Characteristics of short-duration extreme rainfalls in Selangor, Malaysia

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The characteristics of short-duration (say less than 1 hour) extreme-rainfall events are of great importance in the engineering design of small and medium-sized hydraulic structures, such as road culverts and urban storm sewers. Therefore, engineers concerned with urban drainage works are constantly in need of the basic statistical characteristics of short-duration rainfall for calculating runoff. A short-duration rainfall analysis for Kuala Lumpur and part of the Malaysian state of Selangor was made by Desa (1997) but a detailed analysis is still lacking for other raingauges in the state. Here we analyse historical rainfall records from raingauges from the whole of Selangor (Fig. 1), located in the equatorial region, so as to provide information on short-duration extreme rainfalls and to estimate their frequency of occurrence (usually in terms of return period in years). The results reported will not only be useful in the design of the urban drainage structures that may be constructed in the region of Selangor but will also provide a dataset of extreme rainfalls that have occurred in the equatorial region.

Meteorological causes of extreme rainfalls over Selangor

The state of Selangor, with an area of 8200 km^2, is located in the western part of peninsular Malaysia and lies near to the equator (Fig. 1). It receives widespread heavy and prolonged rainfall during the summer (June–September) and winter (December–March) seasons, associated with the south-west and north-east monsoon winds respectively. At the same time, because of its nearness to the equator, heavy localised rainfalls of shorter duration, associated with severe convective thunderstorms created by unstable weather conditions, occur throughout the year. Although thunderstorms occur in Selangor throughout the year, they are more numerous and vigorous during the inter-monsoon months of April–May and October–November. Desa *et al.* (2001) showed that about 40% of all heavy rainfalls (those exceeding 5 mm day^{-1} at most raingauges in Selangor) occurred during the inter-monsoon months. The average lifespan of a thunderstorm is about 15–30 minutes, but some may last for several hours when a cluster of thunderstorms affects an area for a prolonged period of time (Petterssen 1969; Desa 1997).

Thunderstorm rainfall in Selangor is often of short duration and localised in nature. A typical example is given by the raingauge at Sekolah Kebangsaan Kampong Lui (location No. 7 in Fig. 1) which recorded an extreme rainfall of 141.5 mm within 1 hour on 18 May 1991. This event caused extensive inundation and damage in and around the area. To ensure adequate protection from such floods, it is necessary that structures such as bridges, highways and railway culverts, urban storm sewers and airfield drainage be designed to take into account the frequency of short-duration extreme rainfall.

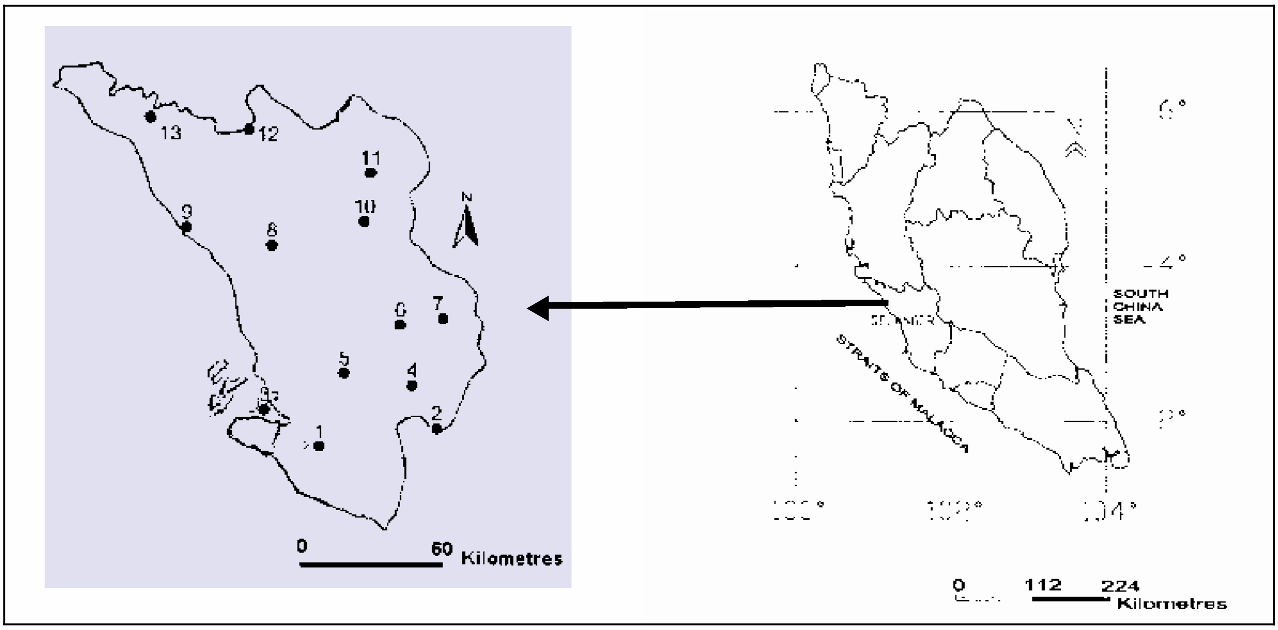

Fig. 1 Locations of study area and the raingauges used, Nos. 1 to 13

Table 1

Self-recording rainfall raingauges in Selangor

Location (see Fig. 1)	Name of raingauge	Period of available data	No. of years
1	Pejabat JPS* Sungai Manggis	1971–98	28
2	Ibu Bekalan Enam kaki	1971–99	29
3	Pintu Kawalan p/s Telok Gong	1974–98	25
4	Setor JPS Kajang	1975–99	25
5	Puchong Drop	1976–98	23
6	Pusat Penyelidikan JPS Ampang	1971–99	29
7	Sekolah Kebangsaan Kampong Lui	1971–99	29
8	Rumah Pam JPS Paya Setia	1974–99	26
9	Setor JPS Tanjung Karang	1971–99	29
10	Kampong Kalong Tengah	1979–99	21
11	Logi Air Kuala Kubu Bahru	1971–99	29
12	Ibu Bekalan Sungai Bernam	1971–99	29
13	Rumah Pam JPS Bagan Terap	1971–99	29

*Jabatan Pengairan dan Saliran (Department of Irrigation and Drainage).

Table 2

Highest recorded rainfall (mm) for different durations (1971–99)

Raingauge No.*	Durations (hours)			
	0.25	0.50	1	6
1	42	60	73	119
2	49	78	91	114
3	47	63	91	156
4	54	71	89	165
5	55	61	91	126
6	54	78	96	125
7	77	81	141	197
8	64	68	112	163
9	74	74	87	174
10	68	68	76	226
11	62	70	95	154
12	62	85	104	147
13	63	64	79	116

* For location see Fig. 1. For name see Table 1.

Table 3

The 25 notable extreme rainfalls (mm) for different durations over Selangor

Rank No.	Duration (hours)				Return period (years)
	0.25	0.50	1	6	
1	77.4	84.6	141.5	226.3	725
2	73.5	80.7	111.5	197.0	363
3	67.5	78.0	103.5	173.5	242
4	63.5	77.5	101.6	165.1	182
5	63.0	77.4	99.4	162.5	145
6	62.5	73.5	96.0	162.2	121
7	61.7	71.4	95.1	155.5	104
8	61.5	71.3	91.8	153.5	91
9	59.0	70.7	90.8	150.0	81
10	58.5	69.9	90.8	148.5	73
11	58.5	69.7	90.7	147.0	66
12	56.0	69.2	90.5	144.2	61
13	54.6	69.0	90.0	143.0	56
14	54.3	68.2	88.7	136.0	52
15	54.0	67.8	88.0	135.6	48
16	53.7	67.5	87.8	131.5	45
17	53.6	67.2	86.9	131.0	43
18	53.0	65.8	86.5	130.5	40
19	52.1	64.1	86.3	128.2	38
20	51.9	63.8	86.0	128.0	36
21	51.4	63.6	85.8	126.9	35
22	51.4	63.5	84.7	125.5	33
23	50.7	63.5	83.9	125.0	31
24	50.6	63.0	82.0	123.5	30
25	50.2	62.5	81.7	122.0	29

Data used

There is a network of 25 self-recording Hattori raingauges which serve to collect rainfall data throughout Selangor. Of these, only 13 raingauges have long-term continuous rainfall data ranging from 21 to 29 years (Table 1). For the purpose of this study, the required data were supplied by the Department of Irrigation and Drainage, Malaysia, in the form of the annual extreme-rainfall depths in millimetres for durations of 0.25, 0.50, 1 and 6 h (Table 2).

Highest recorded short-duration point rainfalls over Selangor

Table 2 shows that the highest recorded rainfalls raingauges in Selangor were: 42–77 mm in 0.25 h (15 min), 60–85 mm in 0.50 h (30 min), 73–141 mm in 1 h, and 114–226 mm in 6 h durations. The raingauge at Sekolah Kebangsaan Kampong Lui recorded the highest rainfall of 77 mm in 0.25 h and 141 mm in 1 h respectively. However, the raingauge at Kampong Kalong Tengah recorded the highest rainfall of 226 mm in 6 h on 26 November 1983.

Short-duration intense rainfalls associated with thunderstorms may be experienced anywhere in Selangor due to the dynamic movement of thunderstorms from one location to another. This phenomenon can occur in random fashion with a low correlation of daily rainfalls between two raingauges (Kinosita 1983). Table 2 also shows that maximum rainfalls for 0.25, 0.50 and 1 h are about 40, 48 and 64% respectively of the 6 h rainfall.

Notable extreme rainfalls for 0.25 to 6 h durations over Selangor

The 25 notable extreme rainfalls that have been recorded in 0.25 to 6 h durations at any location in Selangor are given in Table 3. The reported highest rainfall amounts of 77.4 mm in 0.25 h, 84.6 mm in 0.50 h, 141.5 mm in 1 h and 226.3 mm in 6 h are well corroborated by other values in Table 3. To get an overview of the seasonal occurrence of these rainfalls, the frequency in terms of percentage of the rainfall values belonging to the south-west monsoon months (June–September) and the north-east monsoon months (November–March), when the rainfall is mostly non-convective, and those belonging to the inter-monsoon months (April–May and October–November), when the rainfall is largely convective, are given in Table 4. The tabulated values also suggest that extreme rainfalls of short duration can occur throughout the year but a great majority of them occur in the inter-monsoon months.

Return period analysis of extreme rainfalls

The return period is defined as the average recurrence interval between events of a specified magnitude. The determination of the return period of an extreme rainfall is important because it has a major bearing on the design of flood-related structures. The extreme-rainfall values in Table 3 are used to estimate their return periods.

There were 25 self-recording raingauges functioning in Selangor, so that it is highly likely that the extreme-rainfall values in Table 3 have come from a total population of about 25 × 29 = 725 station-years. Using the 25 highest rainfall values for each duration of 0.25, 0.50, 1 and 6 h, their corresponding return periods, *T*, were calculated from the following equation:

$$T=(N+1)/m$$

where *m* is the rank order of the 25 extreme rainfalls and *N* is the total population of station-years. The calculated return periods are given in Table 3. This table shows that the highest rainfalls of 77.4, 84.6, 141.5 and 226.3 mm for 0.25, 0.50, 1 and 6 h respectively are expected to occur once in about 725 years. The statistical distribution of the extreme rainfalls for all durations follows the Gumbel extreme-value distribution (Gumbel 1941) as plotted in Fig. 2. Figure 2 is useful for estimating design rainfall values with a given duration and return period, in particular for the design of urban drainage systems in Selangor.

Comparison of extreme rainfalls over Selangor with surrounding countries

It is of interest to compare the short-duration extreme rainfalls recorded in the equatorial region of Selangor, Malaysia, with those recorded in the surrounding countries of Australia, China, India, Japan and New Zealand. The comparison is given in Table 5 and the values are plotted as depth–duration curves in Fig. 3. The available extreme-rainfall data indicate that the highest recorded 0.50 h point rainfall is 175 mm at Goonoo Goonoo in Australia, 1 h point rainfall is 230 mm at Florence in Australia (Bureau of Meteorology 1994), and 6 h point rainfall is 830 mm at Linzhuang in China (Tan and Lu 1994). The extreme rainfalls of various durations recorded in the equatorial region of Selangor are considerably lower in magnitude than values record-

Table 4

Percentage frequency of notable rainfalls in different seasons

Duration (hours)	SW monsoon (June–Sept.)	NE monsoon (Dec.–Mar.)	Inter-monsoon April–May, Oct.–Nov.
0.25	20	36	44
0.50	24	28	48
1	28	24	48
6	20	28	52

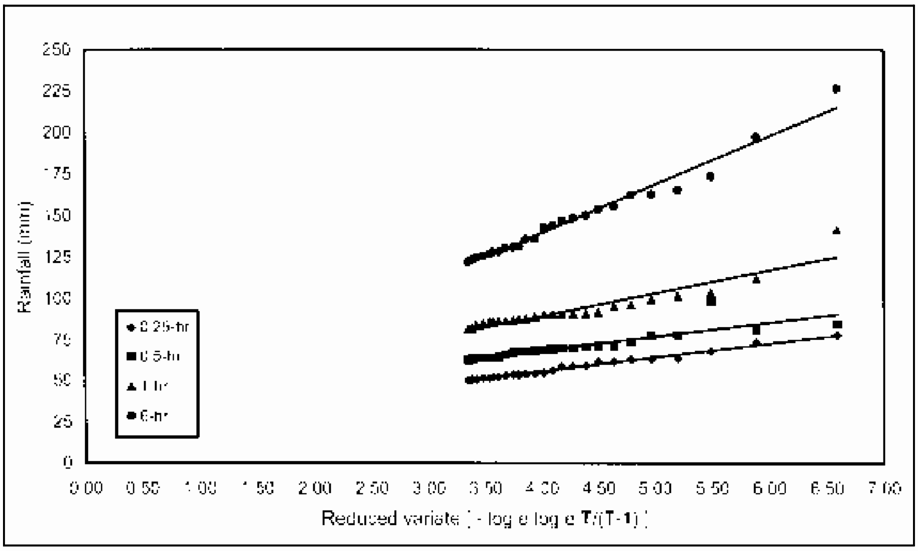

Fig. 2 Rainfall versus reduced variate for various durations

Table 5

Extreme rainfalls (mm) in Selangor in comparison with other countries

Country	Duration (hours) 0.25	0.50	1	6
Australia	75 (Gogango)	175 (Goonoo Goonoo)	230 (Florence)	589 (Mt. Pelion)
China	–	–	401 (Shangdi)	830 (Linzhuang)
India	–	–	129 (Bombay)	–
Japan	–	110 (Koubutsu)	187 (Nagoya)	647 (Saigou)
New Zealand	–	–	107 (Whenuapi)	212 (Saigou)
Selangor	77	85	141	226

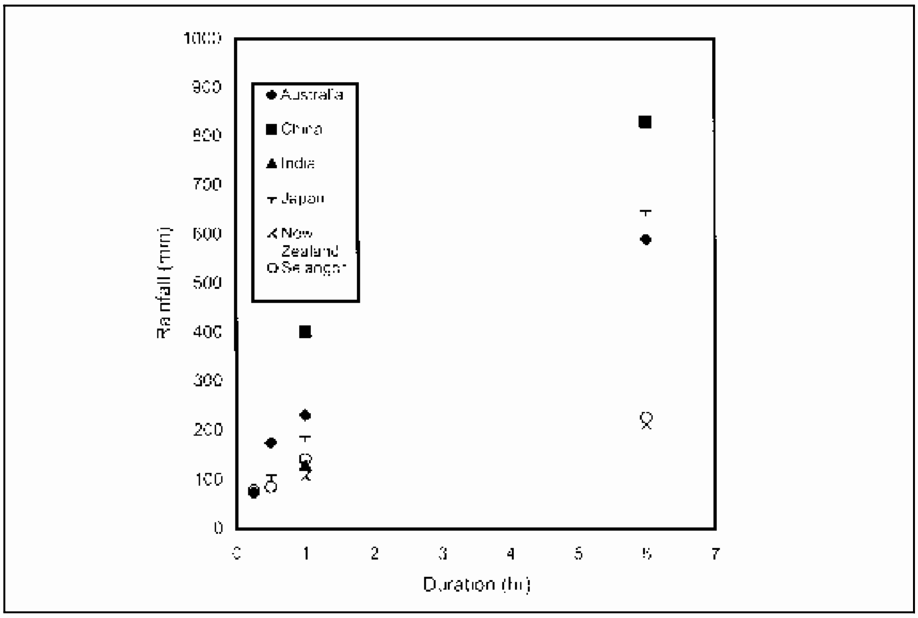

Fig. 3 Depth–duration relationship for various countries in comparison with Selangor

ed in the surrounding countries of Australia, China and Japan. However, the extreme-rainfall values of India and New Zealand are lower in magnitude than those of Selangor. There are some reasons for expecting values to be higher in Australia, China and Japan than in Selangor. The extreme rainfall in Australia, China and Japan normally results from highly organised storms of the hurricane type. Because of the low value of the Coriolis force, highly organised large-scale storms do not exist near the equator, and therefore the extreme-rainfall values are lower in Selangor.

Conclusions

Short-duration extreme rainfalls are often needed in the engineering design of structures that control storm runoff in urban areas. Autographic historical rainfall data (1971–99), recorded by 13 raingauges in Selangor, Malaysia, have been used to provide extreme-rainfall information for durations of 0.25, 0.50, 1 and 6 h. A simple method has been given for estimating design rainfall for a given duration and frequency of occurrence at various locations in Selangor. It has further been found that the highest rainfalls of various durations recorded are less than values recorded in neighbouring countries.

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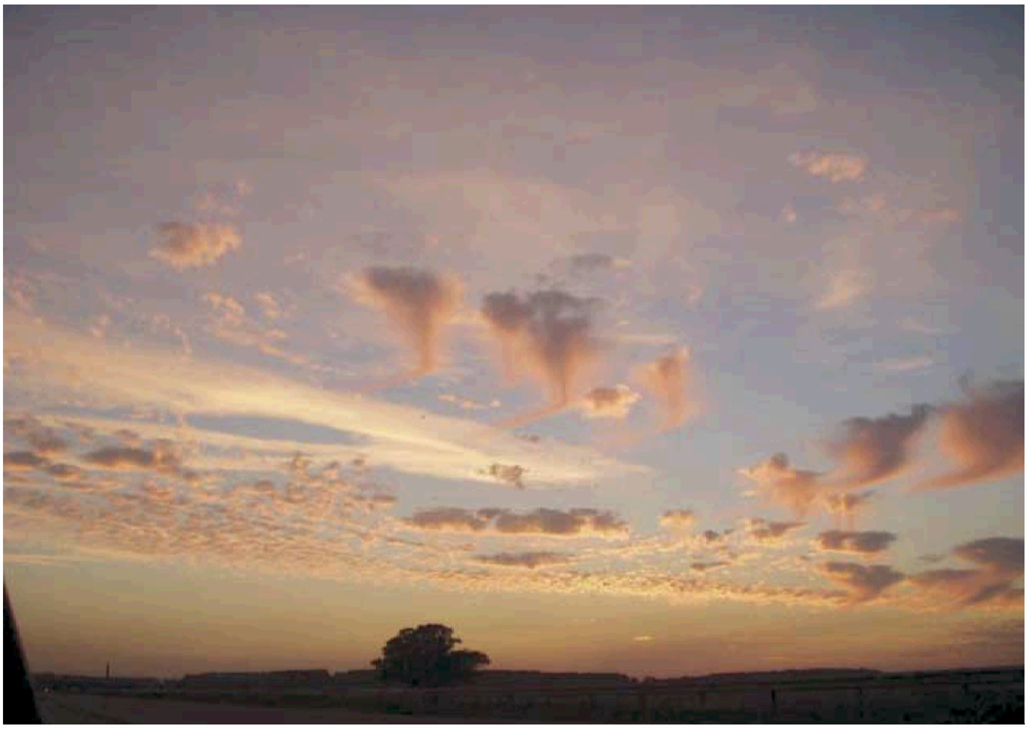

Back-lit altocumulus floccus with virga falling through a significant wind shear. Taken at approximately 1830 GMT on Tuesday 16 September 2003, on the A11 between Norwich and Thetford, Norfolk. (© Ken Horsley.)