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B. ENG. (HONS) CIVIL ENGINEERING

MAY 2013

ASSESSMENT OF MOUNTAIN RANGE EFFECTS IN PENINSULAR MALAYSIA TOWARDS CATCHMENT AND RAINFALL PRECIPITATION USING GIS SPATIAL ANALYSIS

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MAY 2013

Assessment of Mountain Range Effects in Peninsular Malaysia towards Catchment and Rainfall Precipitation Using GIS Spatial Analysis

by

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Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Civil Engineering)

MAY 2013

Universiti Teknologi PETRONAS

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CERTIFICATION OF APPROVAL

Assessment of Mountain Range Effects in Peninsular Malaysia towards Catchment and Rainfall Precipitation Using GIS Spatial Analysis

by

Zul Aiman bin Zulkifli

A project dissertation submitted to the

Civil Engineering Programme

Universiti Teknologi PETRONAS

In partial fulfilment of the requirement for the

BACHELOR OF ENGINEERING (Hons)

(CIVIL ENGINEERING)

Approved by,

____

(AP Dr. Abd Nasir Matori)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ZUL AIMAN BIN ZULKIFLI

ABSTRACT

Water management such as water resource management, flood management, storm water management and river management are a crucial aspect that needs a special attention by the authority. One of the factors that can influence the mentioned aspect is the mountain. It is known that the study of mountains effects towards catchment and rainfall precipitation is very small in Malaysia. The reason might be due to the lack of data and difficult terrain of the mountains. Therefore, using ArcGIS Spatial Analyst Tools, a study is done revealing the mountains effects enough to see the importance of mountains in water management.

ACKNOWLEDGEMENT

Alhamdulillah, praise to Allah The Almighty for granting the author opportunity, health and ability to complete this Final Year Project on "Assessment of Mountain Range Effects in Peninsular Malaysia towards Catchment and Rainfall Precipitation Using GIS Spatial Analysis". This project is a partial fulfilment of the requirement for the Bachelor of Engineering (Hons.) in Civil Engineering for Final Year Final Semester.

First of all, the author would like to express his highest appreciation to Dr. Abd Nasir Bin Matori for his supervision throughout the completion of the project. Difficulties and critical situations faced during the implementation of this project were successfully overcome thanks to his support and commitment.

The author would also like to take this opportunity to thank the staff of Dr. Nik & Associates Sdn. Bhd. for the knowledge that the author gained during the internship period. It was indeed very useful in completing and facilitating the work flow of the project.

Many thank to Dr. Teo Wee as the coordinator of FYP I and Ir. Idris Bin Othman as the coordinator of FYP II in making sure the smooth flow of the entire period of the project.

Not to forget Jabatan Ukuran dan Pemetaan (JUPEM) for providing the digital map, Jabatan Pengairan dan Saliran (JPS) for the rainfall data and National Satellite Meteorological Center (NSMC) from China Meteorological Administration (CMA) for providing the free satellite image for this study. Thank you all for your support.

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Peninsular Malaysia contains numerous mountain ranges running parallel from north to south along the peninsula. The main mountain range in peninsular Malaysia is the Titiwangsa Mountains Range which divides the peninsula between its east and west coasts. The highest peak of Titiwangsa mountain range is Mount Korbu located near the Perak state borderline. Below is the table and figure showing significant mountains in peninsular Malaysia.

Mountain	State	Elevation (m)	Latitude (N)	Longitude (E)
Mount Tahan	Pahang	2187	4°38'	102°14'
Mount Korbu	Perak	2183	4°41'	101°18'
Mount Yong Belar	Perak	2181	4°44'	101°20'
Mount Gayang	Perak	2173	4°46'	101°22'
Mount Chamah	Penang-Kelantan	2171	5°08'	101°20'
Mount Benum	Pahang	2107	3°50'	102°06'

Table 1.1: Summary of significant mountain in Peninsular Malaysia

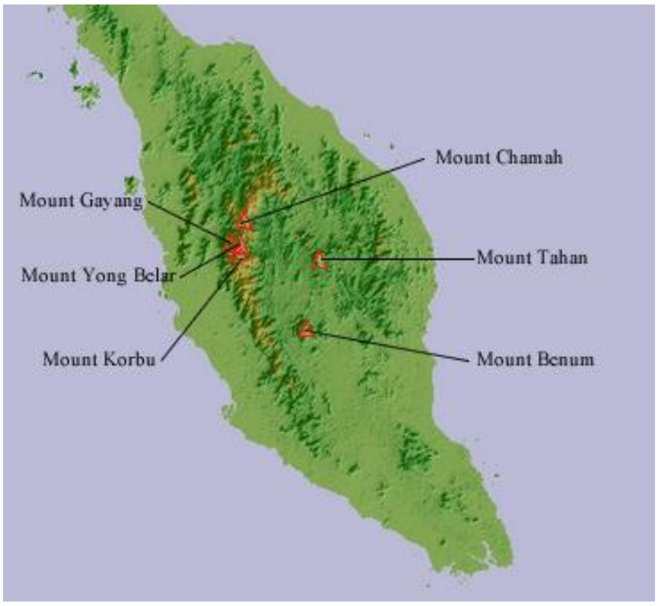


Figure 1.1: Global Digital Elevation Map (GDEM) showing the mountain ranges in peninsular Malaysia

At global scale, mountains' greatest value may be as sources of all the world's major rivers, and many smaller ones (Mountain Agenda, 1998). In country that is having a wet and dry season; mountain plays a role in providing water to the catchment through orographic precipitation which should not be underestimated according to Andrew, Amy & Silvia (2007). Through mountain’s elevation, it affects the water catchment and rainfall precipitation around it serving a significant role in the water management such as water resource management, flood management, storm water management and river management.

As of March 2011, Malaysians statistically use an average of 226 litres of water per person daily. According to Choong (2011) where based on a study, 70% of Malaysians use more water than their necessity as said by the Minister of Energy, Green Technology and Water, Dato’ Sri Peter Chin Fah Kui. This can be deduced that the demand for water is always there making water resource management to be very crucial.

In February 2012, it was reported that around 2000 hectares of forest area at Bekok Dam was encroached exposing about 500,000 people that use the water supply from the area to health threats resulting from the chemical pesticides and fertilisers that seep into the soil (Hammim, 2012). Thus the enforcement of gazette water catchment areas (part of water management) is very important to be implemented strictly by the state governments to avoid damaging activities at the upstream of the water catchment areas as stated by Mohamed Idris (2012) the president of Sahabat Alam Malaysia (SAM) to the media.

This paper studies the effects of mountain range towards the catchment and rainfall precipitation using the GIS tools hoping to understand on how the mountain range in peninsular Malaysia namely Titiwangsa Mountain Range influenced the water catchment and rainfall. This is because once we understand how the mountains play an important role in water management, we can later use this knowledge for its betterment. Nevertheless this paper focuses on the use of GIS application as to show on how it can efficiently help on the study.

1.2 Problem Statement

Water management starts with the distinct water catchment boundary for an efficient planning and development for a particular area. Conventionally, watershed boundary or delineation was done manually using topographic maps. It is prone to error, tedious, and subject to individual judgement which is not efficient as stated by Abdallah *et al.* (2006). Other than that, rainfall analysis using isohyet is also not efficient when using the conventional method such as Thiessen, Arithmetic Mean and Isohyetal method which requires long and tedious calculation for the creation of isohyet. Therefore, automated watershed boundary delineation and isohyet creation is used to replace the conventional method using computer-aided method such as using GIS technology which has the potential to overcome many conventional analysis problems (Oliver, David & Ian, 1997).

1.3 Objectives

The objectives of this paper are identified as follows:

i. To use GIS spatial analysis tool to assess the effect of peninsular Malaysia mountain range on the catchment area and precipitation.
ii. To assess the orographic precipitation in peninsular Malaysia mountain range.

1.4 Study Area

The study area chosen for this paper is the Cameron Highland and Hulu Langat area. Both of the areas are located near and within the peninsular mountain range. Cameron Highland study area highest point is 2123.86 meter while Hulu Langat is 1477.26 meter. Both areas are satisfactory for the study as their difference in height is adequate enough to achieve both of the objectives of the paper.

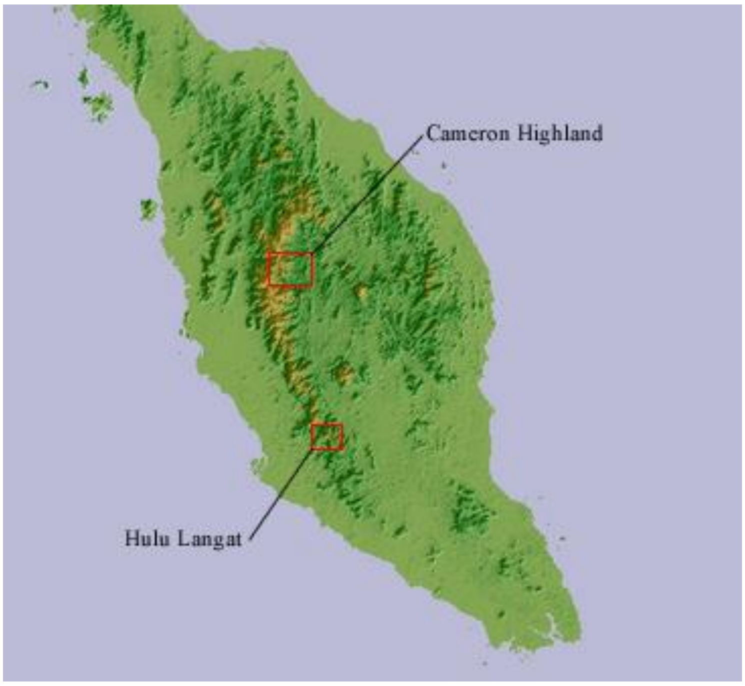


Figure 1.2: Study area which is located within the peninsular mountain range

1.5 Scope of Study

The study is delimited to see the effects of mountain range in peninsular Malaysia towards the catchment area and the rainfall precipitation using GIS spatial analysis. It is assumes for watershed delineation that the catchment area is solely depends on the contour not considering the whole topography of the land (eg. man-made structure like building). The isohyets study is based on the cumulative rainfall data for five months based on the typical northeast monsoon and southwest monsoon in Malaysia. Judgement made for the isohyets are based on the effect of the land elevation only not discussing into detail other rainfall causes like the tropical depression and typhoon. The wind is also assumes to always blow according to the monsoon direction to make the judgement a lot easier.

The whole process is designed to be completed in two semesters (two phases). The scope of study for the first phase is to do research as well as gathering the required data of the study area. Besides, the goal for the first phase is to get use with the software and relating theoretical knowledge as well as the practical in doing the project. The second phase which is the implementation part include the process in obtaining the watershed delineation and the isohyets for the study area as the output of the project.

CHAPTER 2

LITERATURE REVIEW

Several studies related to this paper are reviewed for further understanding on the project. Relevant concepts and methods are explained briefly in this chapter for the purpose of supporting this paper objectives and methodology.

2.1 Orographic Precipitation (Minder & Roe, 2009)

This paper explains about the fundamentals, science and observation of orographic precipitation. It is very important concepts that must be understand first before proceeding with the study.

As stated by Roe (2009), orographic precipitation is a precipitation that has been generated or modified by topography, typically through the forcing of vertical atmospheric motions. The influence of mountains upon rain and snowfall is often profound, creating some of the Earth's wettest places like Cherrapunji in India, where monsoon flow encounters the southern Himalayas receiving 26.5 metres of rain in one year and driest places like the central valleys of the Atacama Desert, shielded by surrounding mountains whose can go for decades without rainfall. Orographic effects on precipitation are also responsible for some of the planet's sharpest climatic transitions. The classic example is the 'rain shadow'; for a mountain range oriented perpendicular to the prevailing winds, precipitation is greatly enhanced on the windward side and suppressed in the lee.

Orographic precipitation is shaped by countless number of non-linear processes operating on scales ranging from the 1000 km size of storms and major mountains to the sub-micron size of cloud droplets. Still, the most fundamental of these processes are thermodynamic in nature and are well understood. Almost all orographic influences on precipitation occur due to rising and descending atmospheric motions forced by topography. These motions can be forced mechanically, as air impinging on a mountain is lifted over it, or thermally, as heated mountain slopes trigger buoyancy-driven circulations. Rising motion causes the air to expand and cool, which is important since the amount of water that may exist as vapour in air is an approximately exponential function of temperature (described by the Clausius

Clayperon equation). Thus if cooling is sufficient, air saturates and the water vapour condenses into cloud droplets or forms cloud ice crystals. These droplets and crystals grow by various processes until they become large enough to fall as rain and snow. It is important to emphasize that moist ascent over topography alone is typically insufficient to generate precipitation: these orographic effects mainly modify precipitation during pre-existing storms (e.g. Browning et al., 1974; Smith, 2006). Conversely, when air descends it warms and dries, and both cloud and precipitation evaporate.

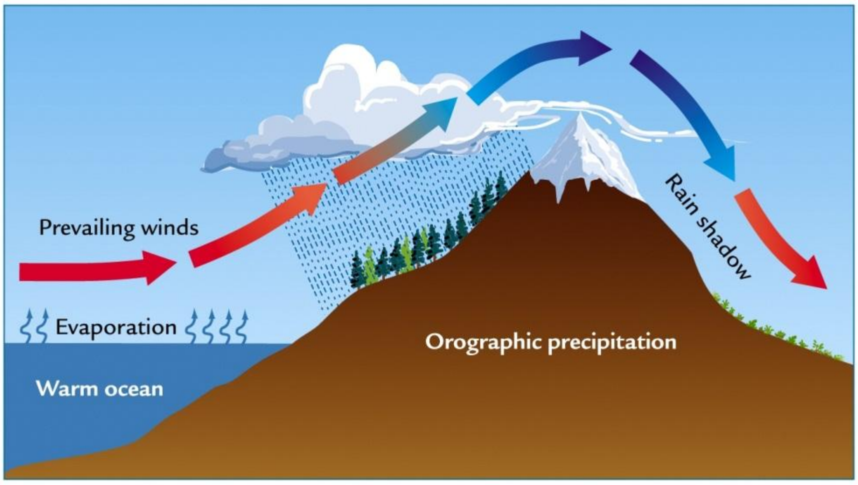


Figure 2.1: Orographic precipitation explained

Orographic precipitation processes strongly shape the climate in and around mountainous regions. Orographic influences can be pronounced on spatial scales ranging from the size of individual hills to the scale of major mountain ranges, and on temporal scales from the duration of a brief snow squall to the long-term climatology. Almost all orographic influences are fundamentally caused by topographically driven ascending and descending atmospheric motions that force condensation and evaporation. However, these basic forces combine with a wide range of dynamical and microphysical processes to shape the precipitation distribution. Since different physical processes can be important for different storms and for different mountain ranges, orographic precipitation influences may take many forms.

2.2 DEM Pre-Processing for Efficient Watershed Delineation (Dean & Zichuan, 2000)

This study presents the methodology for DEM pre-processing that provides the basis for fast (sub-minute) and consistent watershed delineation on DEMs of any resolution and size using desktop GIS technology. This methodology is referred to as Fast Watershed Delineation method (FWD). It has been initially developed in 1997 (Djokic et al., 1997) as part of the watershed delineation project developed for the Texas Natural Resource Conservation Commission.

The FWD methodology is based on the following key factors:

1. The derived terrain properties (flow direction, flow accumulation, etc.) do not change unless the DEM changes, and are not a function of watershed delineation for any particular point, but rather of the DEM itself and thus do not have to (and should not) be linked to the individual watershed delineation operation.
2. The time needed to delineate a watershed is a function of the grid (DEM) size – the more cells in a grid, the longer will be the processing time, and vice versa.
3. The key property of a watershed boundary is that it completely and uniquely defines the area from which the (surface) water drains to the watershed outlet. Any point outside of that area does not contribute to the flow at the outlet point, and thus is not of direct interest for problems related to that watershed.

In this study, the method to obtain watershed delineation and its sub-watershed is listed. The steps are (described in more detail in Esri, 1997 and Olivera & Maidment, 1999):

1. Determine flow direction grid (DEM derived property).
2. Determine flow accumulation grid (DEM derived property).
3. Specify a "stream" threshold on the flow accumulation grid. This operation will identify all the cells in the flow accumulation grid that are greater than the provided threshold. A new grid is formed from those cells ("stream" grid). This grid will be an indication of the drainage network. It is important to note that the threshold value in this process does not have any particular geomorphologic meaning through which we are trying to identify the "real" drainage network, but is rather used as a means for watershed partitioning.

Higher thresholds will result in less dense network and less internal subwatersheds, while lower thresholds will result in dense network and more internal subwatersheds. The choice of threshold value and its impact on the delineation performance will be discussed later.

4. Stream grid is converted into stream segments, where each head segment and segment between the junctions has a unique identifier.
5. Subwatersheds (in grid format) are defined for each of the stream links in the stream link grid.
6. Subwatershed and stream grids are vectorized to produce subwatershed and stream polygon and polyline themes respectively. Additional vector processing might be needed to clean-up the data and insure correct connectivity and directionality.

An overview of the process is presented in Figure 2.2:

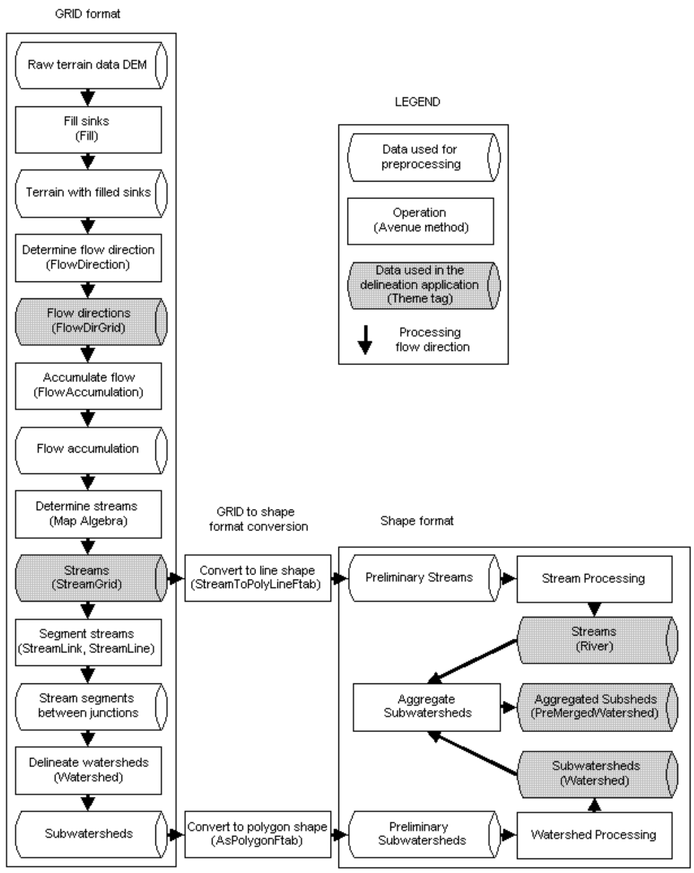


Figure 2.2: Processing flow for initial, arbitrary sub-watershed delineation (from Esri, 1997)

The FWD methodology described in this paper allows efficient and consistent watershed delineation on DEMs of any size. The speed of delineation can be controlled by the user during the pre-processing stages, and can be in the order of five to ten seconds per watershed on most of today's desktop systems, allowing for a truly interactive operation. The required pre-processing needs to be done only once for a given DEM and can be done at a different location from the one where the actual delineation work will be performed. This allows pre-processing of regional datasets that are then distributed to the end users who can immediately apply to delineation tools on that dataset. The same method of FWD will be adopted in this project for watershed delineation.

2.3 The Impact of the Typhoon to Peninsular Malaysia on Orographic Effects (Fuyi, Hwee & Khiruddin, 2011)

The objective of this paper is to see the orographic effects in peninsular Malaysia due to the typhoon. The study area is the mountain ranges in peninsular Malaysia focusing at Tahan Mountains range and Titiwangsa Mountains range. The study uses the remote sensing techniques using the precipitation estimation and Global Digital Elevation Model (GDEM) from the satellites. The typhoon chosen for the study is the Typhoon Ketsana in year 2009.

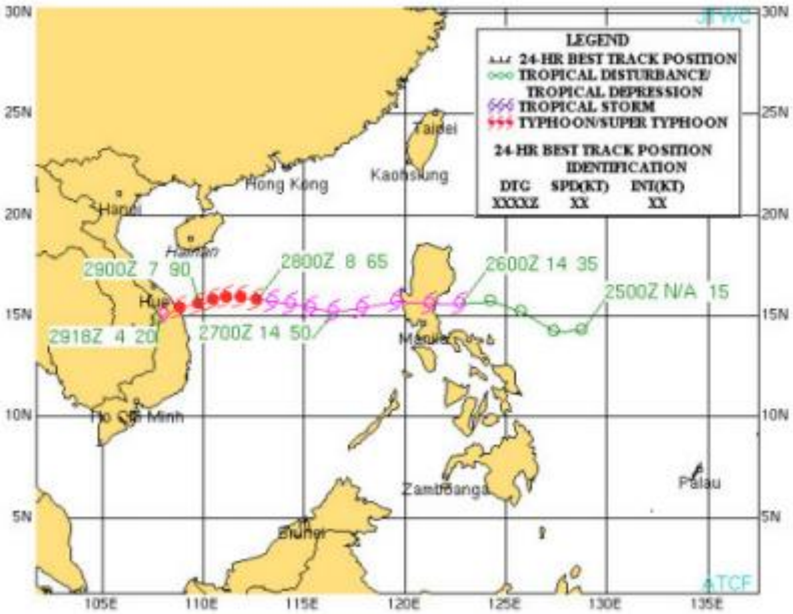


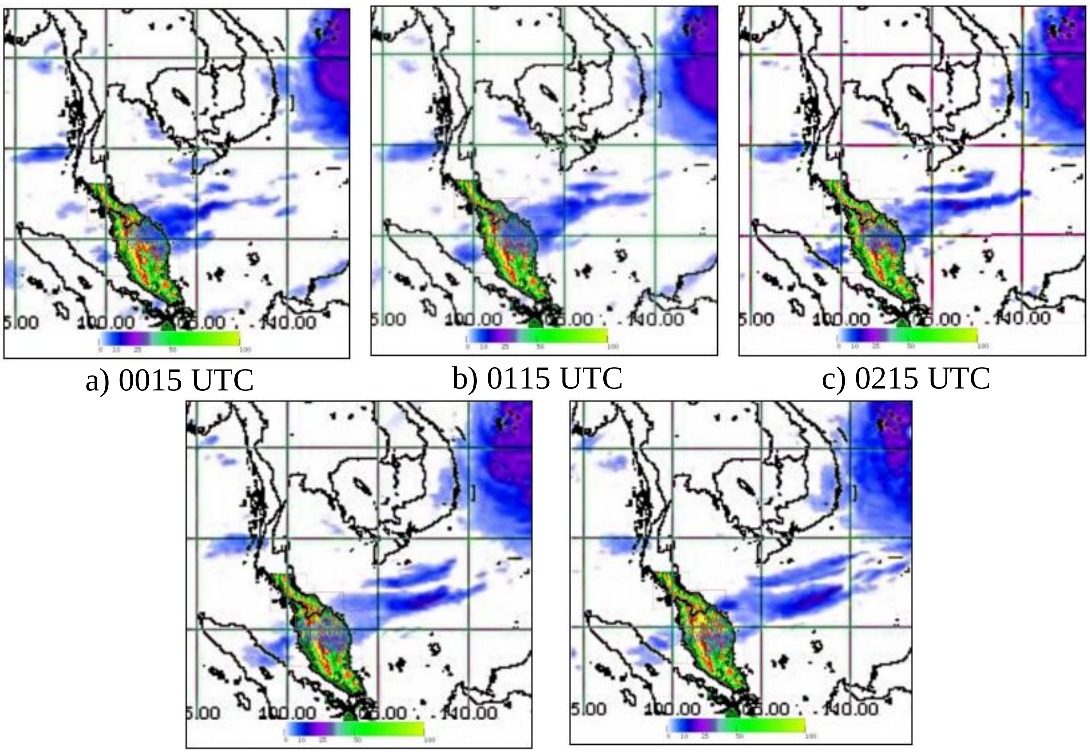
Figure 2.3: The track and stage development of Typhoon Ketsana

Although the typhoon is not in direct path to peninsular Malaysia but the tail effect of the typhoon is significant. The intensity of the rainfall can be referred to the rainfall scale on the images in Figure 2.4. Rainfall patterns are influenced by typhoon Ketsana since the atmospheric circulation is changed based on the typhoon motion. The rainfall distribution pattern at the northeast peninsular Malaysia (refer from Figure 2.4a to 2.4e) was tend to move toward the centre of the typhoon since the typhoon system has lower pressure centre. Wind is blowing towards the low pressure centre of the typhoon so the clouds will follow the wind path as well. Thus, the rainfall distribution patterns tend to distribute along the outer flow of the typhoon.

According to the images Figure 2.4a to 2.4e, the rainfall patterns are significantly extended toward typhoon within these 5 hours. Hence, rotation of the typhoon is believed able to vary low level atmospheric circulation since the phenomena proved that typhoon is able to vary the atmospheric circulation in synoptic scale. The deeper the central pressure of the typhoon, the higher the wind speed will move towards its centre. Besides that, typhoon rotation forced rainfall towards its direction. There is another factor that is mountains terrain may also change the rainfall distribution patterns. Many previous studies have been made for the typhoon-orography interaction over Taiwan Island which always hit by the typhoon.

Fig. 2.4a shows rainfall dominant at the northeast part of the peninsular Malaysia. The rainfall distribution is blocked by 2nd to 5th highest mountains Mount Korbu; Mount Yong Belar; Mount Gayang and Mount Chamah respectively located at the northern part of Titiwangsa Mountains (refer to Table 1.1) so no rain occurs at northwest region but it gather at northeast regions. Moreover, raining movement is significantly blocked and slowed down by the Mount Tahan. Thus no rain occurs behind this mount. Nevertheless, parts of the rainfall continue to move forward due to the typhoon development system. Therefore, the rainfall pattern is tending to move at east and northeast direction. This is because the rainfall location is located at the western south of the outer flow of the typhoon.

After an hour, the extended rainfall patterns toward typhoon Ketsana is more significant (Figure 2.4b). Precipitation still unable to travel through northwest since Titiwangsa Mountains is high enough to block its movement. On the other hand, rainfall has passed over the Mount Tahan because the typhoon system forces the cloud move towards it and then passed over the mount. At this moment, the rainfall distribution is gathering at the northeast of peninsular Malaysia from higher terrains to coastal regions. In the following hour (Figure 2.4c), raining patterns is not much different with the previous hour. The only different at 0215 UTC is the precipitation move forward a bit so rain stopped over northern part of Kelantan region. The raining cloud is further extending to typhoon system.



a) 0015 UTC b) 0115 UTC c) 0215 UTC

d) 0315 UTC e) 0415 UTC

Figure 2.4: Five selected FY-2D satellite images of rainfall distribution patterns study in 27 Sep 2009

Rains had cover through the Titiwangsa Mountains and move towards northwest part of peninsular Malaysia which can be view in Figure 2.4d. At the same time, raining cloud from the northwest side also travel to the Titiwangsa Mountains and meet with the opposite raining cloud at the northeast side. From the image, the rainfall is distinct occur at 2nd to 5th highest mountains over the Titiwangsa Mountains. Another rainfall event move to south of the peninsular Malaysia had been stuck by the Mount Benum at Pahang state (near to middle of the peninsular Malaysia). The raining activity is slowed down by Mount Benum. The other rainfall area over the South China Sea continues to move forward to typhoon system.

At 0415 UTC on 27 Sep, most raining events happened at the centre and east side of peninsular Malaysia which is Pahang and Terengganu (refer to Figure 2.4e). Nevertheless, rainfall rate around this region is also increasing. This rainfall activity seems like stuck in the lower elevation area surrounded by higher topography or mountains terrain. The raining cloud over the South China Sea is distinctly going to join with the typhoon system due to the high low pressure system. In addition, the rainfall rate is increasing and its coverage becomes wider and wider when the raining cloud is close to the typhoon system.

Overall, this paper gives a general idea of what to expect as the outcome of the study. Moreover, the method using the satellite image of precipitation estimation is adopted for this study to support the results obtained.

CHAPTER 3

METHODOLOGY

3.1 Key Milestone and Study Plan

The project is divided into two phases, namely FYP I conducted in the first semester and FYP II in the following semester. Activities done in FYP I are mostly covering the researches made related to the topic, understanding in great extent of the topic as well as the gathering of the data and information. Familiarization of the software that is going to be used in the project is also done in the first semester in order to ease the work flow during the FYP II.

The approach of this project is based on examination and understanding of the scope of work and the timing for the completion of the project. In accordance with the milestones provided in the guideline for final year project, several have been identified and summarized for FYP I and FYP II in Table 3.1 and Table 3.2 respectively.

Key Milestone	Proposed Week
Submission of Extended Proposal Defence	Week 6
Proposal Defence	Week 10
Submission of Interim Draft Report	Week 13
Submission of Interim Report	Week 14

Table 3.1: Key milestone for FYP I

Key Milestone	Proposed Week
Submission of Progress Report	Week 8
Pre-EDX	Week 11
Submission of Draft Report	Week 12
Submission of Dissertation (soft bound)	Week 13
Submission of Technical Paper	Week 13
VIVA	Week 14
Submission of Project Dissertation (hard bound)	Week 15

Table 3.2: Key milestone for FYP II

A detailed activity and work processes flow for FYP I and FYP II can be explained in Table 3.3 and Table 3.4 respectively.

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Selection of Projection Title**														
2	**Preliminary Research Work**														
	- Research on topic														
	- Familiarize with the software														
3	**Submission of Extended Proposal**														
4	**Proposal Defence**														
5	**Project Work**														
	- Data gathering														
	- Start-off activities														
6	**Submission of Interim Draft Report**														
7	**Submission of Interim Report**														

Table 3.3: Gantt chart representing the process flow for FYP I

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Continuation of Project Work**														
	- Detailed study area														
	- Determine location on map														
	- Delineation of watershed														
	- Processing rainfall data														
	- Isohyet creation														
2	**Submission of Progress Report**														
3	**Continuation of Project Work**														
	- Satellite image research														
4	**Poster Presentation**														
5	**Submission of Dissertation**														
6	**Submission of Technical Paper**														
7	**VIVA**														
8	**Submission of Hard Bound**														

Table 3.4: Gantt chart representing the process flow for FYP II

3.2 Project Methodology

For the first objective, the software used in the project is the ArcGIS software developed by Environmental System Research Institute (Esri) currently in version 10 since it provides a complete system in designing and managing the GIS data. The software is used both to create the watershed delineation and the isohyet for the study area.

For the second objective, images from China's Feng Yun-2D (FY-2D) satellite are taken to assess the orographic precipitation at the peninsular Malaysia mountain range. This information is used to strengthen the results obtain from the isohyet creation.

The process flow of the project is illustrated in Figure 3.1 below and the detailed process methodology is explained in details in achieving the objectives.

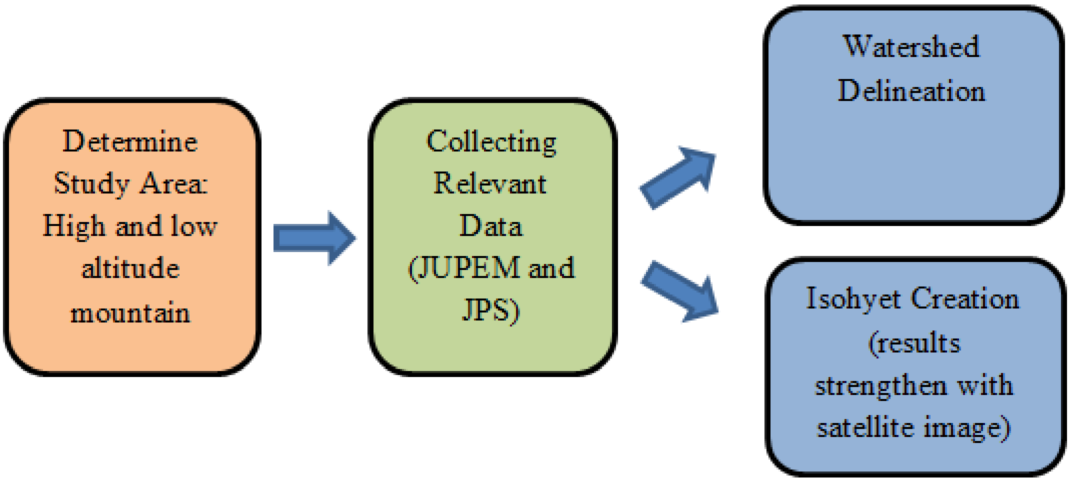


Figure 3.1: The process flow of the whole project

3.2.1 Selecting Study Area

As mention before, the study areas are Cameron Highland and Hulu Langat. The selection was made based on many factors. The most important factor is the elevation of the area. Since the manipulated variable for the study is the height of the mountain, Cameron Highland is chosen for high altitude mountain and Hulu Langat is chosen for low altitude. The second factor influencing the selection is the availability of the data. Jabatan Ukuran dan Pemetaan (JUPEM) digital map and Jabatan Saliran dan Pengairan (JPS) rainfall data must be available for the purposes of the study. Thus considering all factors, the final chosen study areas are Cameron Highland and Hulu Langat.

3.2.2 Collecting Relevant Data

The effect of the mountain range altitude is studied toward the catchment and rainfall precipitation. Thus for the catchment, topography map is obtain from JUPEM and rainfall data is obtain from JPS.

The topography map is the restricted type and the format is in vector data stored in AutoCAD drawing format (.dxf). The scale of the map is 1:25,000 which includes cultural features, vegetation, cultivations, hydrography and relief drawing.

For rainfall data, the data obtained is the rainfall intensity (in millimetres) for every 15 minutes from the autologger of the rainfall stations. The rainfall data processed is taken from 1st Nov 2010 until 31st March 2011 which is for northeast monsoon and 1st May 2011 until 30th Sept 2011 for southwest monsoon. For both Cameron Highland and Hulu Langat, only six rainfall stations near the area are available and are chosen for the study.

3.2.3 Watershed Delineation

Watershed delineation process shown in this chapter is using the Cameron Highland area as an example. Hulu Langat watershed delineation will be using the same process as describe in this chapter. Full output results will be shown in the next chapter.

<u>Creating Digital Elevation Model (DEM)</u>

The data is obtained in the form of drawing format (.dxf) which consists of many layer including contours. The first step to process the map is to delete the other layers except the contours. Then the map is saved (.dwg) and added into the ArcGIS software exporting the contour polylines into shapefile.

It is very important to set the projection of the map in the first step by using the *Define Projection* tool. The Projected Coordinate System is used where the unit of measurement is typically in feet or meters different from the Geographical Coordinated System where the unit of measurement is in decimal degrees for latitude and longitude.

The projection used for the study area is the Kertau_RSO_Malaya in meters. The Kertau datum is used since the study area is located in the Peninsular Malaysia. Malaysia uses two datums which is the Kertau datum for Peninsular Malaysia and Timbalai datum for Sabah and Sarawak.

Once the projection is set up, the *Topo to Raster* tool is selected and the shapefile is used as the input feature and is saved as *CamDEM30*. A cellsize of 30m is chosen as accordance to the Mapping Center Answer (Esri, 2010) as shown in Figure 3.2.

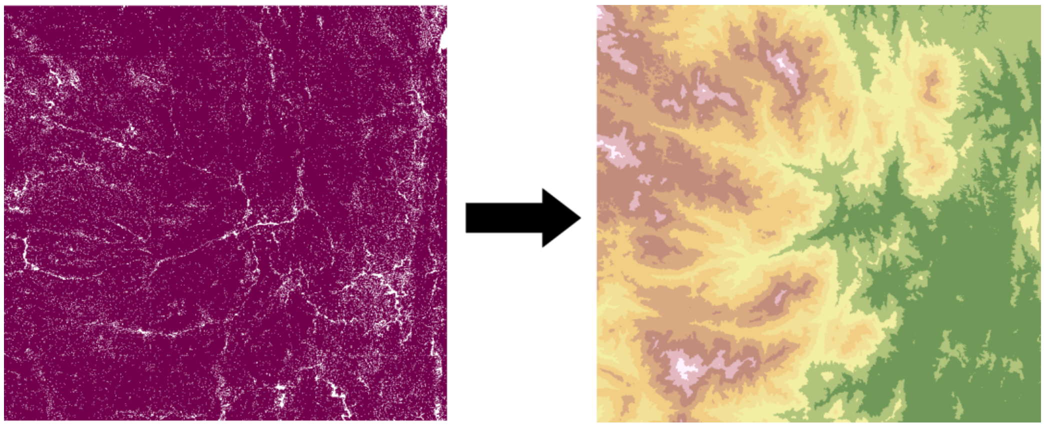


Figure 3.2: Topo to raster process

Filling Sinks

This function is used in creating a depression-less DEM. The grid created earlier contains cells with different elevation and when a cell is surrounded by cells with higher elevation, water will trap in that particular cell and will not flow (Merwade, 2011). It is crucial to fill the sinks because the network should be that of the continuation of flow path of each cell that will finally flow to the edge of the grid and when this fails, the trapped cell may drain into each other causing endless processing loop (Surface hydrologic modelling, 2010).

Figure 3.3a and Figure 3.3b below show the illustration of what filling does, either chopping off tall cells or filling in sinks:

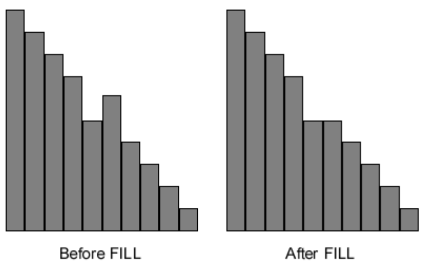


Figure 3.3a: Chopping off tall cells

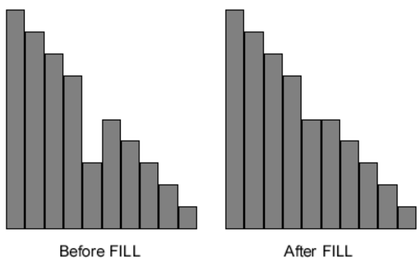


Figure 3.3b: Filling in sinks

The *Fill* tool is used and the *DEM30* is used as the input surface raster and the output is saved as *CamFill.* (Figure 3.4)

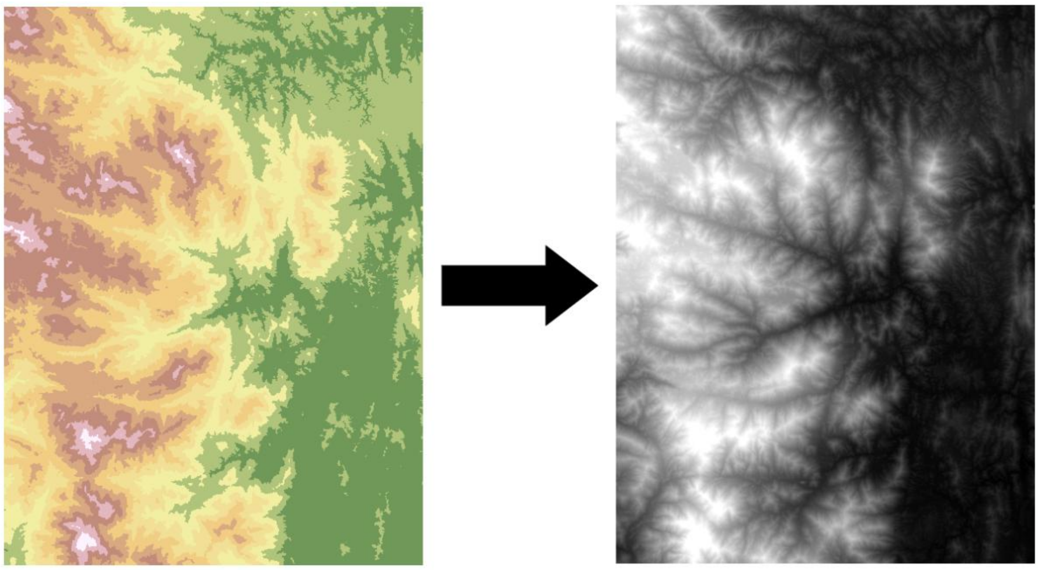


Figure 3.4: Fill process

Identifying Flow Direction

Flow direction is needed to determine where the landscape will drain by implying coded cells representing the direction of the flow. Note that the coding numbers "do not have any absolute, relative, or ratio meaning, they are just used as numeric place holders for nominal direction data values (since grid values are always numeric)." as stated in the Surface Hydrology Modelling (2010). An illustration of the input and output of the data is shown in Figure 3.5 where the coding of each direction is shown.

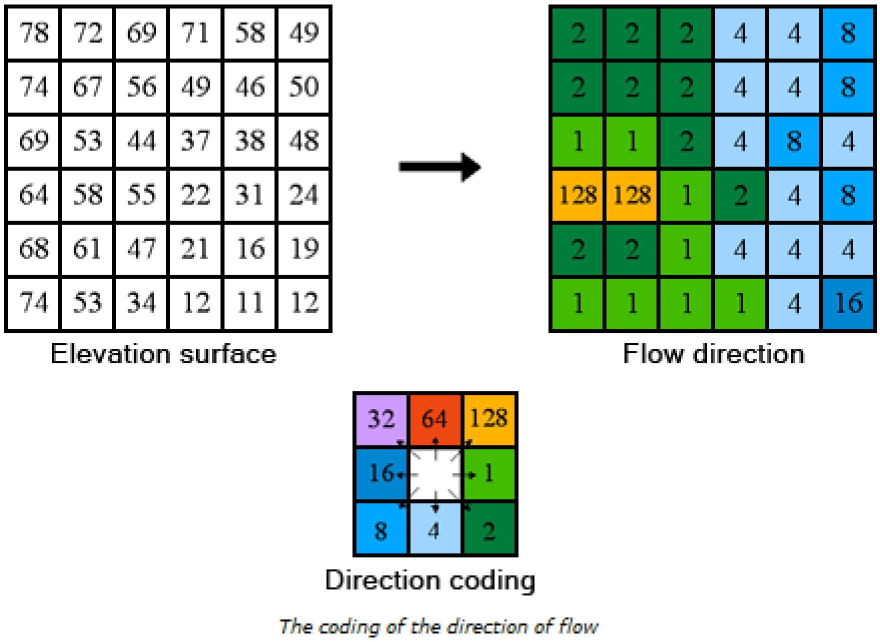


Figure 3.5: An illustration for the elevation input and flow direction output

The *Flow Direction* tool (Figure 3.6) is used and the *CamFill* is used as the input surface raster and saved as *CamFlowDir.*

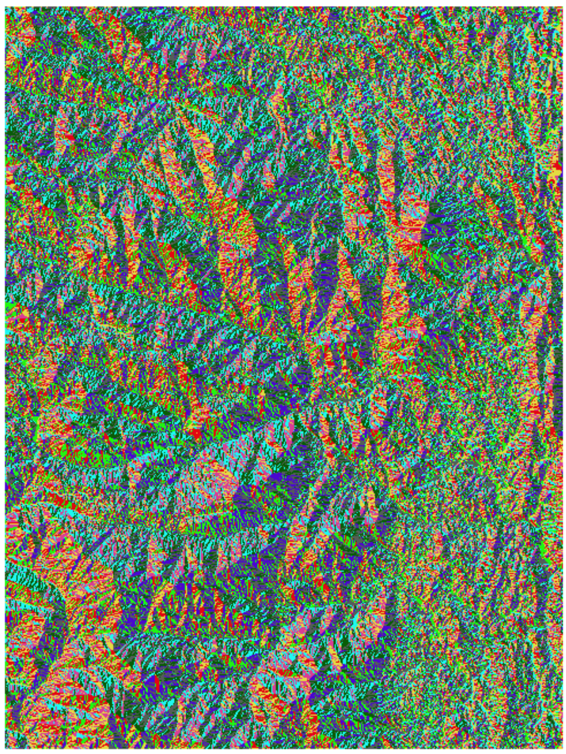


Figure 3.6: Flow direction

Identifying Basins

The *Basin* tool is used to identify the basins that flow to each outlet point on the map edge and the *CamFlowDir* is used as the input flow direction raster and saved as *CamBasin*. The desired basin is then selected as shown in Figure 3.7.

Figure 3.7: Basin highlighted

The purpose of this step is to extract the desired basin and process only that particular basin. The selected basin is then converted into polygon to provide as a boundary for clipping raster in the next step.

Clipping Raster

The *CamFlowDir* is used as the input raster for clipping process with the identified basin, *CamBasin* polygon as the output extent using the *Clip* tool. The output raster is saved as *CamFDirClip*. Note that the 'Use Input Features for Clipping Geometry' box is ticked in order to obtain a clipped geometry exactly as the input features perimeter and the output can be shown in Figure 3.8.

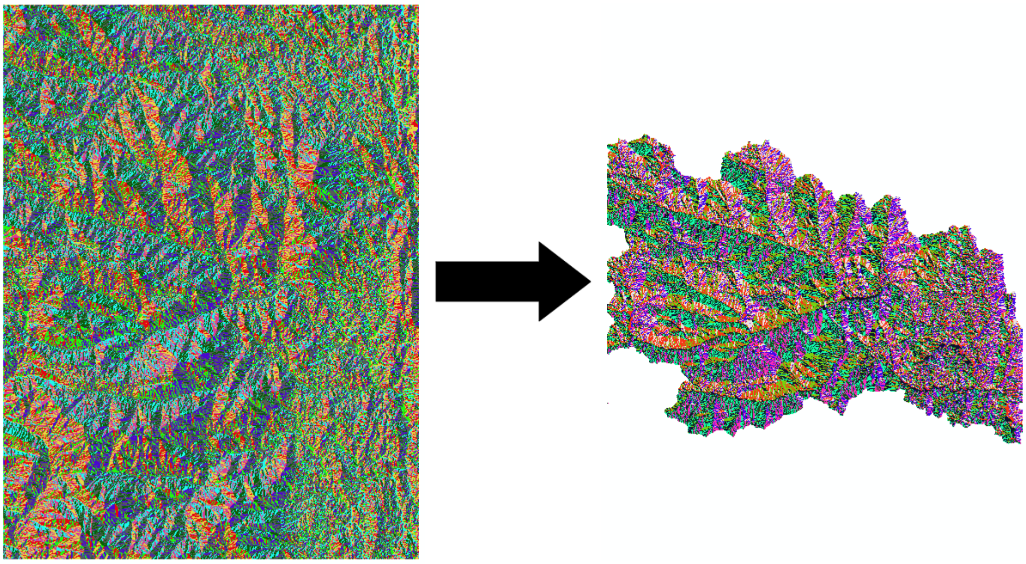


Figure 3.8: Clip process

Creating Flow Accumulation

This function accumulates the number of cells that are draining to any particular cell in the DEM taking the flow direction grid as the input. In the graphic below, the top left image shows the direction of travel from each cell and the top right the number of cells that flow into each cell.

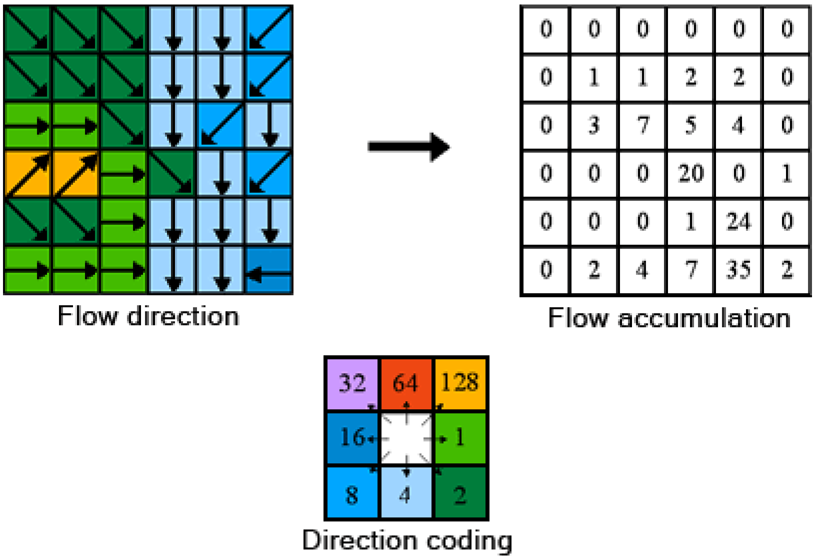


Figure 3.9: An illustration of flow direction input and flow accumulation output

The end result of this activity is to generate a network of high-flow cells (Surface hydrology modelling, 2010) as shown in **Figure 3.10**.

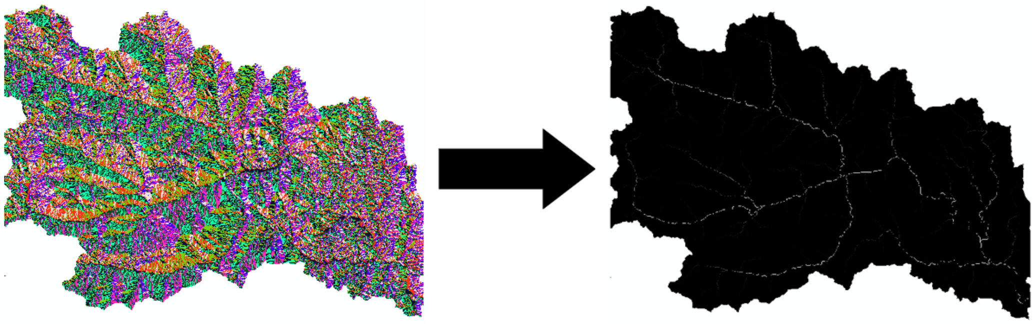


Figure 3.10: Flow accumulation process

Identifying Stream Network

Flow accumulation generated earlier will be the input to create a stream network as it shows the high-flow cells that will define a network (Merwade, 2011). An assumption is made by Merwade (2011) is that a stream is defined when a certain area (threshold) drains to a point. Assuming an area of 9km² to be the threshold, the number of cells corresponding to the area is:

$$Corresponding\ Cells = \frac{9{,}000{,}000}{30 \times 30}$$

$$= 10{,}000$$

Where 9,000,000 is the assumed threshold area in m^2 and 30m is the DEM resolution used in the study.

The indication of the number is that any cells with flow accumulated greater than 10,000 cells will have a value of 1 and displayed as a stream network.

The *Raster Calculator* tool is used using the *CamFlowAcc* as the input and saved as *CamStream* as shown in Figure 3.11.

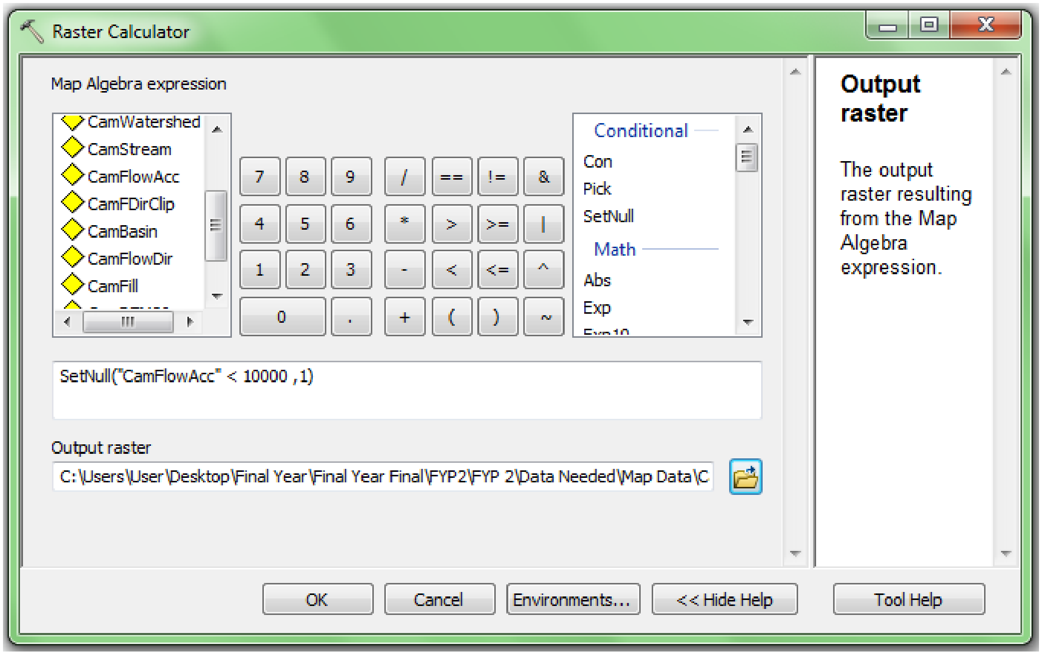


Figure 3.11: Raster calculator

Identifying Stream Link

Stream link is the line that connects two successive junctions, a junction and the outlet, or a junction and the drainage divide. An illustration of the said elements is shown in Figure 3.12. Stream link functions to give unique Ids to each stream links available in the network.

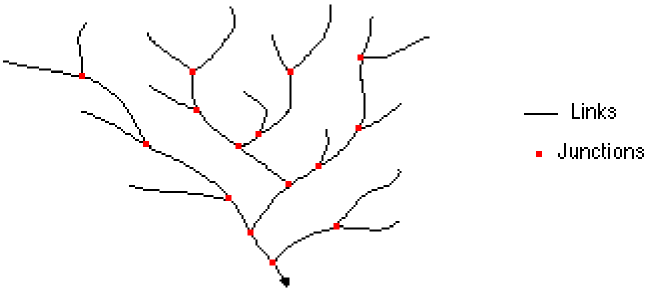


Figure 3.12: An illustration of links and junctions

Use the *Stream Link* tool and provide *CamStream* and *CamFDirClip* as the input stream raster and input flow direction raster respectively to obtain the stream link as shown in Figure 3.13.

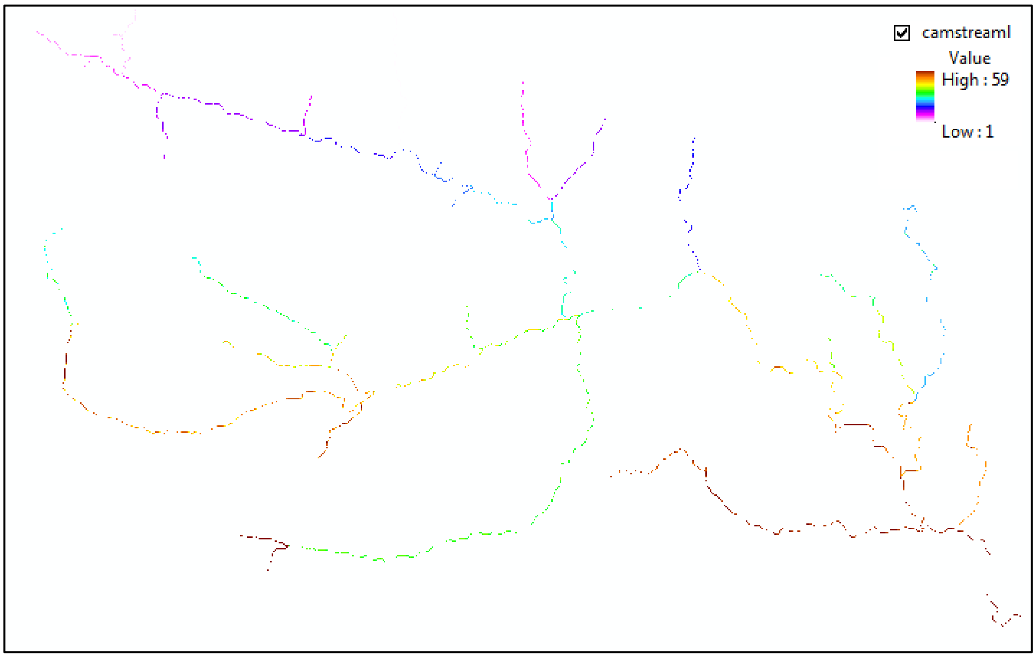


Figure 3.13: Stream link output

Watershed Delineation

This process gives out the sub-basin delineation of *CamBasin* within the *CamBasin* (shp.) perimeter. The *CamStreamL* computed before will be the input feature pour point data for the *Watershed* tool in dividing the sub catchment.

The delineated watershed raster is then converted into vector format using *Raster to Polygon* tool. The final output of the delineated watershed and the stream network is shown in Figure 3.14.

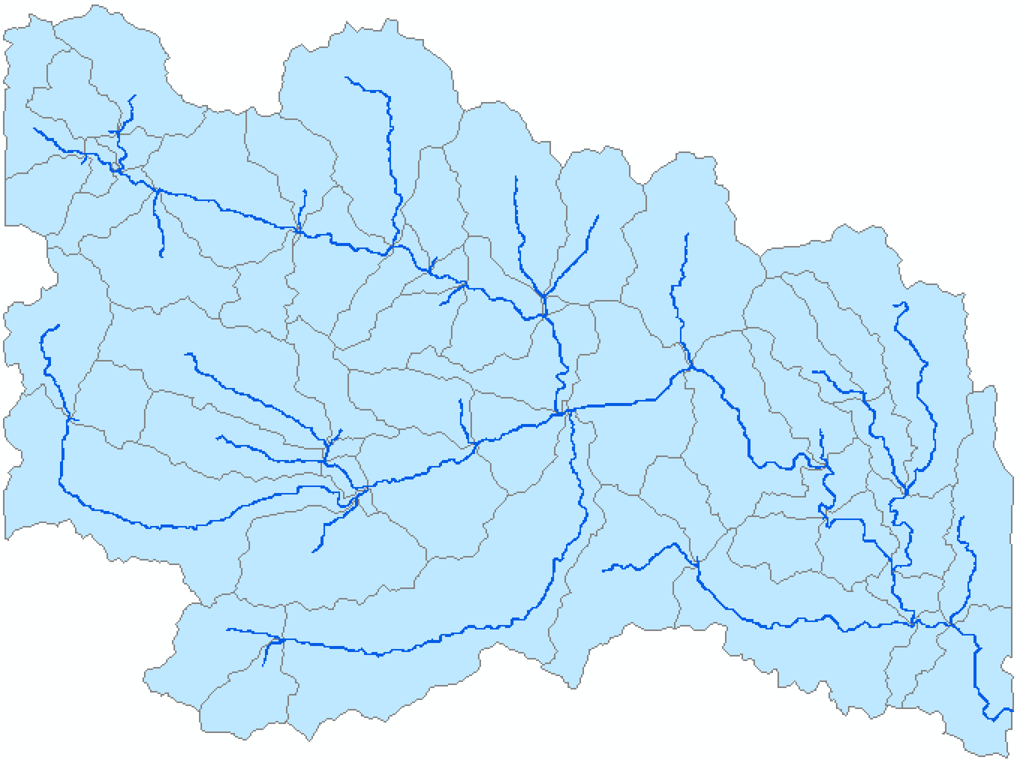


Figure 3.14: Watershed delineated

3.2.4 Isohyet Creation

The isohyet creation shown in this chapter will be using the Cameron Highland during northeast monsoon as an example. For southwest monsoon and Hulu Langat isohyet creation, the process used is the same as described in this chapter. Full results will be shown in the next chapter.

<u>Creating Inverse Distance Weighted (IDW)</u>

Inverse distance weighted (IDW) interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. The surface being interpolated should be that of a locationally dependent variable.

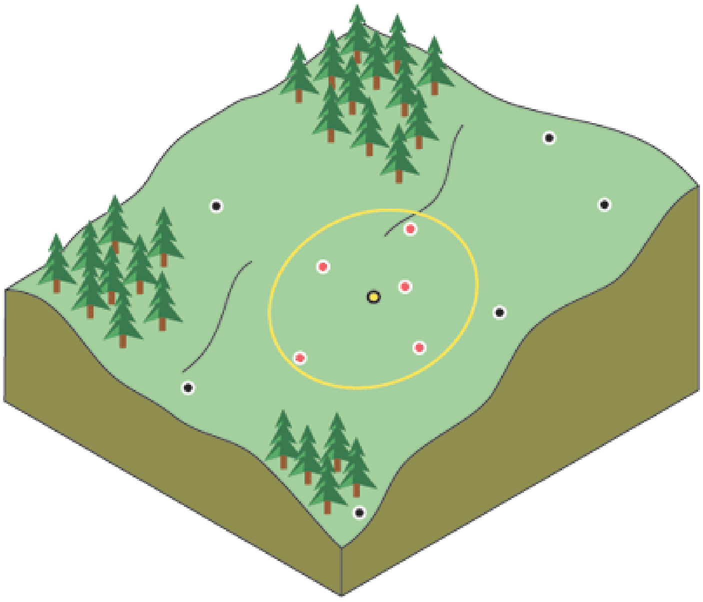


Figure 3.15: An illustration of IDW neighbourhood for selected point

The rainfall data for each rainfall stations is first extracted from the autologger into excel file (.xslx). The data for each station is separated into two sets which is the northeast monsoon and the southwest monsoon. The rainfall data is then added up from the start of the monsoon until the end giving the total rainfall for each set. Below is the summary of rainfall precipitation for all the stations.

ID	Station Name	Nov 10 - Mar 11 rainfall (mm)	May 11 - Sep 11 rainfall (mm)	Y	X
4414036	Ldg. Boh (Bhg. Kilang)	1056.7	849.5	492539.87	381408.37
4414037	Ldg. Boh (Bhg. Selatan)	668.3	941.9	491458.71	383562.72
4414038	Ldg. Boh (Bhg. Boh)	695.9	628.6	492223.79	384489.58
4513033	Gunung Brinchang	1408.7	1134	499770.49	376806.83
4514031	Ldg. Teh Blue Valley	789	0	507436.13	380835.83
4514032	Ldg. Tehh Sg. Palas	532.9	308.8	499759.5	380505.01

Table 3.5: Cameron Highland rainfall station information

ID	Station Name	Nov 10 - Mar 11 rainfall (mm)	May 11 - Sep 11 rainfall (mm)	X	Y
3118102	Sek. Keb. Kg. Sg. Lui	1119	1179.6	430709.55	351143.13
3118103	Kg. Sg. Lui	1206.2	1024.7	430502.7	351128.23
3119001	Sawah Sg. Lui	956.3	1127.3	434413.48	350981.56
3119002	Lalang Sungai Lui	1020	981.8	434404.93	346989.06
3119104	Bt. 30, Jln Genting Peres	1192.2	1010.4	437091.58	347444.03
3218101	TNB Pansun	1064.6	1068.3	431122.62	355125.55

Table 3.6: Hulu Langat rainfall station information

The excel data summary is then added into the ArcGIS software and the XY data is displayed. Once the stations are displayed, they are then exported into shapefile for the *IDW* tool.

Using the *IDW* tool, the shapefile is used as the input point features with the rainfall as the Z value field and the output file is saved as *IDW1103*. The cell size will be set as 30m corresponding with the cell size of the DEM.

Figure 3.16: IDW rainfall (Nov 10 – Mar 11)

Contouring

To compare the effect of the mountain altitude towards rainfall precipitation more clearly, the IDW of all sets will be depict as contour lines. *Contour* tool is used and the input raster *IDW1103* is chosen. The *Contour Interval* is set to be 50 (based on the IDW range) and the *Based Contour* is set as 500. These setting will give an equal comparison between each set of data later on. The output file is saved as *CamCont1103.*

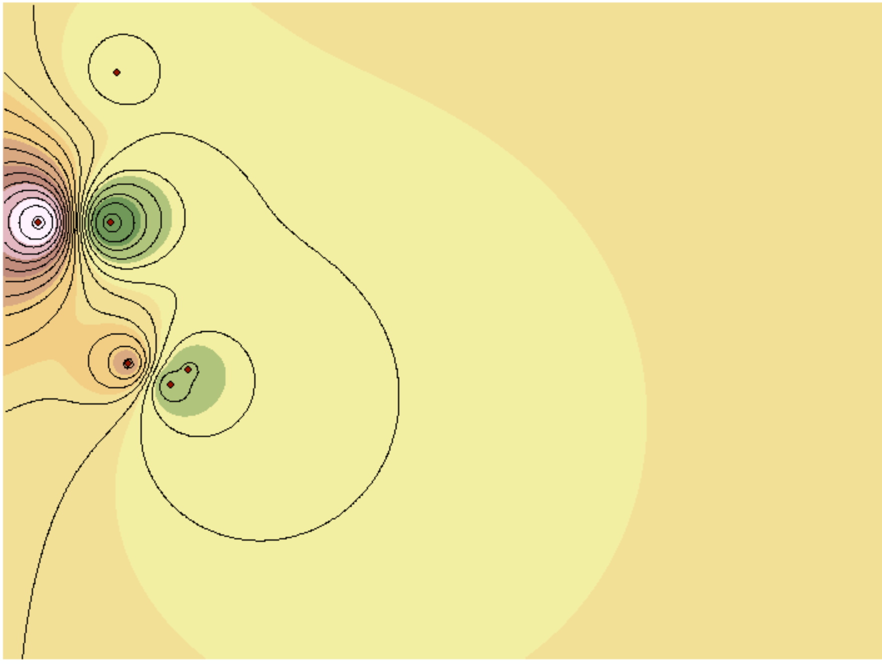


Figure 3.17: Contour made from IDW

Intersecting Contour

The first input features used for the *Intersect* tool is the *CamCont1103* and the second input is the *CamBasinPolygon.* It is important to set the contour as the first input and the polygon as the second input to make sure the process is a success. The output is saved as *CamContInt1103*.

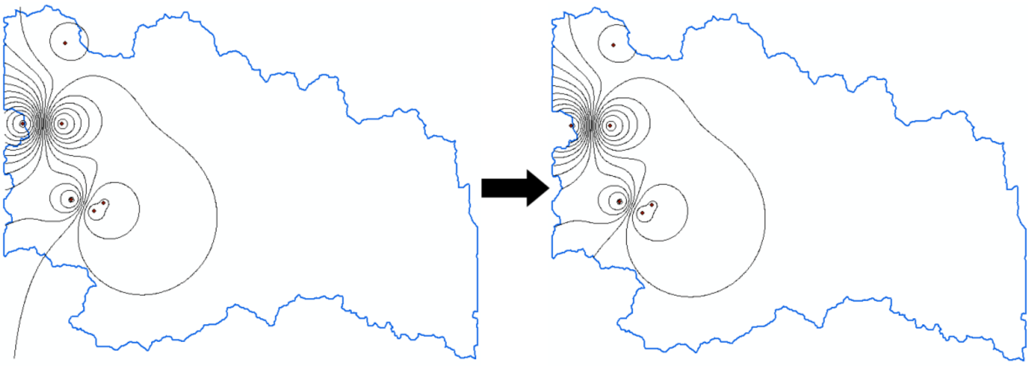


Figure 3.18: Intersecting contour process

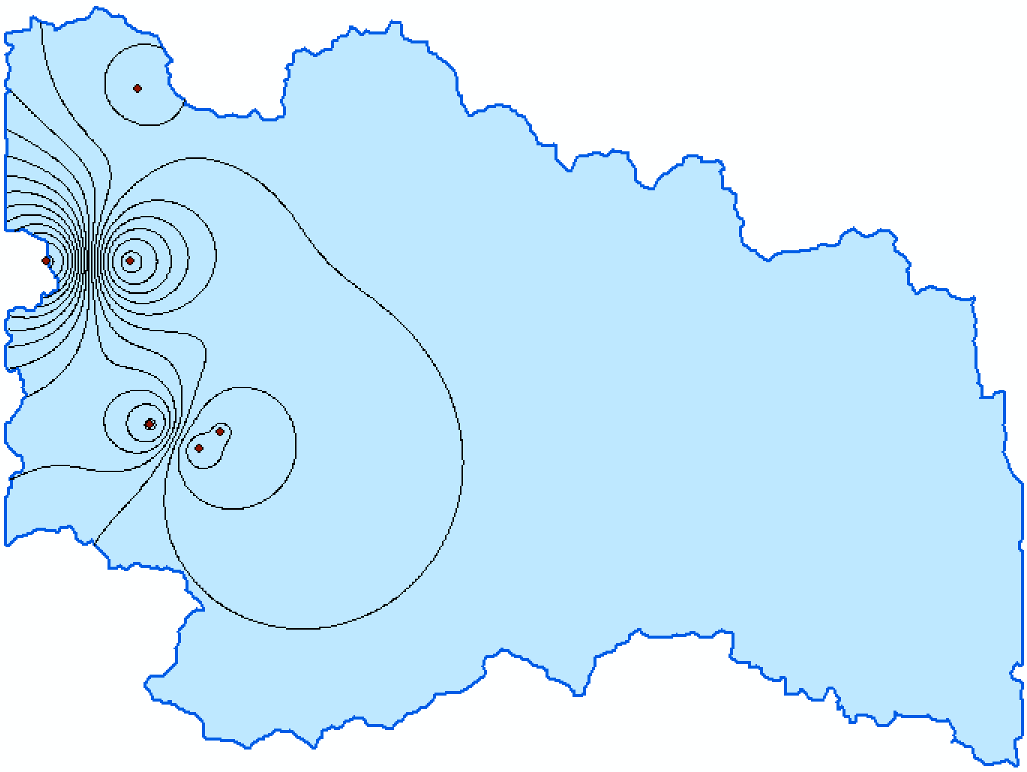


Figure 3.19: Contour intersected

CHAPTER 4

RESULT AND DISCUSSION

4.1 Watershed Delineation

4.1.1 Cell Size of DEM

According to Mapping Center Answer provided by Esri (2010) tabulated in Table 4.1, the most suitable cell size for the desired map scale is the 30m DEM.

Print Media, e.g, ~300 DPI		
Pixel Size	Largest Scale	Smallest Scale
~2m	1:2,000	1:10,000
~5m	1:9,000	1:24,000
~10m	1:24,000	1:100,000
~30m	1:100,000	1:250,000
~90m	1:250,000	1:500,000

Table 4.1: The suggested pixel size for different scale provided by Esri

A comparison was made between a 30m DEM and 120m DEM and the result can be shown in Figure 4.1 below. Based on the figure, it clearly shows that the DEM with higher resolution (30m) gives out a finer impression of the land while on the other hand; the 120m DEM gives out a courser impression of the land.

The important of choosing the correct DEM resolution for the study is that it can affect the spatial analysis of other important point in delineating a good watershed. Thus, the 30m DEM is used for further analysis and processing.

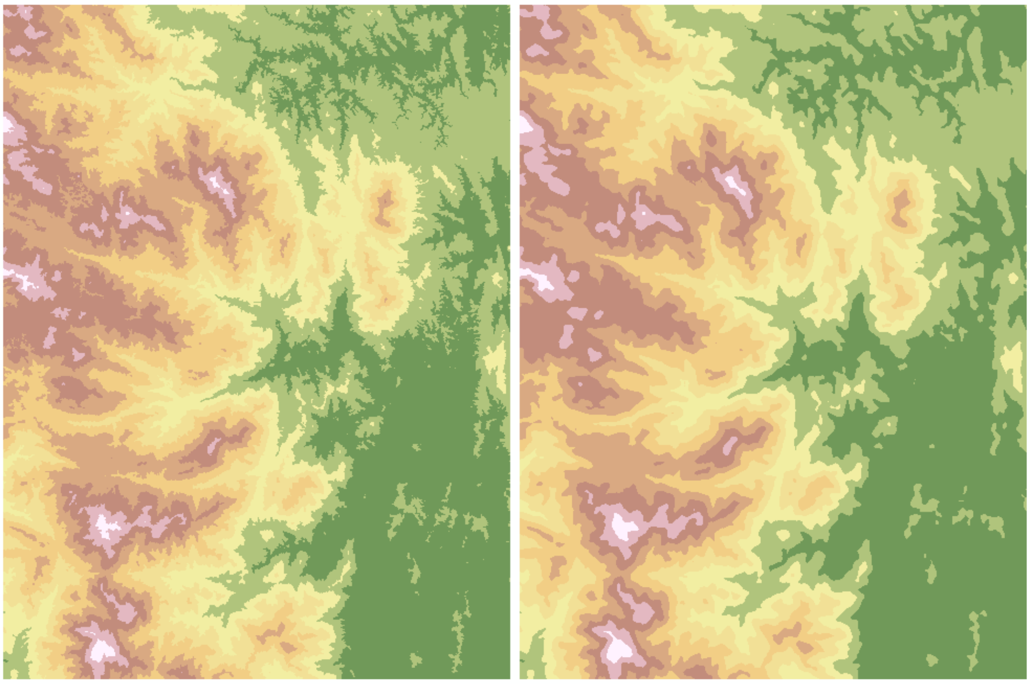


Figure 4.1: The comparison between a high resolution DEM (DEM 30 on the left) and low resolution DEM (DEM 120 on the right)

4.1.2 Threshold Area for Stream Network

A few other assumptions on the threshold area were made and the results obtained are shown in Figure 4.2 below.

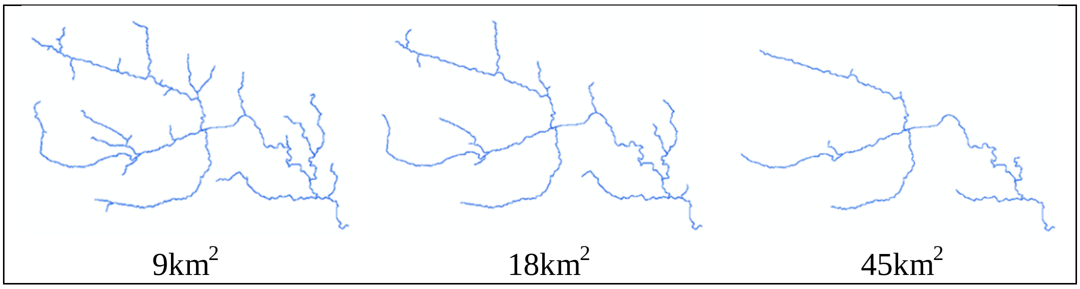


Figure 4.2: The comparison of different threshold areas.

Based on the figure above, it can be observed that larger threshold area gives less dense stream whereas a smaller threshold area gives denser stream network. Depending on the necessity of the study, an appropriate threshold area is determined and in this case, a threshold area of 9km^2 is chosen.

4.1.3 Comparison of Catchment Area

To assess the mountain range effect on the catchment, two watersheds delineation are created. The results are that for Cameron Highland, the catchment area delineated is 1045.29 km^2 with 59 sub-basins in one basin. For Hulu Langat area, the catchment area is 229.14km^2 with 19 sub-basins. Below is the table and figures showing the comparison between the two study areas:

Study Area	Highest Point (m)	Catchment Area (km^2)	Sub-Basin
Cameron Highland	2123.86	1045.29	59
Hulu Langat	1477.26	229.14	19

Table 4.2: Study area delineation summary

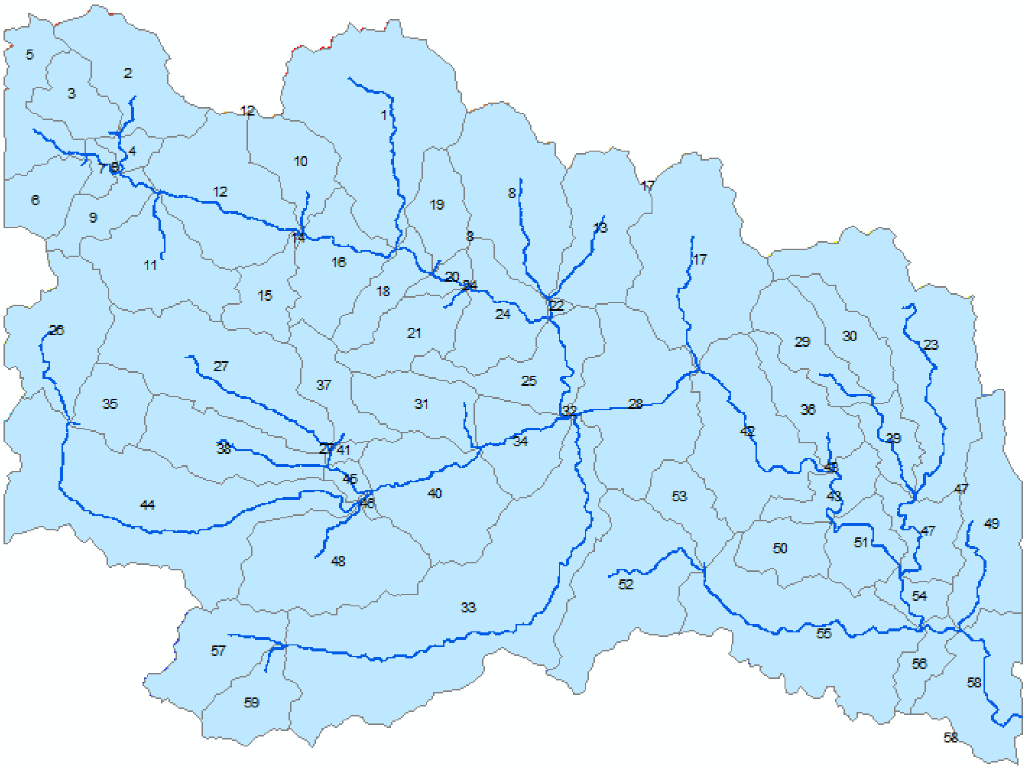


Figure 4.3: Cameron Highland catchment with sub-basins labelled

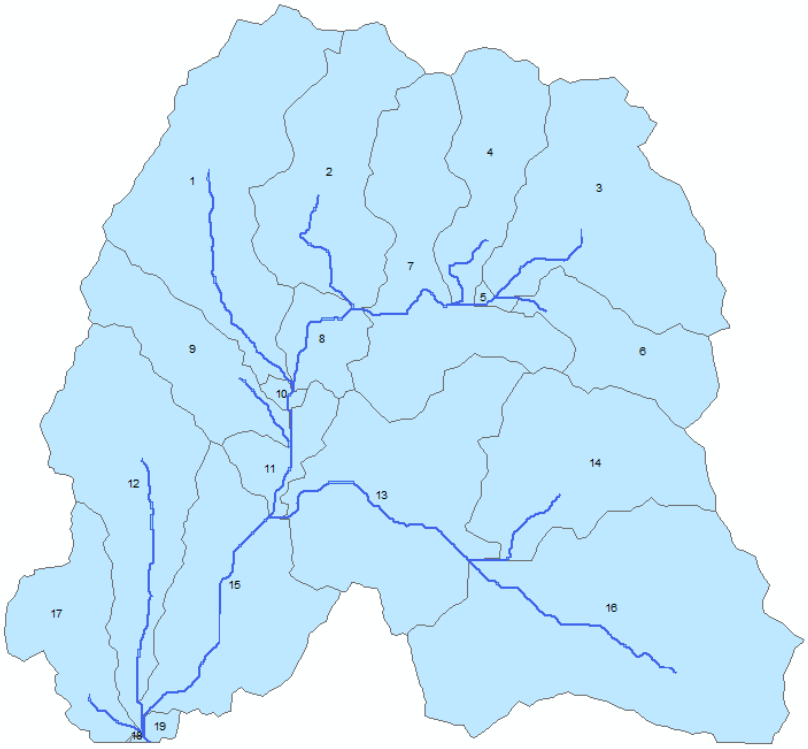


Figure 4.4: Hulu Langat catchment with sub-basins labelled

It can be deduced that high elevation of land will affect directly to the size of the catchment. Higher elevation will gives bigger catchment area and lower elevation will give a smaller catchment area. Nevertheless, one have to bear in mind that the area delineated is highly dependable to the chosen cell size. Low resolution might produce a different size of catchment making the study not effective.

The importance of studying the size of catchment is that it is needed for the hydrological analysis. The analysis made will be used for water management for the betterment of the country. Focusing on the mountainous area, since Malaysia has many mountains, better understanding on the catchments of the mountains will greatly help the water management. For example, to optimize the cost for analysis for water management, one must able to predict the suitable place to install the hydrological and rainfall stations. Thus watershed delineation will help to obtain this optimization especially in difficult area such as the mountain.

Below are the figures showing the available rainfall stations which are not enough for an intensive study.

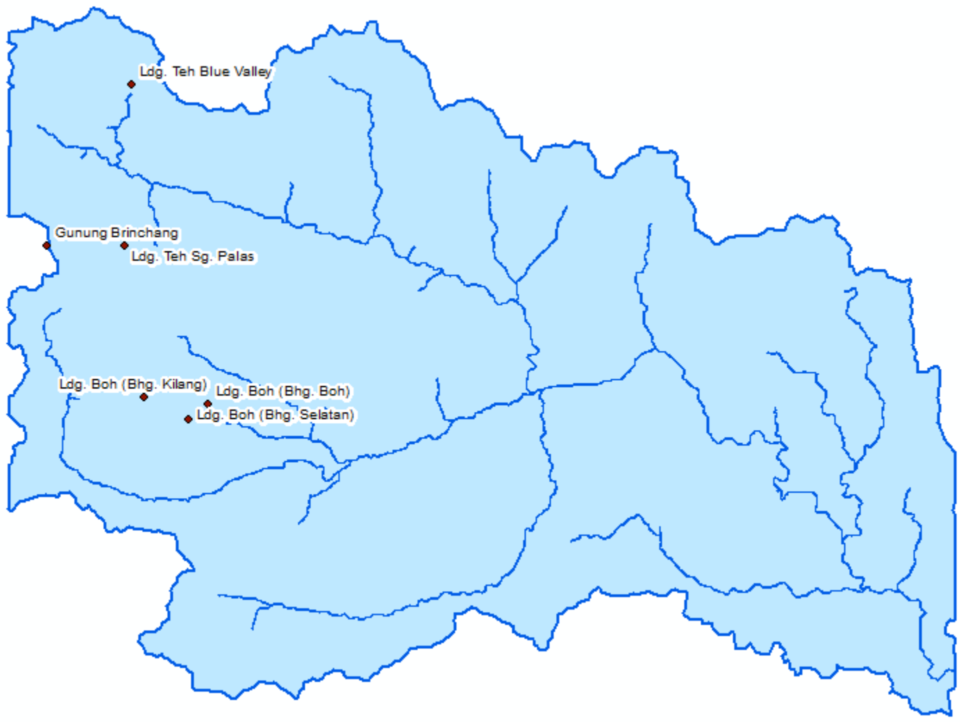


Figure 4.5: Cameron Highland catchment showing the available rainfall stations

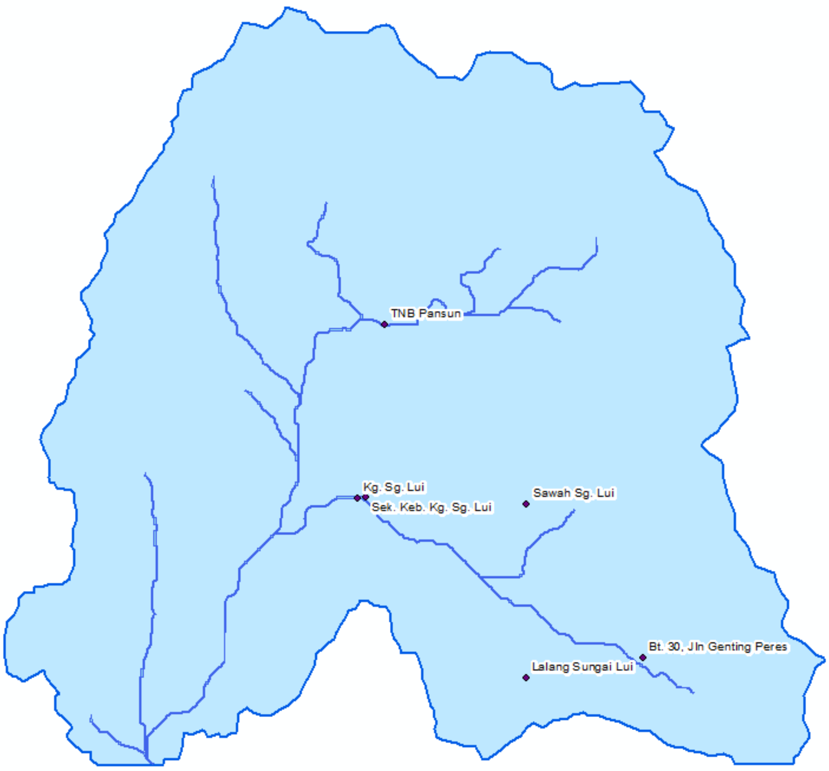


Figure 4.6: Hulu Langat catchment showing the available rainfall stations

4.2 Isohyet Assessment

4.2.1 Comparison of Isohyet

The isohyet created in this study includes the isohyet during northeast and southwest monsoon at Cameron Highland and Hulu Langat. Below is the isohyet comparison between northeast and southwest monsoon at Cameron Highland and Hulu Langat.

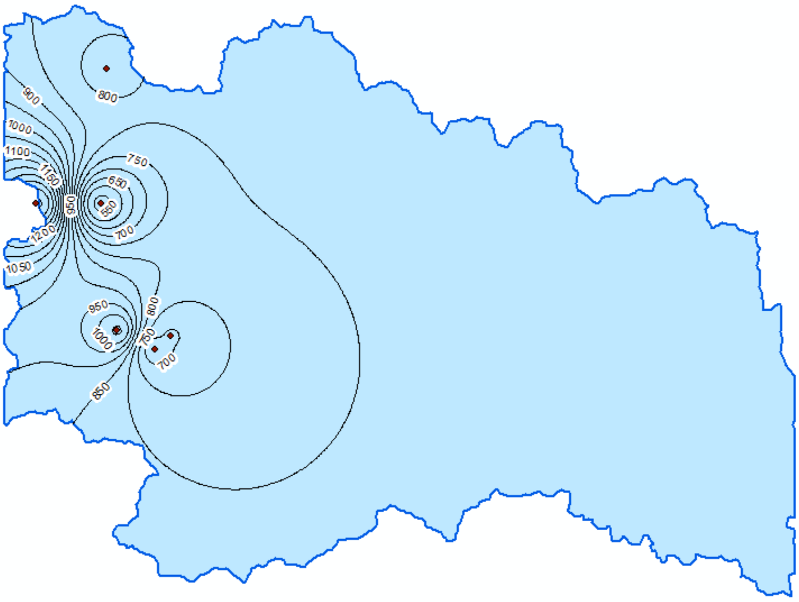


Figure 4.7: Cameron Highland isohyet during northeast monsoon

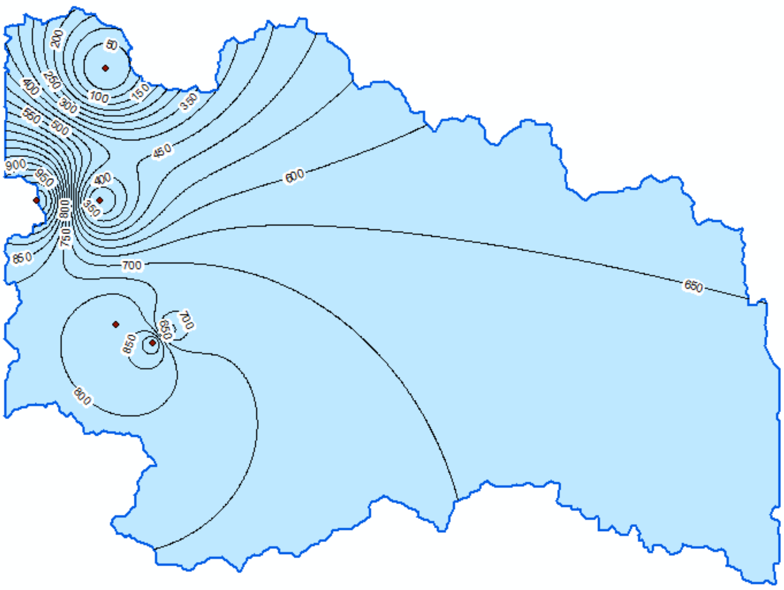


Figure 4.8: Cameron Highland isohyet during southwest monsoon

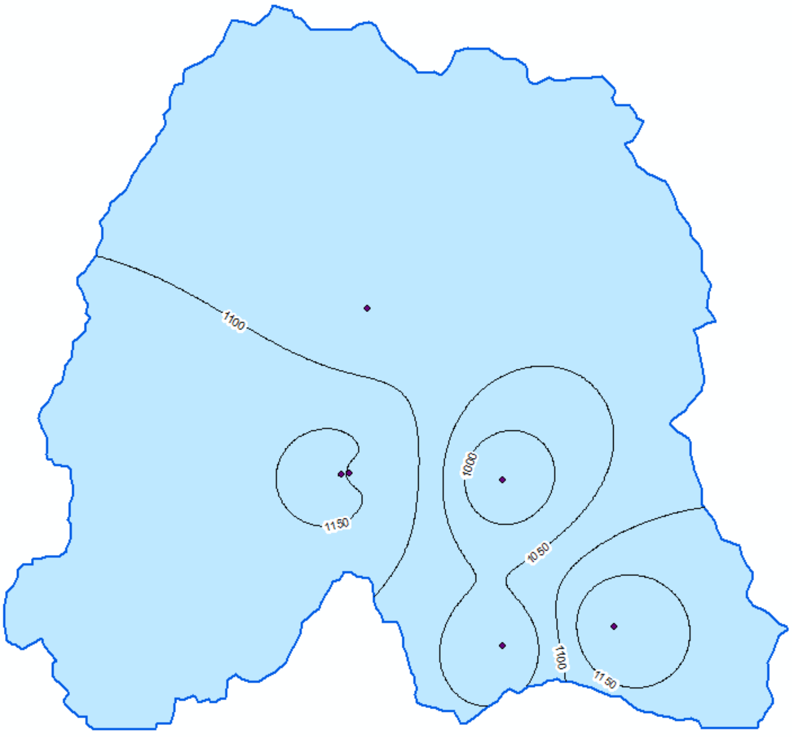


Figure 4.9: Hulu Langat isohyet during northeast monsoon

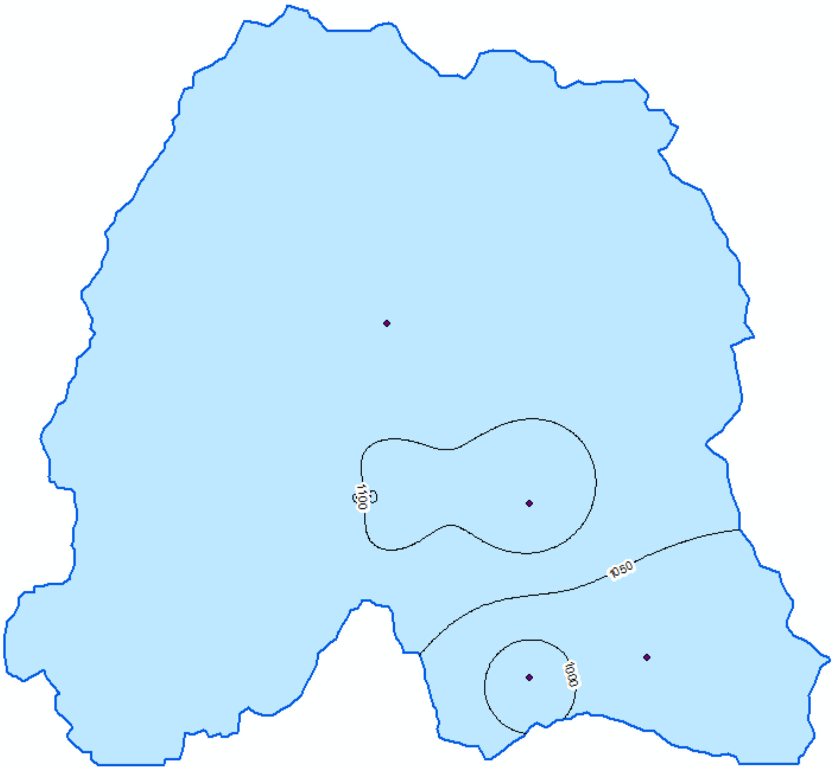


Figure 4.10: Hulu Langat isohyet during southwest monsoon

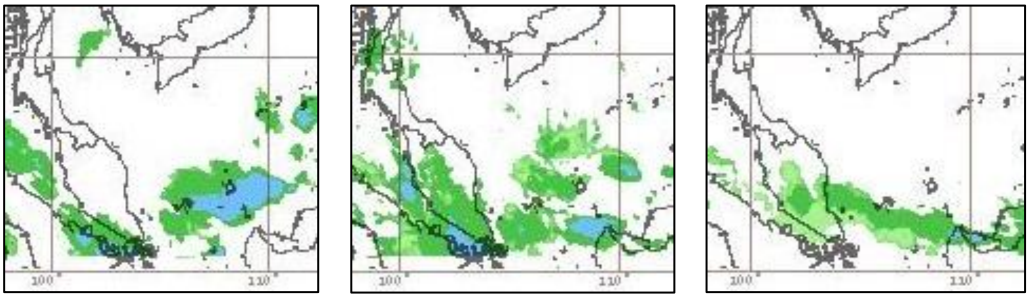
The six rainfall stations at Cameron Highland experience a cumulatively higher rainfall (highest shown is 1200mm of rain) during the northeast monsoon and distinctively lower rainfall during the southeast monsoon (highest shown is 950mm). Hulu Langat on the other hand does not show much difference between the cumulative rainfall of northeast monsoon and southwest monsoon. The highest in northeast monsoon is 1150mm and 1100mm in southwest monsoon which is only 50mm difference.

As mention before, it is assume that the wind blows according to the direction of the monsoon to make the assumption easier. Thus based on orographic precipitation theory, one can deduce that the reason of higher rainfall during the northeast monsoon at Cameron Highland is because of its height. The wind blow the humid air towards Cameron Highland peak (called the windward side) and due to its high elevation, the air that moves towards the peak experience adiabatic cooling causing it to condense near the summit. Compared to the southwest monsoon, the air is blown from the southwest of the peninsular. Thus according to the orographic precipitation theory, the rainfall will be less or none at all at the Cameron Highland (which is now the leeward side) due to height of the mountain that causing the rain to fall more at the windward side compared to the leeward side.

As for Hulu Langat area, it is mention before that there is no significant difference between northeast and southwest monsoon in term of rainfall intensity. Thus one can deduce that the height of Hulu Langat area is not enough for the orographic precipitation to happen. Precipitation on Hulu Langat area may be caused by other factor such as the tropical depression.

4.2.2 Satellite Proving

To prove the orographic precipitation along the mountain range, satellite images for each one hour showing the precipitation estimation are taken from 0000 hour on 29th January 2011 until 2400 hour on 31st January 2011. Below are the three significant images for this study.



29th Jan 2011 at 0000 hour | 29th Jan 2011 at 0730 hour | 31st Jan 2011 at 1130 hour

Figure 4.11: Precipitation estimation from FY-2D satellite image

One can see that as the rainfall precipitation reaches the mountain range around 0730 hour on 29th Jan, it takes about three days before the precipitation is able to leave the area (on 1130 hour on 31st Jan). One can say that the precipitation cloud got "stuck" when going through the mountain range thus proving that orographic precipitation can be seen along the mountain range of peninsular Malaysia.

The importance of this orographic precipitation study is to understand on how the mountain in Malaysia is subjected to orographic precipitation. Even though Malaysia is always experiencing wet seasons which mean the water is always abundant, one must not neglect the important of orographic precipitation to the water management. Great understanding of orographic effect, for example as shown in the previous study in Chapter 2.1 where sudden precipitation can happens due to typhoon kilometres away; can help in the term of flood management. Thus orographic precipitation is something that must be consider for intensive study of hydrological analysis.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The effects of mountain ranges in peninsular Malaysia can be seen in the catchment and rainfall precipitation. With higher elevation of the mountain, the catchment area will be bigger and rainfall precipitation around mountain range is proven to be subjected to orographic precipitation. Thus the first objective to use the GIS spatial analysis to assess the effects is achieved and the second objective of assessing the orographic precipitation in peninsular Malaysia's mountains is also achieved. Conclusion can also be made that using GIS tools for the study did tremendously help in finishing the study. GIS tools help in the sense of cutting the time for processing of the data in addition of visualizing the data in an assessable manner.

First recommendation for the study is to use the latest digital map data. As the data provided by JUPEM is in the year of 2001, some area of the land in the study area might have changed in this recent year. Second recommendation is to have a greater number of rainfall data which is very important in assessing the orographic precipitation. Bergeron (1961) once stated that no country has rainfall stations dense enough to give a summary picture of the precipitation conditions. Even now, rainfall stations are often few and far between. Gauges themselves also suffer from a number of errors, including the disturbance of the local airflow which has systematic elevation biases (Roe, 2005). Thus for rainfall analysis, they are only point measurements and any extrapolation to a continuous field must make implicit or explicit assumptions about how orography influences precipitation (e.g., Daly et al. 1994).

In conclusion, objectives of the paper are achieved. In depth understanding of concept, using the ArcGIS software and dense data can highly improve this study paper.

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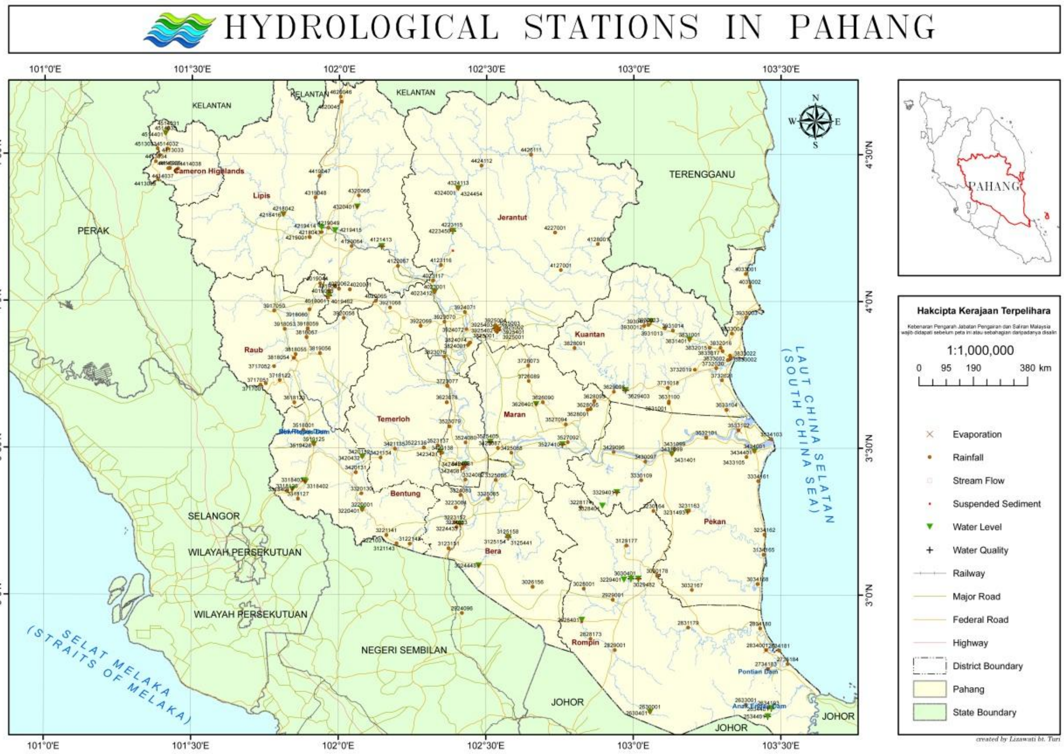
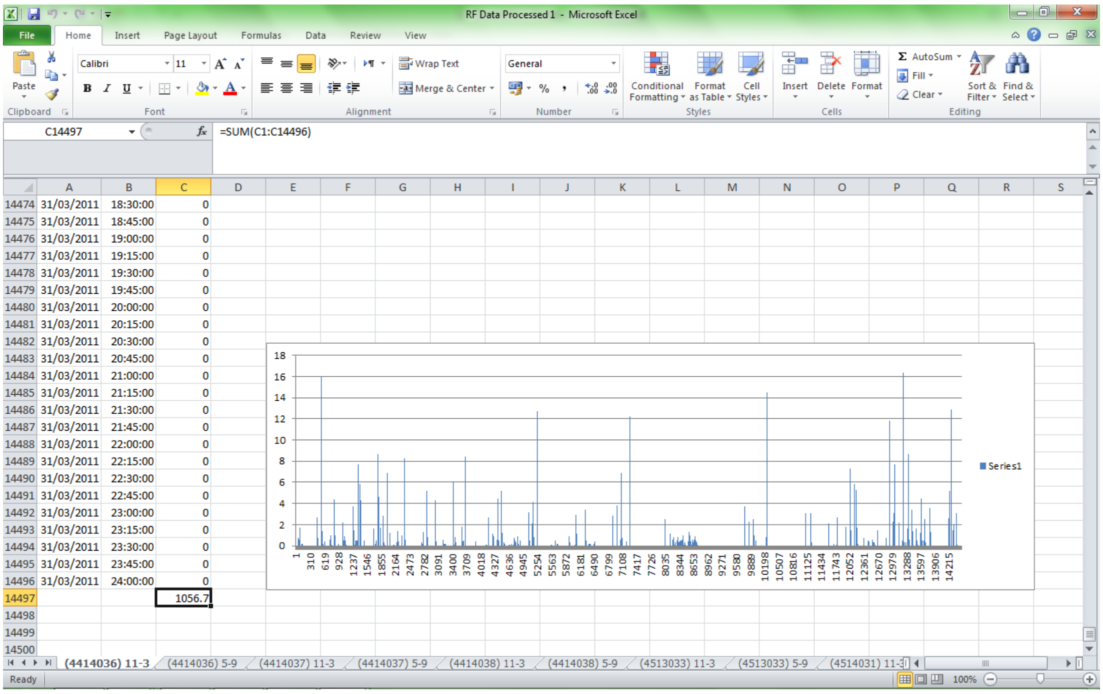
APPENDICES



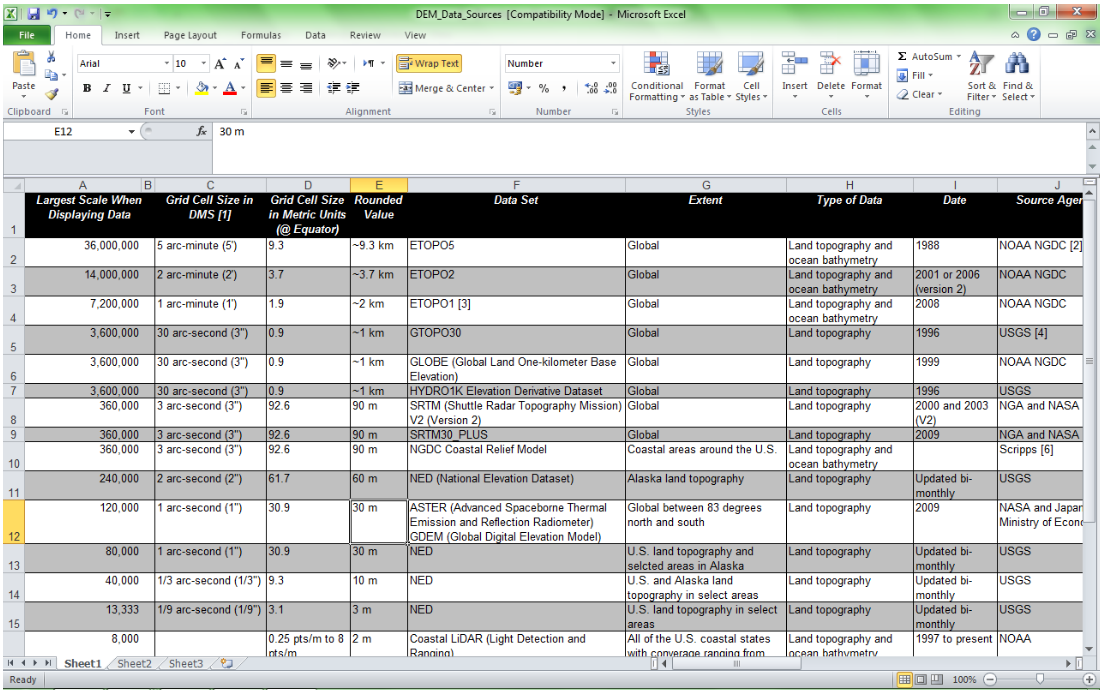
Appendix 1: Rainfall stations located within the mountain ranges are chosen by studying the map provided by JPS. Figure above showing all hydrological stations located in Pahang

STATION NO	STATION NAME	FUNCTION	STATE	DISTRICT	RIVER	RIVER BASIN	YEAR OPEN	YEAR CLOSE	ISO	ACTIVE	MANUAL	TELEMETRY	LOGGER	PROJECT STN	LATITUDE	LONGITUDE	OWNER	ELEV	CATCH AREA	STESEN PEDALAMAN
4413033	Jalan Quarry, Brinching	RF	Pahang	C/Highlands	Sg. Bertam	Pahang	02/29	07/65	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	04 29 45	101 23 25	JPS			FALSE
4413034	Stn. Kajicuaca C.Highlands	RF	Pahang	C/Highlands	Sg. Bertam	Pahang	01/25		FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	04 28 25	101 22 40	PKM			FALSE
4413035	Ldg. Folly Ringlet, Cameron Highlands	RF	Pahang	C/Highlands	Sg. Bertam	Pahang	05/27	1973	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	04 24 55	101 23 05	JPS			FALSE
4414036	Ldg. Boh (Kawasan Kilang)	RF	Pahang	C/Highlands	Sg. Bertam	Pahang	11/47		TRUE	TRUE	TRUE	FALSE	TRUE	FALSE	04 27 05	101 25 30	Ldg.			FALSE
4414037	Ldg. Boh (Bhg. Boh)	RF	Pahang	C/Highlands	Sg. Bertam	Pahang	04/48		TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	04 26 30	101 26 40	Ldg.			FALSE
4414038	Ldg. Boh (Bhg. Selatan)	RF	Pahang	C/Highlands	Sg. Bertam	Pahang	04/48		TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	04 26 55	101 27 10	Ldg.			FALSE
4414040	Mardi C Highlands	RF	Pahang	C/Highlands	Sg. Bertam	Sg.Pahang			FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	04 27 00	101 25 12				FALSE
4419047	Stn. Keretapi Chegar Perah	RF	Pahang	Lipis	Sg. Tenum	Pahang	05/62		TRUE	TRUE	FALSE	FALSE	TRUE	FALSE	04 25 30	101 56 00	JPS			FALSE
4424112	Sek. Keb. Kg. Pagi	RF	Pahang	Jerantut	Sg. Tembeling	Pahang	12/64		TRUE	TRUE	TRUE	FALSE	TRUE	FALSE	04 27 40	102 29 00	Sek.			FALSE
4426111	Ulu Tembeling, Balai Penghulu	RF	Pahang	Jerantut	Sg. Tembeling	Pahang	08/48	11/62	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	04 29 55	102 39 05	JPS			FALSE
4513033	Gunung Brinchang di C.Highlands	RF	Pahang	C/Highlands	Sg. Palas	Pahang	05/54		TRUE	TRUE	FALSE	TRUE	TRUE	FALSE	04 31 00	101 23 00	JPS			FALSE
4514031	Ldg. Teh Blue Valley	RF	Pahang	C/Highlands	Sg. Palas	Pahang	04/48		TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	04 35 10	101 25 10	Ldg.			FALSE
4514032	Ldg .Teh Sg. Palas di Cameron Highlands	RF	Pahang	C/Highlands	Sg. Palas	Pahang	04/64		TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	04 31 00	101 25 00	Ldg.			FALSE
4514035	Sungai Ikan, C Highlands	RF	Pahang	C/Highlands	Sg.Ikan	Sg.Pahang			FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	04 34 12	101 24 36				FALSE
4620045	Paya Paloh	RF	Pahang	Lipis	Sg. Tenum	Pahang	09/46		TRUE	TRUE	TRUE	FALSE	TRUE	FALSE	04 40 40	102 00 30	JPS			FALSE
4620046	Merapoh	RF	Pahang	Lipis		Pahang	1996		FALSE	TRUE	FALSE	TRUE	TRUE	FALSE	04 41 40	102 00 18	JPS			FALSE

Appendix 2: Rainfall stations locations are determine by the inventory provided by JPS. Figure above showing some inventory of rainfall stations in Pahang

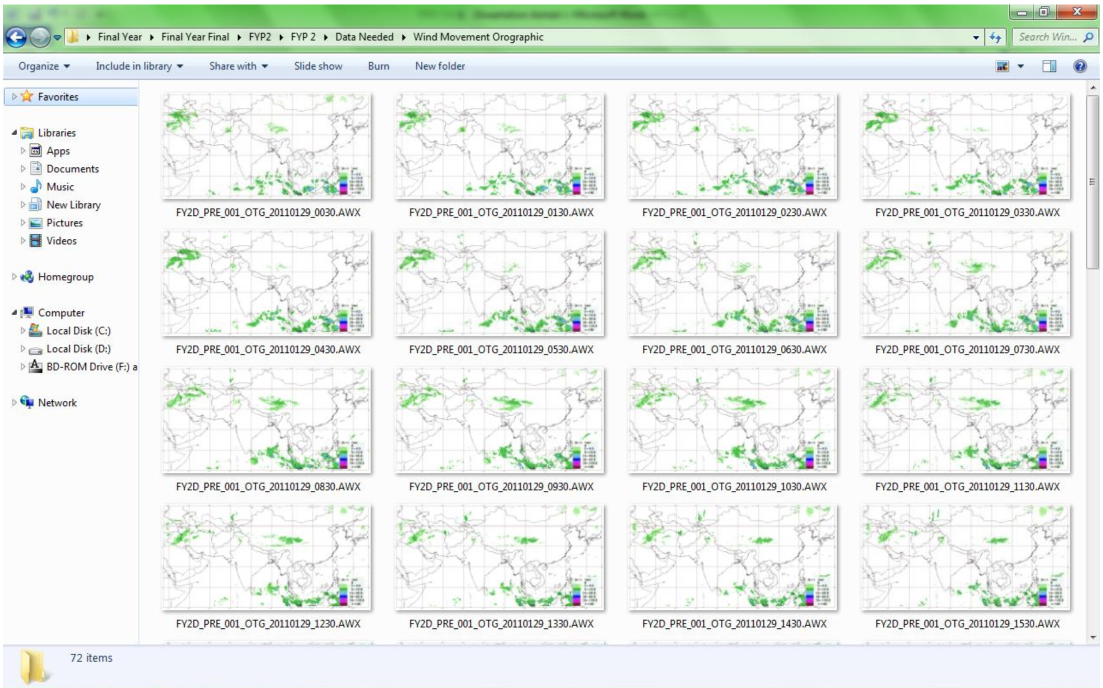


Appendix 3: Raw rainfall data are calculated and summarize for further study. Figure showing rainfall station ID: 4414036 data during northeast monsoon



Largest Scale When Displaying Data	Grid Cell Size in DMS [1]	Grid Cell Size in Metric Units (@ Equator)	Rounded Value	Data Set	Extent	Type of Data	Date	Source Ager
36,000,000	5 arc-minute (5')	9.3	~9.3 km	ETOPO5	Global	Land topography and ocean bathymetry	1988	NOAA NGDC [2]
14,000,000	2 arc-minute (2')	3.7	~3.7 km	ETOPO2	Global	Land topography and ocean bathymetry	2001 or 2006 (version 2)	NOAA NGDC
7,200,000	1 arc-minute (1')	1.9	~2 km	ETOPO1 [3]	Global	Land topography and ocean bathymetry	2008	NOAA NGDC
3,600,000	30 arc-second (3")	0.9	~1 km	GTOPO30	Global	Land topography	1996	USGS [4]
3,600,000	30 arc-second (3")	0.9	~1 km	GLOBE (Global Land One-kilometer Base Elevation)	Global	Land topography	1999	NOAA NGDC
3,600,000	30 arc-second (3")	0.9	~1 km	HYDRO1K Elevation Derivative Dataset	Global	Land topography	1996	USGS
360,000	3 arc-second (3")	92.6	90 m	SRTM (Shuttle Radar Topography Mission) V2 (Version 2)	Global	Land topography	2000 and 2003 (V2)	NGA and NASA
360,000	3 arc-second (3")	92.6	90 m	SRTM30_PLUS	Global	Land topography	2009	NGA and NASA
360,000	3 arc-second (3")	92.6	90 m	NGDC Coastal Relief Model	Coastal areas around the U.S.	Land topography and ocean bathymetry		Scripps [6]
240,000	2 arc-second (2")	61.7	60 m	NED (National Elevation Dataset)	Alaska land topography	Land topography	Updated bi-monthly	USGS
120,000	1 arc-second (1")	30.9	30 m	ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) GDEM (Global Digital Elevation Model)	Global between 83 degrees north and south	Land topography	2009	NASA and Japan Ministry of Econ
80,000	1 arc-second (1")	30.9	30 m	NED	U.S. land topography and selcted areas in Alaska	Land topography	Updated bi-monthly	USGS
40,000	1/3 arc-second (1/3")	9.3	10 m	NED	U.S. and Alaska land topography in select areas	Land topography	Updated bi-monthly	USGS
13,333	1/9 arc-second (1/9")	3.1	3 m	NED	U.S. land topography in select areas	Land topography	Updated bi-monthly	USGS
8,000		0.25 pts/m to 8 pts/m	2 m	Coastal LiDAR (Light Detection and Ranging)	All of the U.S. coastal states with converage ranging from	Land topography and ocean bathymetry	1997 to present	NOAA

Appendix 4: DEM data sources is used as guideline for the selection of appropriate DEM cell size



Appendix 5: All 72 hours of satellite images are obtained and studied to see the pattern of the rainfall precipitation estimation