (CDF) is fitted to each group comprising of the data values for a specific duration. It is possible to relate the maximum rainfall intensity for each time interval with the corresponding return period from the cumulative distribution function. For a return period (T), its corresponding cumulative frequency (F) is expressed as (2)

$$F = 1 - \frac{1}{T} \tag{2}$$

Once a cumulative frequency is known, the maximum rainfall intensity is determined using Gumbel's Extreme Value Distribution.

4.1 Gumbel's Extreme Value Distribution

The most commonly used frequency distribution functions applicable in the hydrological studies is expressed by (3)and is known as the general equation of *the hydrologic frequency analysis*. The frequency analysis using frequency factors hasbeen explained below.

The magnitude (X_T) of a hydrologic event may be represented as the mean,μ,plus the departure ΔX_T of the variate from the mean.

$$X_T = \mu + \Delta X_T \tag{3}$$

The departure ΔX_Tmay be taken as equal to the product of the standard deviation σ and a frequency factor K_T; that is, $\Delta X_T = K_T\sigma$ .The departure ΔX_T and the frequency factor K_T are functions of the return period and the type of probability distribution to be used in the analysis. Therefore, the equation as given in (3) may be expressed as (4)

$$X_T = \mu + K_T \sigma \tag{4}$$

4.2 IDF Empirical Equation

IDF empirical equation are the equation that estimates the maximum rainfall intensity for the different duration and returns period. Different procedures and formulas have been proposed in literature (Chow, 1964; Bell, 1969; Chen, 1983; Aron et al. 1987; Kouthyari and Garde, 1992). IDF is a mathematical relationship between the intensity of rainfall, i, the duration, t_d, and the return period, T. In this study empirical equation as given in (5) is used

$$i = a^*(t_d)^{-c} \tag{5}$$

Where i is the rainfall intensity in mm/hr.t_d is the rainfall duration in minutes, a & c are the fitting parameters.

5 Results and Discussions

The probability distribution method is carried out to determine the rainfall and their corresponding return period. Thus various short duration rainfalls like 5, 10, 15, 30, 60 and 120 minutes have been estimated from this evaluated rainfall intensity for different return period, as shown in Table-1.

By using the rainfall intensity of as per Table-1, for various durations, intensity duration frequency curve is plotted for various return periods, as shown in Fig.2

TABLE 1
ESTIMATION OF SHORT DURATION RAINFALL OF GUWAHATI CITY

Duration (min)	Return Period (Years)					
	2	5	10	25	50	100
	Rainfall Intensity, (i) for Different Reriod, (mm/hr)					
15	84.00	105.63	119.74	137.84	151.24	163.70
30	76.63	92.81	103.36	116.90	126.92	136.24
60	62.73	79.96	91.20	105.62	116.30	126.22
120	28.64	40.39	48.05	57.89	65.17	71.94
360	9.75	16.18	20.37	25.75	29.73	33.44
1440	4.17	5.11	5.73	6.51	7.10	7.64

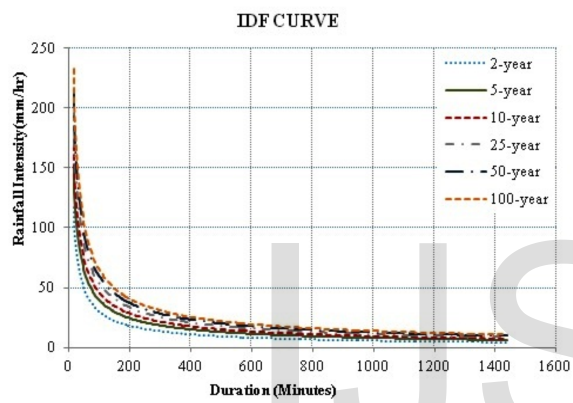

Fig. 1. Intensity Duration Frequency Curve

Data in Table-1, when plotted in a bilogarithmic paper shows that the intensity value decreases as duration increases and for a particular duration as return period increases rainfall intensity tends to increase, Fig.3

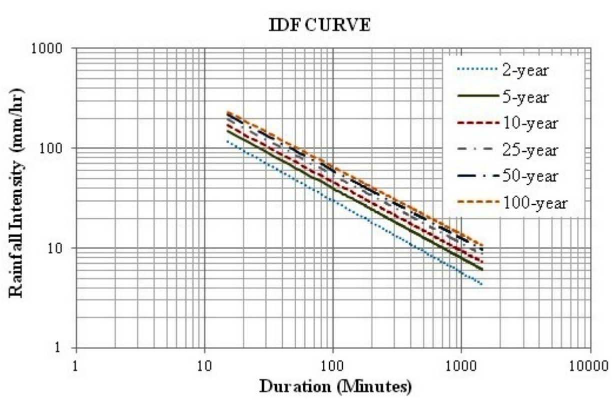

Fig. 2. Intensity Duration Frequency Curve in log paper

tions upper case Arabic numerals, then upper case Arabic numerals, separated by periods. Initial paragraphs after the section title are not indented. Only the initial, introductory paragraph has a drop cap.

TABLE 2
RAINFALL IDF EMPIRICAL EQUATION FOR RESPECTIVE RETURN PERIOD

Intensity,I (mm/hr)	$i=a*(t_d)^{-c}$ t_d= duration (mins)		Correlation Coefficient R^2
Return Period, T (years)	a	c	
2	821.43	0.721	0.9600
5	983.80	0.699	0.9589
10	1095.40	0.690	0.9534
25	1241.30	0.683	0.9457
50	1350.40	0.679	0.9403
100	1452.30	0.676	0.9375

5 Conclusion

Rainfall Intensity, Duration and Frequency relationship for Guwahati city using short duration rainfall data has been generated.

Various 'a' and 'c' parameter values for return periods of 2, 5, 10, 25, 50 and 100 years have been derived from which rainfall intensity for a given duration of a rainfall event canbe easily calculated.

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