CATCHMENT DELINEATION AND PARAMETERIZATION USING GIS TECHNIQUE FOR KUANTAN RIVER

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for the award of the

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ABSTRAK

Bandar Kuantan mempunyai sejarah mengalami banjir sejak beberapa dekad lalu. Oleh kerana masalah banjir, pihak berkuasa tempatan telah menghabiskan banyak wang dalam kerja-kerja pengurangan banjir untuk mengurangkan kesan banjir kepada masyarakat. Dalam hal ini, Sungai Kuantan telah dikenalpasti sebagai salah satu sungai yang menyumbang kepada masalah banjir. Curahan hujan yang lebat boleh menyebabkan lebihan kenaikan larian ke paras air yang tinggi dan menyebabkan kawasan itu mengalami banjir. Tambahan pula, Kuantan telah mengalami perkembangan pesat. Penggunaan tanah diubah untuk menampung permintaan untuk pelbagai tujuan seperti tujuan perumahan, perindustrian dan pertanian. Oleh itu, untuk merealisasikan perubahan lembangan sungai dan ciri-ciri permukaan, mengkaji ciri-ciri kawasan tadahan adalah perlu. Kajian ini menggunakan data satelit (ASTERGDEM) untuk menggambarkan dan menentukan parameter kawasan tadahan Sungai Kuantan menggunakan Sistem Maklumat Geografi (GIS). Ia adalah satu proses untuk menentukan ciri-ciri kawasan tadahan sebagai langkah awal projek tebatan banjir. Pra-pemprosesan data satelit telah dijalankan untuk meningkatkan ketepatan data ketinggian. Parameter kawasan tadahan seperti luas, cerun, dan centroid lembangan telah diekstrak dan parameter ini adalah input penting untuk menghasilkan pemodelan hujan-hujan dalam kajian akan datang. Di samping itu, hasil daripada kajian ini adalah penting untuk memberikan maklumat awal mengenai ciri-ciri tadahan kepada pihak berkuasa tempatan seperti Jabatan Pengairan dan Saliran

ABSTRACT

Kuantan City has a history of experiencing the flood since past decades. Due to the flood problem, the local authority has spent a lot of money in the flood mitigation work to reduce the impact of the flood on society. Kuantan River has been identified as one of the rivers that contributes flood problem. Heavy rainfall can cause the excess of runoff rise to the high water levels and cause the area to be flooded. Moreover, Kuantan has experienced a rapidly developed. The land use is changed to accommodate the demand for many purposes such as residential, industrial and agricultural purposes. Therefore, to realize changes of river basin and surface features, study the characteristics of the catchment is necessary. This study utilized satellite data (ASTERGDEM) to delineate and parameterize the catchment area of Kuantan River catchment using Geographical Information System (GIS). It was a process to determine the characteristics of catchment as the first step of flood mitigation project. Pre-processing of satellite data was carried out to improve the accuracy of elevation data. Catchment parameters such as area, slope, and basin centroid were extracted and these parameters is an important input for rainfall-runoff modeling for future studies. In addition, the result from this study was important to give initial information on characteristics of the catchment to the local authorities such as Department of Irrigation and Drainage.

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LIST OF ABBREVIATIONS

ASTERGDEM	Advance Spaceborne Thermal Emission Radiometer Global Digital Elevation Model
DEM	Digital Elevation Model
GIS	Geographical Information System
HEC-GeoHMS	Hydrologic Modelling Center-Geospatial Hydrologic Modelling System
HMS	Hydrologic Modelling System
ESRI	Environmental Systems Research Institute

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter briefly explains the background of the study, problem statement, the objective and scope of the study, expected outcome and the significance of this study.

1.2 Background

Water is essential for life. It plays important role in supporting all human activities so that human beings need water significance to the rapidly increasing number of the human population especially in developing area. Planning of water resources in a catchment is an initial step to provide a platform and improvement of water resources continuing to meet the desires of water in the future. Poor management of water resources caused water availability fails to be fulfilled to the maximal level especially during the dry season or it also may lead to the occurrence of the flood in that area. Therefore, a comprehensive approach for water resources requires management plan especially in the management of catchment.

Catchment is the natural unit of land which water from direct precipitation, rainfall, and other storage collects in a channel and flows downhill to a common outlet at which the water enters another water body such as a stream, river, wetland, lake or the ocean (Dilip G. Durbude & Sharma, 2001) . In the context of any water resources development project, the information concerning the quantity of available water is very crucial. The characteristics of the river basin define the quantity of runoff from it. These characteristics include land use, soil type, and morphometric parameters.

By using available technologies, the characteristics of the catchment can be identified. Current research in past few years on catchment hydrology as well as practical management of water resources is based on catchment delineation for estimating runoff from rainfall and evaporation data. In earlier times, catchment delineation was mainly directed by the technique of hand delineation. Nowadays, there is an easier way to delineate catchment, which by computer modeling using GIS technique. The GIS has been widely used for catchment delineation and classifying river network. The delineation of watershed using GIS mainly based on Digital elevation model (DEM) data. Computer modeling provides many advantages compared to manual techniques. Development Geographical Information System (GIS) and Digital Elevation Models (DEM) enable to examine the phenomenon the natural surface of the earth through spatial modelling (Indharto, 2004). According to Cheng (2016), because of the capability of the GIS to handle a large amount of spatial and attribute data, it has become a critical tool in hydrological modeling. The derivation and aggregation of hydrologic parameters from different sources can be assisted by some of the GIS features.

1.3 Problem Statement

Malaysia experiences many major flood events in the past few years due to prolong rainfall occurrence. The flood occurrence has caused many negative impacts to the society such as properties loss and affecting the water quality. Due to the flood problem, the Malaysian government has spent a lot of money in the flood mitigation work to reduce the impact of the flood on the society. Flood occurrence is usually caused by the runoff of rainwater which occurs because of the rain volume exceeding the storage capacity in the natural and artificial storage. The process of rainfall-runoff will be influenced by terrain, geology, soil, area, slope, and plant-types (Chang, 2009).

Kuantan River basin has been subjected to the flood since past decades due to its tropical climatic condition. After three decades of a catastrophic flood in 1971, the year 2001/02 experienced havoc flood with the magnitude of 3.9 brought by continuous heavy rainfall during the northeast monsoon, which hit most of the part of Peninsular Malaysia. Pahang was inundated beneath water after nearby rivers overflowed affected 18,000 people and 22,940 square kilometers (EKA, 2002). Besides, right after 10 years, another worst flood circumstance in years 2011/12 has paralyzed Kuantan. Sudden flood due to nonstop massive rainfall affected almost 6,000 flood victims reportedly; several roads were seriously flooded, and hundreds of vehicles stuck in subsequent of the poor drainage system that cannot cater heavy rain (Kuala Lumpur Post, 2012). The unexpected massive flood, a moment ago in 2013 occurred due to prolonged heavy rainfall and land-use change really conveyed serious risk to society. Kuantan was rigorously distressed. Around 14,044 people evacuated and major damages occurred in terms of electricity, road's structure, structures, and belongings hence government suffered from the substantial financial cost for repairing flood damages (Jamaludin et al., 2013).

1.4 Objectives

The main objectives of this study are to delineate and parameterize the catchment of Kuantan River using GIS technique. However, pre-processing of satellite data was carried out to improve the accuracy of elevation data. Hence, this study is undertaking by these following summarized objectives:

a) To carry out pre-processing of satellite data (ASTERGDEM).

b) To delineate and parameterize the catchment of Kuantan River using GIS technique.

1.5 Scope of Study

scope of this study will only concentrate on the Kuantan River Catchment. To meet the objectives, the study covers the following scopes:

a) The collection of related secondary data sources such as digital elevation model (DEM) of Kuantan River catchment and river network of Kuantan river catchment.

b) Carry out the pre-processing of satellite data using ArcHydro tool in GIS software.

c) Carry out the processing of delineated watershed using HEC-GeoHMS extension in GIS software.

1.6 Expected Outcomes

This study is expected to utilize the GIS technique on mapping the characteristics and parameterize the Kuantan River catchment. The usage of GIS has improved the wisdom of the decision-making process by enlightening data accuracy and accessibility of satellite data and subsequently leads better resolution. It also will be helpful in providing catchment information for related local authority for managing water resources in planning for future development.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter describes a review of the literature on hydrology, watersheds, elevation, Geographical Information System (GIS) and hydrologic modeling from previous research studies that related to this study for my better understanding.

2.2 Watershed

A watershed is a basin-like landform well-defined by highpoints and ridgelines that run down into lower elevations and stream valleys. In other words, a watershed explains a zone of land that comprises a mutual set of streams and rivers that all drain into a particular larger body of water, such as a larger river, a lake or an ocean (Palaka, 2016).

Wilson (1990) defines a watershed as the amount of land and water at the surface will affect the runoff in a particular place or river cross sections and states that each control point on the river has its own sub-catchment. However, Horton (2003) defines the difference between a catchment area of effective and ineffective. The effective catchment area is as described by Wilson (1990), while not effective catchment area is defined as the runoff cannot reach out of the catchment.

According to Dilip G. Durbude (2015), the most important part in generating runoff is the known physical characteristics of the watershed and it significantly affects the hydrological behavior of the watershed. The prospect performance of this hydrological behavior of watershed can be estimated by conceptual modeling. Geological maps and information may be already available in some countries around the world. Nevertheless, the scale of map frequently be small and the information is not detailing enough to cover the watershed in demand.

2.2.1 Kuantan River watershed

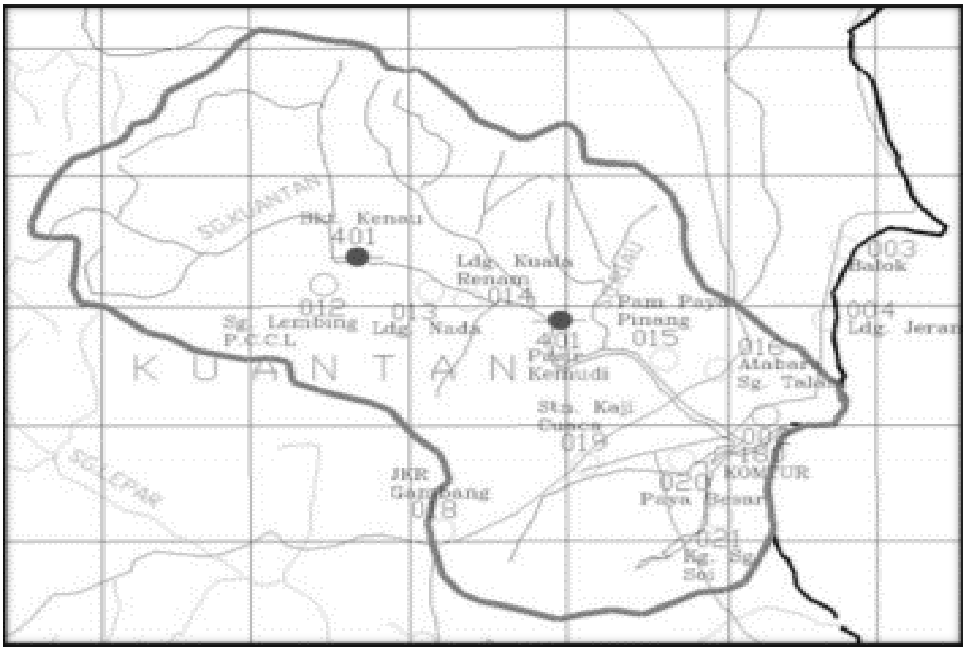

Figure 2.1: Kuantan River Catchment

The study was located at Kuantan River watershed. Kuantan is the capital city of Pahang, which is the largest state of Peninsular Malaysia. This city is located on the east coast of Peninsular Malaysia and located approximately 3’53 North and 103’21 East in the tropical rainforest country. Kuantan District, of which the city is a part, covers an area of 2,967 square kilometers. 2065 square kilometers from the total area has been designated as Kuantan Municipal Council (known as Majlis Perbandaran Kuantan) area that means this area will receive MPK services. Then, the remaining area has been gazetted as permanent reserve forest, which serves as the water catchment area for Kuantan and Maran. (Dr. Gayl D. Ness, 2004).

According to the study, the catchment is in the city of Kuantan is 2630 square kilometers and there are at least 26 major river systems involved. Kuantan river flows from Hutan Simpan Reman Cereh to Kuantan City before discharge into the South China Sea, then four main tributaries discharge into downstream of Kuantan River namely Soi River, Belat River, Pandan River and Pinang River. Increased peak flow in the watershed is due to the development in the watershed and in turn, will increase the problem of flooding on the downstream side of the catchment area (Bengstson, 2010).

From the previous record, on 2013 and 2014, floods have occurred in Kuantan, and it was caused by several factors, namely drain that has been made specified for emergency cases such as flash flood have been blocked and the other factor is there is not enough area that applied rainwater harvesting system. By the year 2015, about 488,409 population of Kuantan, the population living in urban areas has increased to 60% of the population due to the new urban areas and extension of existing administrative (Hui et.al, 2015).

2.3 Geographical Information System (GIS)

Geographical Information System (GIS) is an information system that can store, display, analyze, and manipulate data associated with data spatial (spatial data). The ability of this system is not limited to the display of digital maps but also can do the work of analysis, analyzing, attribute and spatial data, identify patterns of behavior, and displays the results of the analysis are shown in the rating system has an accurate reference point on the earth. GIS has appeared as an important provision device for dealing with water resources using digital elevation models (DEMs) of land surface topography. GIS is now acknowledged as a beneficial tool for accumulating water resources information. Water management agencies are constructing GIS data sets to support their operations. (Paritosh Gupta & Rajendra M Tamhane, 2000).

A digital representation of the watershed is provided by GIS which can be in-cooperate with which the hydrological modeling. Hydraulic modeling is an important process because it can help in the activity such as hydrological planning and conservation of the water resources. On the uses, GIS will produce two types of data which are the vector data (Shapefiles) and the raster data (Grids, TINs (Triangulated Irregular Networks) and Image) which will be used in the hydrological model. GIS propositions technologically proper method for land resource assessment, allocating different land use patterns, flood management, irrigation water management, and valuation and monitoring of the environmental effect of watershed projects (Aher et al., 2014).

2.4 Hydrologic modeling

According to Singh and Woolhiser (2002), the hydrologic modeling mostly involved the development of theories, concepts, and models of individual modules of the hydrologic cycle such as channel flow, infiltration, subsurface flow, evaporation, overland flow and base flow. Table 2.1 below shows the list of most popular event, continuous runoff model for hydrologic modeling.

Table 2.1 Selected simulation models in hydrology (After Bedient et al., 2008)

Model	Author	Date	Description
HEC-HMS	HEC	1998,2006	Hydrologic modelling system (replacing HEC-1)
HEC-RAS	HEC	1995, 2006	River analysis system (replacing HEC-2)
SCS-TR55	USDA SCS	1975	Hydrologic simulation model
SWMM	Huber and Dickinson	1971, 1988, 2005	Storm water management model

2.4.1 Hydrologic Engineering Centre – Geographical Hydrologic Modelling System (HEC-GeoHMS)

According to Honeycutt (2013), the Geospatial Hydrologic Modelling Extension Modelling Extension (HEC-GeoHMS) has been established as a geospatial hydrology toolkit for hydrologists and engineers with partial GIS capability. Spatial Analyst extension is available from the Environmental Systems Research Institute, Inc. (ESRI). Hec-GeoHMS analyze digital terrain data by transforming the drainage paths and watershed boundaries into a hydrologic data structure that denotes the drainage network. The program permits users to visualize the spatial information, perform spatial analysis, and delineate streams and subbasin.

2.5 Digital Elevation Model (DEM)

Recent day, GIS and remote sensing are the common technologies used in environmental studies. Hassan (2006) stated that these technologies are very useful when it comes to the environmental studies. The studies may include land use changes, flooding event, and landslide. The increasing of flooding events in past few years leads to the usage of these technologies increased. These technologies represented a better visualization of the actual condition of the ground surfaces area of the earth.

Digital Elevation Model is a digital representation of earth's topography. DEMs can be used to derive geomorphometric parameters, topographic attributes, morphometric variables or terrain information in general. In combination with other spatial data, digital elevation models are an important database for topography-related analyses. A coordinate system can derive a complemented different georeferenced 3D and be presented in a 3D perspective view or as a 2D-map projection (Sulaiman, 2012).

Digital elevation model (DEM) can be allocated into two types, includes a vector that represents in points and raster that represents by the grid. DEM and single image are regularly generated using the photogrammetric product. These digital elevation model (DEM) has to be created as to obtain a correct geo-referencing, which is only possible on a digital elevation model (DEM). Typically, the existing and any not classified worldwide digital elevation model (DEM) are having low and insufficient accuracy and reliability for certain application which may affect the results in the future.

2.6 Google Earth

Google Earth is a virtual globe based on geographical information programme and 3D maps. It simplifies mapping of the Earth by the superimposition of images gained from an aerial photograph, satellite imagery, and geographic information system (GIS) 3D globe. Google Earth performs digital elevation model (DEM) data collected by NASA's Shuttle Radar Topography Mission (SRTM) and aiding 3D view of the whole earth. (Xiaqing Wu, 2007)

Google Earth is useful for many applications such as visualizing earth feature, earth resource mapping, town planning, simulation of the disaster event and monitoring road traffic or congestion. Moreover, Google earth has customary itself as a useful tool for classroom teaching, high-end research, and data sharing and broadcasting tool. This well supported by the fact that Google Earth has been downloaded more than a billion times since October 2011. Started in June 2005, Google Earth offers high-resolution elevation data using the simulated globe system and Shuttle Radar Topography Mission (SRTM) data for its elevation model (Arabinda, 2014).

CHAPTER 3

METHODOLOGY

3.1 Introduction

In performing the hydrologic model, it will involve a few steps of creating the model in the GIS software, which is data collection, pre-processing, and processing. The flow of work for the whole process is shown in Figure 2.

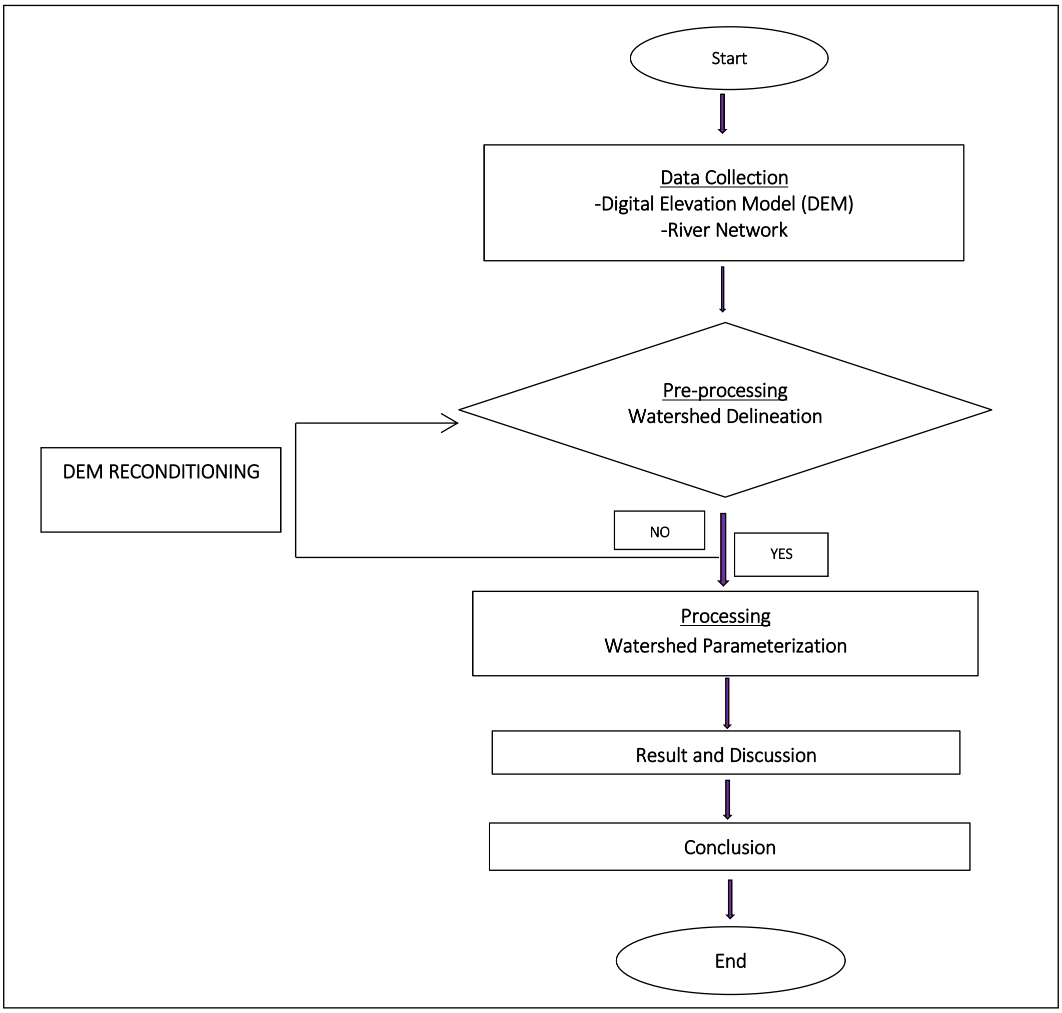

Figure 3.1: Work Flow Chart

3.2 Data Collection

For the purpose of this study, relevant collected data related to Kuantan River catchment is used. The source of data collection for this study is secondary data. Secondary data is used readily available digital from related public agencies. Table 3.1 shows the data type and data sources required for this study.

Table 3.1: Types and sources of data required

No	Data Type	Data Source
1	ASTER DEM	USGS Earth Explorer
2	River Network	Google Earth

A Digital Elevation Model (DEM) is a specialized database that represents the relief of a surface between points of known elevation. By interpolating known elevation data from sources such as ground surveys and photogrammetric data capture, a rectangular digital elevation model grid can be created. The DEM required for this project is a 30m resolution model obtained from the official website (https://earthexplorer.usgs.gov/). This digital elevation model used as an input for the delineation process in GIS. Figure 3.1 shows DEM used for this study.

This study also required a river network as an input vector stream in GIS for DEM reconditioning process to increase the degree of agreement between stream networks delineated from the DEM and the input vector stream. The river network for this study is obtained from Google Earth. Google Earth is a free software that enables users to visualize, edit, and create geographic information. It also enables to draw the entire length of river and labels for access points or other important locations.

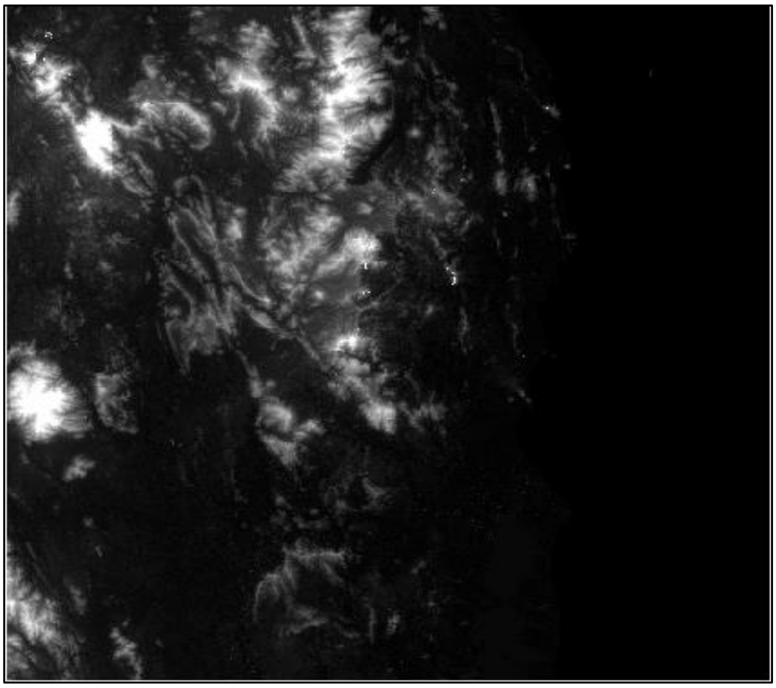

Figure 3.2: Digital Elevation Model of Kuantan River Catchment from USGS Earth Explorer.

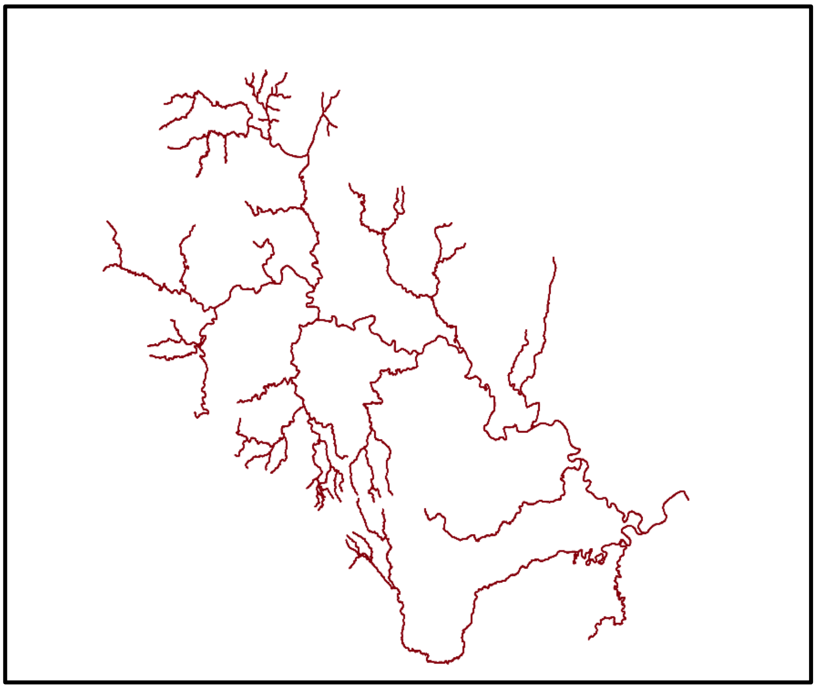

Figure 3.3: River network of Kuantan catchment obtained from Google Earth.

3.3 Pre-processing

This is phase of preparation of data for processing work and analysis in for the watershed processing. Pre-processing uses DEM to satisfy the surface drainage pattern. Before the pre-processing takes place in this study, there was, one step should be considered. In this study, the raw DEM obtained from the official website Earth Explores comes in four tiles. There is required to stitch them together before extract the data from only the study area. This is where DEM has been mosaicked. Figure 3.4 shows the step to stitch or mosaic four tiles DEM together.

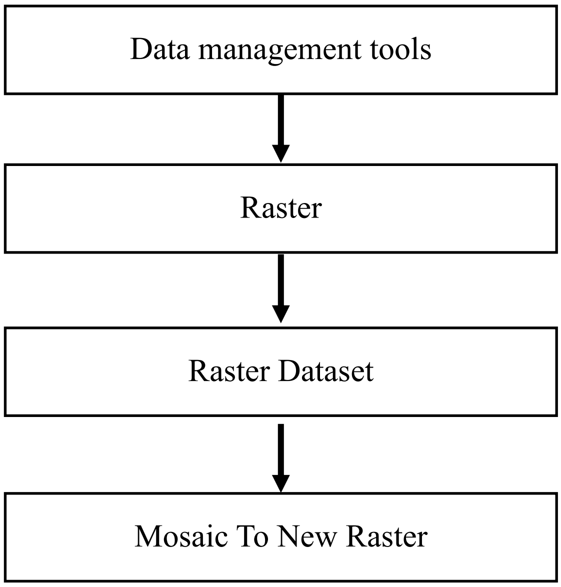

Figure 3.4: Flowchart of mosaic DEM

Once pre-processed, the DEM and its derivatives can be used for efficient watershed delineation and stream network generation. Noted that to perform all the steps in the pre-processing menu in sequential order, from top to bottom without skip by using Hec-GeoHMS extension. Watershed processing will take places after all the step in this pre-processing completed. Figure 3.5 shows the flowchart of pre-processing using Hec-GeoHMS.

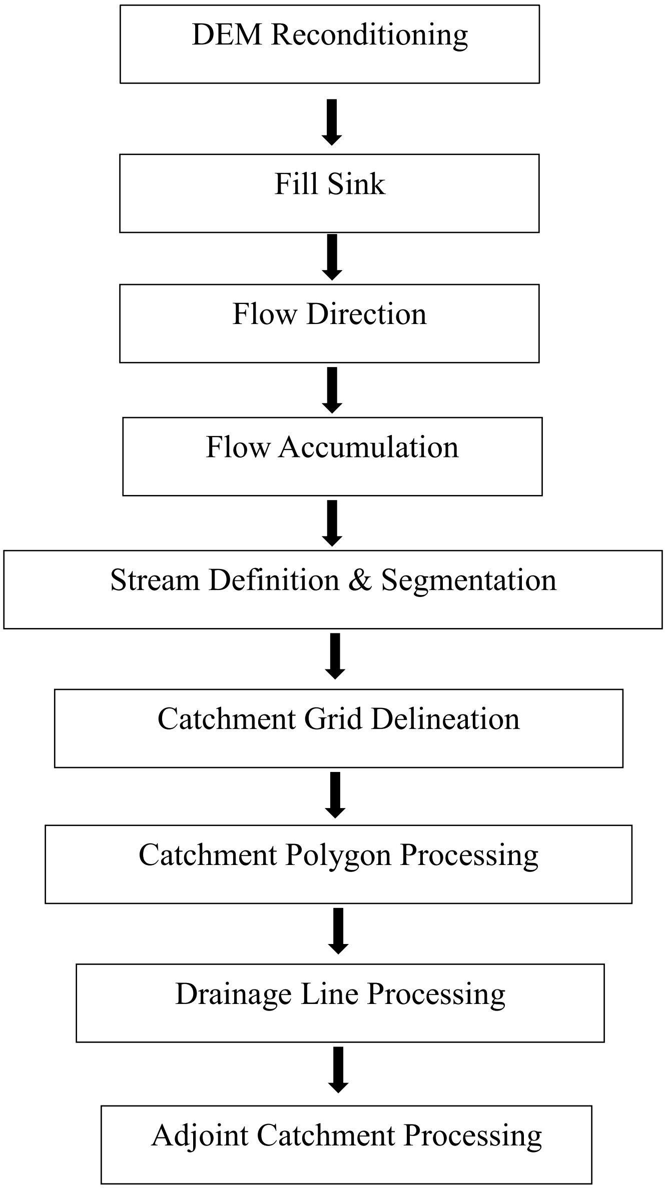

Figure 3.5: Flowchart pre-processing using Hec-GeoHMS.

3.3.1 DEM Reconditioning

DEM reconditioning is a step involves modifying the elevation data to be more reliable with the vector stream. DEM reconditioning might not be required depending on the initial quality of the DEM. This function needs a raw DEM and river network as an input and both have to be presented on the map. Once, in this study, the stream network delineated was not same as the actual path of the river network. Therefore, DEM reconditioning was carried out to force the process of extracting the stream network and drainage line from DEM will follow the actual river network that obtained from Google Earth. By doing this step, it can surge the point of arrangement between stream network delineated from the DEM and the actual river network.

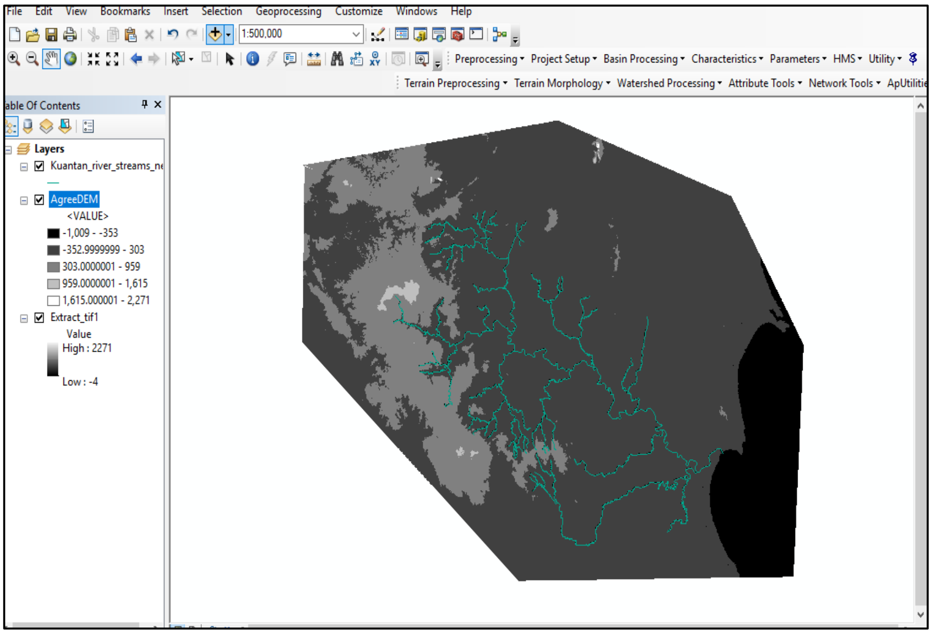

Figure 3.6: Dialog box of reconditioned DEM of Kuantan River Catchment

3.3.2 Fill Sinks

Fill sinks is a function involves filling the sinks in a grid. For instance, if a cell is surrounded with higher elevation cell, the water may be trapped in that cell and cannot flow out. Hence, this function will overcome this problem by modifying the elevation value.

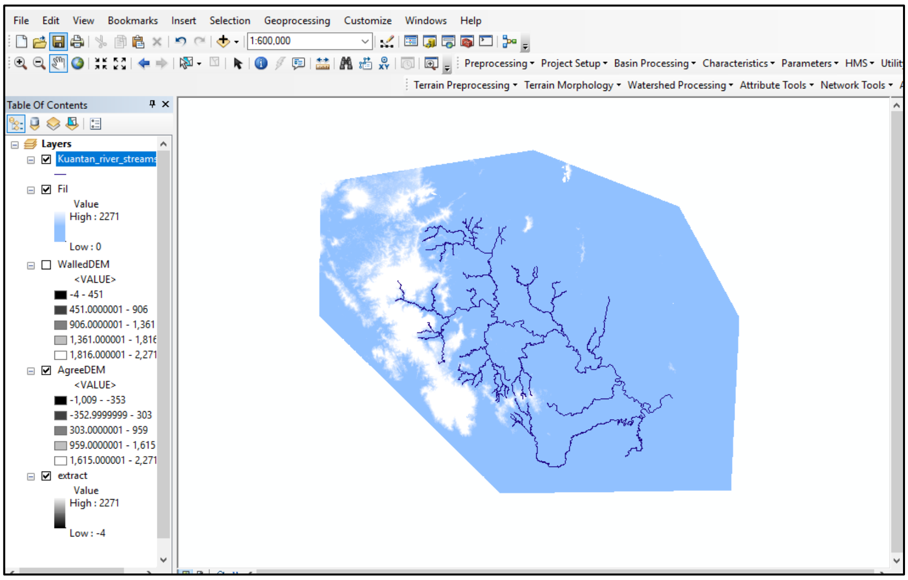

Figure 3.7: Dialog box of fill sinks.

3.3.3 Flow Direction

Flow direction is a function that will calculate the direction for a given grid. The direction of the steepest descent from a cell is known by the values in the cells of the flow direction grid.

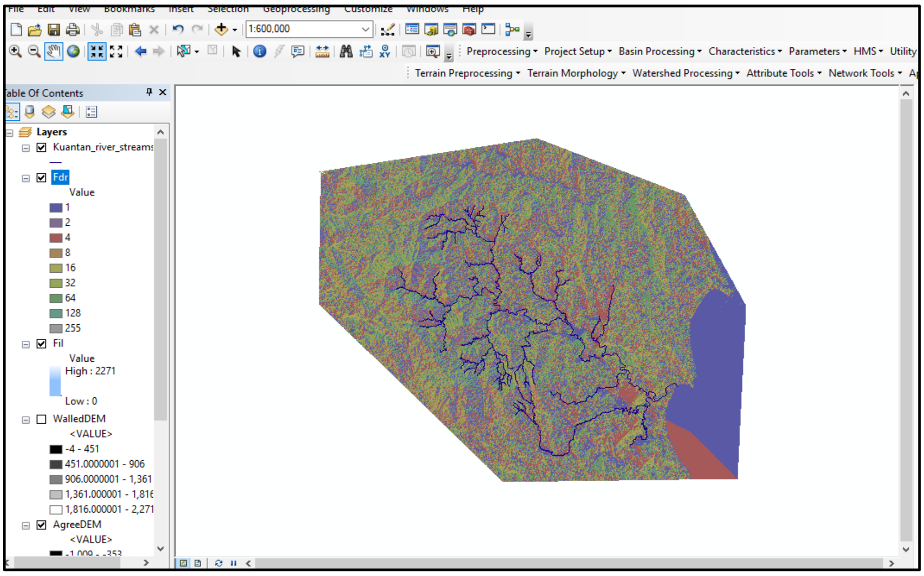

Figure 3.8: Dialog box of flow direction

3.3.4 Flow Accumulation

Flow acculumation is a function that will calculate the flow accumulation grid that consists of an accumulated number of cells upstream for each cell in the input grid.

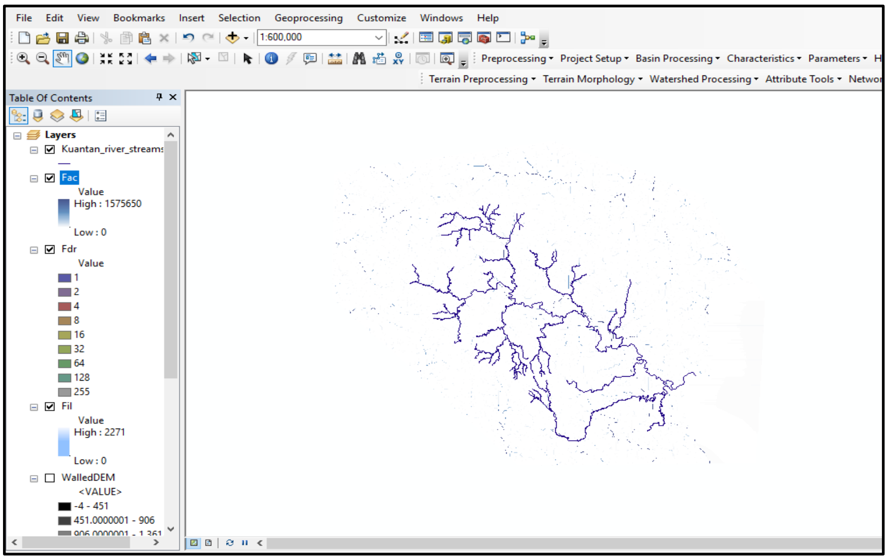

Figure 3.9: Dialog box of flow accumulation

3.3.5 Stream Segmentation and Stream Definition

This function will create a grid of stream segment that has their own unique identification. A segment may be defined as a segment between two junctions or may be a head segment. All the cells in the segment will have the same grid that is detailed to that segment.

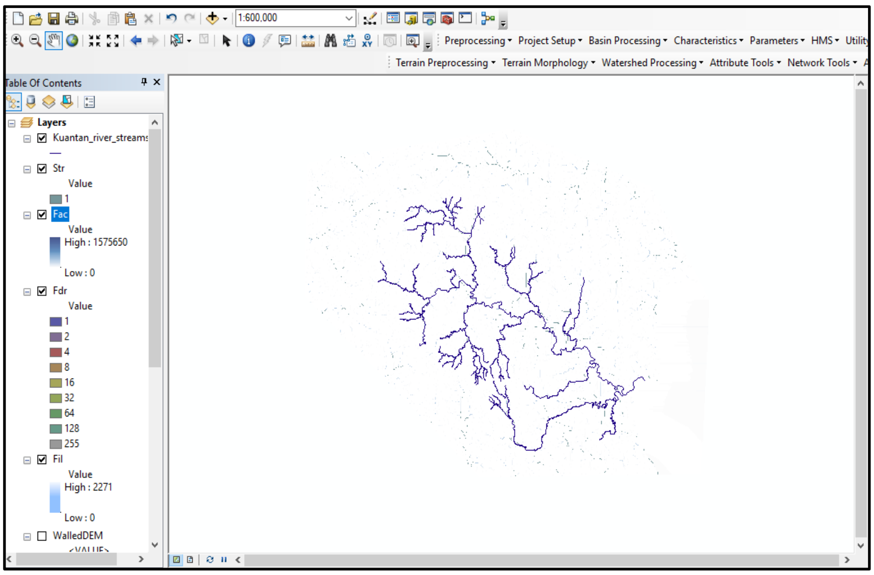

Figure 3.10: Dialog box of stream segmentation and stream definition

3.3.6 Catchment Grid Delineation

Catchment grid delineation is a function that creates a grid in which each cell carries a grid code. This code indicates the exact location for a catchment in each cell. The value for this code also corresponds to the value created by the stream segment grid.

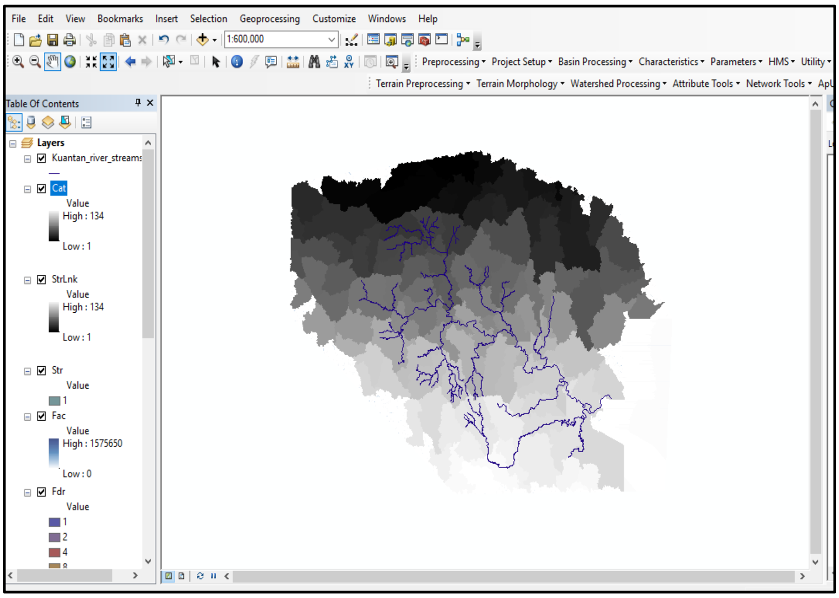

Figure 3.11: Dialog box of catchment grid delineation

3.3.7 Catchment Polygon Processing

Catchment polygon processing is a function that alters a catchment into a catchment polygon feature. It will use grid computed in the previous step to create a vector layer of the subbasin.

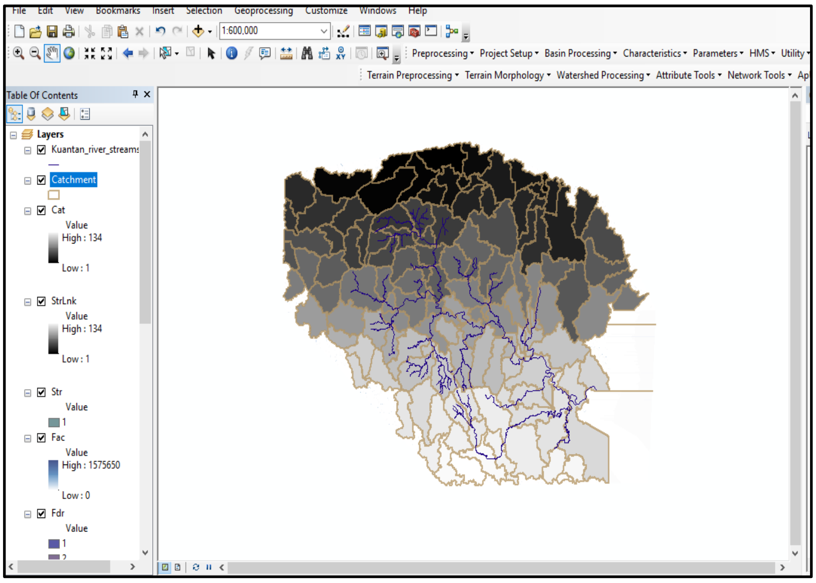

Figure 3.12: Dialog box of catchment polygon processing

3.3.8 Drainage Line Processing

Drainage line processing is a function that will convert the input stream network grid into a drainage line feature class. This drainage line conveys its position in the catchment grid.

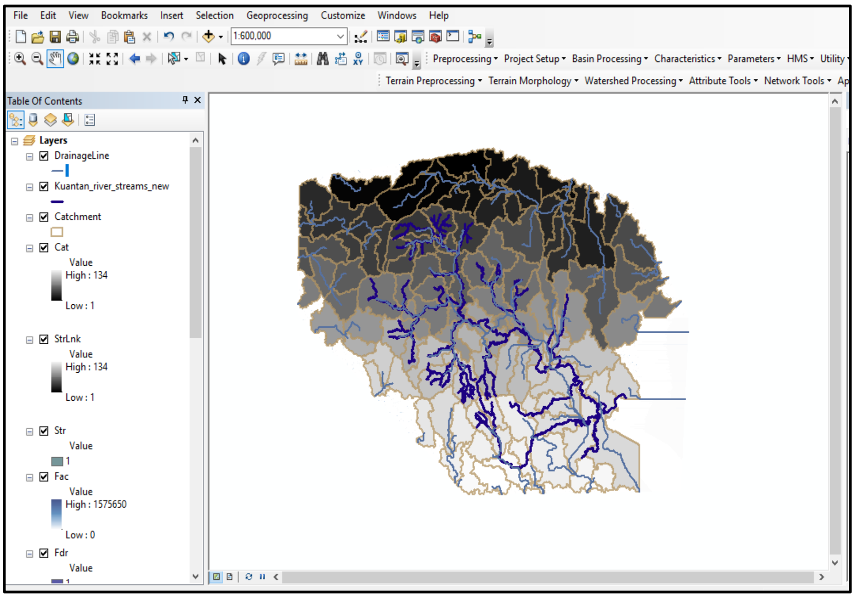

Figure 3.13: Dialog box of drainage line processing.

3.3.9 Adjoint Catchment Processing

This function will generate the aggregated upstream catchments from the previous step. It was performed to enhance the computational performance for delineating subbasin and improve data extraction in the next watershed processing.

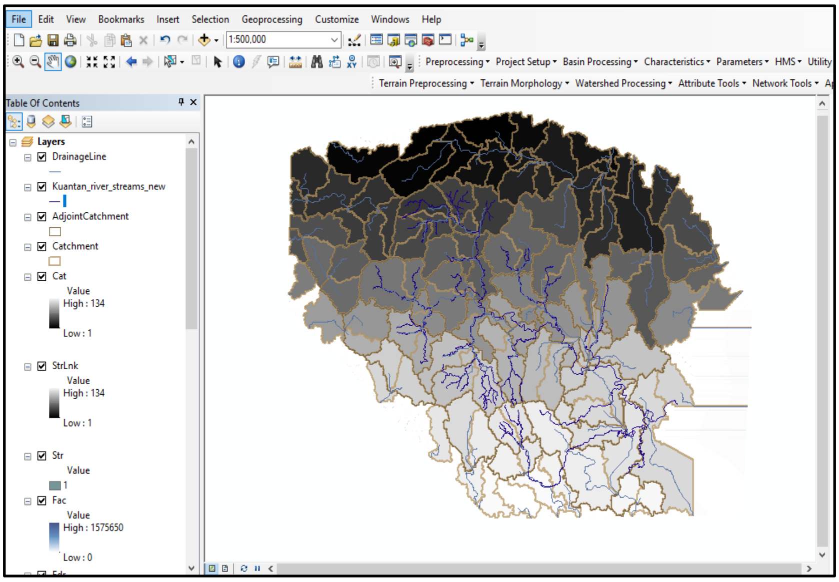

Figure 3.14: Dialog box of adjoint catchment processing

3.4 Processing

This step will use Hec-GeoHMS extension to parametrize the catchment. HEC-GeoHMS is a tool that helps the user to extract all necessary data to create the HEC-HMS project. To start the extraction process, the user must specify the location of the outlet of the river. HEC-GeoHMS will then use the previous pre-processing dataset for the specified drainage area upstream outlet to run the flow analysis. The summarization of the whole process using Hec-GeoHMS is presented in Figure 3.15.

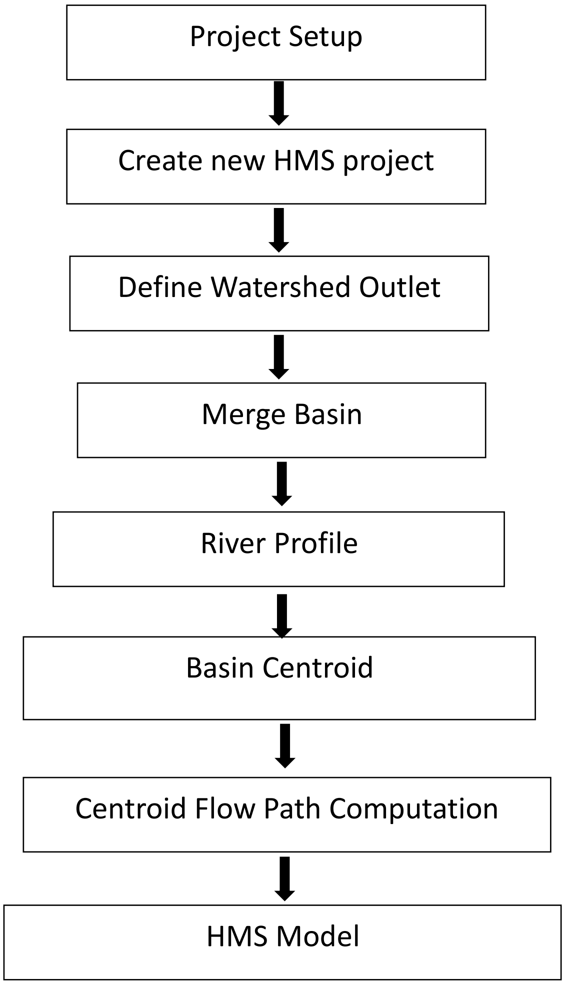

Figure 3.15: Flowchart of watershed processing.

3.4.1 Project setup

Project setup is responsible for extracting data that will be used to develop the necessary information to create an HEC-HMS project. The approach for extraction comprises identifying a control point at the downstream outlet. This location symbolizes the downstream boundary for the HEC-HMS project. After defining the downstream outlet, HEC-GeoHMS will extract data from the datasets generated using the previous pre-processing step for the drainage area upstream of the outlet.

3.4.2 Create new HMS project

A new data frame will be created and the name will be set to the new project name. For this study, I named it Kuantan_RiverBasin. The data of the project from previous pre-processing will be extracted and imported into the new data frame created.

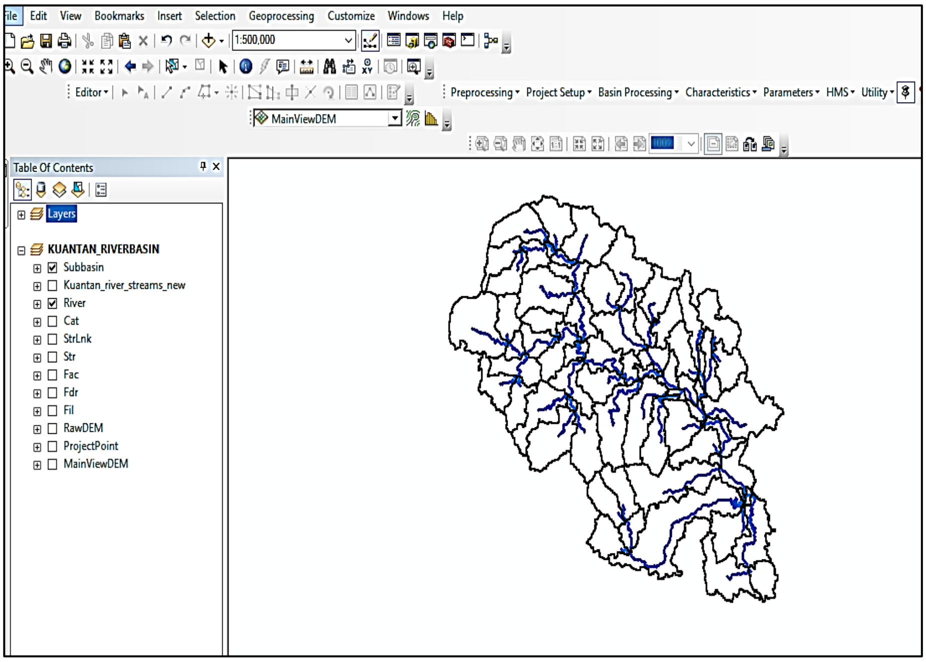

Figure 3.16: Dialog box of generated HMS project for Kuantan River catchment

3.4.3 Define watershed outlet

Before a new project created, the outlet of the projected area must be defined first. Zoom in and select the outlet point. In this step, the data management editor will open to let the user confirm the right data sets correspond to the required project layers. After checking the data, click the OK button. The map will automatically zoom to the area upstream of the outlet point and the drainage area will be shaded.

3.4.4 Merge basin

This function will merge multiple subbasins together into one subbasin. In this process, I managed to merge about 189 subbasins into 58 subbasins for Kuantan River Catchment. Noted that the merged basin must be adjacent in an upstream and downstream way.

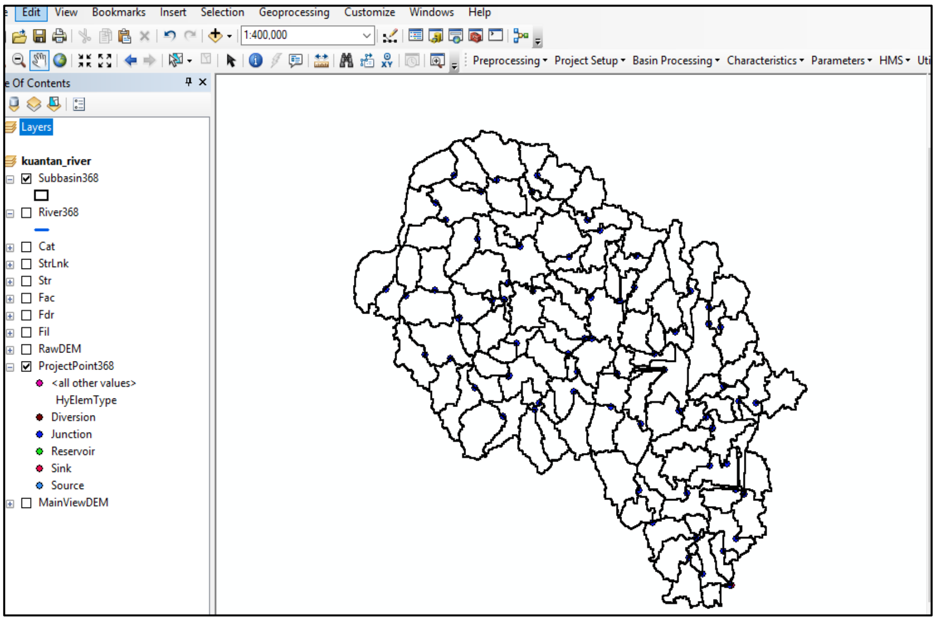

Figure 3.17: Dialog Box of Subbasin before be merged.

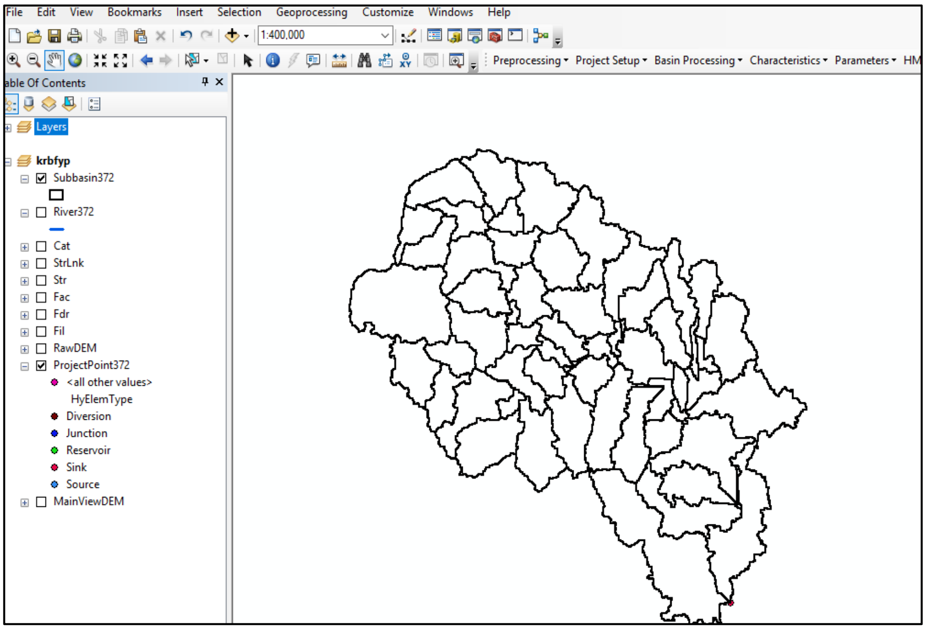

Figure 3.18: Dialog box of subbasin after merged.

3.4.5 River Profile

River profile is a function that gives information on slopes and grade breaks that can be valuable for choosing delineating points. By extracting values from the terrain model along the streamline, then the river profile created.

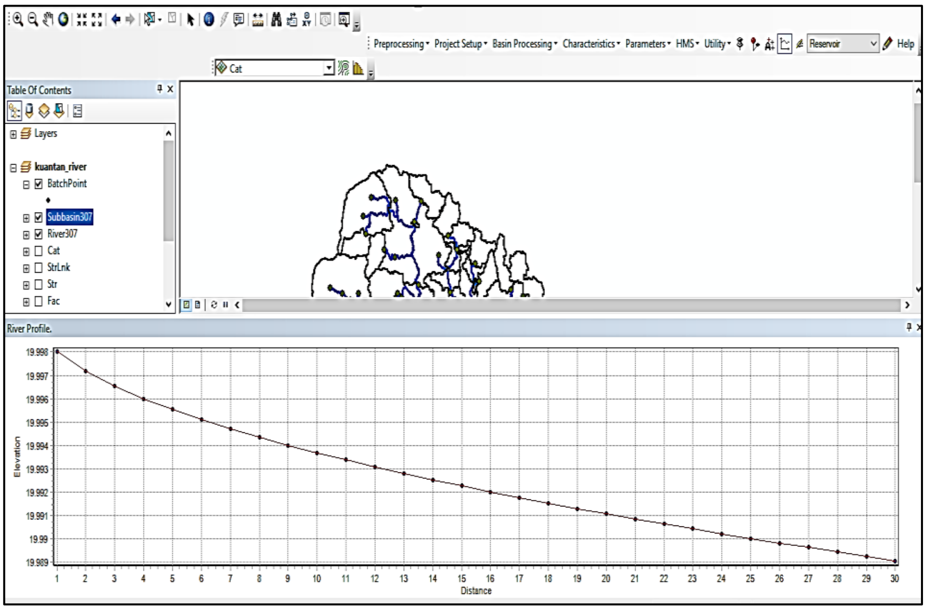

Figure 3.19: Dialog box of river profile of Kuantan River.

3.4.6 Basin Centroid

The basin centroid will involve in identifying the centroid of each subbasin. The function will work on the nominated set of subbasins. The quality of the result is a function of the shape of the subbasins and should be assessed after they generated.

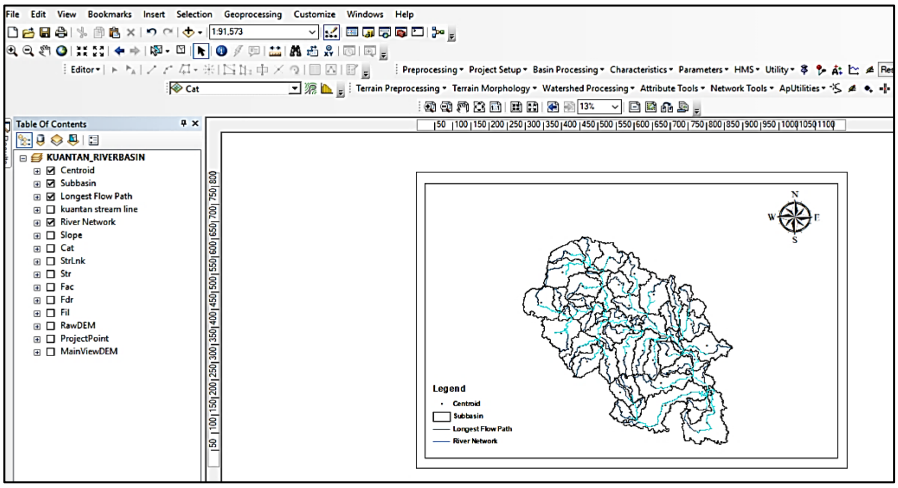

Figure 3.20: Dialog box of basin centroid of Kuantan River catchment

3.4.7 Centroid Flow Path

This operation calculates the centroidal longest flow path by projecting the centroid onto the longest flow path. The centroidal longest flow path is restrained from the projected point on the longest flow path to the subbasin outlet.

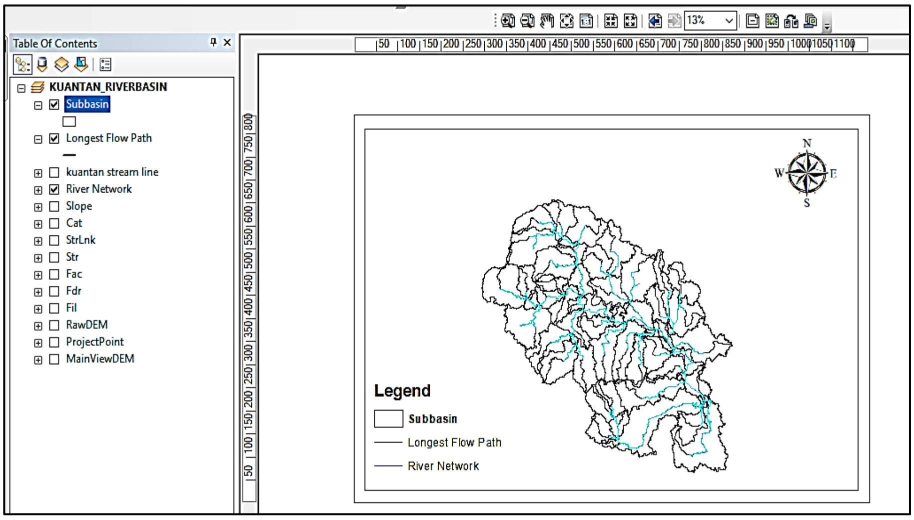

Figure 3.21: Dialog box of Centroid flow path for Kuantan River catchment

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the result on the implementation of the study. By referring to the objectives, the main purpose of this study is to delineate and parameterize the Kuantan River Catchment using GIS techniques. This chapter will be analyze the data collected during the study.

4.2 Discussion

Kuantan River Catchment was delineated visually in this by referring to the elevation from Digital Elevation Model (DEM). The processing of DEM to delineate the catchment also known as terrain pre-processing performed using ArcHydro tools extension in GIS application is to increase the efficiency of that data. In a hydrographical analysis, efficiency means primarily minimizing the expense of acquiring data and time required for completing the analysis. This pre-processing will generate the hydrologic information such as stream network, subbasin, drainage surfaces along with the hydrologic parameters such as the river length, river slope, subbasin area in the catchment.

The delineation of the Kuantan river catchment resulted in 58 subbasins and 21 rivers in total. The main river is Kuantan River and it flows from the upstream of the catchment before be discharged to the South China Sea. In term of the river position in this catchment, major of the rivers are located at midstream of the catchment, several rivers at the upstream and minor rivers at downstream. The Table 4.1 and Figure 4.1 below showed the information that has been analyzed.

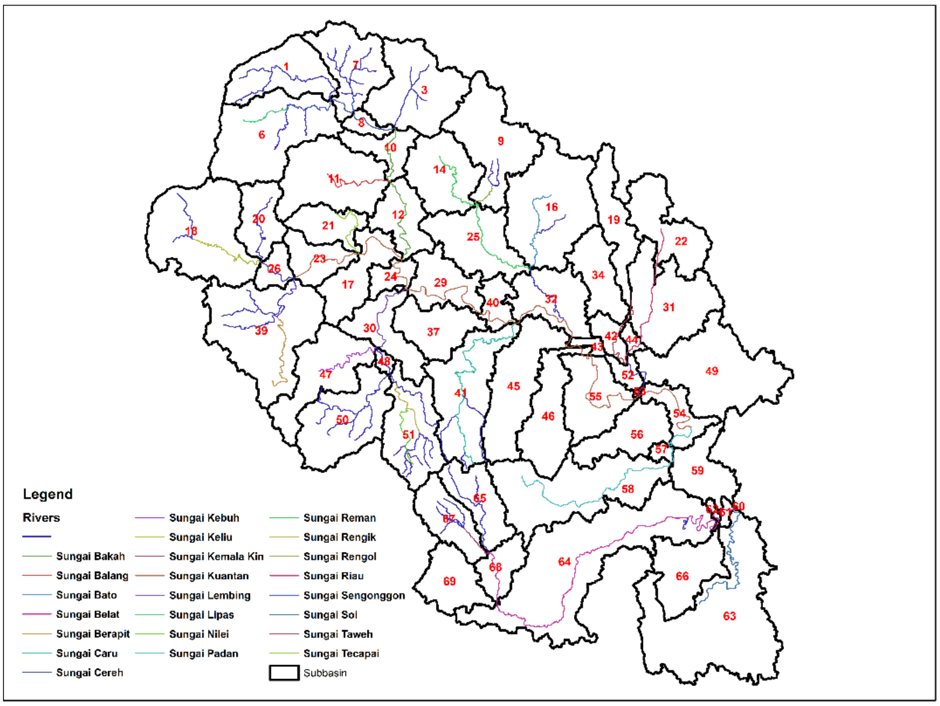

Figure 4.1: Subbasins and river networks in Kuantan River Catchment.

Table 4.1: Result of river network in Kuantan River catchment.

No	River	Discharge to	Position
1	Kuantan River	South China Sea	Main River
2	Belat River	Kuantan River	Downstream
3	Kemala Kin River	Belat River	Downstream
4	Pandan River	Kuantan River	Downstream
5	Soi River	Kuantan River	Downstream
6	Bato River	Kuantan River	Midstream
7	Caru River	Kuantan River	Midstream
8	Kebuh River	Lembing River	Midstream
9	Lembing River	Kuantan River	Midstream
10	Reman River	Kuantan River	Midstream
11	Rengik River	Lembing River	Midstream
12	Rengol River	Reman River	Midstream
13	Riau River	Kuantan River	Midstream
14	Taweh River	Kuantan River	Midstream
15	Cereh River	Bakah River	Upstream
16	Bakah River	Kuantan River	Upstream
17	Balang River	Bakah River	Upstream
18	Berapit River	Kuantan River	Upstream
19	Keliu River	Kuantan River	Upstream
20	Segonggon River	Cereh River	Upstream
21	Tercapai River	Kuantan River	Upstream

Table 4.2 shows the characteristic of Kuantan River delineated catchment using the same technique. The total of subbasin in this catchment is 58. The object ID in the first column of the table indicates rows in the table in a geodatabase and it automatically generated during the watershed processing. It used by GIS to display of selected subbasin and perform identify operation on it. The second column is basin area that measured in metre square in range of 0.19 to 112.50 m^2. The third column shows basin slope of each delineated subbasin in range of 0.09 to 1.01 and the last column is the river network that located in each delineated subbasin.

Table 4.2: Catchment characteristic of Kuantan River.

No.	Object ID	Basin Area (m^2)	Basin Slope	River Network
1	1	37.91	0.34	Cereh River
2	3	44.47	0.40	Bakah River
3	10	49.48	0.44	Bakah River
4	12	39.95	0.36	Bakah River
5	11	15.52	0.14	Balang River
6	16	57.89	0.52	Bato River
7	61	30.86	0.28	Belat River
8	62	46.76	0.42	Belat River
9	64	33.89	0.30	Belat River
10	66	36.74	0.33	Belat River
11	68	55.11	0.50	Belat River
12	69	43.54	0.39	Belat River
13	39	49.48	0.44	Berapit River
14	41	46.26	0.42	Caru River
15	6	28.26	0.25	Cereh River
16	8	30.68	0.28	Cereh River
17	47	53.50	0.48	Kebuh River
18	18	27.40	0.25	Keliu River
19	20	21.52	0.19	Keliu River
20	26	47.07	0.42	Keliu River
21	65	17.94	0.16	Kemala Kin River
22	67	41.81	0.38	Kemala Kin River
23	17	40.94	0.37	Kuantan River
24	23	54.80	0.49	Kuantan River
25	24	48.30	0.43	Kuantan River
26	29	37.91	0.34	Kuantan River
27	32	37.36	0.34	Kuantan River
28	37	59.68	0.54	Kuantan River
29	40	26.41	0.24	Kuantan River

30	43	56.65	0.51	Kuantan River
31	45	21.34	0.19	Kuantan River
32	46	10.64	0.10	Kuantan River
33	53	13.30	0.12	Kuantan River
34	55	59.50	0.53	Kuantan River
35	56	49.79	0.45	Kuantan River
36	59	51.77	0.47	Kuantan River
37	54	9.71	0.09	Kuantan River
38	30	66.42	0.60	Lembing River
39	48	47.13	0.42	Lembing River
40	50	43.66	0.39	Lembing River
41	57	16.70	0.15	Padan River
42	58	3.90	0.04	Padan River
43	14	36.12	0.32	Reman River
44	25	38.28	0.34	Reman River
45	51	41.68	0.37	Rengik River
46	9	11.26	0.10	Rengol River
47	22	77.80	0.70	Riau River
48	31	38.72	0.35	Riau River
49	44	0.19	0.00	Riau River
50	7	10.27	0.09	Segonggon River
51	60	9.71	0.09	Soi River
52	63	99.57	0.89	Soi River
53	19	112.50	1.01	Taweh River
54	34	35.31	0.32	Taweh River
55	42	42.74	0.38	Taweh River
46	49	31.42	0.28	Taweh River
57	52	25.79	0.23	Taweh River
58	21	33.71	0.30	Tercapai River

Besides, the extraction of hydrologic information such as river length, river slope, basin area, basin slope, longest flow path, basin centroid, and centroidal longest flow path from a DEM was accomplished through GIS application. The generation of the hydrology parameters of the watershed was carried using Hec-GeoHMS extension and to be used in the rainfall-runoff modeling. Figure 4.2 below showed the parameter of Kuantan River Catchment and Table 4.2 showed the description of the parameters extracted from this catchment delineation and its application.

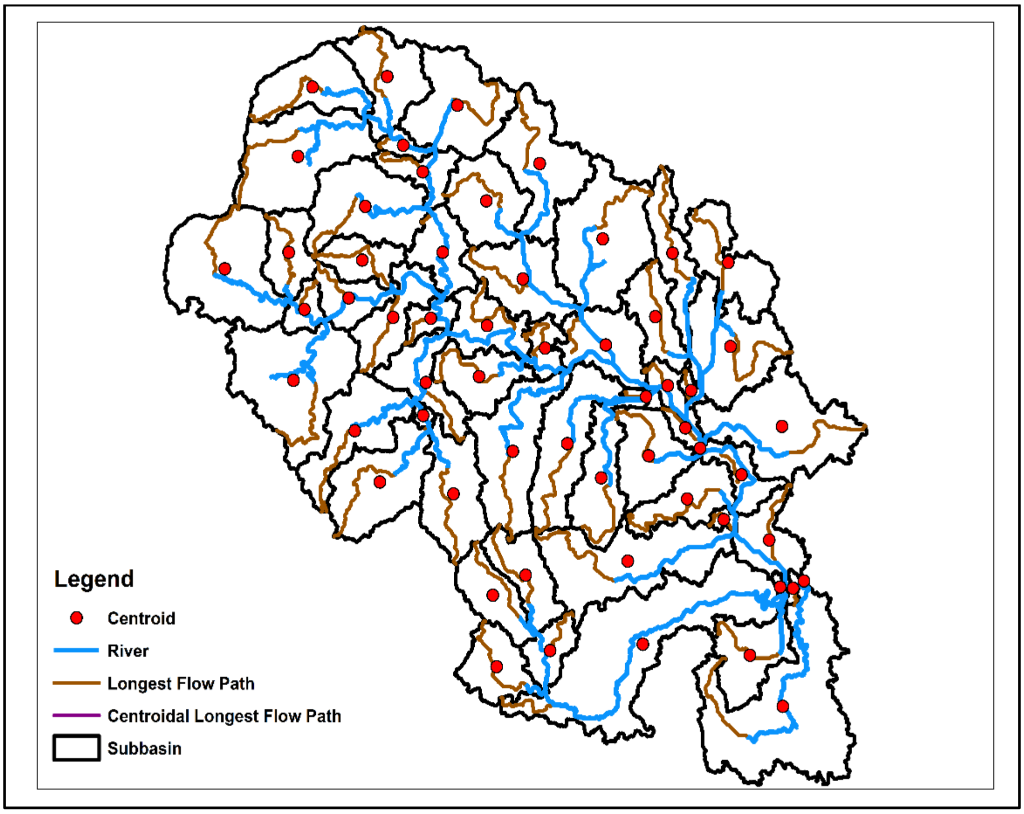

Figure 4.2: Parameters of Kuantan River catchment.

Table 4.3: Catchment parameters and its application.

Parameters	Description	Application
River Length	The channel length is measured along the mainstream from the basin outlet to its source.	Rainfall-runoff modeling
River Slope	The difference in elevation measured along the main river between the outlet and the upper end of the main river divided by the river length.	
Basin Area	The total area of land that collects precipitation and drains it off to a common outlet.	
Basin Slope	The difference in elevation measured along the basin divided by basin length.	
Longest Flow Path	The longest distance that water will travel from any point in the basin to the watershed outlet.	
Basin Centroid	The centroid of basin.	
Centroidal Longest Flow Path	The longest distance that water will travel from centroid of the basin to the watershed outlet.	

CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter presented the conclusions that have been drawn based on the results and some recommendations for future studies. Generally, the research is successfully finished which the result of this research based on the characteristics of the Kuantan River catchment was determined.

5.2 Conclusion

For the overview, the objectives of the study have been achieved throughout the literature review and research. The main point of this study is to delineate and parameterize the catchment area of Kuantan River, Pahang. By carrying out preprocessing of terrain, the accuracy of the DEM data could be improved. Hence, delineation and parameterization of Kuantan River catchment using GIS can be done accurately.The visualize model produced will allow for exchanges, organize, store, manage, and retrieve the information for decision support to urban development management in Kuantan. The GIS model as a tool replaces the manual method to keep all the records regarding observed the rating. Meanwhile, the GIS technique is eased the work process significantly compared with the manual method.

Besides, GIS is a software mutual with a database permits the manipulation, analysis, and production or plotting of data with geospatial locations. The database is a significant part of the system. ASTERDEM is reliable elevation data for the study of the large catchment area. Hence, the GIS can handle the elements needed for urban growth and development in Kuantan region.

In other words, the usage of GIS has improved the wisdom of the decision-making process by enlightening data accuracy and accessibility of satellite data and this subsequently leads better resolution. It will be helpful in providing catchment information for related local authority for managing water resources in planning for future development. Hence, this study will act as a preliminary study of proposing the use of characteristics catchment in local urban planning. As a recommendation for future studies, rainfall-runoff modeling can be developed using the output of this study.

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