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A study of maximum values of within-storm rainfall

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ABSTRACT. Design engineers often requir. adjustment factors for converting the among-storm rainfall to within-storm rainfall. For this purpose depth-transformation curves for 2-year return period for the Indian region have been compiled a id presented. For return periods of 25 years and above the adjustment factor was found to be nearly 1·0.

1. Introduction

Frequency analysis of point rainfall is required for hydrological design purposes. The data for such analysis are based either on partial duration series or annual series. These maximum values for different durations, in any particular year, often come from different storms and are generally larger for all durations than the corresponding within-storm values, *e.g.*, any 1-hr maximum value is generally larger than the 1-hr maximum value within a 24-hr maximum storm. Hence the rainfall value for a particular duration and return period found from the among-storm annual maximum rainfall series will generally be larger than the corresponding value found from the within-storm annual series.

It has been observed by hydrologists that the maximum flood peaks are generally produced by storms of long duration containing high intensity spells, whereas only low flood peaks are produced by short duration storms though the rainfall intensity in the storms may be higher. Hence it is advisable to take the design rainfall value of the required duration and frequency computed from the within-storm rainfall values.

Intensity-frequency rainfall charts are generally based on among-storm rainfall values. To convert the values picked up from these charts to within-storm values, adjustment factors are therefore to be found out from the study of the within-storm rainfall. Hershfield (1958) has provided depth-transformation curves for the Middle Atlantic Region of the United States for finding adjustment factors for converting the among-storm rainfall to within-storm rainfall for 2-year return period. No study of the within-storm rainfall has been made for the Indian region. The present paper is an attempt in this direction.

TABLE 1

Stations and period of data used

State	Station	Geographical Co-ordinates		Period of data (yrs)
		Lat. (°N)	Long. (°E)	
Delhi	New Delhi	28° 35′	77° 12′	20
Uttar Pradesh	Bamrauli	25° 27′	81° 44′	17
Bihar	Jamshedpur	22° 49′	86° 11′	17
Madhya Pradesh	Thikri	22° 04′	75° 24′	14
Maharashtra	Mahabaleshwar	17° 56′	73° 40′	28
Maharashtra	Colaba	18° 54′	72° 49′	32

2. Data

Six recording raingauge stations situated in different parts of India for which 15-min and 1-hr rainfall tabulations for a fairly long period were availalbe, were chosen for the study. Table 1 gives the list of the stations and period of data used for each station.

3. Method

The annual maximum (among-storm) values for each station for durations of 15, 30 and 45 min and 1, 3, 6, 9, 12, 15 and 24 hrs were found from the 15-min and 1-hr tabulations. After this, the annual maximum (within-storm) values for duration of say 15 min within annual 24, 15, 12, 9, 6, 3 and 1-hr and 45 and 30-min maximum (among-storm) values already found, were obtained. Similarly 30-min (within-storm) values within 15, 12, 9, 6, 3 and 1-hr and 45-min (among-storm) values were obtained. Similarly within-storm values for durations of 45 minutes

TABLE 2

Average percentage ratio of within-storm values to among-storm values

Within storm	Return periods (yr)	Duration									
		15-min	30-min	45-min	1-hr	3-hr	6-hr	9-hr	12-hr	15-hr	24-hr
24-hr	2	73·8	78·3	78·8	80·0	91·6	94·3	96·3	98·8	98·5	100·0
	5	83·5	87·7	88·2	89·0	96·9	97·6	98·1	97·9	99·1	100·0
	10	88·0	91·8	92·2	92·8	99·0	98·9	98·8	97·5	99·4	100·0
	25	92·3	95·9	95·9	96·2	100·9	100·1	99·4	97·1	99·7	100·0
	50	94·8	98·2	97·9	98·1	101·9	100·8	99·7	96·9	99·8	100·0
15-hr	2	73·3	78·7	79·5	81·1	92·6	96·1	97·8	100·1	100·0	
	5	83·4	88·1	88·6	90·0	97·7	98·5	98·6	98·3	100·0	
	10	88·2	92·1	92·3	93·7	99·7	99·4	98·9	97·6	100·0	
	25	92·7	96·1	96·0	97·2	101·5	100·3	99·0	96·9	100·0	
	50	95·2	98·3	98·1	99·1	102·5	100·7	100·9	96·5	100·0	
12-hr	2	75·1	80·3	81·0	82·1	94·3	97·2	99·2	100·0		
	5	84·0	88·6	89·1	90·3	98·1	98·3	99·0	100·0		
	10	88·2	92·3	92·6	93·8	99·7	98·7	99·0	100·0		
	25	92·3	95·8	95·8	97·1	101·0	99·2	98·9	100·0		
	50	94·5	97·8	97·7	98·6	101·8	99·4	98·8	100·0		
9-hr	2	76·4	82·6	83·3	85·1	95·9	98·6	100·0			
	5	86·4	91·5	91·6	93·4	98·9	99·3	100·0			
	10	91·0	95·2	94·9	96·7	100·1	99·6	100·0			
	25	95·5	98·9	98·1	99·8	101·2	99·8	100·0			
	50	97·9	101·0	99·9	101·5	101·7	99·9	100·0			
6-hr	2	77·5	84·2	85·1	87·0	98·0	100·0				
	5	87·5	92·4	92·5	94·4	99·3	100·0				
	10	92·1	95·9	95·8	97·4	99·9	100·0				
	25	96·5	99·4	98·8	100·2	100·4	100·0				
	50	98·9	101·3	100·5	101·8	100·7	100·0				
3-hr	2	79·5	86·3	88·1	89·7	100·0					
	5	89·3	93·1	93·7	95·1	100·0					
	10	94·0	96·0	96·2	97·3	100·0					
	25	98·5	98·9	98·4	99·3	100·0					
	50	101·1	100·6	99·7	100·5	100·0					
1-hr	2	87·6	94·0	93·4	100·0						
	5	92·5	96·1	94·7	100·0						
	10	94·6	97·1	95·3	100·0						
	25	96·7	97·9	95·9	100·0						
	50	97·8	98·5	96·1	100·0						
45-min	2	91·4	99·1	100·0							
	5	94·5	99·3	100·0							
	10	96·2	99·5	100·0							
	25	97·5	99·7	100·0							
	50	98·3	99·8	100·0							
30-min	2	94·2	100·0								
	5	96·7	100·0								
	10	97·7	100·0								
	25	98·9	100·0								
	50	99·6	100·0								

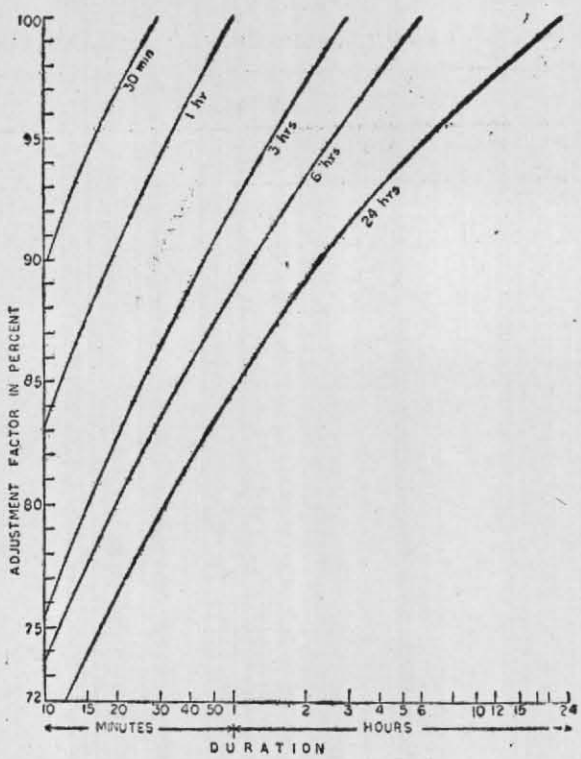

Fig. 1

Depth-duration transformation diagram for two-year return period

TABLE 3

Annual max. values for durations of	Total No. of values considered	Percentage No. of values found within annual max. storms of corresponding years of duration of								
		30-min	45-min	1-hr	3-hr	6-hr	9-hr	12-hr	15-hr	24-hr
15 min	128	61	56	43	36	33	30	27	27	29
30 min	,,	—	79	60	48	46	42	41	41	37
45 min	,,	—	—	54	47	43	40	36	39	35
1 hr	,,	—	—	—	56	53	49	46	46	43
3 hr	,,	—	—	—	—	80	71	70	69	63

and 1, 3, 6, 9, 12 and 15 hours, were obtained. Each of the annual maximum series, thus obtained, was subjected to frequency analysis using Gumbel's (1954) extreme value technique. For each station, for a particular duration, the percentage ratios of within-storm values to among-storm values for return periods of 2, 5, 10, 25 and 50 years, were found. The mean ratios for all the stations for each duration and return period were calculated. The results are given in Table 2. The mean ratios for 2-year return period and for durations of 30 min, 1, 3, 6 and 24 hr were plotted on a semi-log paper and smooth curves were drawn (Fig. 1).

The annual maximum values (among-storm) for all the six stations for durations of 15, 30 and 45 min and 1 and 3 hr, were examined to find out how many of them were also the within-storm values. The results are given in Table 3.

TABLE 4

Period of data (yrs)	Highest value: Duration	Rainfall amount	Date	Time (IST)	Return period	Whether the highest value is found within annual max. storms of corresponding year of duration of: 30-min	45-min	1-hr	3-hr	6-hr	9-hr	12-hr	15-hr	24-hr
					New Delhi									
20	15 min	30·0	2-8-61	0530-0545	19	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	30 min	49·3	7-9-48	0830-0900	15	—	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	45 min	69·6	7-9-48	0815-0900	28	—	—	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	1 hr	73·2	7-9-48	0800-0900	26	—	—	—	Yes	Yes	Yes	Yes	Yes	Yes
	3 hr	115·6	2-8-61	0300-0600	37	—	—	—	—	Yes	Yes	Yes	Yes	Yes
					Bamrauli (Uttar Pradesh)									
17	15 min	40·0	16-8-61	1315-1330	19	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	30 min	63·5	10-8-54	1330-1400	16	—	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	45 min	86·4	10-8-54	1330-1415	25	—	—	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	1 hr	74·7	16-8-61	1300-1400	11	—	—	—	Yes	Yes	Yes	Yes	Yes	Yes
	3 hr	111·8	30-6-51	1000-1300	13	—	—	—	—	Yes	Yes	Yes	Yes	Yes
					Jamshedpur (Bihar State)									
17	15 min	34·5	20-5-49	1545-1600	19	No	No	No	No	No	No	No	No	No
	30 min	52·7	23-6-56	1615-1645	14	—	Yes	Yes	Yes	Yes	Yes	No	No	No
	45 min	71·1	10-6-49	0015-0100	21	—	—	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	1 hr	91·4	10-6-49	0000-0100	25	—	—	—	Yes	Yes	Yes	Yes	Yes	Yes
	3 hr	151·4	29-6-53	1000-1300	22	—	—	—	—	Yes	Yes	Yes	Yes	Yes
					Thikri (Madhya Pradesh)									
14	15 min	25·9	31-8-54	1530-1545	8	Yes	No	No	No	No	No	No	No	No
	30 min	40·6	13-8-53	1530-1600	8	—	Yes	Yes	Yes	Yes	Yes	No	No	No
	45 min	53·3	13-8-53	1515-1600	8	—	—	Yes	Yes	Yes	Yes	No	No	No
	1 hr	61·0	13-8-53	1500-1600	10	—	—	—	Yes	Yes	Yes	No	No	No
	3 hr	110·7	1-9-54	1400-1700	15	—	—	—	—	Yes	Yes	Yes	Yes	Yes
					Mahabaleshwar (Maharashtra)									
28	15 min	39·9	8-8-54	1745-1800	395	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	30 min	42·2	8-8-54	1745-1815	42	—	Yes	No	No	Yes	Yes	Yes	Yes	Yes
	45 min	53·3	31-8-32	1830-1915	45	—	—	Yes	No	No	No	No	No	No
	1 hr	54·9	8-8-54	1700-1800	25	—	—	—	Yes	Yes	Yes	Yes	Yes	Yes
	3 hr	108·7	23-6-51	2100-2400	23	—	—	—	—	Yes	Yes	Yes	Yes	Yes
					Colaba (Maharashtra)									
32	15 min	32·0	25-9-56	2215-2230	26	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	30 min	62·0	25-9-56	2215-2245	47	—	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	45 min	80·3	25-9-56	2200-2245	27	—	—	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	1 hr	102·4	10-9-30	0200-0300	56	—	—	—	Yes	Yes	Yes	Yes	Yes	Yes
	3 hr	253·5	10-9-30	0100-0400	186	—	—	—	—	Yes	Yes	Yes	Yes	Yes

TABLE 5

Average percentage ratio of within-storm to among-storm values for 2-yr return period

Within-storm	Duration among-storm															
	15-min		30-min		1-hr		2-hr		3-hr		6-hr		12-hr		24-hr	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
24-hr	74	77	80	81	85	85	89	89	91	91	95	94	97	97	100	100
6-hr	77	81	84	86	89	90	93	94	96	96	100	100	—	—	—	—
3-hr	80	85	87	90	92	94	97	97	100	100	—	—	—	—	—	—
1-hr	88	92	94	96	100	100	—	—	—	—	—	—	—	—	—	—
30-min	94	96	100	100	—	—	—	—	—	—	—	—	—	—	—	—

A — Ratios for Indian regions

B — Ratios for USA (Hershfield)

The highest values recorded at each station for durations of 15, 30 and 45 min and 1 and 3 hr were also examined to find whether these values are found within annual maximum storms of corresponding years of different durations. The results are shown in Table 4.

4. Results

It is seen from Table 2 that the ratios increase as the return period increases. For the same return period, the ratio increases as duration increases. It is also seen that for the same return period and duration, the ratio increases as the duration of the within-storm decreases. The ratio varies from 0.73 to 1.0 depending on the duration and the return period.

The ratios (A) for 2-year return period from the curves of Fig. 1 are given in Table 5 along with the Hershfield ratios (B). It is evident from this table that the ratios are almost identical with those found by Hershfield.

It may be seen from Table 2 that the return period has significant effect on the ratio. For return period of 25 years and more, the ratio may be taken to be nearly 1.0. It indicates that higher among-storm and within-storm values are almost the same, *i.e.*, the higher values of different durations mostly form part of longer duration storms. It may be seen from Table 3 that more than 54 per cent of annual maximum values form part of longer duration storms. This table also shows that the percentage number of annual maximum values of a particular duration found within-storms decreases as the period of the within-storms increases. But almost all the highest values at each station are within-storm values as is seen from Table 4. The highest 15 min value of 34.5 min with return period of 19 years at Jamshedpur was not found to be within annual maximum storms, but still it was seen to form part of a storm of duration of $4\frac{1}{2}$ hr. The highest 15-min value of 25.9 mm with return period of 8 years at Thikri was within 30-min maximum storm only and was seen to form part of a storm of duration $1\frac{1}{2}$ hr. At Mahabaleshwar 30 min and 45 min highest values, though not within some of the maximum storms, were part of storms of duration of $15\frac{3}{4}$ hr and 7 hr respectively. It shows that a few of the higher values, generally of less than 25-yr return period and of very short duration only (15 min or so) may not form part of very long duration storms. For small basins design engineers are mostly concerned with rainfall values for durations of more than 30 min and upto 9 hours and return period of more than 25 years and such values are seen to form part of longer duration storms with adjustment factor of nearly 1.0.

5. Summary

The adjustment factors for converting 2-yr point rainfall values to within-storm values may be obtained from the depth-duration transformation diagram (Fig. 1). The adjustment factor for 25-yr and above values may be taken to be nearly 1.0.

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