

## **RUNOFF ASSESSMENT OF WATERSHED IN SOUTH JOHOR OF MALAYSIA**

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**Received: June 22 2016; Accepted: November 25, 2016; Published: January, 2017**

### **Abstract**

Runoff potentiality of Johor Bahru watersheds was evaluated based on identifying SCS-CN method. Land use and soil series were considered to define the Hydrologic Soil Group (HSG) of watershed area. Based on soil characteristics and infiltration rate, soils of the watersheds belonged to two soil groups namely C and D. Considering these two soil groups, weighted curve numbers were defined ranging from 82 to 87. Daily event rainwater was collected to calculate the surface runoff for the period 2008-2013. After getting the daily runoff, monthly runoff pattern was analyzed with associated monthly rainfall data to define the runoff contribution for the watersheds. The analysis revealed that the higher monthly mean runoff for the study period was 65, 62, and 60 mm and runoff percentage was 32, 31 and 30% for the watersheds 5, 3 and 13, respectively. Whereas, lower value showed for the watersheds 6 and 1 had runoff 25% and 26% respectively. The result showed that only 28% of rainwater contributed to the surface runoff of Johor Bahru watershed which provided the information for eroded soil transportation and for planning of surface water management.

**Keywords:** SCS-CN, surface runoff measurement, water shed Johor Bahru

### **1. Introduction**

Surface runoff has been recognized as a major factor for sediment transportation in hydrological cycle. In this process, the rainwater falls on the ground surface, erodes the loose soil and ultimately transports the sediment into the streams or rivers. In any watershed area, surface runoff plays an important role for its impact on environment, water quality and flood issues. Climatic and physiographic factors are also a domain for influencing the surface runoff on catchments area. Rainfall and its characteristics such as intensity, duration and frequency are the climatic factors for surface runoff. Physiographic factors are watershed and its drainage characteristics, slope, watershed size, land use and soil moisture. High rainfall intensity results in rapid runoff which ultimately causes flash flood in the watershed. Higher storm water excluding evaporation and infiltration causes excessive surface runoff in any

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agricultural area [1] and this runoff and peak flow in rivers depend on watershed characteristics [2, 3].

Soil Conservation Service (SCS) is popular and widely applied method to calculate the direct surface runoff for its simplicity and flexibility characteristics [4, 5]. This runoff is considered for surface water resources management and planning in a watershed [6-11]. SCS [12] uses curve number (CN) from hydrologic soil group to calculate the runoff for a particular rainfall of watershed area. Besides direct runoff estimation, this method is capable of establishing CN values for various antecedent moisture conditions [13]. The CN is defined to calculate surface runoff using a function of soil type, land use and antecedent moisture of watershed [14-18]. Based on the characteristics of the watershed and previous rainfall pattern, the antecedent moisture condition is divided into dry, normal and wet conditions. The normal class is considered as a reference condition for CN values of the watershed.

In the application of SCS-CN method, different land use patterns and hydrologic soil group are also contributing in defining CN values for different degree of surface runoff. The agricultural land, altered over time for the environmental and economic factors, cause the impact on surface runoff [19-22].

Application of the SCS-CN method for runoff estimation trends to give a general idea of surface water distribution pattern in Johor Bahru watersheds, which is under tropical region exhibiting heavy rainfall. In this method, CN was considered to assess the surface runoff at Johor Bahru watersheds. For large watershed area, weighted CN was introduced for calculation of accurate surface runoff. Weighted CN was used for watersheds with variable conditions of land cover, soil type and land use. Johor Bahru watershed area exhibited two hydrologic soil groups C and D which belonged to different patterns of land use. C and D groups show the greater CN values contributing the greater surface runoff based on soil texture. Curve number relating with soil group map produce the zonation for surface runoff potentiality of the watershed area. Weighted curve number was considered for the large watershed area on the basis of soil group and CN values of this region. Therefore, an attempt was made to calculate the surface runoff potentiality of Johor Bahru watersheds for best practice of surface water resources management.

## **2. Materials and Methods**

### **2.1 The study area and data**

The location of the study area on Peninsular Malaysia map is shown in Fig. 1. Johor Bahru consists of 17 watersheds with about 1436 sq. km area. The watersheds were delineated from the drainage pattern of the area shown in Fig. 2. The watersheds consisted of 12 soil series (Fig. 3) with 27 land use patterns (Fig. 4). Considering rainfall stations of Johor Bahru, the mean annual rainfall was about 2500 mm. Elevation of the study area varied from 3 to 977 m above mean sea level. In Malaysia, the average mean daily evaporation is 4.5 mm (i. e. 1644 mm per

annum). Although evapotranspiration and infiltration are important in continuous hydrologic simulations, only surface runoff from precipitation was focused in this study. Surface runoff of any watershed is normally controlled by land use patterns and the land management practices. Based on soil characteristics, only C and D hydrologic soil groups were classified for the study area [23]. This soil group classification was based on water infiltration rate through the soil. In general, clay soil under the category D of soil type had the lowest infiltration rate and produced highest runoff potentiality.

The soil group and land use map of Johor Bahru watersheds were prepared by geographical information system (GIS) software (Arc GIS 10). Although, Soil and Water Assessment Tool (SWAT) is developed for predicting runoff and soil erosion of a watershed under different management practices, SCS-CN method is considered in this research for its flexibility behaviors for the assessment of surface runoff of Johor Bahru watersheds. Curve number varied due to specific land use pattern and hydrologic soil group in the study area. Hydrologic soil group was defined on the basis of soil characteristics for the analysis of surface runoff (Table 1). CN values were defined for specific land use for hydrologic soil groups C and D. In these watersheds, particular land use belonged to the both soil groups. For this, a weighted CN was calculated for the watershed made up of several land uses and soil types.

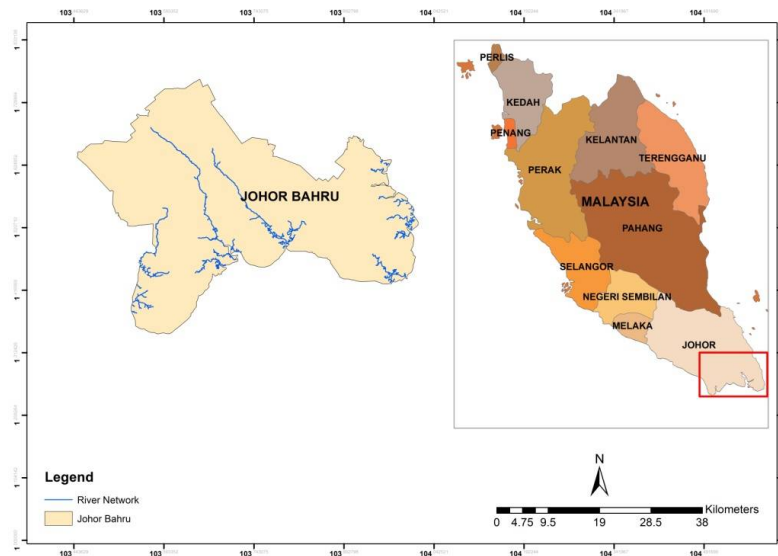


Fig. 1. Map of the study area

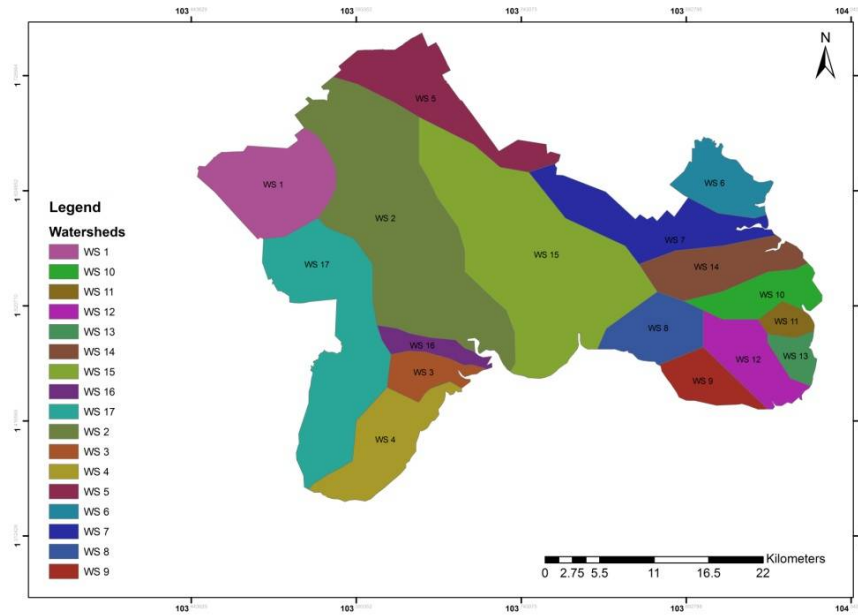


Fig. 2. Watersheds in Johor Bahru

**Table1:** Classification of soil groups C and D

Soil characteristics	Soil Group
Clay loams, shallow sandy loam, soils low in organic content and soils usually high in clay	C
Soils that swell significantly when wet, heavy plastic clay and certain saline soils	D

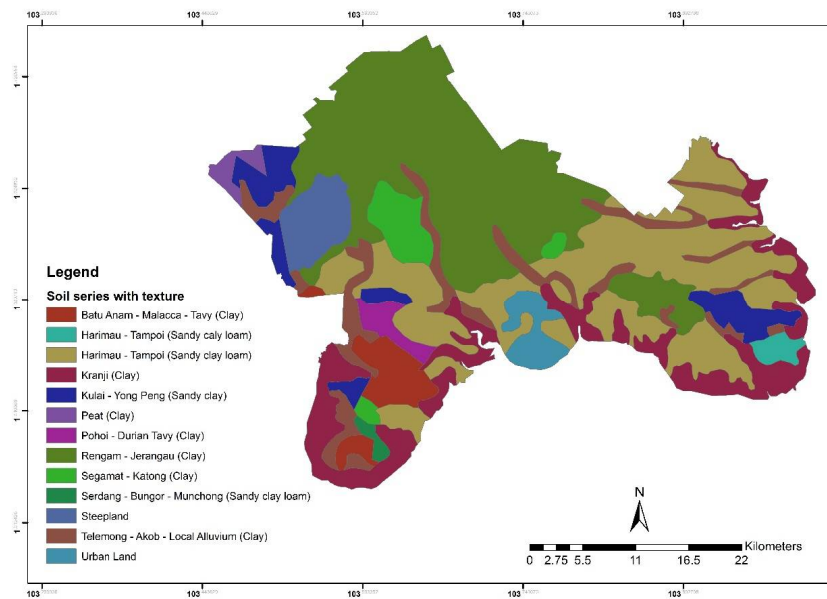


Fig. 3. Soil series map of the study area

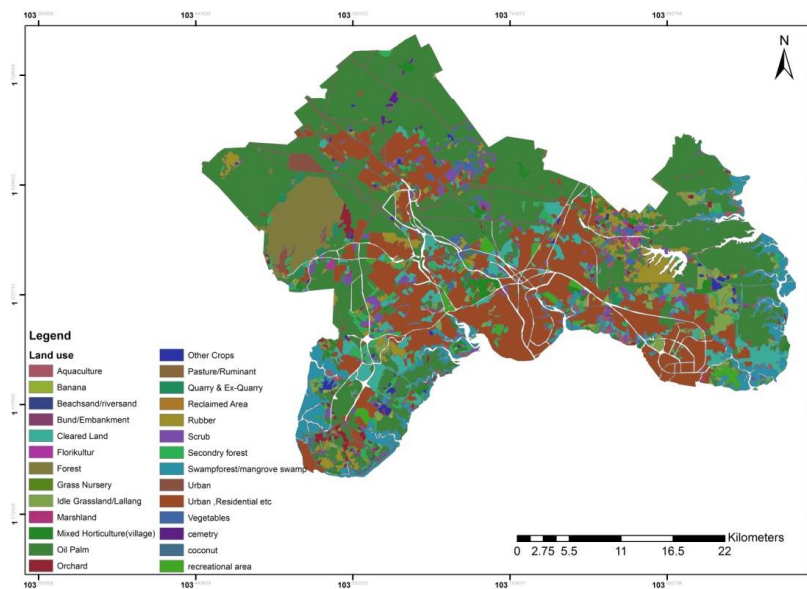


Fig. 4. Land use map of the study area

The soil series of Johor Bahru watersheds were classified from its soil characteristics. All soil series of this area were matched with the hydrologic soil group. After analyzing soil properties of these watersheds, only hydrologic soil groups C and D were defined for this area for having its own soil characteristics (Fig. 5). The land use patterns of this area dominates the surface runoff potentiality of watershed area where oil palm, forest, rubber, swamp forest and urban-residential area occupied 54%, 25%, 8%, 5% and 3% respectively of the total watershed area (Fig. 6) and contributed the runoff of this region.

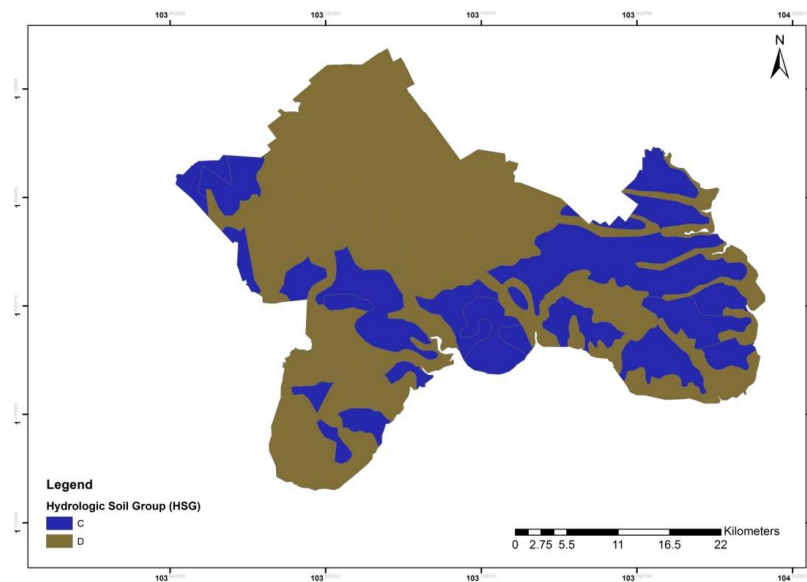


Fig. 5. Hydrologic soil group map of Johor Bahru watershed

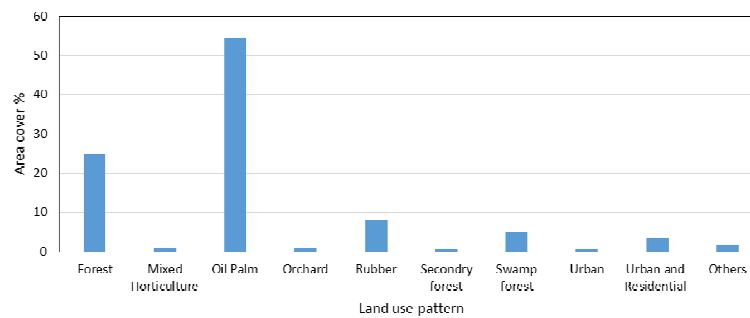


Fig. 6. Land use patterns at Johor Bahru watershed

As the study area is close to the Melaka state of Peninsular Malaysia, monthly surface runoff of Johor Bahru watersheds was compared with the five watersheds of Melaka Tengah. The surface runoff was calculated by the same procedure which was already described in the methodology section. Daily event rainfall was considered to calculate the surface runoff by using SCS-CN method for the period 2006-2012. These data sets were prepared for monthly runoff analysis for Melaka watersheds. The analysis revealed that the monthly surface runoff varied between 23% and 30% in the Melaka watersheds (Fig. 7). These data also represent the monthly rainfall-runoff pattern of Melaka watersheds.

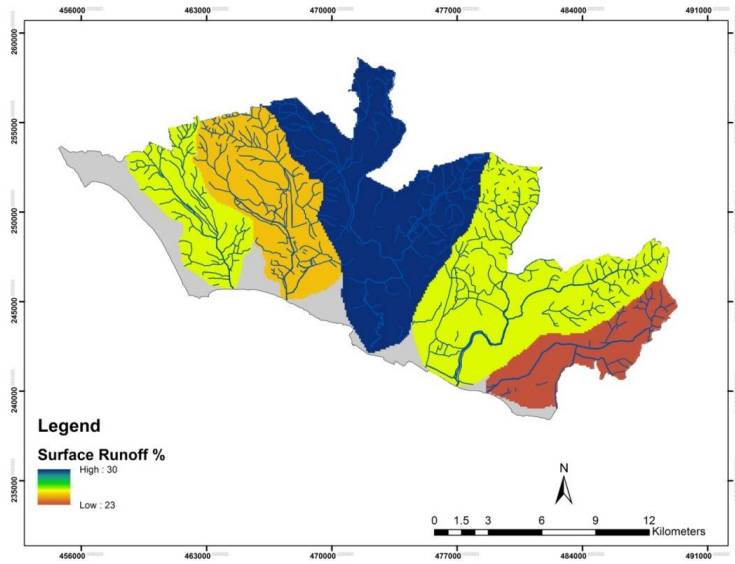


Fig. 7. Surface runoff in Melaka watersheds

## 2.2 SCS-CN method

The Soil Conservation Service Curve Number (SCS-CN) [24] was considered to calculate the surface runoff for different watersheds in Johor Bahru. The fundamental surface runoff equation is given below (Eq. 1)

$$R_{wi} = \frac{\{P - (I_a)_{wi}\}^2}{\{P - (I_a)_{wi}\} + S_{wi}} \quad (1)$$

where,  $w_i$ = watershed number,  $R_{w_i}$ = Runoff,  $P$  = Rainfall,  $S_{w_i}$ = Potential maximum retention and  $(I_a)_{w_i}$ = Initial abstraction and this abstraction is expressed in watershed studies by the following empirical equation (Eq. 2):

$$(I_a)_{w_i} = 0.2 S_{w_i} \quad (2)$$

Putting the  $(I_a)_{w_i}$  values in equation 1 and is expressed as (Eq. 3)

$$R_{w_i} = \frac{(P - 0.2 S_{w_i})^2}{P + 0.8 S_{w_i}} \quad (3)$$

$S_{w_i}$  is a function of soil and land cover conditions through the weighted curve number ( $CN_{w_i}$ ) of a particular watershed. SCS method defines the potential retention and the equation is expressed as (Eq. 4)

$$S_{w_i} = \frac{1000}{CN_{w_i}} - 10 \quad (4)$$

where,  $CN_{w_i}$ = weighted runoff curve number. This curve number is a dimensionless number and ranges  $0 \leq CN_{w_i} \leq 100$ . The higher curve number value shows higher runoff potential of a watershed.  $CN_{w_i}$  is defined by weighting the CN's of different subareas in proportion to the land cover associated with each CN value for a catchment. The CN was calculated by Eq. 5.

$$CN_{w_i} = \sum_{j=1}^n \{ \sum (CN_{Cj} \times A_{Cj}) + \sum (CN_{Dj} \times A_{Dj}) \} \quad (5)$$

where,  $CN_{Cj}$ = CN for a particular land use for soil group C;  $CN_{Dj}$ = CN for a particular land use for soil group D; and  $A_{Cj}$  and  $A_{Dj}$  = land use pattern percentage for soil groups C and D.

The curve number in the above equation represents average antecedent runoff condition. Runoff is often influenced by extremely dry antecedent runoff conditions or wet antecedent runoff conditions in a significant hydrologic event. The antecedent runoff conditions of the above curve numbers were considered within a reasonable range of weighted curve number estimates due to the area is under the hydrologic soil group only C and D. Hence, the observed variability of rainfall-runoff response was presented by average antecedent moisture condition parameter.

### 3. Results and Discussion

In Johor Bahru watersheds, each of twelve soil map unit represents a particular soil texture. Clay and silty clay were the dominant soil textures in the study area. Hydrologic soil group, soil series and texture of these watersheds are shown in Table



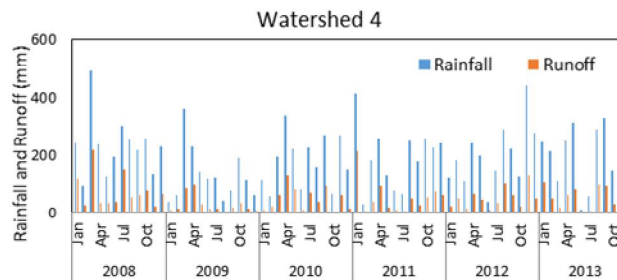
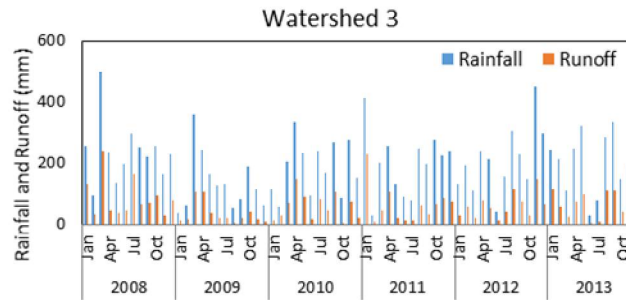
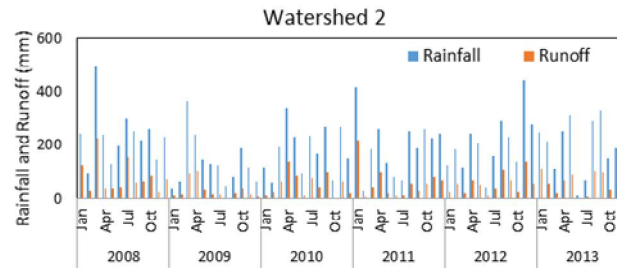
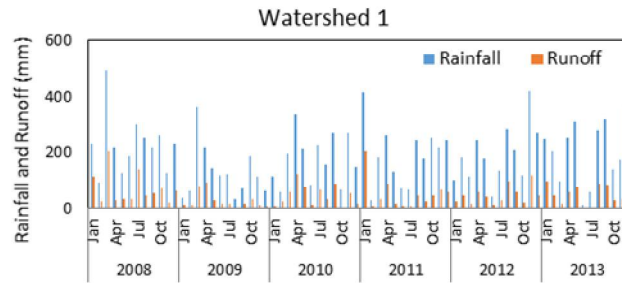
2. The land use patterns of this area were under the hydrologic soil groups C and D. Runoff curve numbers were defined on the basis of land use under C and D soil groups. Oil palm occupied most of the study area. In Malaysia, curve numbers are analyzed for forest, undisturbed lands, agriculture and urbanized areas on different hydrologic soil groups [25-29].

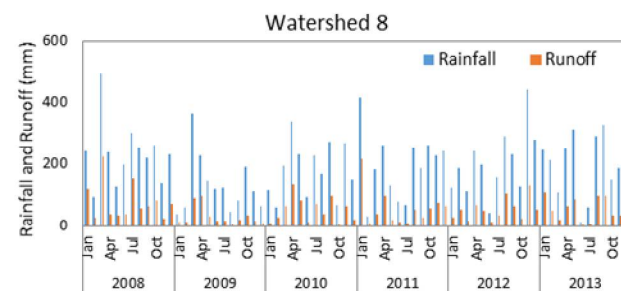
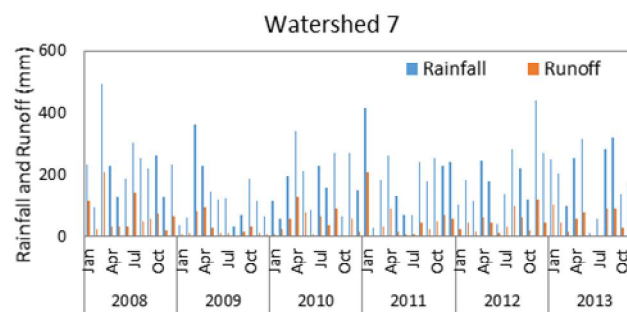
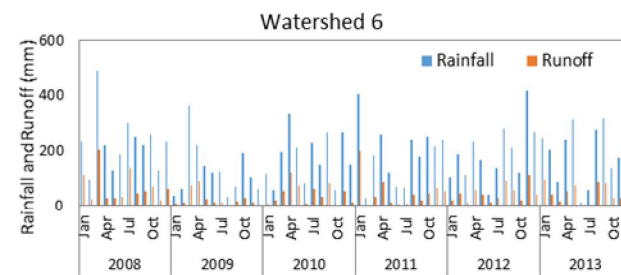
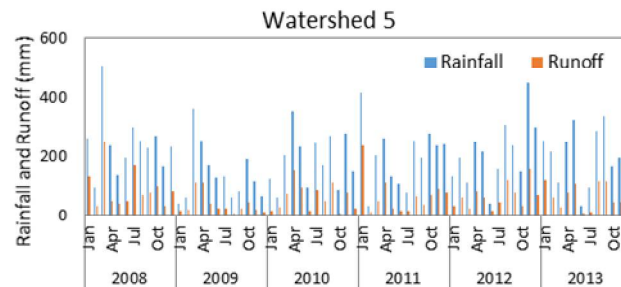
**Table 2:** Hydrological soil group classification of Johor Bahru

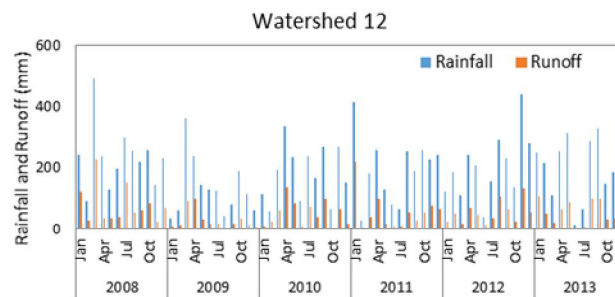
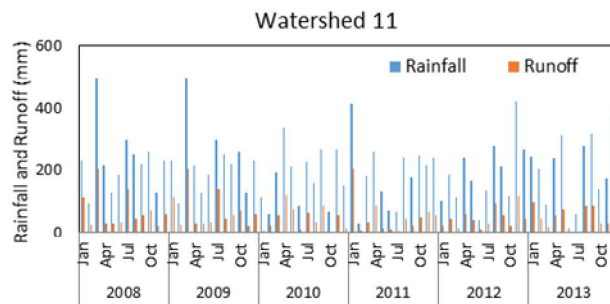
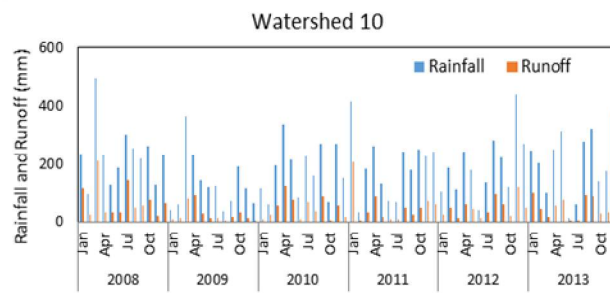
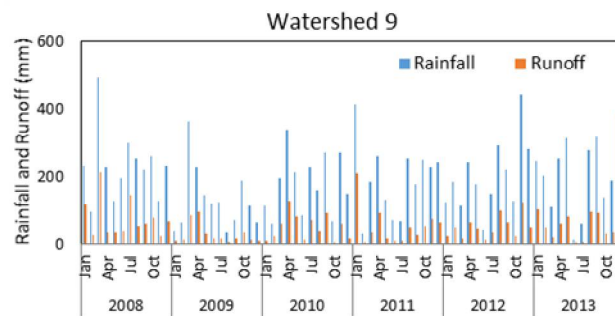
Soil Mapping Unit	Soil Texture	Hydrologic Soil Group (HSG)
BatuAman-Melaka-Tavy	Clay	D
Kranji	Clay	D
Rengam-Jerangau	Clay	D
Harimau-Tampoi	Sandy clay loam	C
Telemong-Akob-Local Alluvium	Clay	D
Segamat-Katong	Clay	D
Kulai-Yong Peng	Sandy clay	C
Pohoi-Durian-Tavy	Clay	D
Serdang-Bungor-Munchong	Sandy clay loam	C
Peat	Clay	C

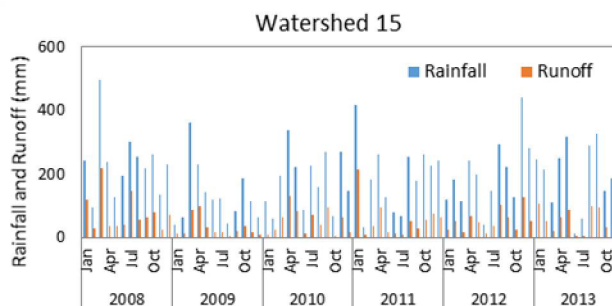
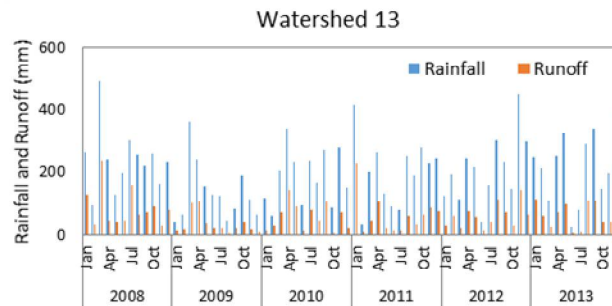
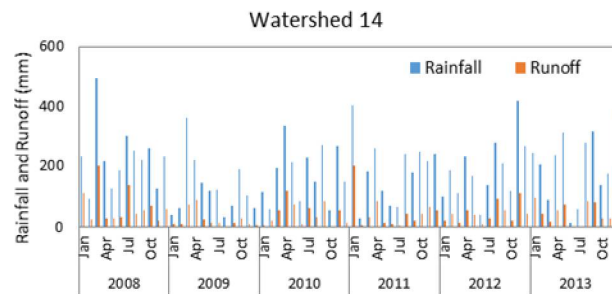
As the land use of watershed belongs to hydrological soil groups C and D, the individual curve numbers were calculated for these two soil groups. The actual weighted curve number of the watersheds was the summation of two weighted curve numbers. After putting the weighted curve number in equation 4,  $S_{wi}$  was calculated for these watersheds. The daily rainfall for Johor Bahru water sheds for the period 2008-2013 was analyzed to calculate the surface runoff. The runoff ( $R_{wi}$ ) was calculated for each watershed by using equation 3. This is valid only for the condition of  $P > 0.2S_{wi}$ . All watersheds of this region follow this condition.

Using SCS method, daily surface runoff was calculated from the daily rainfall event data for 2008-2013 period. Later, the monthly surface runoff was calculated by summing the daily runoff data. Seventy two data sets were considered for monthly analysis to present rainfall-runoff pattern of Johor Bahru watersheds. This analysis reveals that the monthly runoff pattern changes with the particular monthly rainfall pattern. The monthly rainfall and runoff analysis shows the runoff nature of contribution in the studied watersheds (Fig. 8). The runoff varied between 25% and 32% for the watersheds 1 to 17.









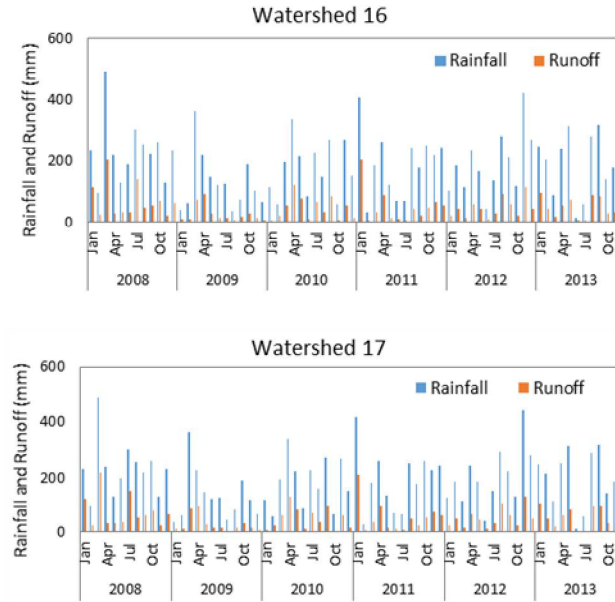


Fig. 8. Monthly rainfall and runoff patterns in the watersheds

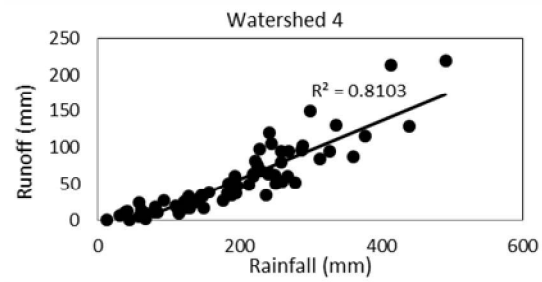
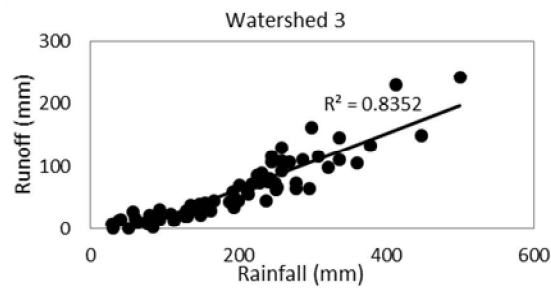
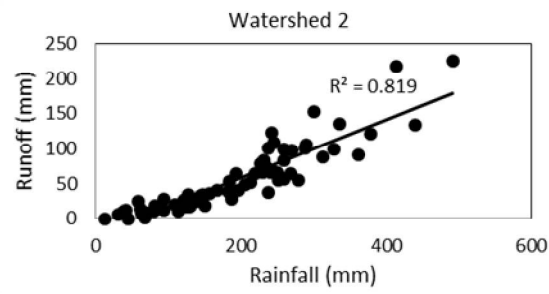
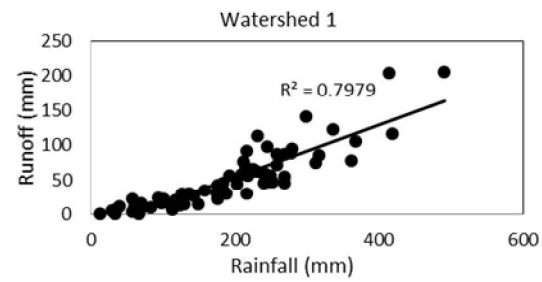
Henceforth, the average surface run off in Melaka Tengah watershed was 26%, whereas the average surface runoff of Johor Bahru watershed was 28% which indicates that monthly surface runoff between Melaka and Johor Bahru watersheds is similar for similar soil series and land use patterns. The surface runoff was varying with the CN values in Johor Bahru watersheds. These CN values were modified and used as runoff curve numbers for average runoff condition for the forest and undisturbed lands on different hydrologic soil groups in Malaysia [30]. Consequently, monthly total runoff volume was calculated for watersheds and it showed that the watersheds 3, 5, 13 contributed most of the surface runoff in the study area. Whereas, the mean annual stream flow at Rantau Panjang station of Johor Bahru was  $37.7 \text{ m}^3/\text{s}$  [31]. The weighted  $CN_{wi}$ ,  $S_{wi}$  and surface runoff percentage values of each watershed of Johor Bharu are shown in Table 3.

**Table 3:** Weighted  $CN_{wi}$ ,  $S_{wi}$  and runoff for the Johor Bahru watersheds

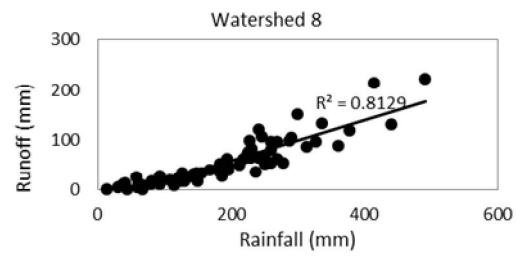
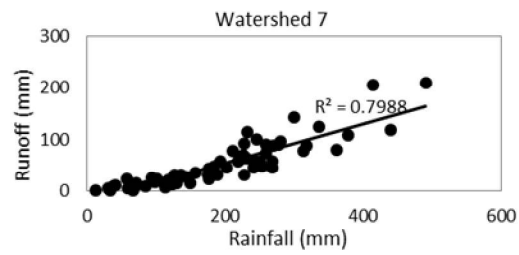
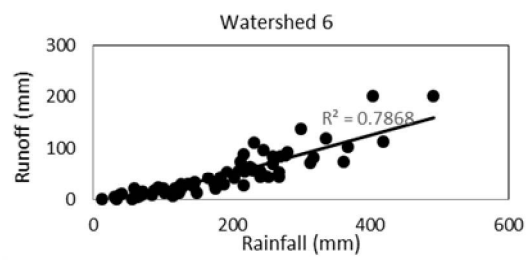
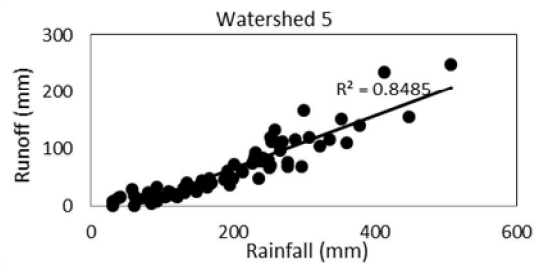
Watershed	Weighted $CN_{wi}$	Value of $S_{wi}$ (mm)	Runoff (%)
1	83	53.30	26
2	85	46.39	29
3	86	41.25	31
4	84	48.57	28
5	87	39.19	32
6	82	55.39	25
7	83	52.35	26
8	84	47.76	28
9	83	50.42	27
10	83	52.58	26
11	82	54.22	27
12	85	46.49	29
13	86	43.02	30
14	82	55.58	25
15	84	48.69	28
16	82	55.55	25
17	84	49.45	28

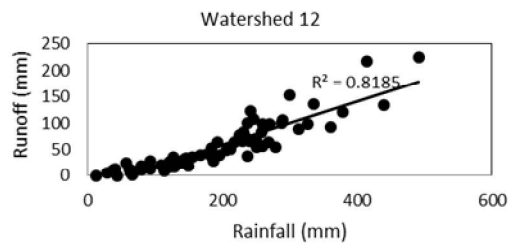
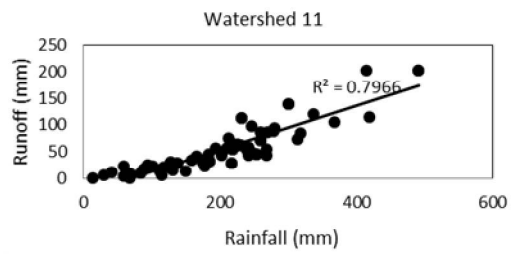
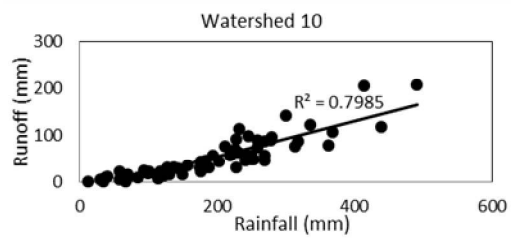
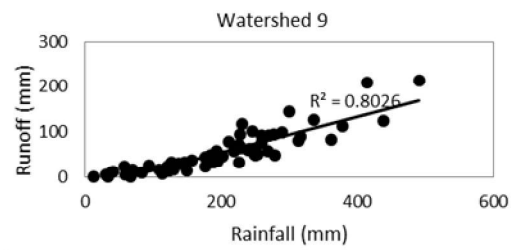
For the seventeen watersheds, all runoff peaks were similar and the maximum value of peak exhibited in monsoonal period. The monthly mean runoff of watersheds 5, 3 and 13 was 65mm, 62mm and 60mm respectively. The lowest mean monthly value was 46mm, 47mm and 49mm for the watersheds 14, 6 and 1 respectively. The runoff fluctuated from one peak to another peak but all peaks occurred during the months of November to February and May to August when most of the rainfall occurred which indicated that the runoff exhibited the watershed characteristics for different degree of effect.

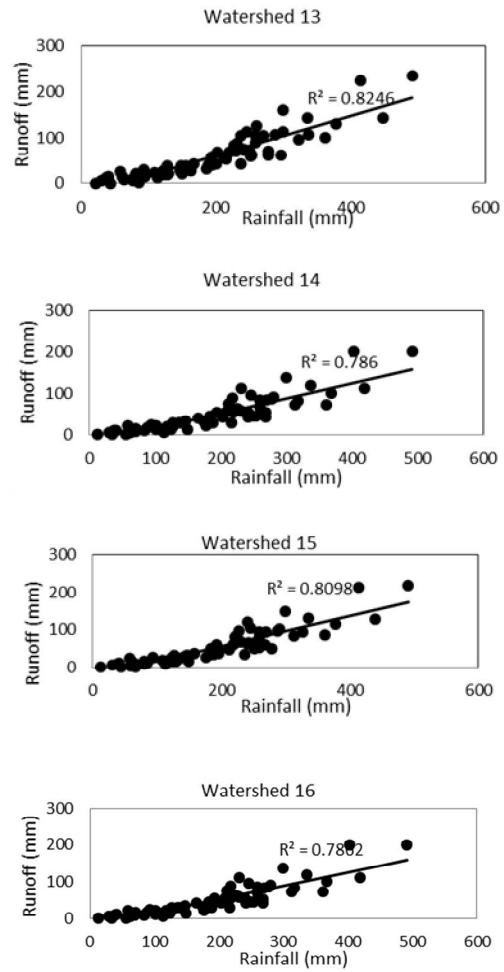
The correlation between estimated monthly rainfall and runoff exhibited a good relation for the studied watersheds (Fig. 9). For the study area, the relation was found to be linear ( $R^2 = 0.78$  to  $0.85$ ). It can be concluded that the surface runoff in Johor Bahru watersheds can be predicted by using SCS-CN method.











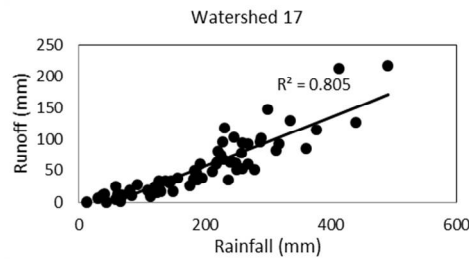


Fig. 9. Estimated monthly rainfall runoff relationship of the study area

#### 4. Conclusions

The SCS-CN method was used to calculate the surface runoff of 17 watersheds in Johor Bahru. The CN values were defined for hydrologic soil groups C and D for each of the land use pattern. Soil series covered these two hydrologic soil group on the basis of soil characteristics and twenty seven land use patterns were exhibited at this region. The weighted curve number was calculated for the watersheds due to the same land use patterns under two hydrologic soil groups. This curve number varied between 2 and 87 for the different watersheds in Johor Bahru. The curves of each watershed represented the surface runoff pattern compared to other watersheds. These curves fluctuated with seasonal variation of rainfall. Most of the surface runoff was occurring in November to February and May to August. The Watersheds 3, 5 and 13 had most of the surface runoff to contribute the river flow. Due to soil erosion and urbanization, surface runoff transports eroded sediment and quickly deposits to rivers or streams. In Johor Bahru watershed, about 28% of rainfall directly falls to the river or stream as surface runoff. This runoff provides valuable information for eroded soil transportation and rainwater distribution. It may be useful for surface water management and planning and potentiality of groundwater recharge.

#### Acknowledgements

Financial support by research grant number PY/2014/01708 (Q. J130000. 2509. 08H38) and Vote 4L827 (TRGS grant) of Universiti Teknologi Malaysia (UTM). JSPS-ACP program also gratefully acknowledged.

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