Mausam, (1987), **38**, 1, 85-88

551.577.23 : 551.57

Rainfall intensity for local drainage design in Lucknow and its neighbouring area

S. N. KATHURIA
Central Water Commission, New Delhi

SURINDER KAUR and A. K. MEHRA
Meteorological Office, New Delhi

(*Received 18 March 1985*)

सार — इस अध्ययन का प्राथमिक उद्देश्य शहरी जल निकास प्रणाली की अभिकल्पना के लिए अभिकल्प तूफान अनुमानों के परिकलन के लिए वर्षा के आंकड़ों का विश्लेषण करना है। लखनऊ के चारों तरफ 0.5° अक्षांश और 0.5° देशान्तर में पड़ने वाले आस-पास के संलग्न क्षेत्रों के लिए 24 सामान्य वर्षामापी स्टेशनों और 3 स्वतः अभिलेखन वर्षा मापी स्टेशनों द्वारा अभिलेखित वर्षा के आंकड़ों के विश्लेषण द्वारा प्रसंभाव्य वर्षा का सांख्यकीय दृष्टि से अनुमान लगाया गया। इसमें निम्नलिखित विभिन्न पहलुओं का अध्ययन किया गया —

(क) कथित क्षेत्र में तूफानी वर्षा का कालगत वितरण और

(ख) 6 घंटे तक और 2 तथा 5 वर्षों की आवर्ती अवधियों के लिए तथा 6 घंटे की अवधि की तूफानी वर्षा का गहन अवधि बारंबारता विश्लेषण।

ABSTRACT. The primary object of this study is to analyse rainfall data for working out design storm estimates for the design of urban drainage system. The probable rainfall has been statistically estimated by analysing the rainfall data recorded by 24 ordinary raingauge (ORG) stations and 3 self recording raingauge (SRRG) stations falling in and around the area enclosed by 0.5° latitude and 0.5° longitude around Lucknow. The various aspects studied are :

(*a*) Temporal distribution of rainstorms over the said area and

(*b*) Depth duration frequency analysis of rain storms for durations upto 6 hours and for 2 and 5 years return periods.

1. Introduction

In a developing country, the priorities for economic development and investment are for food, housing, clothing, health and education. Urban drainage is generally not taken into consideration except when it affects significantly above areas particularly, as a part of flooding of urban area. Failure to provide an adequate urban drainage system seriously affects the life of the people and exposes them to potential health hazards. Thus, urban drainage systems are linked with the overall problem of slum abolition, re-settlement and urban redevelopment. Perhaps, that is why proposals for urban drainage improvements such as in the Delhi metropolitan area (1976) were taken up.

Design engineers concerned with the design of small hydraulic structures like rail and road bridges, culverts, urban drainage system require the estimates of design rainfall of short durations. The temporal and spatial distribution of rainfall within a storm are some of the very important factors which govern the design floods estimation. These rainfall estimates are determined by the analysis of hourly rainfall data recorded by SRRGs. However, the network of SRRG is inadequate in most of the catchments all over the country. But, a huge amount of daily rainfall data recorded by ordinary raingauge stations is available which could be used by converting daily rainfall data into short duration rainfall data.

Rao *et al.* (1983) interpolated the short duration rainfall for a given return period from daily values of rainfall recorded by ordinary raingauges in Lower Godavari basin. The coefficients of regression between short duration rainfall and 24-hour rainfall for a given return period based on 14 SRRGs in the basin were worked out using least square method. They used these coefficients to interpolate short duration rainfall from daily values of rainfall. These interpolated short duration rainfall estimates were compared with actual observations of short duration rainfall of the nearby recording raingauge station.

In this paper, an attempt has been made to study the design of the drainage system in Lucknow and neighbouring area. Following Ramaseshan and Sarma (1978), the study is restricted to short durations upto 6 hours and return periods upto 5 years. The hourly rainfall data recorded by SRRG over Lucknow for 25 years and 8 years, SR data each recorded over Kanpur and Bahraich and daily rainfall data recorded

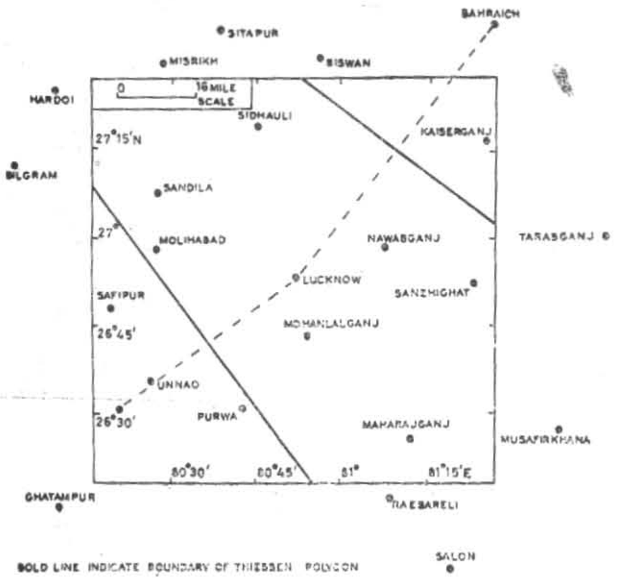


Fig. 1. Location of raingauge stations & Thiessen polygon

over 24 stations falling in and around the area covered by 1/2° latitude and 1/2° longitude around Lucknow for 63 to 70 years have been utilised in the study. The data were processed by frequency analysis and isopluvial maps for 1, 3 and 6 hours and for 2 and 5 years return periods were prepared and are presented in the paper. The temporal distribution of rainstorms over the area were also studied in two categories of rain storm duration, namely, 3 and 6 hours.

2. Data used

The daily rainfall data of 24 stations (Table 1) for the period 50 to 70 years surrounding Lucknow have been used in the study (Fig. 1). The hourly rainfall data of Lucknow for 25 years and 8 years, SR data of Kanpur and Bahraich have also been utilised.

3. Methodology

The rainfall data were analysed using Gumbel's extreme value distribution.

3.1. *Application of Gumbel's extreme value distribution*

According to Gumbel's (1958) distribution, the probability density function $F(x)$ is given by

$$F(x) = \exp\left[-\exp\{-\alpha(x-u)\}\right] \tag{1}$$

where x is the extreme rainfall likely to be equalled or exceeded once in a given return period, on an average. The parameters α and u can be estimated by the maximum likelihood procedure as given in the following steps :

(*i*) Arrange the data into ascending order.

(*ii*) Calculate the sextile means.

(*iii*) Calculate the mean ($\bar{x}$) and standard deviation (σ) of the sextile means.

(*iv*) Calculate

$$\hat{\alpha} = 0.8333\,\bar{x} \tag{2}$$

$$u_0 = \bar{x} - 0.4833\,\sigma \tag{3}$$

TABLE 1

List of ORG stations used

District	Station	Period of data (Years)
(1) Lucknow	Lucknow	70 (1901-70)
	Mohilabad	63 (1901-63)
	Mohanlal Ganj	63 (1901-63)
(2) Kanpur	Kanpur	66 (1901-64, 67, 68)
	Derapur	66 (1901-64, 67, 68)
	Ghatampur	66 (1901-64, 67, 68)
(3) Unnao	Unnao	65 (1901-64, 67)
	Safipur	65 (1901-64, 67)
	Purwa	65 (1901-64, 67)
(4) Sitapur	Sitapur	65 (1901-63, 65, 67)
	Biswan	65 (1901-63, 65, 67)
	Sidhuli	50 (1901-50)
	Misrikh	65 (1901-63, 65, 67)
(5) Hardoi	Hardoi	66 (1901-64, 67, 68)
	Sandila	66 (1901-64, 67, 68)
	Bilgram	65 (1901-63, 64, 68)
(6) Raibareli	Raibareli	66 (1901-64, 67, 68)
	Maharaj Ganj	66 (1901-64, 67, 68)
	Salon	66 (1901-64, 67, 68)
(7) Gonda	Tarab Ganj	66 (1901-64, 65, 67)
(8) Barabanki	Nawabganj	61 (1901-59, 61, 62)
	Sanehighar	65 (1901-64, 67)
(9) Sultanpur	Musafirkhanna	65 (1901-64, 67)
(10) Bahraich	Kaisarganj	66 (1901-64, 67, 68)

TABLE 2

Reduction factors used for computing short duration 24-hour rainfall

Station	Ratios with respect to 24 hours 1-hr	3-hr	6-hr
Lucknow	0.36	0.58	0.71
Kanpur	0.38	0.61	0.74
Bahraich	0.35	0.57	0.69

These values are used to initiate the maximum likelihood solution.

(*v*) Tabulate

$$x_i = (x_i - u_0)/\hat{\alpha} \tag{4}$$

(*vi*) Compute

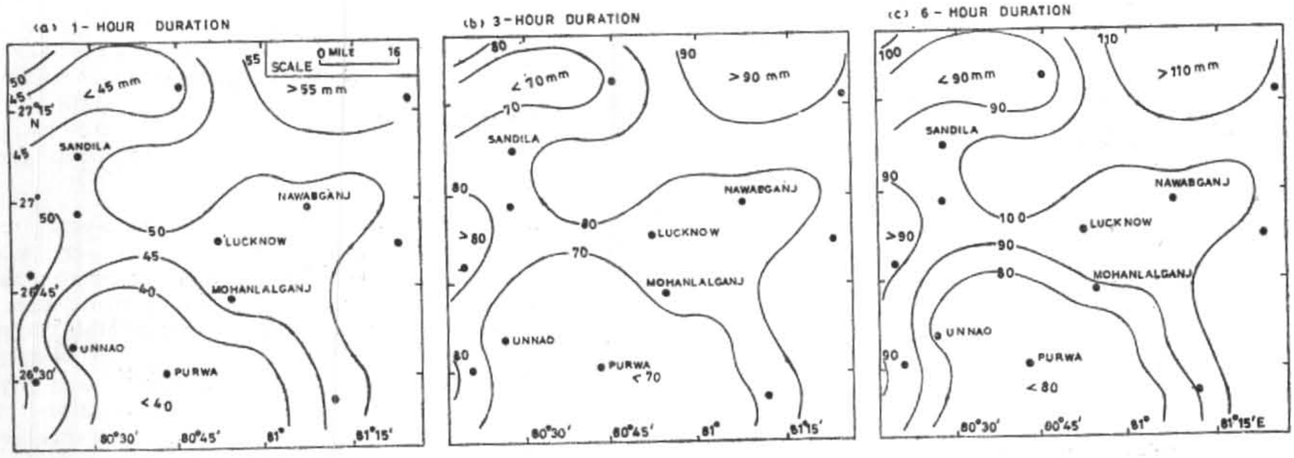
$$P = N - \sum_{i=1}^{N} e^{-x_i} \tag{5}$$

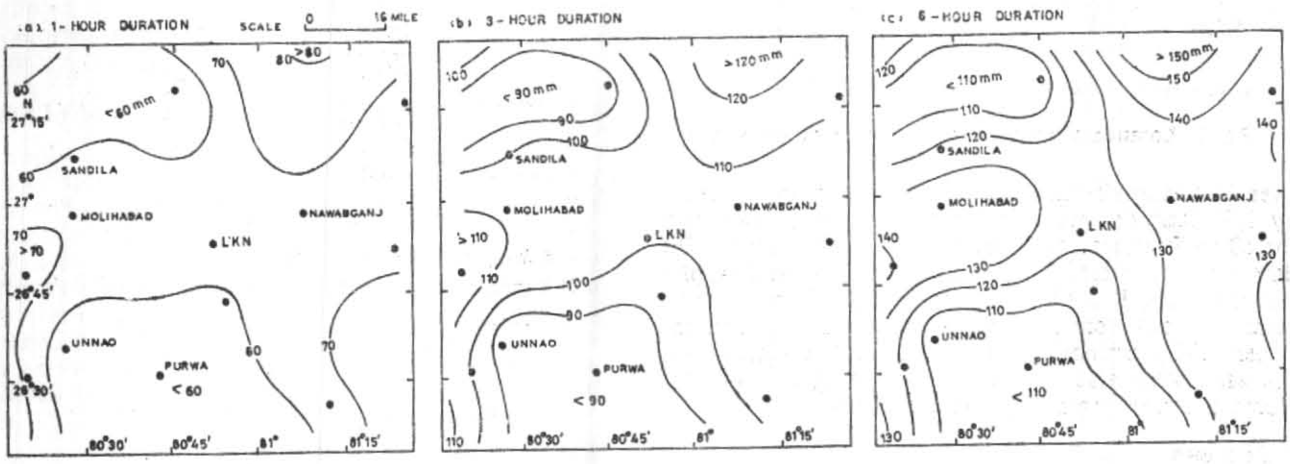
$$R = N - \sum_{i=1}^{N} x_i + \sum_{i=1}^{N} x_i \,.\, e^{-x_i} \tag{6}$$

(*vii*) Compute corrections $\delta\alpha$, δu_0 to the values $\hat{\alpha}$, u_0 given by

$$\delta\alpha = (0.26P - 0.608R)\,\hat{\alpha}/N, \tag{7}$$

$$\delta u_0 = (1.11P - 0.26R)\,\hat{\alpha}/N \tag{8}$$





Figs. 2 (upper) & 3 (lower). Isopluvial maps of Lucknow and its neighbourhood for 2 & 5-yr return periods respectively

TABLE 3

Rainfall estimates (X_T) with standard error (SE) for various short durations for Lucknow station

Duration (hour)	Mean (mm)	SD (mm)	Return period 2-year X_T (mm)	2-year SE (mm)	5-year X_T (mm)	5-year SE (mm)	50-year X_T (mm)	50-year SE (mm)	100-year X_T (mm)	100-year SE (mm)
1	53.8	18.7	50.8	3.6	68.5	5.6	106.0	11.0	116.9	12.6
3	86.0	31.7	80.7	6.2	110.8	9.5	174.6	18.7	193.1	21.4
6	106.7	48.2	98.4	8.9	141.7	13.7	233.5	26.9	260.1	30.6

TABLE 4

Temporal distribution of rainfall

	Duration (hr) 1	2	3	4	5	6
Category I (%)	71	92	100	—	—	—
Catgory II (%)	56	73	81	92	97	100

(*viii*) The corrected estimates become

$$\hat{\alpha} = \alpha + \delta\alpha, \quad (9)$$

$$u = u_0 + \delta u_0. \quad (10)$$

Repeat the above procedure from step (*v*) to step (*viii*) till corrections $\delta\alpha$, δu_0 become small.

The rainfall estimates (X_T) for a particular return period (T) may be computed by

$$X_T = u + Y_T/\alpha \quad (11)$$

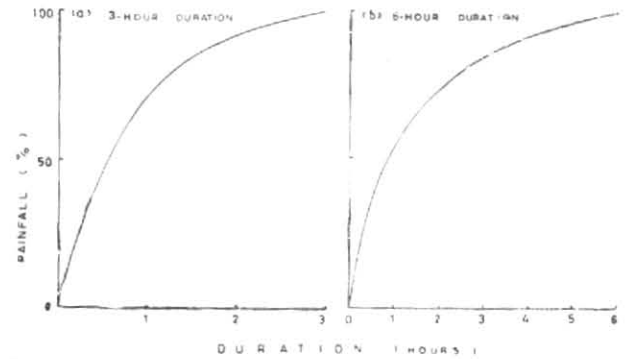
$$Y_T = -\ln \ln [T/(T-1)] \quad (12)$$

where, Y_T is the reduced variate, corresponding to T-yr return period. The standard error for the rainfall estimates, X_T using the maximum likelihood method for the estimation of parameters is given by :

$$\mathrm{SE}\,(X_T) = \frac{1}{\alpha N^{1/2}}\,(1.11 + 0.52 Y_T + 0.61 Y_T^2)^{\frac{1}{2}} \quad (13)$$

3.2. *Interpolation of short duration rainfall from daily values*

The daily rainfall of 24 stations were processed for the selection of the annual daily maximum series. The



Figs. 4(a & b). Average temporal distribution of rainfall

annual daily maximum series were converted into annual 24 hours maximum series by multiplying by a factor of 1.16. The factor of 1.16 has been worked out from the average of ratios of 24 hours annual maximum rainfall recorded by three SRRGs, namely, Lucknow, Kanpur and Bahraich to the synominous daily annual maximum rainfall values recorded by the same ORG station. Rainfall estimates for 2 and 5 years return periods were obtained by using the frequency analysis. These rainfall estimates are based on annual maximum series. These have to be converted into partial duration series in order to obtain realistic estimates. The multiplying factors of 1.13 and 1.04 are used for 2 and 5 year return periods respectively (Dhar and Kulkarni 1970).

The hourly rainfall data of Lucknow, Kanpur and Bahraich were processed by frequency analasis. The rainfall estimates for duration 1, 3, 6 and 24 hours for 2-year return period were used to compute the short duration (1, 3 and 6 hours) rainfall ratios with respect to 24-hour rainfall estimate. These respective station ratios (Table 1) were used to interpolate short duration rainfall estimates from 24 hours rainfall estimates for all the stations falling in the polygons drawn in the basis of Thiessen polygons in the study area (Fig. 1).

3.3. *Temporal distribution of rainfall*

All the rain storms above 3 cm amount in 3 hours or 6 hours recorded over three SR stations were collected for this study. The temporal distribution is studied under two categories of storm durations, namely, 3 and 6 hours. The percentage ratios of hourly rainfall were computed with respect to 6 hourly (or 3 hourly) accumulated rainfall. The percentage ratios were plotted against durations for all storms and an average curve was drawn.

4. Results and discussions

Gumbel's extreme value distribution with estimation of parameters by maximum likelihood procedure was adopted for the computation of rainfall estimates of specified return periods and durations. Using the hourly rainfall data recorded over Lucknow, Kanpur and Bahraich and daily rainfall data recorded over 24 stations in neighbouring area of Lucknow, return periods estimates for short durations and daily annual maximum series were computed. The rainfall estimates for Lucknow for various short durations 1, 3 and 6 hours and for 2, 5, 50 and 100 years return periods which may be used for the design of road and railway bridges in small and medium catchments in the study area are provided in Table 3. The rainfall estimates of daily values for 2 and 5-year return periods for all 24 stations were converted into 24 hours rainfall estimates using the conversion factor of 1.16 and adjustment factors of 1.13 and 1.04 respectively.

The ratios of rainfall estimates for 2-year return period of 1, 3 and 6 hours durations were worked out with respect to 24-hour rainfall estimates as explained in section 3.2 above. These ratios were utilised to interpolate 1, 3 and 6 hours rainfall estimates from 24-hour rainfall estimates in respect of 24 stations. These interpolated rainfall estimates for 2 and 5 years return periods and 1, 3 and 6 hours durations were plotted on base maps and isohyetal analysis was carried out. These isohyetal maps (restricted upto 1/2° latitude and 1/2° longitude around Lucknow) are depicted in Figs. 2 & 3. The standard errors in the estimation of rainfall estimates for specified return periods and duration can be estimated from Eqn. (13). These standard error estimates for 2 and 5 years return periods for 1, 3 and 6 hours durations are tabulated (Table 3).

The temporal distribution studies were done by collecting rainstorms above a threshold value of 3 cm rainfall recorded in 3 and 6-hour durations. The study, was done under two categories of duration, namely (a) storms of 3 hour duration, (b) storms of 6 hours duration. The percentage of hourly rainfall with respect to 3-hour (6-hour) rainfall were worked out and plotted *versus* duration of rainfall for all the rainstorms. The average curves averaging over all the storms were drawn. The average temporal distribution of storms of 3 and 6 hours duration are depicted in Fig. 4 (a) & (b) and the results are tabulated (Table 4).

It may be added that the design estimate tabulated in Table 3 and Figs. 2 & 3 are point estimates and may be adopted for drainage in small basins of areas upto 25 km². An appropriate areal reduction factor may be applied for adopting these values to design drainage system for basins of catchment area more than 25 km².

Acknowledgements

The authors are thankful to Shri A. D. Mohile, Chief Engineer, Central Water Commission, New Delhi for helpful discussions. The authors are also thankful to referee for his comments, inclusion of which enhanced the clarity of the paper.

References

Dhar, O.N. and Kulkarni, A.K., 1970, *Indian J. Met. Geophys.*, **21**, 2, p. 259.

Gumbel, E.J., 1958, *Statistics of Extremes*, Columbia University Press, New York.

Hershfield, D.M., 1965, *J. Am. Water Works Association*, **57**, p. 965.

Master Plan Organisation, 1976, Outline of the Master Plan of Drainage in the Union Territory of Delhi, Report of experts committee of flood control department, Delhi Administration, Delhi.

Ramaseshan, S. and Sarma, P.B.S., 1978, Urban Hydrological Modelling and Catchment Research in India, IHP Report 4, CSIR, New Delhi.

Rao, D.V.L.N., Goyal, S.C. and Kathuria, S.N., 1983, *Mausam*, **34**, p. 291.