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"Integrated River Basin Management (IRBM) : Hydrologic Modelling Using HEC-HMS for Sungai Kurau Basin, Perak"

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Abstract

Progressive increase in landuse changes within a river basin usually will have dire impact to the hydrologic behaviour of the basin. The impact will be very serious if the changes took palace in haphazard, unplanned, and uncontrolled manner. Landuse changes and urbanisation has always been blamed as among the major causes of the increase in the magnitude and frequency flooding and contributer to pollution. These issues were again discussed in year 2000 during the National Conference of Sustainable River Basin Management in Malaysia by Keizrul (2000). In this study, HEC-HMS were used to develop hydrologic model for Sungai Kurau Basin and to acces the hydrology response due to the landuse changes in Sungai Kurau Basin based on the available data. These models were calibrated on year 2004 and validate on year 1999. The simulated model were fit with the observed data and shows that the HEC-HMS are suitable model to predict the hydrologic changes in Sungai Kurau Basin.

Keywords: GIS, Hydrologic Modelling, HEC-HMS 3.1, and ArcView

1.0 Introduction

Lin et al. (2007) had studied that combination a landuse change model, landscape metrics and a watershed hydrological model with an analysis of impacts of future landuse scenarios on landuse pattern and hydrology. Lin et al (2007) applied the model to assess the impacts of different landuse scenarios that include various spatial and non-spatial policies in watershed and revealed that future landuse patterns different between spatial policies. Moreover, Lin et al. (2007) said that patterns of future agricultural land patches obviously differed among agricultural land conversation policies.

The importance in this study is being able to predict the hydrologic modeling of the Kurau basin using HEC-HMS. This project will analyze the impact of landuse change to hydrologic behaviour of the study area and by utilise Geographical Information Systems (GIS) and current technology such as Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) for catchments management. HEC-HMS was developed to predict the water resources management (long-term) and flood management (the short-term).

The specific objectives of this study are:

a) To develop Hydrologic Model for Sungai Kurau Basin
b) To access the hydrology response of the catchments due the land use change

However, this paper are describing on development of hydrologic modelling for Sungai Kurau Basin in term of calibration and validation that the pattern of simulated flow are fit with the observed flow. The acces of the hydrology response will be carried out later.

2.0 Study Area

Sungai Kurau (Figure 2.1) represents the main drainage artery of the basin, draining an area of approximately 682 km^2 that is generally low lying. The river originates partly in the Bintang Range and partly in the Main Range where the terrain in the upper reaches is steep and mountainous. Mid valleys of the river are characterized by low to undulating terrain, which give way to broad and flat floodplains. Ground elevations at the river headwaters are moderately high, being 1,200 m and 900 m respectively in Batu Besar and Batu Ulu Trap. The slopes in the upper 6.5 km of the river averaged 12.5% whilst those lower down the valleys are much lower, of the order of 0.25% to 5%.

A dam has been constructed at 65 km upstream of the rivermouth at the mid section of the rivers to form the Bukit Merah Reservoir. This dam operates principally to irrigate the paddy areas immediately below the Reservoir. Upstream of the Reservoir are two river subsystems, namely the Kurau River subsystem and the Merah River subsystem. Both drain through undulating to steep terrain. Areas in the former subsystem have been developed extensively for tree crop while the Pondok Tanjong Forest Reserve forms the main land use of the latter subsystem. The upper portion of Kurau River basin falls in the District of Larut, Matang and Selama while the downstream portion is in the Kerian District. Both Districts are in the State of Perak. Largely rural in nature, Kurau River basin has many riverine villages established from the mid to the lower reaches of the river.

It was reported (utusan, 2007) in 10 September 2007 that 578 people from 141 families from three villages (Kampung Batu 40, Kampung Balik Bukit, Kampung Abu Hasan Bah) in the District Kerian had to be evacuated when two-metre-high floodwaters refused to recede for a week. Dewan Undangan Negeri Alor Pongsu's member, Sham Mat Sahat said the occurrence of floods caused spillover water from the Bukit Merah reservoir after heavy rain during four to five hours a day for 3 days.

From the above statements, heavy rainfall from the upstream river system cause flooding to the downstream areas because the Bukit Merah reservoir is not capable to store the excess water from the upstream. HEC-HMS model were used to predict the hydrologic model for the upstream area of Sungai Kurau Basin

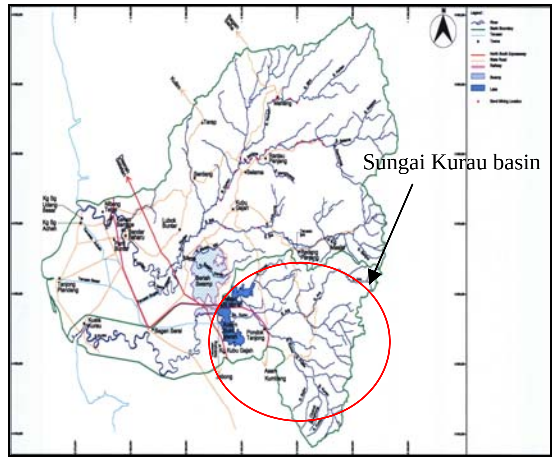

Figure 2.1 Kurau River Basin

3.0 Model Description

3.1 Hec-Geo HMS

It is a geospatial hydrology toolkit for engineers with limited GIS experience[USACE-HEC, 2003]. It is an extension package used in ArcView software. In this study, Hec-GeoHMS is used to derive river network of the basin and to delineate subbasins of the basin from the digital elevation model (DEM) of the basin.

The Geo-spatial Hydrologic Modeling Extension (HEC-GeoHMS) uses ArcView and Spatial Analyst to develop a number of hydrologic modeling inputs. Analyzing digital terrain information, HEC-GeoHMS transforms the drainage paths and watershed boundaries into a hydrologic data structure that represents the watershed response to precipitation. In addition to the hydrologic data structure, capabilities include the development of: grid-based data for linear quasi-distributed runoff transformation (ModClark), the HEC-HMS basin model, physical watershed and stream characteristics, and background map file.

HEC-GeoHMS provides an integrated work environment with data management and customized toolkit capabilities, which includes a graphical user interface with menus, tools, and buttons. The program features terrain-preprocessing capabilities in both interactive and batch modes. Additional interactive capabilities allow users to construct a hydrologic schematic of the watershed at stream gages, hydraulic structures, and other control points. The hydrologic results from HEC-GeoHMS are then imported by the Hydrologic Modeling System, HEC-HMS, where simulation is performed.

3.2 HEC-HMS 3.1.1

HEC-HMS is the US Army The HEC-HMS program is the updated program from the HEC-1, and designed for more functions than the HEC-1. The difference of HEC-HMS from HEC-1 is that the HEC-HMS is running with a windows appearance, while the HEC-1 is working with MS-DOS program. The Hydrologic Modeling System (HEC-HMS) is designed to simulate the precipitation-runoff processes of dendritic watershed systems. It is designed to be applicable in a wide range of geographic areas for solving the widest possible range of problems. This includes large river basin water supply and flood hydrology, and small urban or natural watershed runoff. Hydrographs produced by the program are used directly or in conjunction with other software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation. The program is a generalized modeling system capable of representing many different watersheds. A model of the watershed is constructed by separating the hydrologic cycle into manageable pieces and constructing boundaries around the watershed of interest. Any mass or energy flux in the cycle can then be represented with a mathematical model. In most cases, several model choices are available for representing each flux. Each mathematical model included in the program is suitable in different environments and under different conditions. Making the correct choice requires knowledge of the watershed, the goals of the hydrologic study, and engineering judgment. The program features a completely integrated work environment including a database, data entry utilities, computation engine, and results reporting tools. A graphical user interface allows the seamless movement between the different parts of the program. Program functionality and appearance are the same across all supported platforms. (Scharffenberg and Fleming, 2006)

4.0 Data

HEC-HMS model is used as tool for the hydrologic modeling of Sungai Kurau basin. Data necessary for the simulation process are information on present and future landuse, hydrologic soil group, hydrological records, topography map, landuse maps and data deemed relevant to the study, Table 3.1 .

Table 3.1 Data for HEC-HMS and the Sources

	Data	Source
a.	Topography map of Kurau River catchment in AutoCAD format.	The Department of Survey and Mapping Malaysia (JUPEM)
b.	Hydrological records such as rainfall data and its station and also water level station.	The Department of Irrigation and Drainage (DID)

4.1 Rainfall

A total of sixteen rainfall gauging stations in the Sungai Kurau basin have been identified but only four rainfall stations have been selected for this study as shown in Table 4.1. The hourly rainfall data and daily rainfall data were used in hydrograph simulation. The hourly rainfall data is more accurate to quantify the volume and peak flow of simulation. Meanwhile for the daily rainfall data, distributions using the hourly rainfall data as colored in green in table 4.1 were use as reference to the daily rainfall data to get the hourly rainfall data for each station.

Table 4.1 Rainfall Stations use in HEC-HMS model.

Station_Id	Station	Increment
4908013	Ibu Bekalan Semeneh at Batu Kurau	Daily
4908018	Pusat Kesihatan Kecil at Bt. Kurau	Hourly
5007020	Ldg. Pondoland at Pondok Tanjung	Daily
5007029	Ibu Bekalan Jelai	Daily

Source: Department of Irrigation and Drainage, Hydrology Division

4.2 Water Level and Streamflow

A total of four (4) streamflow gauging stations have been identified which are located in the study area. The stations are in Table 4.2 below. However, only two (2) streamflow gauging stations at Bt 14, Sungai Kurau and Pondok Tanjung were selected in this study. Locations of rainfall and discharge station were shown in Figure 4.1.

Table 4.2 Streamflow Station use in HEC-HMS model

Station Id	Station	Increment
4907422	Sg. Kurau at Bt. 14 Jln. Taiping	Hourly
5007421	Sg. Kurau at Pondok Tanjung	Hourly
5007423	Sg. Ara at Bt. 20 Jln. Taiping	Hourly
5108401	Sg. Ulu Ijok	Hourly

Source: Department of Irrigation and Drainage, Hydrology Division.

Table 4.3 Parameter Used in the HEC-HMS

Element	Method	Parameter
Subbasin	Loss rate-SCS Curve Number Loss	Initial abstraction Curve Number
	Transform-SCS Unit Hydrograph	Time Lag
	Baseflow-Recession	Initial type-discharge Initial discharge Recession constant Threshold type Threshold ratio
Reach	Muskingum Cunge	Length Slope Manning's n Shape Bottom Width Side Slope (xH:1V)

Simulation

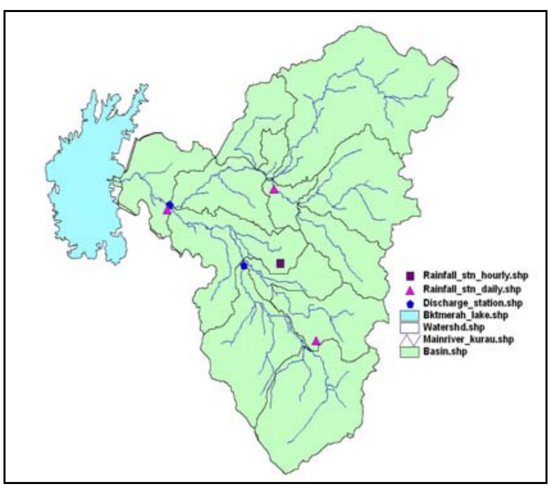

Figure 4.1 Locations of Rainfall and Discharge Stations for Sg Kurau basin

4.3 Study Reach

A reach is an element with one or more inflow and only one outflow. Inflow comes from other elements in the basin model. If there is more than one inflow, all inflow is added together before computing the outflow. The reach element can be used to model rivers and streams.

4.4 Selecting a Routing Method

For this modelling, Muskingum-Cunge Routing Method was used because it is based on the combination of the conservation of mass and the diffusion representation of the conversation of the momentum.The length should be the total length of the reach element and the slope should be the average slope for the whole reach. The Manning's n (roughness coefficient) should be the average value for the whole reach. Method used in initial study as summarized in Table 4.3. Figure 4.2 shows the watersheds after terrain processing, basin processing, hydrologic parameter and HMS processing using HEC-GeoHMS.

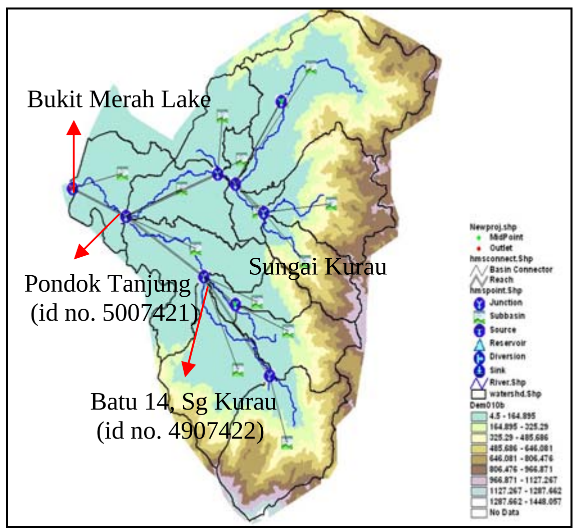

Figure 4.2 Sungai Kurau Basin after HMS Processing using HEC-GeoHMS

The configuration HEC-HMS for Sungai Kurau model is depicted in Figure 4.3. There are nine (9) nodes for the flows from every subcatchments and channel. The observed discharge data recorded at node R40 which is Pondok Tanjung station (id no. 5007421) and JR130 which is Batu 14, Batu Kurau station (id no. 4907422).
There are 13 subcatchments used to represent the hydrologic model in Sungai Kurau which is can be divided into two (2) rivers namely Sungai Kurau and Sungai Ara. All the subcatchments were name

during the hec-geoHMS process and can be recognized depend on their location. The flow will linked from Sungai Ara and Sungai Kurau and finally meet at the junction call Pondok Tanjung as shown in Figure 3.4 and link through the oulet which is Bukit Merah Lake.

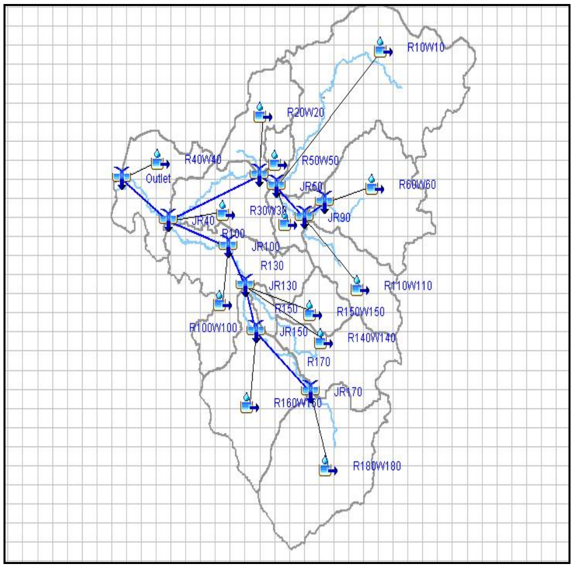

Figure 4.3 HEC-HMS Layout Model

5.0 Simulation with HEC-HMS

Calibration is a process to determine the properties or parameters which describe a system. Some parameters such as initial abstraction, curve number, impervious, lag time, initial discharge, recession constant and ratio are determined through calibration process where the parameters are adjusted until the observed and simulated hydrograph are almost fitted well. Some parameters such as slope, manning's n, bottom width, shape, and length of river are obtained from topographic map and hec-geohms process.

The model is calibrated and validated using the 22 October – 31 October 2004 and 20 October 1999 – 31 October 1999 rainfall runoff data respectively. The calibration and validation went through the two processes as:

- Calculation of the average rainfall throughout the catchment area by using the weighted Thiessen Polygon method. The weighted rainfall factors and the Thiessen polygon method are shown in Table 5.1 and Figure 5.1.
- Determination of parameters as such the losses, catchment routing and channel routing, and baseflow discharge.

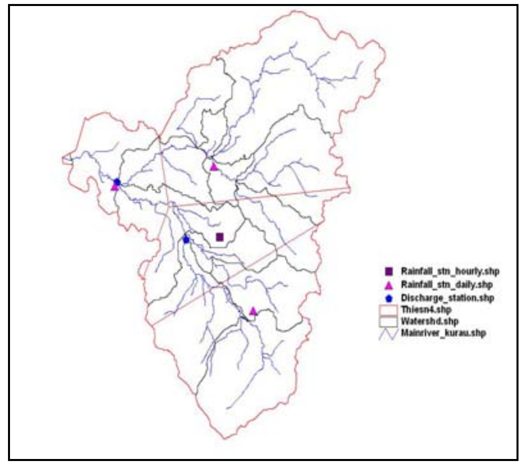

Figure 5.1 Thiessen Polygon Method

Table 5.1 Weighted Rainfall Factor

Sub-basin	Area (km^2)	Weighted Rainfall Stations			
		5007029	5007020	4908018	4908013
R10W10 Kg Sungai Ara	75.389	-	-	1.00	-
R20W20 Titi Gantung	16.584	1.00	-	-	-
R30W30 Main Sg Ara	21.698	0.58	0.4	0.02	-
R40W40 Pondok Tanjung	22.864	0.01	0.99	-	-
R50W50 Sg Ara	4.678	-	1	-	-
R60W60 Jalan Air Itam, Sg Jelai	30.157	-	1	-	-
R90W90 Sg Jelai	8.310	0.95	0.05	-	-
R100W100 Sg Kurau	40.668	-	0.22	0.78	-
R110W110 Kg Bt 20	19.437	0.09	-	0.6	0.31
R140W140 Kg Jabi	36.636	-	-	0.39	0.61
R150W150 Batu 14	3.871	-	-	1.00	-
R160W160 Kg Changkat Lobak	32.099	-	-	1.00	-
R180W180 Kg Perak	47.154	-	-	1.00	-

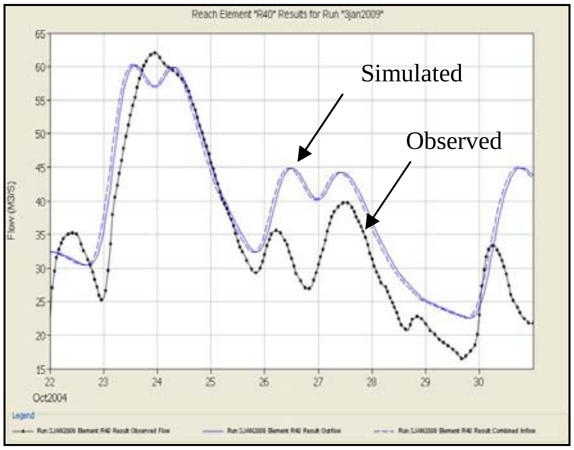

Figure 5.2 Runoff Hydrograph for R40 at Pondok Tanjung Discharge Station (Calibration)

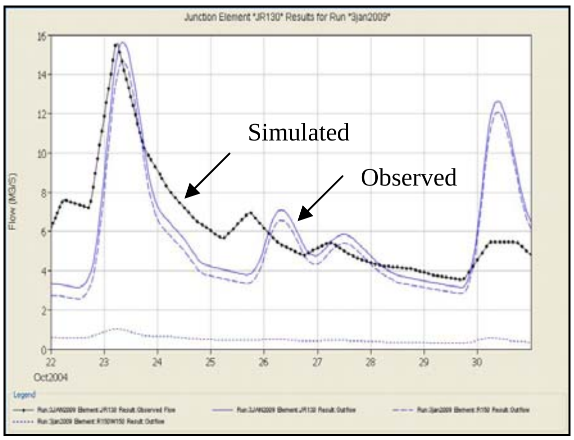

Figure 5.3 Runoff Hydrograph for JR130 at Batu 14 Discharge Station (Calibration)

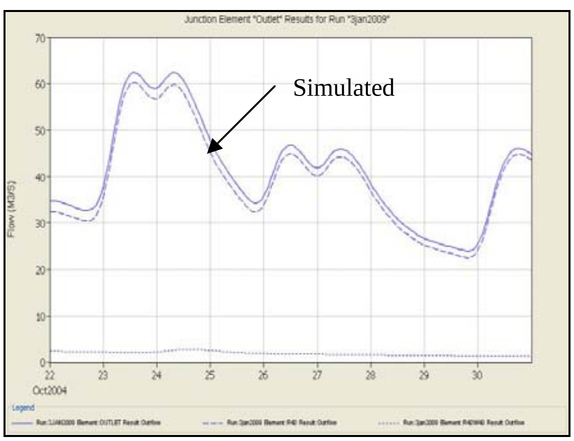

Figure 5.4 Runoff Hydrograph at the Outlet (Calibration)

From the calibration results, shows that the peak flow at R40 at Pondok Tanjung discharge station were closely fit with the obesrved peak flow, but after that the flow were slowly reduce and the pattern between compared and observed were not fit well. This may due to the location of rainfall and weigted rainfall that used in the modelling Hec-Hms.

6.0 Model Validation

The calibrated model parameters are validated by using hourly interval event rainfall starts from 20 October 1999 until 31 October 1999. The validation results are shown in Figure 6.1 and Figure 6.2 for the discharge station at Pondok Tanjung station (id no. 5007421) and Batu 14, Batu Kurau station (id no. 4907422). Simulated hydrograph for catchment outlet are shown in Fgure 6.3.

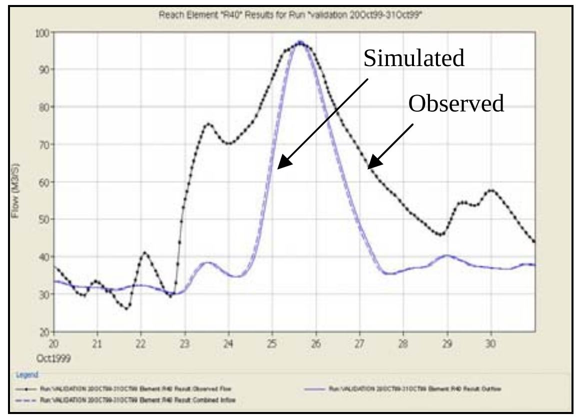

Figure 6.1 Runoff Hydrograph for R40 at Pondok Tanjung Discharge Station (Validation)

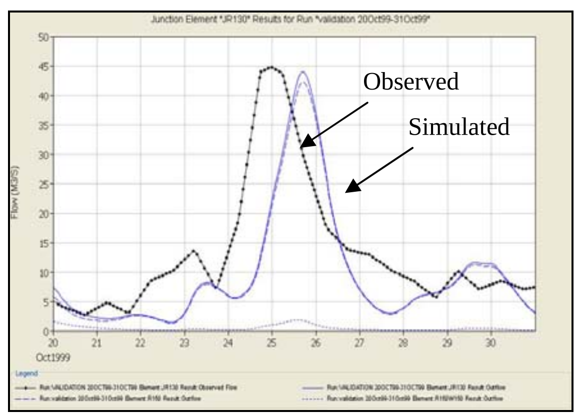

Figure 6.2 Runoff Hydrograph for JR130 at Batu 14 Discharge Station (Validation)

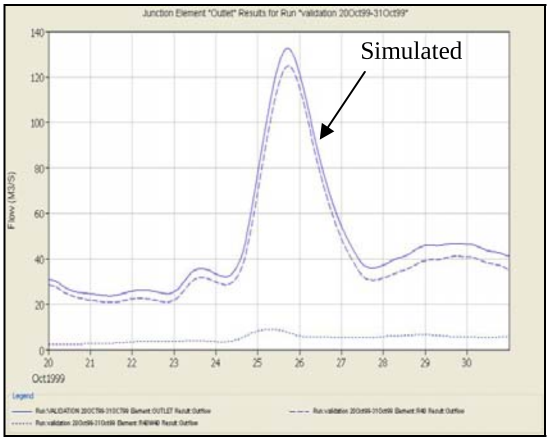

Figure 6.3 Runoff Hydrograph at the Outlet (Validation)

A larger level of uncertainty was noticeable in the calibration and validation of these results. But the calibrations were fitted well with the observed flow, and flow produce are similarly follow the pattern of observed. Validation results obtained for the R40 at Pondok Tanjung are not good compare the calibration, this is because only four rain gauges were used in the analysis and only one rain gauges has hourly data and the rest of it are in daily time series, so the daily data are using the hourly rain gauge as reference to produce the hourly data. The result from the analysis rainfall is not accurate because of this problem. These discrepancies can be seen from the result during validation at R40 and JR130 were there are many differences between the simulated flow and the observed. Hope in the future, more automatic ranfall stations will be installed with hourly increment data, so that the model will produce the best result.

7.0 Conclusion

Hydrologic Modelling has been widely used for various purposes. All the area of the state increases their level of development, infiltration capacity of the terrain decreases because of increasingly the percentage of impervious area and the treat of flooding becomes even more pronounced. This study presents a methodology and development of Hydrologic modeling that may solve the flood hazard.

This study presents the strategy of employing ArcView 3.2 and HEC-HMS in determining spatially distributed runoff and to evaluate and identify the capability of HEC-HMS in the transformation of the rainfall for the Sungai Kurau basin's area.

Moreover, hopes that more research were done for all catchments in Malaysia to solve the flooding problems.

Acknowledgements

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