International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 4, Issue 5, May-2018

Developing rainfall intensity-duration-frequency relationship for Hyderabad city in India

Manoj Kumar[*1] and Yatindra Kumar[2]
[1] Master's student, Dept. of Civil Engineering, PunjabEngineering College Chandigarh India, *e-mail:* kalzangtanzin@gmail.com
[2]Assistant Professor, Department of Civil Engineering, PunjabEngineering College Chandigarh India, *e-mail:*yatindre.iitcivil@gmail.com

Abstract:Accurate andcurrent rainfall characterization is an important tool for water related system design. The intensity, duration, and frequency relationship (IDF) of rainfall occurrence can be done through regular records of hourly rainfall data. The objective of this study is to generate the intensity-duration-frequency relationships of precipitation, using the method of Gumbel theory of distribution and Log Pearson type III distribution. The data set are used from gage in Hyderabad city, the capital of Andhara Pradesh: hourly rainfall data for the 19 years from 1993-2011. Hourly data is used to develop updated IDF relationships. IDF curves were prepare for return periods of 2, 5, 10, 25, 50, and 100 years for 1-, 2-, 4-, 8-, and 24 hour durations. The updated IDF relationship definitely show a huge change in rainfall characteristics compared with other older relationships for the area surrounding Hyderabad, India. The result obtained showed that in all the cases the rainfall intensities obtained using Gumbel distribution are slightly than the results obtained using the LPT III distribution.

KEYWORDS: IDF curves; Rainfall intensity; Rainfall change; Rainfall frequency relationships.

1. Introduction

The project area of the study is Hyderabad, located at altitude of17° 22' 31" N and 78° 28' 27" E. The altitude of the rainfall station is 542 meter above mean sea level. Hyderabad has a tropical wet and dry climate bordering on a hot semi-arid climate. The annual mean temperature is 26.6 °C (79.9 °F); monthly mean temperatures are 21–33 °C (70–91 °F). Heavy rain from the south-west summer monsoon falls between June and September, supplying Hyderabad with most of its mean annual rainfall. Since records began in November 1891, the heaviest rainfall recorded in a 24-hour period was 241.5 mm (10 in) on 24 August 2000. Rainfall in this region is due to south-west monsoon from the Indian Ocean.It is known that rainfall study is very important topic for water resources and irrigation designers to evaluate problems related to rainfall as flood. This research provides some insight into the way in which the rainfall is estimated in Hyderabad. Since area of the Hyderabad is not much large and has almost same climate conditions from place to place. Arelation has to be obtained to estimate rainfall intensities for different durations (1. 2, 4, 8, 24 hour) and return periods of 2,5, 10, 25, 50, and 100 years. The development of such relationships was done as early as in 1932 (Bernard 1932). Since then, so many relationships have been constructed for several parts of the earth. So many studies have been done on rainfall analysis in various regions of the world. Koutsoyiannis et al.,(1998) and Koutsoyiannis(2003 0 cited that IDF relationship is a mathematical relationship between the rainfall intensity*i*,duration *d*, and return period *T*. Lekanoyebande (1982), studied "Deriving rainfall intensity-duration-frequency relationship and estimates for regions with inadequate data" used type 1 extreme- value distribution (Gumbel) was applied to the annual extreme rainfall data sets generated by 11 rainfall zones to estimate the parameters and hence the intensity-duration-frequency (IDF) rainfall. The chi-square test confirmed the appropriateness of the fitted distribution. Gumbel graphical plots and the computed confidence limits also showed that the Gumbel EV-1 function fits well the empirical distribution. Indeed the IDF curves allows us to estimate the return period of an observed rainfall event or conversely of the rainfall amount corresponding to a given return period for different aggregation times.

The analysis of Trenberth et al. (2003) notes that Clausius-Clapeyron equation relating vapour pressure and temperature suggests a 7 percent increasein atmospheric water content for each 1°C increase in average annual temperature. This results of low-level moisture convergence, local rainfall rates greatly exceed average regional or global evaporation rates; therefore, rainfall intensities could be expected to increase at a increase rate at least as large as 7 percent per °C. However, this differs from the accepted 1–2% per °C increase in total annual precipitation depths (Intergovernmental Panel on Climate Change (IPCC)). To restore the differences in these predictions, it follows that low and medium intensity precipitation events will be less common, and precipitation would trend toward less frequent, higher intensity events (Trenberth et al. 2003). This argument is supported by global climate model predictions (UKHI and CSIRO9; Hennessy et al.1997)and by an investigation of rainfallrecords for the large region of central India (Goswami et al. 2006). Also, the recent of work of Bandyopadhyay et al. (2009) has shown muchincrease in atmospheric water content in India, affirming theconnection between atmospheric water and temperature. Althoughthe spatial distribution of this change in precipitation character is unknown, it would mean greater risk of both dry spells and floods for some regions even though annual precipitation totals may increase slightly.With the recent improvement in technology like remote sensing and satellitedata,Awadallah et al. (2011)conducted a study for developing IDF curves in scarce data region using regional analysis and satellite data. Awadallah et al. (2011)presented a methodology to succeed the lack of ground stations rainfall by the joint use of available ground data with Tropical Rainfall Measuring Mission (TRMM) satellite data to develop IDF curves and he used a method to develop ratios between 24-hr rainfall depth and shorter duration depths.

2. Data collection

Rainfall intensity data are veryimportant for water resource engineering works, because on the basis of this, the designs will be made. Data collecting are perhaps, the most difficult part of the paper.Data from different climatological stations in and around Hyderabad city were obtained from the Indian Meteorological Department. The data set are used from gage in Hyderabad city, the capital of Andhara Pradesh: hourly rainfall data for the 19 years from 1993-2011. Hourly data is used to develop updated IDF relationships. IDF curves were prepared for return periods of 2, 5, 10, 25, 50, and 100 years for 1-, 2-, 4-, 8-, and 24 hour durations.With few missing data and the other stationshave very few records of the data which are not presentableat all to be considered in the study.

3. Development of Intensity Duration Frequency Curves.

For many hydrologic examination, planning or design problems valid or dependable rainfall intensity estimates arerequired. Rainfall intensity duration frequency relationship comprises the reckonof rainfall intensities of different durations and recurrence intervals. There are frequently used theoretical distribution function were applied in different regions all over the world (e.g. GEV, Gumbel, Log normal, Pearson type III distributions). Gumbel distribution methodology was sueon different region all over the world.

Frequency analysis techniques are used to develop the relationship between the rainfall intensity, storm duration, and return periods from rainfall data for the regions under study. These techniques are: Gumbel distribution,and log Pearson Type III distribution.

3.1 Gumbel theory of distribution

For Gumbel distribution methodology was choose to perform the flood probability analysis. The Gumbel theory of distribution is the most globally used distribution for IDF analysis owing to its properness for modelling maxima. It is comparatively simple and uses only extreme events (maximum values or peak rainfalls). The Gumbel method calculates the 2, 5, 10, 25, 50 and 100 year return intervals for each duration period and requires several calculations. Frequency precipitation PT (in mm) for each duration with a designate return period T (in year) is given by the following equation:

$$PT = Pave + KS \quad (1)$$

Where K is Gumbel frequency factor given by:

$$K = -\frac{\sqrt{6}}{\pi}\left[0.5772 + ln\left[ln\left[\frac{T}{T-1}\right]\right]\right] \quad (2)$$

Where *Pave* is the average of the maximum precipitation correlate to a specific duration.

In effective use Gumbel's distribution, the arithmetic average in equation (1) is used:

$$Pave=\frac{1}{n}\sum_{i-1}^{n} Pi \tag{3}$$

Where Pi is the individual extreme value of rainfall and n is the number of events or years of record. The standard deviation is calculated by equation (4) computed using the following relation:

$$S=\left[\frac{1}{n-1}\sum_{i=1}^{n}(Pi-Pave)^3\right]^{1/2} \tag{4}$$

Where S is the standard deviation of P data. The frequency factor (K), which is a function of the return period and sample size, when multiplied by the standard deviation provides the retreat of a desired return period rainfall from the average. Then the rainfall intensity, IT (in mm/h) for return period T is obtained from:

$$IT=\frac{P_t}{T_d} \tag{5}$$

Where Td is duration in hours.

The frequency of the rainfall is generally specified by reference to the annual maximum series, which composed of the largest values observed in each year. An alternative data format for rainfall frequency studies is that based on the peak-over threshold concept, which consists of all precipitation amounts greater than certain thresholds selected for different durations.

Due to its uncomplicated structure, the annual-maximum-series method is more popular in practice (Bogra, Vezzani and Fontana, 2005).

Table 1. The intensities mm/h for all durations are tabulated by using Gumbel distribution.

Return period T (Years)

DURATION	2	5	10	50	100
1H	39.45	64.3	80.74	117	132.34
2H	27.64	50.8	66.17	99.93	114.22
4H	16.16	34.58	46.81	73.67	85.05
8H	9.26	20.85	28.54	45.44	52.59
24H	4.25	10.87	15.27	24.85	29.05

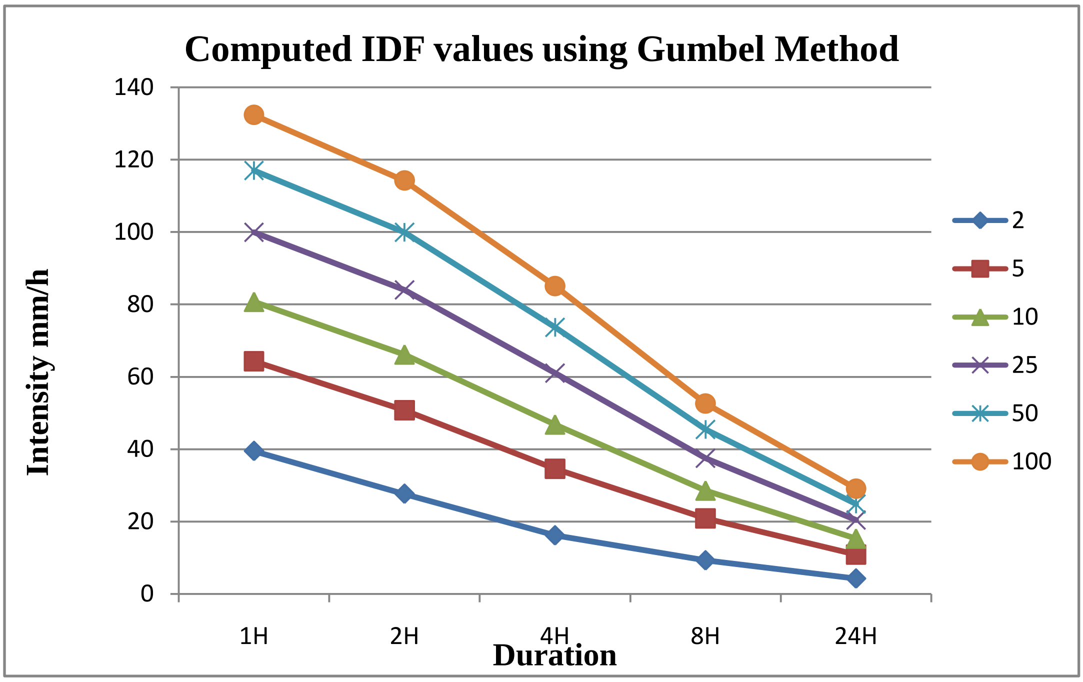

Fig 1. Intensity frequency curves for 1-,2-,4-,8-, and 24h durations.

3.2 Log Pearson type III

The LPT III probability model is apply to calculate the rainfall intensity at different rainfall durations and return periods to form historical IDF curves for each station. It is commonly used in Vietnam. LPT III distribution includes logarithms of the calculated values. The mean and the standard deviation are determined using the logarithmically transformed data. In the same way as with Gumbel method, the frequency precipitation is obtained using LPT III method. The simplified equation for this latter distribution is given as follows:

$$P^{*}=\log(pi) \quad (6)$$

$$P_{T}^{*}=P_{ave}^{*}+K_{T}S^{*} \quad (7)$$

$$P_{ave}^{*} = \frac{1}{n}\sum_{i=1}^{n} P^{*} \quad (8)$$

$$S^{*}=\left[\frac{1}{n-1}\sum_{i=1}^{n}(Pi-Pave)^{2}\right]^{1/2} \quad (9)$$

where P_T^*, P_{ave}^* and S* are as defined previously in Section 3.1 but based on the logarithmically transformed Pi values; i.e. P* of Eq. (6). K_T is the Pearson frequency factor which depends on return period (T) and skewness coefficient (Cs). The skewness coefficient, Cs, is need to calculate the frequencyfactor for this distribution. The skewness coefficient is

calculated by Eq. (9) (see Chow 1988) and Burke and Burke (2008).

$$Cs=\frac{n\sum_{i=1}^{n}(Pi^{*}-Pave^{*})^{3}}{(n-1)(n-2)(S^{*})^{3}} \quad (10)$$

K_T values can be obtained from tables in many hydrology references; for example (reference Chow 1988. By knowing the skewness coefficient Eq. (10) and the recurrence interval, the frequency

factor, K_T for the LPT III distribution can be determined. The antilog of the solution in Eq. (7) will provide the estimated extreme value for the given return period.

Table 2. The intensities mm/h for all durations are tabulated by using LPT III distribution.

Return period T (Years)

Duration	2	5	10	25	50	100
1H	39.56	63.21	81.63	100.02	116.35	131.83
2H	26.84	51.57	65.59	83.68	98.77	115.51
4H	16.11	33.64	47.04	61	74.59	84.78
8H	8.73	19.92	28.23	37.12	45.22	52.34
24H	4.32	10.48	15.66	19.82	24.45	28.36

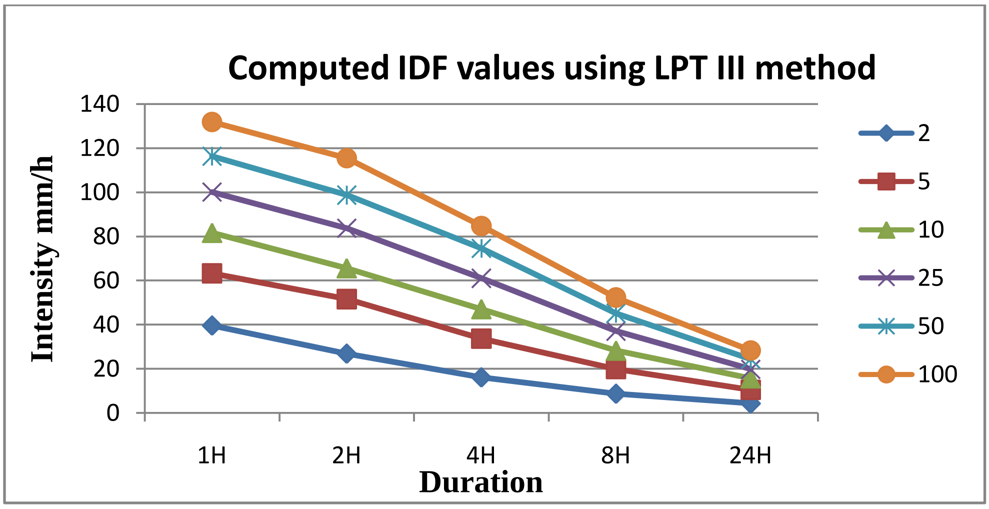

Fig 2. Intensity frequency curves for 1-,2-,4-,8-, and 24h durations.

4. Goodness of fit test

The purpose of the test is to decide how good a fit is between the frequency of occurrence observed in a sample and the expected frequencies obtained from the hypothesized distribution. A goodness-of-fit test between observed and expected frequencies is based on the chi-square quantity, which is expressed as,

$$\chi^2 = \sum_{i=1}^{k} (O_i - E_i)^2$$

Where,χ^2 is a random variable whose sampling distribution is very closely by the chi square distribution. The symbols *Oi* and *Ei*entitled the observed and expected frequencies, respectively, for the *i*-th class interval in the histogram. The symbol *k* represents the number of class intervals. There is no fixed rule for the option of the number of class intervals. If the observed frequencies are close to the corresponding anticipatefrequencies, theχ^2 value will be small, designate a good fit; otherwise, it is a poor fit. A good fit leads to the obtaining of (null hypothesis), where as poor fit leads to its refusal. The critical region will, therefore, fall in the right tail of the chi-square distribution.

5. Result and analysis

The aim of this study was to develop IDF curves to estimate the rainfall intensity at Hyderabad regions in India. The IDF curves are used as an assistancewhen designing drainage structures for any water resources engineering project. The curve allows the engineer to design safe and economical flood control measures. Rainfall estimates in mm and their intensities in mm/hr for various return periods and different durations were studied using the two techniques: (Gumbel and LPT III). The results are listed in Tables 1and 2for the region. According to the IDF curves, rainfall estimates are increasing with increase in the return period and the rainfall intensities decrease with rainfall duration in all return periods. Rainfall intensities climb in parallel with the rainfall return periods. The results obtained from the two methods have good consistency. Also, the rainfall IDF relations were calculated and tabulated for the region. Figs. 1 and 2 show results of the IDF curves obtained by Gumbel and LPT III methods for Hyderabad city. It was seen that there were small differences between the results obtained from the two methods, where Gumbel method gives slightly higher results than the results obtained by Log Pearson III.

6. Conclusions

This study has been carry out to derive a relationship between intensities and durations for a number of recurrence intervals ranging between 2 and 100 years and establishment of IDF curves using data from recording station for Hyderabad region by using two distribution methods: Gumbel, and LPT III distribution. The results obtained using the two approximates are very close at most of the return periods and have the same trend. The results acquire from that work are steady with the results from previous studies.

References

Clapeyron constraint on changes in extreme precipitation under CO2 warming”.Clim. Dyn.,28(4), 351-363.

Dupont, B.S., Allen, D.L., 2000. Revision of the Rainfall Intensity Duration Curves for the Commonwealth of Kentucky.Kentucky TransportationCenter, College of Engineering, University ofKentucky, USA.

D.Koutsoyiannis, D.Kozonis, and A.Manetas, "A mathematical Framework for StudingRainfall Intensity-Duration-Frequency Relationship",J.Hydrol., 206: 118-135, 1998

Godavari River basin of India by restoring traditional water storage systems.Clim.” Dev.,1(3), 229-240.

Gujja, B., Dalai, S., Shaik, H., and Goud, V. (2009). “Adapting to climatechange

Kothyari, U. C., and Garde, R. J. (1992). “Rainfall intensity-durationfrequencyformula for India.” J. Hydrol. Eng., 118(@),323-336..

Raiford, J.P., Aziz, N.M., Khan, A.A., Powel, D.N., 2007.Rainfall depth–duration–frequency relationships for South Carolina, and Georgia. American Journal of Environmental Sciences 3 (2), 78–84.

S.A. AlHassoun "Developing an empirical formulae to estimate rainfall intensity in Riyadh region”, Journal of King Saud University-Engineering Sciences (2011).

V.T. Chow, "Handbook of Applied Hydrology", McGraw-Hill Book, 1988.