Rainfall runoff modeling for the basin in Bukit Kledang, Perak

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Abstract. A fundamental problem in studying a hydrological system is that most of the reaction takes place underground. Precipitation Runoff demonstrating of the Johan River basin was carried out using HEC-HMS technique. The model can improve decision-making about the hydrological problem, whether that be in water resources planning, flood protection and mitigation of contamination. The result shows that the rainfall-runoff model for the Bukit Kledang basin is slow depending on the relative travel time of basin and also associated with soil type, land used, multiple storms and seasonality.

1. Introduction
Rainfall runoff from areas where solid waste is sorted, stored or treated is invariably contaminated to some extent. Waste spilled or lost from waste management areas may build up in soil or on other surface and be transported by runoff after rainfall. According to Semadeni-Devies [1] the storm water pollutant load generated by a specific event depends on storm intensity, the time lapse and the rate of sediment accumulation between storms.

Runoff is one of the significant hydrologic boundaries utilized in the watershed the executives. Appraisal of the surface runoff which fundamentally relies upon the meteorology, geography, topography, soil and land use design is required for legitimate arranging of the hydraulic structures just as relief of natural hazard in the region. There are many methods available for the determination of runoff based on the above factors [2]. Several models of runoff simulations have been proposed and applied to urban runoff prediction, such as the Sacramento model presented by Burnash et al. [3], Tank model presented by Sugawara [4], HBV model simulated by Bergstro, [5], MIKE 11/NAM model obtained by Nielsen et al. [6] and Havnø et al. [7] and the Soil Conservation Service curve number (SCS-CN) method presented by Yousuf et al. [8]. According to Yousuf et al. [8], the SCS-CN is one of the most enduring methods among these models for estimating the volume of direct surface runoff in ungauged rural catchments.
A mathematical model was used by Jasrotia et al. [9] to estimate rainfall runoff in combination with remote sensing data and GIS using SCS CN and runoff potential map method. The runoff from SCS curve number model modified by conventional database and GIS was estimated by Ashish Pandey et al. [10]. Amutha et al. [11] showed that the GIS-integrated SCS-CN method of runoff estimation can be effectively used in watershed management. Pandey et al. [12] concluded that the land use input of the SCS-CN model is an important parameter input. Nayak et al. [13] obtained that the measured and intimated runoff depth using GIS and CN has a good correlation.

2. The Kledang watershed
Sg. Kledang is located at the Menglembu area, concentrated with industrial outlet. Sungai Kledang flows for 6.4 km into Menglembu area before entering Sungai Kinta. There are two contributors for this site (Figure 1) which are the residential estate and the industrial area. The Sg. Kledang originating from housing estate of Taman Bukit Kledang Indah will meet-up with the industrial area and then flows into the Kinta River.

3. Methodology
The Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) in Figure 2, is design to simulate the precipitation-runoff processes of dendritic drainage basin. It is design to be applicable in wide range of geographic areas for solving the widest possible range of problem. This includes large river basin supply and flood hydrology and small urban or natural watershed runoff. The program is a generalized model system capable of representing many different watersheds. A model of the watershed is constructed by separating the water cycle into manageable pieces and constructing boundaries around the watershed of interest.

The main steps of HEC-HMS methodology adopted in the present study as depicted in Figure 2 is summaries below:

- Create river basin from Digital Elevation Model (DEM) using GIS tool in HEC-HMS.
- Created Metrological Model from rainfall data of rain gauges located in the basin using HEC-HMS.
• Input time-series rainfall data in HEC-HMS model
• Create Control Model to provide simulation data
• Create Simulation Run model by integrating basin model, metrological model, and control model
• Running of the simulation Model
• Analysis of Result

Figure 2. Flow Chart of HEC-HMS model.

3.1. Basin Model
In this study, the basin model was created using GIS tool in HEC-HMS. The DEM was imported into the HEC-HMS and process using GIS tool, the result of basin model as shown in Figure 3. The basin area include 13.73 km² and perimeter 19.7 km. Sg. Johan located in the middle of the basin with 2 km length.
3.2. SCS Curve Number Method (SCS-CN)

The SCS Curve Number is a method of measurement for the surface runoff. This integer or parameter is introduced and developed by the United States Department of Agriculture (USDA). The object of the curve number is to define the average conditions for the purpose of design. The curve number was initially designed for agricultural watersheds with a land slope of 5% and an initial rainfall loss of 20% due to infiltration. The initial abstractions consist of lack of interception, surface storage and infiltration prior to runoff.

Table 1. Different soil group classifications.

| Soil characteristics                                      | Soil group |
|-----------------------------------------------------------|------------|
| Deep sand, deep loess, and aggregated silt                | Group A    |
| Shallow loess and sandy loam                              | Group B    |
| Clay loam, shallow sandy loam, soils low in organic content, and soils usually high in clay | Group C    |
| Soils that swell significantly when wet, heavy plastic clap and certain saline soils | Group D    |

As per soil characteristics, soils in the study region fall within the hydrological soil groups A, B, C and D as shown in Table 1. In general, soil group A (sandy soil) has the highest infiltration rate and a lower runoff capacity. Conversely, soil group D (clay soil) has the lowest infiltration rate and provides the highest runoff potential. Other groups of soil fall between them.

3.3. Metrological Model

This model is one of the primary components of the investigation which make metrological limit conditions for the basin. This metrological model can be utilized with various basin models. Result figured by the metrological model were coordinated with the sub-basin in the basin model utilizing the name of the sub-basin.
3.4. Control Specification
The function of control specification is to monitor the model regarding to starting and ending simulation at explicit time. The date and timing are imported in the model.

4. Results and discussion

4.1. Evaluation of Model Performance
Lumped models treat the catchment area as a single homogenous unit. Spatial variability of catchment parameters is disregarded in lumped models presented by Moradkhani and Sorooshian [14]; Singh [15]. Average values over the catchment are used such as mean soil storage and uniform precipitation amounts according to Beven [16] and Risema [17]. The catchment characteristics are set as equal for the entire area and often cause over or under parameterization [17]. In these models, a single runoff output value is measured at the outlet of the sub basin area. Lumped models accurately simulate average runoff condition with short computing time. All data, including input, output, and parameters, are constant over time and space in the lumped model. By assuming homogeneity over the sub basin area, lumped models lose the spatial resolution of the results. Empirical and conceptual models typically run spatially as lumped models.

4.2 Evaluation of rainfall-runoff relation
The relationship between rainfall and surface runoff is complex, since it depends on a variety of factors related to the watershed and meteorology. The results obtained in Table 1 below described the peak discharge at study area were 43.4 m³/s for 13.73 km² of drainage area. The peak discharge occurs after 18 hours of rainy days and the rainfall data are collected over a period of two days. On the first day of data collection, there was rain all day and no rain on the second day of data collection.

| Hydrologic Element | Drainage Area (km²) | Peak Discharge (m³/s) | Time of Peak | Volume (mm) |
|-------------------|---------------------|-----------------------|--------------|-------------|
| Subbasin 1        | 13.73               | 43.4                  | 09Aug2020, 00:00 | 174.74     |
| Sink-1            | 13.73               | 43.4                  | 09Aug2020, 00:00 | 174.74     |

From the point of view of the management of radioactive waste, this result must be seen in the scope of the mitigation of contamination. In the worst case scenario, if the waste disposal cap infiltrated by meteoric rainfall, the surface contamination will be transported by the surface runoff in the disposal area. According to the simulation in Figure 4, the runoff generation in the study area gives a slow rate depending on the relative travel time of basin and also associated with soil type, land used, multiple storms and seasonality.

The analysis of the findings presents that the runoff yield was in proportion to the precipitation. In additional, runoff has not been a consistent trend. It is obvious that the days of higher rainfall will produce higher runoff and vice versa. Besides, the result obtained showed that the annual runoff yield can be predicted by annual rainfall data with better accuracy using SCS-CN method. The retention in the sub-basin model is attributed by its moderately disturbed forest characteristics and soil characteristic in the study area that represent as soils that swell significantly when wet, heavy plastic clap and certain saline soils. The primary requirement to calculate surface runoff by SCS-CN method involved infiltration rate in each land use element. Base on the land use element in the study area, it’s represent a moderate disturbed forest that lowest runoff depth. This is due to the fact that the soil erosion happens in the moderate disturbed forest contributes to land degradation. Lal and Cummings [18] presented shifting cultivation practised in these field may lead to significant reduction in infiltration rates and saturated hydraulic conductivity.
During the wet season, after storm events and even in the dry season, a degraded forest discontinues adequate infiltration and groundwater recharge via vertical percolation, despite gain from evapotranspiration. Chappel et al. [19] also states that decreased soil infiltration capacity leads to decrease stormflow pathways, particularly on hill slopes, implying negative feedback on the generation of runoff. Ground cover beneath the trees, particularly leaf litter, was more effective than the amount of canopy cover in reducing runoff. During the less intense storms, canopy cover was more effective, but was ineffective when the intensity of rainfall was high. Brabec et al. [20], Hatt et al. [21], Olivera and DeFee [22] and O’Driscoll et al. [23] presented increase in urbanization and impervious surface in watershed strongly impacts the stream hydrology and this linearly increases of the runoff.

5. Conclusion

HEC-HMS 4.5 hydrological model is used to simulate the rainfall runoff in the Bukit Kledang watershed. The area is resistant to flooding and displays high variability in monsoon precipitation. The area of study is characterised by a limited supply of runoff data. The rainfall-runoff simulation is based on hourly rainfall data. It is likely that rainfall values are one of the biggest uncertainties and vary spatially and temporally. Digital Elevation Model (DEM) 1m was used by Geospatial Hydrologic Modeling Extension (HEC-GeoHMS) and ArcHydro extension in ArcGIS 10.6 to delineate the sub-watershed and generate the stream network. HEC-GeoHMS was also used as a meteorological model for use in HEC-HMS to delineate the physical properties and create the input file in the form of sub-basin boundaries. Careful study has been done to assign the CN to the land use. Simulated results should be validated based on field measurement parameters and field observations due to the inadequacy and lack of observed data. Based on the present analysis, rainfall-runoff from basin area is likely to be an insignificant sources of radioactive contamination in the surface area to the vicinity environment. Conceptually, the rainfall-runoff model for the Bukit Kledang basin is slow because the soil type in the basin is sandy clay, which is classified as Group D in the soil group. While land use for the basin area is a type of forest that provides an interpretation of the slow rate of surface water runoff. In conclusion, depending on the relative travel time of the basin, the rainfall-runoff model for the Bukit Kledang basin is slow and also associated with the type of soil land used, multiple storm and seasonality.

Figure 4. Simulation of rainfall-runoff model at study area.
6. References

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