Hydrologic Analysis of Watershed by Generation of Rainfall Intensity Duration Frequency Curves

M. Inayathulla[1], Mohammed Rafi[2]
[1]Professor, Department of Civil Engineering, U.V.C.E, Bangalore University, India
[2]PG Student, Major Water Resources Engineering, U.V.C.E, Bangalore University, India

***Abstract*- Application of short duration rainfall is necessary in analysis, planning and design of natural storm drainage system. Present study is Markandeya watershed Belagavi District Karnataka. Geographically at a 75⁰52'08.77" to 76⁰22'16.66" E longitude and 13⁰10'50.77" to 13⁰27'39.95" N latitude. It covers an area 1028.38 sq.km. Daily rainfall data of 8 stations for the years 1988 to 2015 collected from Indian Meteorological Department (IMD). The IMD empirical reduction formula was used to estimate the short duration rainfall. The rainfall depth for various return periods were predicted using different probability distributions. The Chi-Square goodness of fit was used, to arrive at the best statistical distribution among Normal and Gamble's distribution. Chi-Square showed that Normal distribution is the best probability distribution. The IDF curves were plotted for short duration rainfall of 5, 10, 15, 30, 60, 120, 720, 1440 minutes for a return period of 2, 5, 10, 25, 50 and 100 years for stations with peak rainfall values.**

***Index terms*- Chi-square test, Daily Rainfall, Gumble's distribution, IDF Curves, Normal distribution and Watershed**

1.INTRODUCTION

Urban areas if excess precipitation occurs in the short duration of period which is vulnerable effect in densely populated areas have a high risk of flash floods due to rigid and flexible pavement surfaces parking lots increases runoff by less the amount of rain absorbed by the ground during periods of heavy rainfall, floods on roads and buildings low spots, such as underground parking, garages and basement, especially subway station and rail line are also vulnerable to flash flood, to minimize such problem design of natural storm water drainage using Isopluvial maps and IDF. Isopluvial map is line on map connecting equal amount of precipitation. (Intensity-Duration-Frequency) is Rainfall Intensity (mm/hr.), Duration is defined as the period of time over which rainfall is measured is called duration. Frequency is the number of times, during a specified period of years, that precipitation of a certain magnitude or greater occurs or will occur at a station is called frequency. The IDF-relationships give an idea about the frequency or return period of a mean rainfall intensity or rainfall volume that can be expected within a certain period.

2. STUDY AREA

Present study Markandeya watershed Belagavi district Karnataka. Geographically at a 75⁰52'08.77" to 76⁰22'16.66" E longitude and 13⁰10'50.77" to 13⁰27'39.95" N latitude. Watershed covers an area 1028.38 sq.km. Maximum elevation of 959m and minimum elevation of 462m, there are eight rain gauge station considered in this study area i.e.,(Ankalgi, Desur, Heribagewadi, Jamboti, Nesargi, Sulebhavi, Sutagati and Uchagao). Markandeya River is one of the tributaries of River Ghataprabha, originates at Bailur village and flow at a length of 66 km before it joins the Ghataprabha river near the Taluk Gokak, Belagavi. Belagavi district, a northern dry region of Karnataka state.

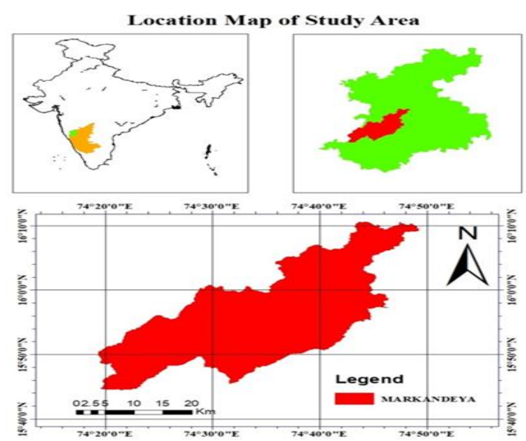
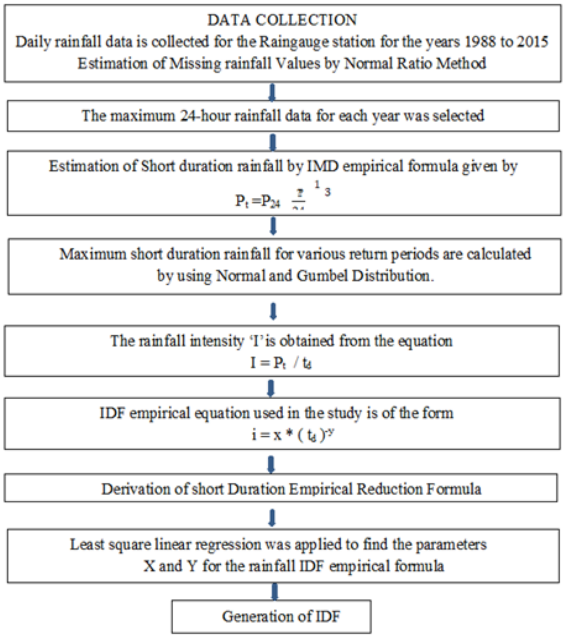


Fig.1 Location Map of Markandeya watershed

3. METHODOLOGY



Methodology for development of IDF curves

Daily rainfall data is collected for the Raingauge station for the years 1988 to 2015, the maximum 24-hour rainfall data for each year was selected. Estimation of Short duration rainfall by IMD empirical formula, Maximum short duration rainfall for various return periods are calculated by using Normal and Gumbel's Distribution. The rainfall intensity 'I', is obtained and Generation of IDF.

3.1 Estimation of Short duration rainfall by IMD empirical formula given by

$$P_t = P_{24} \left(\frac{t}{24}\right)^{1/3}$$

Where,

P_t is the required rainfall depth in mm

P_{24} is the daily rainfall in mm and

t is the duration of rainfall for which the rainfall depth is required in hr.

Indian Meteorological Department (IMD) uses an empirical reduction formula for estimation of various duration like.

5min,10min,15min,30min,1hr,2hr,12hr and 24hr rainfall values from annual maximum values for return period of 2,5,10,25,50,75,100 years

3.2 The rainfall intensity 'I' is obtained from the equation

$I = P_t / t_d$

Where,

P_t is the rainfall in mm for 't' minutes and

t_d is the duration in hours.

There are many types of theoretical distributions, for our studies two distributions are consider, Normal and Gumble's distributions. These equivalent distributions are originated according to certain theoretical assumptions and restrictions. Such theoretically designed distributions are called theoretical distributions

3.3 Normal Distribution

Short duration rainfall (mm) values of 5min,10min,15min,30min,1hr,2hr,12hr and 24hr.

Calculation Mean and Standard deviation taking a day's maximum rainfall value throughout yearly days from 1988 to 2015.

Frequency precipitation in mm $x_T = \mu + K_T \sigma$

Where,

$P_t (X_T)$ is the required rainfall depth in mm

K_T is the frequency factor

The frequency factor for normal distribution is given by

$$k_T = \frac{x_T - \mu}{\sigma}$$

This is same as the standard normal variate z i.e., frequency factor k_T = z

Then rainfall intensity calculated by

$I = P_t / t_d$

3.4 Gumbel's distribution

Gumbel's distribution is a statistical method often used for predicting extreme hydrological event such as floods. The equation for fitting the Gumbel distribution to observed series of flood flow at different return periods

$X_T = \bar{X} + K_T \sigma_x$

$P_t (X_T)$ is the required rainfall depth in mm

K_T is the frequency factor

The frequency factor K_T for Gumbel's distribution is expressed as,

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

Rainfall Intensity: The rainfall intensity I (mm/hr), for return period t is obtained from

$I = P_t / t_d$

Where,

Pt = rainfall in mm for t minutes,

td=duration in hours

4. RESULT AND CONCLUSION

Short duration rainfall values (mm) of 5min, 10min, 15min, 30min, 1h, 2h, 5h, 10h, 12h, and 24h for few years are as shown in below tables

Table.1 Estimation of short duration rainfall for Ankalgi

YEAR	RAINFALL (mm)	$P_t = P_{24}\left(\frac{t}{24}\right)^{\frac{1}{3}}$ in mm, Where, time t is in hours							
Duration in Minutes		5	10	15	30	60	120	720	1440
1988	56	8.48	10.68	12.23	15.41	19.41	24.46	44.45	56.00
1989	83	12.57	15.84	18.13	22.84	28.77	36.25	65.88	83.00
1990	31	4.69	5.91	6.77	8.53	10.75	13.54	24.60	31.00
1991	54	8.18	10.30	11.79	14.86	18.72	23.59	42.86	54.00
1992	47	7.12	8.97	10.26	12.93	16.29	20.53	37.30	47.00
1993	45	6.81	8.59	9.83	12.38	15.60	19.66	35.72	45.00
1994	82	12.42	15.64	17.91	22.56	28.43	35.82	65.08	82.00
1995	41.4	6.27	7.90	9.04	11.39	14.35	18.08	32.86	41.40
1996	53.4	8.09	10.19	11.66	14.69	18.51	23.32	42.38	53.40
1997	98	14.84	18.70	21.40	26.97	33.97	42.81	77.78	98.00
1988	125	18.93	23.85	27.30	34.40	43.34	54.60	99.21	125.00
1999	52	7.87	9.92	11.36	14.31	18.03	22.71	41.27	52.00
2000	47	7.12	8.97	10.26	12.93	16.29	20.53	37.30	47.00
2001	44	6.66	8.39	9.61	12.11	15.25	19.22	34.92	44.00
2002	50	7.57	9.54	10.92	13.76	17.33	21.84	39.69	50.00
2003	35	5.30	6.68	7.64	9.63	12.13	15.29	27.78	35.00
2004	46	6.97	8.78	10.05	12.66	15.95	20.09	36.51	46.00
2005	70	10.60	13.35	15.29	19.26	24.27	30.58	55.56	70.00
2006	96	14.54	18.32	20.97	26.42	33.28	41.93	76.20	96.00
2007	48	7.27	9.16	10.48	13.21	16.64	20.97	38.10	48.00
2008	47	7.12	8.97	10.26	12.93	16.29	20.53	37.30	47.00
2009	220	33.31	41.97	48.05	60.54	76.27	96.09	174.61	220.00
2010	188.4	28.53	35.94	41.15	51.84	65.31	82.29	149.53	188.40
2011	48	7.27	9.16	10.48	13.21	16.64	20.97	38.10	48.00
2012	49	7.42	9.35	10.70	13.48	16.99	21.40	38.89	49.00
2013	109	16.51	20.80	23.81	29.99	37.79	47.61	86.51	109.00
2014	92	13.93	17.55	20.09	25.31	31.89	40.18	73.02	92.00
2015	36.8	5.57	7.02	8.04	10.13	12.76	16.07	29.21	36.80

Table.2 Mean and Standard Deviation for Various Duration of Ankalgi station

Duration in minutes	5	10	15	30	60	120	720	1440
Mean	7.95	10.01	11.46	14.44	18.19	22.92	41.65	52.47
Standard deviation	7.54	9.49	10.87	13.69	17.25	21.74	39.50	49.77

Return period	2 year	5 year	10 year	25 year	50 year	75year	100year
Duration in (hr)	Rainfall intensity (mm/hr)	Rainfall intensity (mm/hr)	Rainfall intensity (mm/hr)	Rainfall intensity (mm /hr)	Rainfall intensity (mm /hr)	Rainfall intensity (mm/hr)	Rainfall intensity (mm/hr)
0.08333	95.35	171.50	211.29	253.70	281.10	296.65	305.70
0.16667	60.07	108.04	133.10	159.82	177.08	186.88	192.58
0.25	45.84	82.45	101.58	121.97	135.14	142.62	146.96
0.5	28.88	51.94	63.99	76.83	85.13	89.84	92.58
1	18.19	32.72	40.31	48.40	53.63	56.60	58.32
2	11.46	20.61	25.39	30.49	33.78	35.65	36.74
12	3.47	6.24	7.69	9.23	10.23	10.80	11.13
24	2.19	3.93	4.84	5.82	6.45	6.80	7.01

Table.3 IDF values by Normal Distribution result of Anklagi Station

Table.4 IDF values by Gumble's Distribution results of Ankalgi Station

Return period	2	5	10	25	50	75	100
Duration in (hr.)	Rainfall Intensity(mm/hr)	Rainfall Intensity(mm/hr)	Rainfall Intensity(mm/hr)	Rainfall Intensity(mm/hr)	Rainfall Intensity(mm/hr)	Rainfall Intensity(mm/hr)	Rainfall Intensity(mm/hr.)
0.08333	80.49	160.42	213.33	280.18	329.78	358.61	379.01
0.16667	50.71	101.06	134.39	176.50	207.75	225.91	238.76
0.25	38.70	77.12	102.56	134.70	158.54	172.40	182.21
0.5	24.38	48.58	64.61	84.85	99.87	108.61	114.78
1	15.36	30.61	40.70	53.45	62.92	68.42	72.31
2	9.67	19.28	25.64	33.67	39.64	43.10	45.55
12	2.93	5.84	7.77	10.20	12.00	13.05	13.80
24	1.85	3.68	4.89	6.42	7.56	8.23	8.69

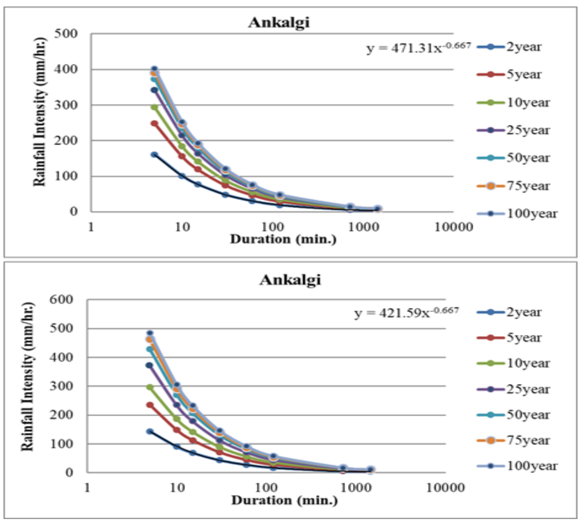


Fig.2 IDF curves for various Return Periods by Normal Distribution and Gumble's Distribution of Ankalgi Station

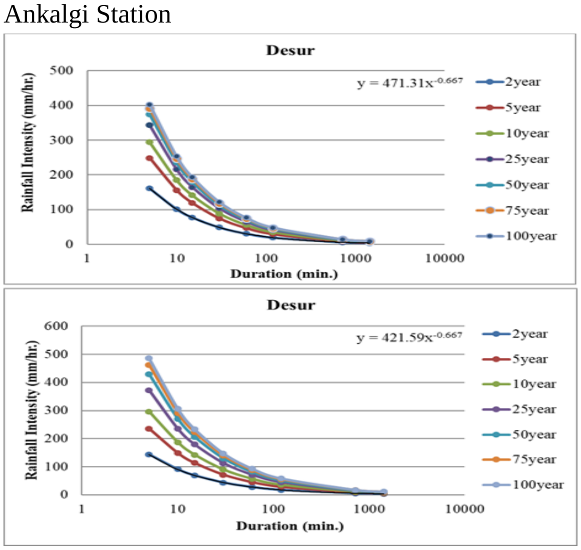


Fig.3 IDF curves for various Return Periods by Normal Distribution and Gumble's Distribution of Desur Station

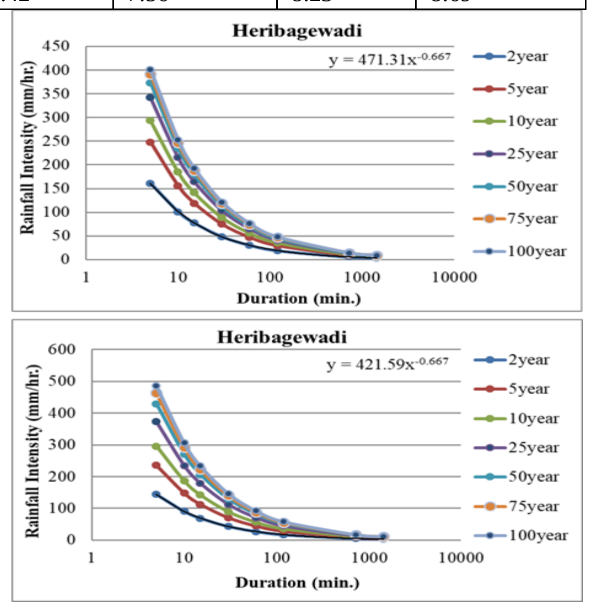


Fig.4 Rainfall IDF curves for various Return Periods by Normal Distribution and Gumble's Distribution of Heribagewadi Station

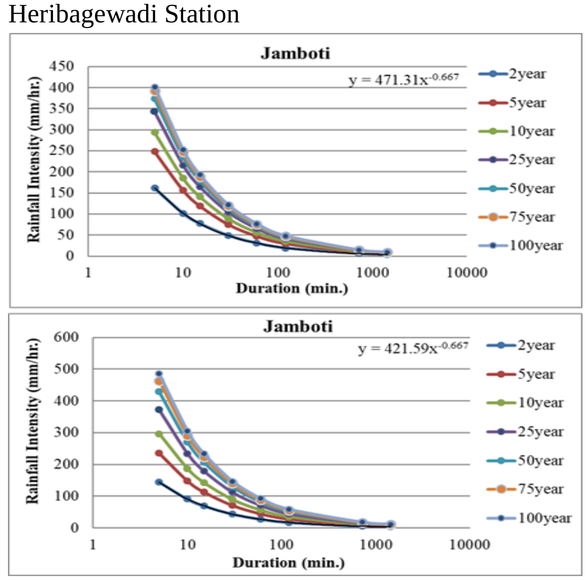
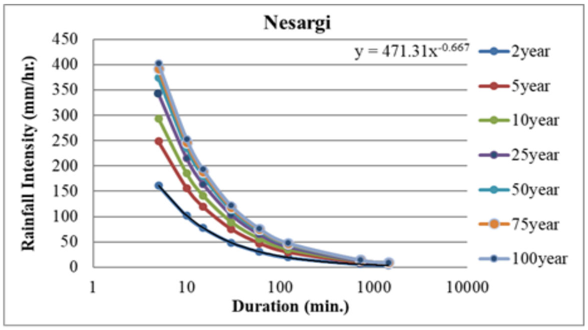


Fig.5 Rainfall IDF curves for various Return Periods by Normal Distribution and Gumble's Distribution of Jamboti station



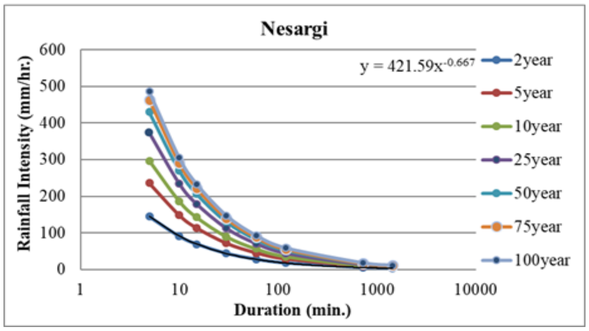
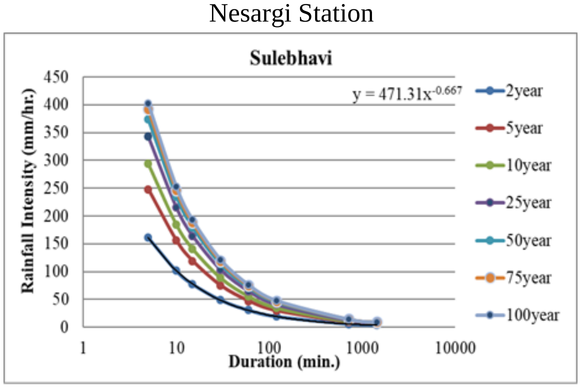


Fig.6 Rainfall IDF curves for various Return Periods by Normal Distribution and Gumble's Distribution of Nesargi Station



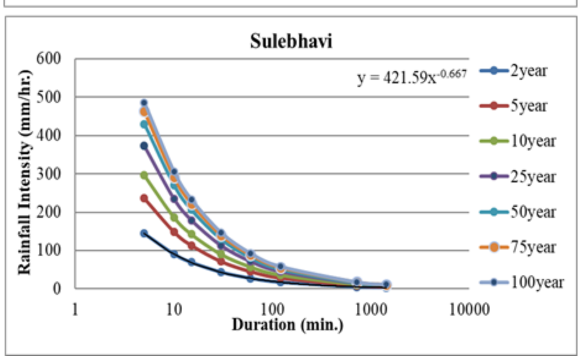
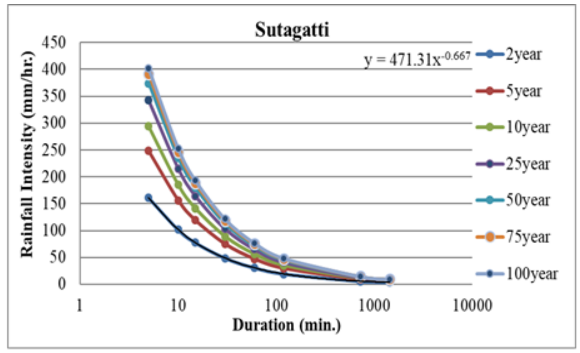


Fig.7 Rainfall IDF curves for various Return Periods by Normal Distribution and Gumble's Distribution of Sulebhavi Station



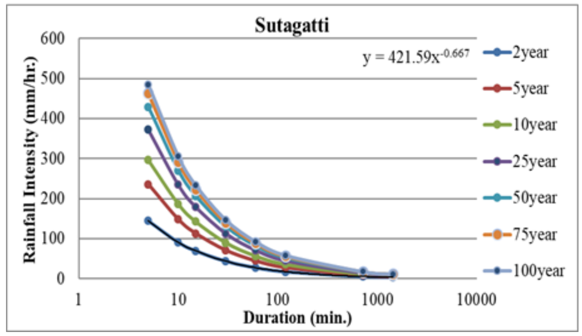
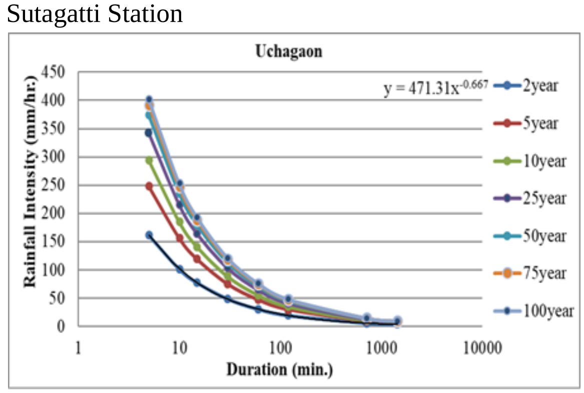


Fig.8 Rainfall IDF curves for various Return Periods by Normal Distribution and Gumble's Distribution of Sutagatti Station



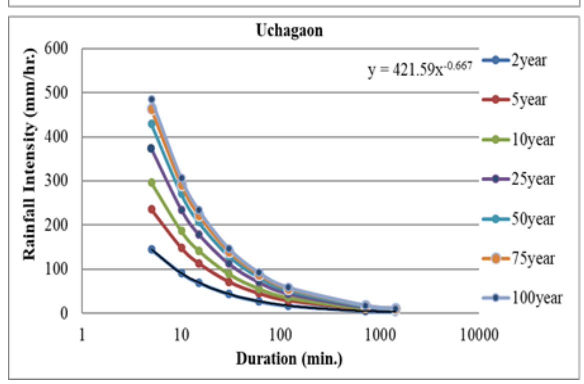


Fig.9 Rainfall IDF curves for various Return Periods by Normal Distribution and Gumble's Distribution of Uchagaon Station

Table.5 Chi-Square test for Ankalgi Rain gauge Station

Chi-Square	Normal Distribution			Gumbel Distribution		
Duration in min.	Observed values	Expected	Chi-square	Observed values	Expected	chi-square
5	7.94592	19.23	6.62	7.95	21.45	8.50
10	10.0112	24.23	8.34	10.01	27.02	10.71
15	11.46	27.73	9.55	11.46	30.94	12.26
30	14.4387	34.94	12.03	14.44	38.98	15.45
60	18.1916	44.02	15.16	18.19	49.11	19.46
120	22.92	55.48	19.10	22.92	61.87	24.52
720	41.6484	100.79	34.70	41.65	112.43	44.56
1440	52.4737	126.99	43.72	52.47	141.65	56.14

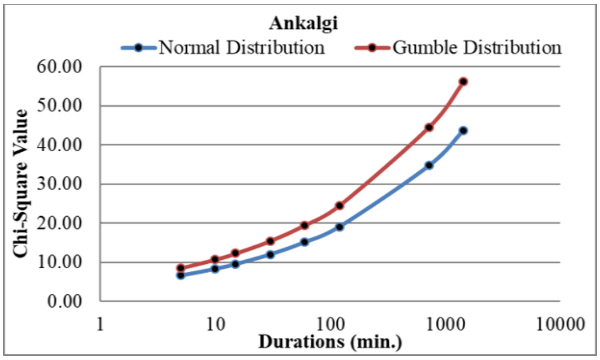


Fig.10 Chi-Square test for Ankalgi Rain gauge Station

5. CONCLUSION

It is observed that the station JAMBOTI (644.74 mm/hr.) has high rainfall intensity and NESARGI (177.15mm/hr.) has less rainfall intensity occurred at 100-year return period with short duration and among two distribution. Normal Distribution is best fit from Chi-square test result had normal distribution has less deviation from Gumble's distribution as shown fig.10 remaining stations had Normal distribution is best fir. It shows that the maximum intensity occurs at short duration with large variations with return period. This study helps in planning and design of Natural Storm Drainage and other water resource project in Ghataprabha basin

REFERENCES

[1] Bell F.C (1969) "Generalized rainfall-duration-frequency relationship" ASCE J. Hydraulic Eng.95:311-327

[2] Bernard, M. M., (1932), "Formulas for rainfall intensities of long durations". Trans. ASCE 6:592 - 624.

[3] Bhaskar, N. R.; Parida, B. P.; Nayak, A. K. 1997. Flood Estimation for Ungauged Catchments Using the GIUH. Journal of Water Resources Planning and Management. ASCE 123(4): 228-238.

[4] Eman Ahmed Hassan E1-Sayed., (2011) "Generation of Rainfall Intensity Duration Frequency Curves for Ungauged Sites", Nile Bain Water Science and Engineering Journal, 4(1):112-124.

[5] Martins Okay Isikwue, Sam Baba Onoja and Kefas J. Laudan, (2012), "Establishment of an Empirical model that correlates Rainfall-Intensity-Duration-Frequency for Makurdi area, Nigeria",

[6] Mohammed Badiuddin Parvez, Chalapathi k, Amritha Thankachan, M Inayathulla, " Modelling of Intensity-Duration Frequency curves for Upper Cauvery Karnataka through Normal Distribution", IJITEE, Vol.9, Issue.1, pp.4480-4502, 2019.

[7] Mohammed Badiuddin Parvez, M Inayathulla, "Statical Analysis of Rainfall for Development of Intensity-Duration-Frequency curves for Upper Cauvery Karnataka by Log-Normal Distribution", International Journal of Scientific Research in Mathematical and Statistical Sciences, Vol.6, Issue.5, pp.12-33, 2019.

[8] Mohammed Badiuddin Parvez, M Inayathulla, "Assesment of the Intensity Duration Frequency Curves for Storms in Upper Cauvery Karnataka Based on Pearson Type III Extreme Value", World Academics Journal of Engineering Sciences, Vol.6, Issue.1, pp.26-46, 2019.

[9] Mohammed Badiuddin Parvez, Chalapathi k, Amritha Thankachan, M Inayathulla, " Isopluvial Maps of Daily Maximum Precipitation for Different Frequency for Upper Cauvery Karnataka", Praxis Science and Technology Journal, Vol.8, Issue.10, pp.20-38, 2019.

[10] Mohammed Badiuddin Parvez, M Inayathulla "Generation Of Intensity Duration Frequency Curves For Different Return Period Using Short Duration Rainfall For Manvi Taluk Raichur District Karnataka", International Research Journal of Engineering and Management Studies (IRJEMS), Volume: 03 Issue: 04 | April -2019.

[11] Mohammed Badiuddin Parvez, M Inayathulla "Modelling of Short Duration Isopluvial Map For Raichur District Karnataka", International Journal for Science and Advance Research in Technology (IJSART), Volume: 05 Issue: 4, April -2019.

[12] M. M. Rashid, 1 S. B. Faruque and 2 J. B. Alam 2012, "Modeling of Short Duration Rainfall Intensity Duration Frequency (SDRIDF) Equation for Sylhet City in Bangladesh. 6. V.T.Chow, "Handbook of Applied Hydrology," McGraw-Hill Book.

[13] V.T.Chow., D.R. Maidment and L.W.Mays, 1988, "Applied Hydrology", McGraw- Hill, Chapter 10 – Probability, Risk and Uncertainty Analysis for Hydrologic and Hydraulic Design: 361 – 398.