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# Distribution of rainfall events in northern region of Peninsular Malaysia

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**Abstract.** Understanding of rainfall characteristics is important in designing Best Management Practices (BMPs) facilities. Because of intermittent rainfall, many researches on hydrology employ the concept of rainfall events. The selection of appropriate rainfall events for treatment design is essential to ensure the effectiveness of BMPs systems. Thus, the objective of this study is to identify the distribution of rainfall event using 6-hour Minimum Inter Event Time (MIT) and to identify the extreme rainfall thresholds over the study area. It shows that the rainfall data series consist of a large number of small events and rainfall depth of less than 2.5 mm (Type 1) contributes the highest percentage toward the overall record. About 63% of the rainfall record consists of Type 2 rainfall depth between 2.6 mm to 80 mm and only 1.3% recorded for rainfall event Type 3 with a depth exceeding 80 mm. It was found that the extreme rainfall threshold in Northern region of Peninsular Malaysia vary from 45 mm to 80 mm for R95 indices and 72 mm to 175 mm for R99 indices. These findings could be used as reference for better BMPs facilities design with extreme rainfall adaptation strategies.

## 1. Introduction

Urbanization increases expansion of urban land uses, yet it correlates with increasing stormwater runoff. Urbanization also results in water contaminants carried out to downstream waterways. Urban stormwater runoff washes out various pollutants and transports to receiving waters thereby leading to the degradation of water quality [1]. Therefore, stormwater runoff has become a major problem as the condition is poorly managed. To alleviate such a situation, Best Management Practices (BMPs) has been applied to ease the concern for environmental protection. The pervious area is replaced with impervious landscapes with the function of promoting infiltration, reducing peak flow, alleviating stormwater runoff pollution and creating an ecological environment during urban development. According to Sharifi et al. [2], effectiveness of BMPs depends on the volume of runoff which is captured and treated. Therefore, detailed knowledge on volume of runoff in urban catchment is crucial for designing BMPs facilities.

Rainfall is the biggest contributor in producing runoff volume. Rainfall, which occurs as a series of continuous event characterized by different depth, amount, duration, intensity and inter event time. Because of intermittent rainfall, many researches on hydrology employ the concept of rainfall events for hydrology analysis as well as for designing BMPs facilities. Smith [3] investigated the effects of rainfall pattern on runoff production in a rural area and reported that runoff production depends on



event rainfall pattern. Moreover, Ahn et al. [4] used event-based model to overcome the limitations of conventional-design storm methodology and continuous simulation method in flood frequency analysis. Rainfall event was also used in designing stormwater treatment system based on water quality and runoff volume. Liu et al. [5] found that small and frequent rainfall events were more appropriate for stormwater treatment performance efficiency. This highlights the need for prudent selection of rainfall events and appropriate runoff volume for stormwater design based.

Separation of rainfall event from continuous record typically depends on the time chosen in (MIT) [6] or Inter-Event Time Definition (IETD) [7] - which is also referred to as antecedent dry period [8]. MIT is defined as the minimum dry period between two rainfall pulses and is the length of 'no rain' or 'dry period' that make two events independent on each other. Adams et al. [9] showed that rainfall event characteristics such as volume, intensity and duration varied according to different MIT. Different MIT provided varying number of rainfall events and shorter MIT have more varied duration and depth compared to rainfall separated by longer MIT [6]. Asquith et al. [10] also identified that an increase of MIT will increase rainfall event depth and have significant impact on the derivation of an Intensity Duration Frequency curve.

Driscoll et al. [11] found that a 6-hour separation time produced the most consistent statistical results when attempting to define individual rainfall event from continuous records. However, Nojumuddin et al. [12] found that 8 hours was the chosen MIT for Johor Malaysia. When considering basin characteristics, MIT values between 1 and 6 hours were suggested for most urban areas [7]. Overall, MIT used for separation of rainfall event ranges from 6 to 8 hours and are widely adopted by many published studies.

It is imperative for adaptation of extreme rainfall event in BMPs facilities be considered as it can assist in future design flows. The rise of global temperature affects the intensity of the extreme rainfall, therefore the study about it is growing. The rainfall thresholds on which a rainfall event can be characterized as extreme vary among country. The different definitions of what is or is not an extreme event are due to the varieties in local features and interaction with the atmospheric circulation. Rainfall depth exceeding 124.4 mm is referred to as extreme rainfall events in India [13]. In the European region, an extreme rainfall threshold differs from region to region and is in the range of 20 mm to 45 mm [14]. They also claimed that the determination of extreme rainfall threshold should be used in different methodologies and indices and the Peaks Over Threshold (POT) method and 99th percentiles indices have been proven to be more efficient in the European region. Evidently, the threshold for extreme rainfall is difficult to set as extreme events are rare and occur on a relatively small and local scale. Despite many studies on this subject being conducted in Malaysia, a large knowledge gap still exists with regard to extreme rainfall threshold and indices. Thus, research on such matters is strongly encouraged.

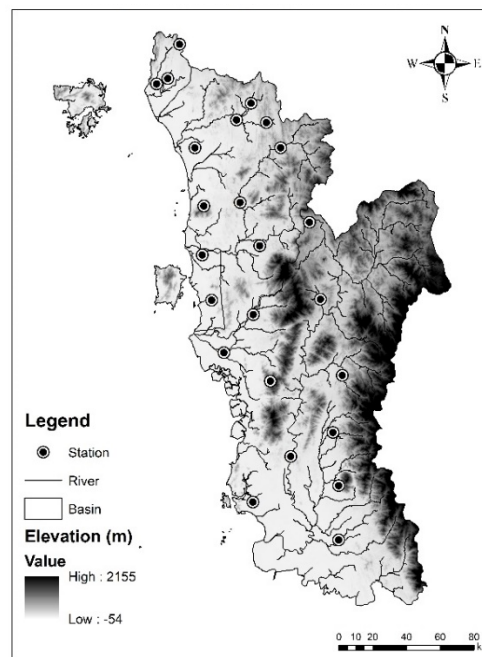
The objectives of this study are: (1) to identify the distribution of rainfall event using 6-hour MIT and (2) to identify the extreme rainfall thresholds over Northern region of Peninsular Malaysia. These findings could be used as reference for better BMPs facilities design with extreme rainfall adaptation strategies.

## 2. Methodology

### 2.1. Study area

Peninsular Malaysia lies in Southeast Asia, has a tropical climate and is located along the latitude between  $1^{\circ}$  and  $6^{\circ}$  N and longitude between  $100^{\circ}$  and  $103^{\circ}$  E. The surface climate is influenced by southeast monsoon season between May and August and by northeast monsoon season between November and February. The Northern region of Peninsular Malaysia comprises the states of Perlis, Kedah, Penang and Perak and it the driest region especially during the southwest monsoon season. Rainfall stations with more than 20 years of historical data were chosen for this study. It is based on suggestions from United States Environmental Protection Agency (USEPA) which recommended at least 20 to 30-year period of rainfall record for analysing rainfall events [15]. All rainfall data were

obtained from the Water Resources Management and Hydrology Division, Department of Irrigation and Drainage (DID), Malaysia. Most of the rainfall data were obtained using automatic recorded rain gauges. There are 26 rainfall stations were examined in this study. Figure 1 presents a distribution of the rainfall stations in Northern region and geographic coordinates of each station are shown in Table 1. To ensure the quality control of the data set, missing data and homogeneity test were applied to the rainfall time series.



**Figure 1.** Distribution of rainfall stations.

**Table 1.** Geographic coordinates of each station.

Rainfall Stations		Location	
ID	Name	Latitude	Longitude
6401002	Padang Katong	06° 26' 45"	100° 11' 15"
6402008	Ngolang	06° 28' 30"	100° 14' 50"
6603002	Padang Besar	06° 39' 25"	100° 18' 35"
5507076	Bt. 27 Jln. Baling	05° 35' 00"	100° 44' 10"
5704055	Kedah Peak	05° 47' 45"	100° 26' 20"
5806066	Jeniang Klinik	05° 48' 50"	100° 37' 55"
6103047	Stor JPS Alor Setar	06° 06' 20"	100° 23' 30"
6108001	Komplek Rumah Muda	06° 06' 20"	100° 50' 50"
6206035	Kuala Nerang	06° 15' 15"	100° 36' 45"
6207032	Ampang Pedu	06° 14' 25"	100° 46' 20"
6306031	Padang Sanai	06° 20' 35"	100° 41' 25"
5204048	Sg. Simpang Ampat	05° 17' 38"	100° 28' 50"
5504035	Lahar Ikan Mati at kepala	05° 32' 05"	100° 25' 50"
4010001	batas	04° 01' 00"	101° 02' 10"
4207048	JPS Telok intan	04° 13' 05"	100° 42' 00"
4311001	Pejabat JPS. Sitiawan	04° 18' 20"	101° 09' 20"
4409091	Pejabat Dearah Kampar	04° 27' 40"	100° 54' 05"
4511111	Rumah Pam Kubang Haji	04° 35' 20"	101° 07' 30"

4807016	Politeknik Ungku Omar	04 <sup>0</sup> 51' 45"	100 <sup>0</sup> 47' 35"
4811075	Bkt. Larut	04 <sup>0</sup> 53' 35"	101 <sup>0</sup> 10' 30"
5005003	Ranc. Belia Perlop	05 <sup>0</sup> 00' 50"	100 <sup>0</sup> 32' 45"
5207001	Jln. Matang Buloh	05 <sup>0</sup> 13' 00"	100 <sup>0</sup> 42' 05"
5210069	Kolam Air JKR.	05 <sup>0</sup> 17' 55"	101 <sup>0</sup> 03' 30"
5710061	Stn. Pemereksaan Hutan Dispensari Kroh	05 <sup>0</sup> 42' 30"	101 <sup>0</sup> 00' 00"

### 2.2. Separation of rainfall event

Visual basic and macro in Microsoft Office Excel is used to develop a program to automatically separate continuous rainfall record into a single event. This program reads the data from a data sheet and automatically detects rainfall event for certain value of MIT. The program would initially separate continuous rainfall data series from excel sheet into a discrete event. Distribution of rainfall events are discussed within three types of rainfall depth as mentioned in previous studies [13, 16]. Table 2 shows the types and classification of the rainfall events. Afterwards, using 6 hours as a value of MIT, the rainfall events are determined. To identify the extreme rainfall thresholds for the study area, two percentile indices were used which is R95 and R99. R95 is total rainfall when exceeding 95<sup>th</sup> percentile define as a very wet days and R99 is a total rainfall when exceeding 99<sup>th</sup> percentile define as extremely wet days. The indices were calculated using Excel. Interpolation method has been used to predict the values of unknown locations using collected known location data. Spatial Analyst is used to interpolated extreme rainfall threshold using Ordinary Kriging Method.

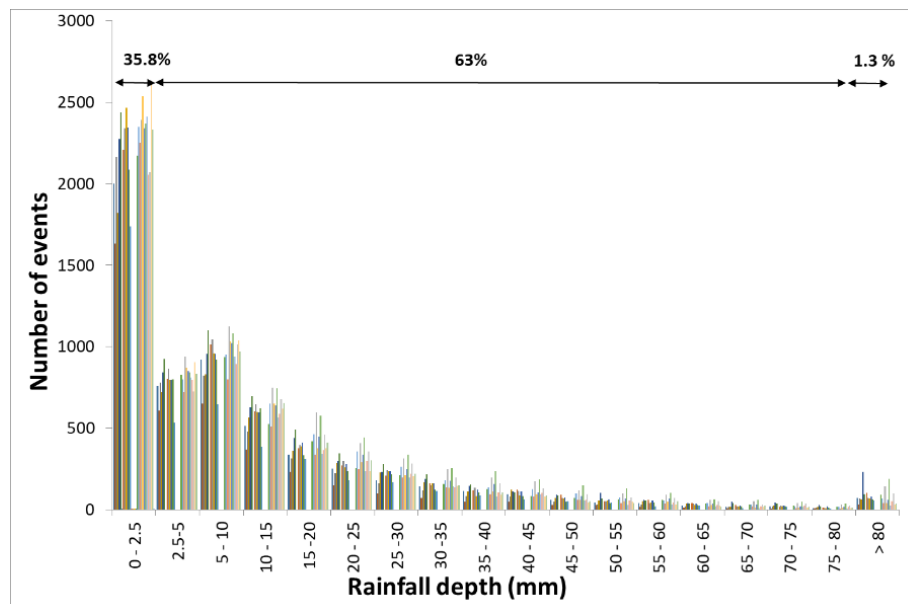
**Table 2.** Types and classification of rainfall event.

Type	Classification	Depth (mm)
Type 1	No Runoff	0 to 2.5
Type 2	Light to heavy rainfall	2.6 to 80
Type 3	Heavy Rainfall	< 81

## 3. Results and discussion

### 3.1. Distribution of rainfall event

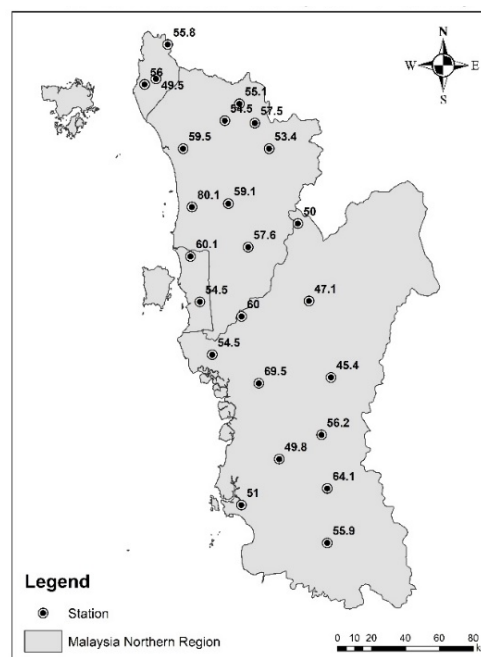
Figures 2 reveal the rainfall distribution for the study area. With 6 hours as MIT, total 6224 events were recorded. It shows that rainfall event consists of a large number of small events and the frequency curve decay as the magnitude of rainfall depth increases. A total of 2226 events (35.8%) were recorded for the event with rainfall depth less than 2.5 mm (Type 1) and this type of rainfall does not produce runoff. About 3919 events (63%) of the rainfall records consists of Type 2 (light to heavy rainfall) rainfall depth between 2.6 mm to 80 mm. This type of rainfall is used in the analysis because such small and more frequent rainfall events would be preferred in designing BMPs facilities since the benefits include efficiency in treatment performance, cost effectiveness and possible saving of inland area [5]. For rainfall event in Type 3 (heavy rainfall) with a depth exceeding 80 mm, Northern region recorded a small percentage with only 79 events (1.3%). Although the percentages are small, heavy and extreme rainfall events have become more frequent in recent years. Heavy rainfall events in the East Coast of Peninsular Malaysia have increased in the past 40 years [17]. Therefore, BMPs facilities need to allay the impact of increasing extreme rainfall events.



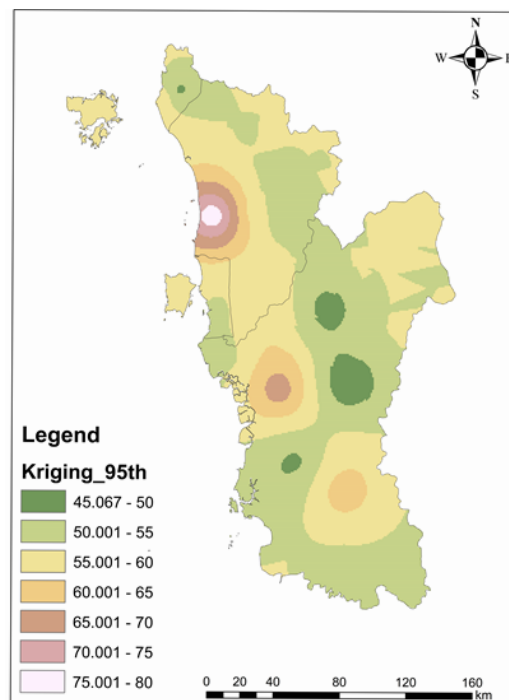
**Figure 2.** Rainfall distribution for the Northern Region.

### 3.2. Extreme rainfall threshold

Figures 3 and 4 shows the extreme rainfall threshold and spatial interpolation result for R95 indices. The threshold values vary from 45 mm to 80 mm. Minimum thresholds magnitude were observed at station ID 4811075 (Ranc. Belia Perlop) with rainfall depth at 45.4 mm. While, maximum threshold value was found at station ID 5704055 (Kedah Peak) with rainfall depth at 80.1 mm. More specifically, for very wet day (R95), only three stations under study had threshold value below than 50 mm (12.5%). The rest gives a threshold value of more than 50 mm.

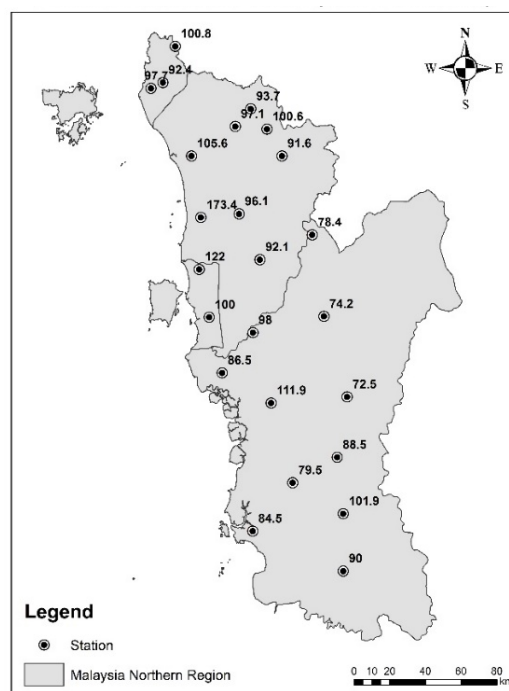


**Figure 3.** Extreme rainfall threshold for R95.

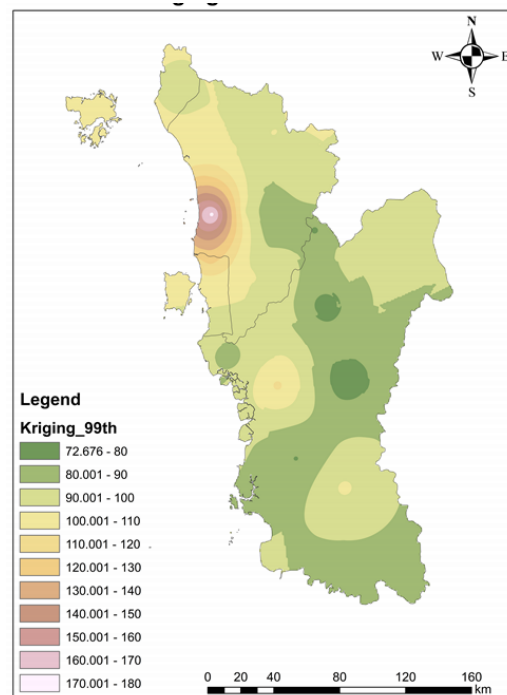


**Figure 4.** Spatial distribution for R95.

Figures 5 and 6 shows the extreme rainfall threshold and spatial interpolation result for R99 indices. For R99 indices, the stations with the highest and lowest threshold remain same as in the R95 indices. Minimum and maximum thresholds magnitude is 72.5 mm and 173.1 mm respectively. For extremely wet day (R99) condition, 83% have a threshold value of over 80 mm and there are seven stations with a threshold value more than 100 mm.



**Figure 5.** Extreme rainfall threshold for R99.



**Figure 6.** Spatial distribution for R99.

#### 4. Conclusion

The main objective of the present study was to identify the distribution of rainfall event using 6-hour MIT. It shows that the rainfall data series consist of a large number of small events and rainfall depth of less than 2.5 mm (Type 1) contributes the highest percentage toward the overall record. About 63% of the rainfall record consists of Type 2 (light to heavy rainfall) rainfall depth between 2.6 mm to 80 mm and only 1.3% recorded for rainfall event Type 3 (heavy rainfall) with a depth exceeding 80 mm. Future studies are encouraged to identify distribution of rainfall event using different MIT. It was found that the extreme rainfall threshold in Northern region vary from 45 mm to 80 mm for R95 indices and 72 mm to 175 mm for R99 indices. The results in the case of the 99<sup>th</sup> percentile indices are much higher compared to 95<sup>th</sup> percentile indices. Further research is clearly needed to determine the most objective way to identify extreme rainfall threshold using different indices because different indices provide different result. According to Zolina et al. [18] and Leander et al. [19], percentile indices might have some uncertainties due to their outlier. However, for urban drainage, Arnbjerg-Nielsen et al. [20] recommended 99.9 percentile and higher for quantiles methods to study about extreme rainfalls. The frequency of extreme rainfall also needs to be studied because it is important in analyzing flood forecasting.

#### Acknowledgement

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