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°10’ north latitude and 91°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 51.3 m whereas the average GL of the rest of the city, except hill and wetlands (Beel), is around 49 m. However, the High Flood Level (HFL) of Brahmaputra at the DC court is 51.37 m as recorded in 1988. The water level of river Brahmaputra remains above 49 m every year for a number of days during the seasons of heavy rain. Therefore, gravity flow of surface runoff of the city into 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) has conducted a study for generating short duration, high-intensity rainfall in Saudi Arabia using IDF studies. Koutrsoyiannis (1998) has suggested the construction of IDF 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.

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 seen that, 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.
The magnitude between precipitation events that equal or exceed the design terms of return, usually in hours. The frequency is expressed as (2)

\[ F = 1 - \frac{1}{T} \]

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 known as the general equation of the hydrologic frequency analysis. The frequency analysis using frequency factors has been explained below.

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

\[ X_T = \mu + \Delta X_T \]

The departure \( \Delta X_T \) may be taken as equal to the product of the standard deviation \( \sigma \) and a frequency factor \( K_T \); that is, \( \Delta X_T = K_T \sigma \). The departure \( \Delta X_T \) 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)

\[ X_T = \mu + K_T \sigma \]

### 4.2 IDF Empirical Equation

IDF empirical equation are the equation that estimates the maximum rainfall intensity for the different duration and return periods. 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

\[ i = a(t_d)^c \]

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

<table>
<thead>
<tr>
<th>Duration (min)</th>
<th>Return Period (Years)</th>
<th>Rainfall Intensity, I (mm/hr) for Different Period,</th>
<th>Correlation Coefficient R²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>84.00</td>
<td>105.63</td>
<td>119.74</td>
</tr>
<tr>
<td>30</td>
<td>76.63</td>
<td>92.81</td>
<td>101.36</td>
</tr>
<tr>
<td>60</td>
<td>62.73</td>
<td>79.56</td>
<td>91.20</td>
</tr>
<tr>
<td>120</td>
<td>28.64</td>
<td>40.39</td>
<td>48.05</td>
</tr>
<tr>
<td>360</td>
<td>9.75</td>
<td>16.18</td>
<td>20.37</td>
</tr>
<tr>
<td>1440</td>
<td>4.17</td>
<td>5.11</td>
<td>5.73</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Return Period, T (years)</th>
<th>a</th>
<th>c</th>
<th>Correlation Coefficient R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>821.43</td>
<td>0.721</td>
<td>0.9600</td>
</tr>
<tr>
<td>5</td>
<td>983.80</td>
<td>0.699</td>
<td>0.9589</td>
</tr>
<tr>
<td>10</td>
<td>1095.40</td>
<td>0.690</td>
<td>0.9534</td>
</tr>
<tr>
<td>25</td>
<td>1241.30</td>
<td>0.683</td>
<td>0.9457</td>
</tr>
<tr>
<td>50</td>
<td>1350.40</td>
<td>0.679</td>
<td>0.9403</td>
</tr>
<tr>
<td>100</td>
<td>1452.30</td>
<td>0.676</td>
<td>0.9375</td>
</tr>
</tbody>
</table>

Fig. 2. Intensity Duration Frequency Curve in log paper

TABLE 2
RAINFALL IDF EMPIRICAL EQUATION FOR RESPECTIVE RETURN PERIOD

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 can be easily calculated.

REFERENCES

[1] Al-Dokhayel, "Regional rainfall frequency analysis for Qasim," B.S. Project, Civil Engineering Department, King Saud University, Riyadh (K.S.A), (1986).


