GEOLOGY AND LANDSLIDES SURVEY USING ELECTRICAL RESISTIVITY IMAGING METHOD AT FRASER HILL, PAHANG

by

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DECLARATION

I declare that this thesis entitled "Geology and Landslide Survey Using Electrical Resistivity Imaging Method at Fraser Hill, Pahang" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ______________________________

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APPROVAL

"I/We hereby declare that I/We have read this thesis and in our opinion this thesis is sufficient in term of scope and quality for the award of the degree of Bachelor of Applied Science (Geoscience) with Honours"

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Geology and Landslide Survey Using Electrical Resistivity Imaging Method at Fraser Hill, Pahang

Muhammad Afnan Iman bin Kamilan, Dr Noorzamzarina binti Sulaiman

ABSTRACT

Fraser Hill is a study area which located in Raub, Pahang. In this study, it will be focusing on geological mapping and also electrical resistivity survey for landslide. It is located in the longitude between 101º45'30'' to 101º47'30'' N and latitude between 3º44'30'' to 3º42'30'' E. Sungai Teruas are set at the research area. Mapping using aerial image and interpretation from previous research conducted to produce the geological map of area Fraser Hill, Pahang with a specific dimension area of study which are 25km² and also doing the survey of landslide. The method uses in geological mapping including from the literature review, aerial photographs, and producing varies map for the study area using GIS. There are two rock units that was identify in research area which consists of granite unit and schist unit. . Landslide has the biggest influenced by the strength of the soil and also distribution of the rock. There are others factors that influence the stability of the landslide such as weathering and also water content. Some of these factor can be detected by using the electrical resistivity survey which also known as ERI. The three landslides have been choosing and for each landslide has been conducted one line to do the resistivity survey. The survey has been conducted in Wenner-Schlumberger array. The result shows the sliding surface of landslide and also low resistivity value. These phenomena in landslide will indicate presence of high water content in the material which is the weak zone of the landslide.

Keywords – geological mapping, Fraser Hill, landslide, ArcGis, Wenner-Schlumberger array, resistivity method

Geologi dan Survei Tanah Runtuh Menggunakan Teknik Elektrik Resistiviti di Fraser Hill, Pahang

ABSTRAK

Kawasan kajian terletak di Bukit Fraser, Raub, Pahang. Dalam kajian ini, akan difokuskan pada pemetaan geologi dan juga kajian keberintangan elektrik bagi tanah runtuh. Kawasan kajian terletak di garis bujur antara 101º45'30" hingga 101º47'30 ' U' dan garis lintang antara 3º44'30" hingga 3º42'30" T. Sungai Teruas terletak di kawasan kajian. Pemetaan menggunakan gambar udara dan penafsiran dari penyelidikan sebelumnya yang dilakukan untuk menghasilkan peta geologi kawasan Bukit Fraser, Pahang dengan dimensi kawasan kajian yang berkeluasan 25km^2 dan juga melakukan tinjauan tanah runtuh. Kaedah yang digunakan dalam pemetaan geologi termasuklah dari membuat kajian literatur, foto udara, dan menghasilkan peta yang bervariasi di kawasan kajian dengan menggunakan GIS. Terdapat dua unit batuan yang dapat dikenal pasti di kawasan penyelidikan yang terdiri daripada unit granit dan unit syis. Tanah runtuh paling utama dipengaruhi oleh kekuatan tanah dan juga penyebaran batu. Terdapat faktor lain yang mempengaruhi kestabilan tanah runtuh seperti luluhawa dan juga kandungan air. Semua faktor ini dapat dikesan dengan menggunakan kajian keberintangan elektrik yang juga dikenali sebagai ERI. Tiga tanah runtuh telah dipilih dan telah dilakukan satu garisan survey keberintangan bagi setiap tanah runtuh. Kajian telah dilakukan dengan susunan Wenner-Schlumberger. Hasilnya menunjukkan permukaan gelongsor tanah runtuh dan juga nilai resistiviti yang rendah. Fenomena kejadian tanah runtuh ini akan menunjukkan adanya kandungan air yang tinggi dalam bahan yang merupakan zon tanah runtuh yang lemah.

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LIST OF ABBREVIATIONS

GPS	GLOBAL POSITIONING SYSTEM
GIS	GEOSPATIAL INFOGRAPHIC SYSTEM
USGS	UNITED STATES GEOLOGY SOCIETY
UMK	UNIVERSITI MALAYSIA KELANTAN
ERI	ELECTRIC RESISTIVITY IMAGING
DEM	DATA ELEVATION MODEL
ERI	ELECTRICAL RESISTIVITY METHOD
JMG	JABATAN MINERAL DAN GEOSAINS

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

Study of geophysics is a study that focused on the physical process that occur on a large and small and others type of scales, it is include from the microscopic scales of properties to the forces like gravity and magnetism that acts towards the planetary and inter-planetary type of scales. Geophysics study is essential because it has an important impact in the welfare to society and the planet of Earth. By using the right equipment the earth physical properties can be measured in certain study. Generally, geophysics is the study to measure the physical properties under the earth's surface. This research is earlier part of final year undergraduate research project which is to investigate about landslide hazard that occur at Bukit Fraser.

Movement of rock or soil residue that move down a slope is called landslide. There are two common things that occur during landslide which they are result of soil failure and rock materials that make up the hill slope and they are driven by gravity forces. In a rock fall, it can require variation of size from a single boulder or topple tons of millions of cubic meters of material in a debris flow. According to Geoscience Australia website landslides can occur due to two factors which are natural and human causes.

In this research electrical resistivity method is use to study the subsurface and weathering grade that affect the landslide hazard. This geophysical method can review the structure and conditions under the surface. Other than that, we also can classify the grade of weathering which is a factor of landslide to occur.

This project also will consist a geological mapping in Fraser Hill area. This geological mapping is conduct to update the geological map and study the general geology of study area. This part will be conduct by interpreting the map such as land use map, stream map, terrain map and others. It will help the study of landslide at that area.

1.2 STUDY AREA

a) Location

Fraser Hill is generally located in Raub District,Pahang and under the administration of the Fraser Hill Development Corporation. According to (Chong, 2004)Fraser Hill name are given due to Scottish traveler Louis James Fraser who bring the tin trade and the impact of mining of tin is ore mine is changed to Golf course in the heart of Fraser Hill.

Fraser Hill is located at central belt of Peninsular Malaysia. It lies on Titiwangsa Range which is act as backbone of Peninsular Malaysia. The geological mapping will be conducted at area South-West of Fraser Hill. The study area will covered 25km² of total area coverage.

In this research there will be two point of landslides that has occurred at road up to the Fraser Hill to be taken as a study area for seismic refraction method. Landslides locality that needs to choose the major or obvious landslides. Other than that, landslides that give the biggest impact to the community, economical, infrastructures are chosen as study area. Figure 1.1 shows the Base Map of Study Area in Fraser Hill, Pahang.

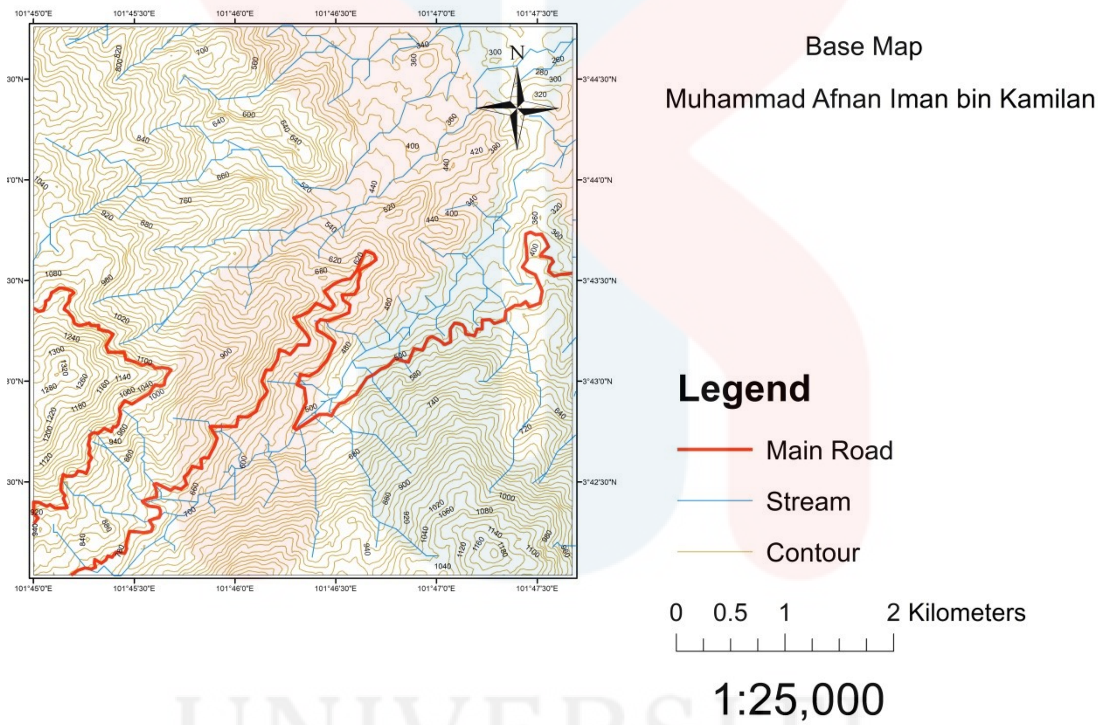

Figure 1.1 Base Map of Study Area in Fraser Hill, Pahang

b) Accessibility

There are two way to access to Fraser Hill which from Kuala Kubu Bharu, Selangor and Raub, Pahang. According to the location of my study area which located at South-West Fraser Hill, the shortest way to access the study area is from Raub, Pahang. The accesses to the study area are easier and comfortable in the main road, however the road are at hilly and unpaved street. The street only has 2 ways for vehicle to go through. The Figure 1.1 shows the accessibility map of my study area.

c) Demography

People distribution in Pahang have a variation ethnic which mostly is Malay by 70%, followed by Chinese 15%, Indian 4%, and others races 4.8%. At Raub itself there are about 178700 people that live in that area. There are approximately 93000 male and 85700 female in that district. The economic activity such as tourism and plantation of oil palm makes other races interested to living in the study area. The people distribution can be seen in Table 1.1

Table 1.1 People Distribution in Pahang, Malaysia

Ethnic	Total population (%)
Malay	70
Chinese	15
Indian	4
Others	4.8

(Source: https://www.citypopulation.de/en/malaysia/admin/06__pahang/)

d) Land use

The definition of land use is referred as the human activity to the land. The landscape of the study area is influenced by the oil palm plantation. Oil palm plantation is located at North-East of my study area. This plantation is becoming the main economic activity at that area. The state government is responsible for the development of economy in Raub, Pahang. All the land use in Fraser Hill or Raub will be monitor by the state government.

Other than that, in the study area there is also reserve forest. This reserved forest is name as Hutan Simpan Bukit Fraser. The reserve forest is located at top of Fraser Hill and located between Selangor, Perak, and Pahang border. The forest is rich in flora and fauna, there are special flora and fauna at this place which is pine tree. It is influenced by the weather and temperature at this places which located at high altitude.

e) Social Economic

The social economic of Bukit Fraser are dominated by full or part time employment, unemployment and labor force. At Fraser Hill area most of the economic social is based on the tourism activity. Other than that, development of economy in oil palm plantation also lead society survive with plantation. Most of the local people owning the tourism activity and plantation that make them gain money by their own. Besides that, at Bukit Fraser has center of education which is school, from that we can say that there is also have people that works as a teacher in the study area.

1.3 PROBLEM STATEMENT

On the road up and down of Fraser Hill there are lots of landslide hazard that can be seen along the road. It is result from the slope cutting in order of urbanization and infrastructures such as road. From this urbanization and infrastructures construction there are lots of landslide occurred at the main road of Fraser Hill.

The landslide hazard can cause many loses such as economic including damages on property, water resources, and casualties and injuries. Geological mapping is needed because the geological features of the area are change overtime. In terms of geological mapping we can identify the correlation between the Fraser Hill geological settings with landslide hazard.

1.4 OBJECTIVES

1. To generate the geological map of South-West of Fraser Hill by using map interpretation.

2. To identify the rock material at subsurface that gave impact to the landslide geohazard.

3. To interpret sliding plane of a landslide at slope using 2-D map of subsurface.

1.5 SCOPE OF STUDY

The study was concentrated on the causes of landslide hazard that occur at Fraser Hill. It is important to know the causes before other step of prevent it to be taken.

In order to study the causes of the landslide at Fraser Hill electrical resistivity method is used in this study. Electrical resistivity is used to determine the subsurface of the soil or rock and the weathering grade of the slope.

The study will be conducted at three points of landslides at road down of Fraser Hill to Raub. The most obvious and large landslides point will be taken as a subject of study.

1.6 SIGNIFICANCE OF STUDY

This research would be an important one to examine the rock weathering quality causes of the landslide. This study will also give important information to the authorities of Fraser Hill to take action and steps to prevent more landslides occurs.

To the community of Fraser Hill they can aware about the geo-hazard activities at their area. It also can prevent more damage happen to infrastructure at Fraser Hill.

The research study will also give enlightenment to the student how to conduct the resistivity survey in order to investigate the landslide hazard.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this part of research will be briefly explain about the background of research on geology, landslides impact due to weathering grades at Fraser Hill, Pahang. The previous research and some general information from others research will be used as a review to the present works. This is important in order to complete the research because from previous works it is easier to find any problem or research gap that can be used on the present works.

2.2 TECTONIC SETTING AND EVOLUTION OF MALAYSIA

Generally, Peninsular Malaysia is divided into three different longitudinal belts which is Western, Central, and Eastern belt (Hutchison, 1977). Every belt has its own distinctive characteristics and geological evolution. As for the western belt it can be subdivided into two more parts which is northwest sector and a Kinta-Malacca sector. The northwest parts cover on Langkawi and Kedah mainland, according to (Koopmans, 1965) area of Langkawi is revised from Devonian to mid-Permian. Then, in the Kinta-

Malacca sector, there was deposition of argillaceous and calcareous sediments in the early Paleozoic followed by more limestone deposition. There is also evidence in this sector that shows metamorphism and folding in the Kuala Lumpur area which is possibly Devonian in age.

The Central Belt predominantly underlie by Permian-Triassic clastics, volcanics and limestone. On the Main Range Granite there are pre-early Devonian deposition of course clastics, argillaceous sediments chert and other rock occur in the marginal belt forms the foothill. On the foothills belt there are ultramafic bodies that were emplaced and during Devonian the whole belt regionally probably undergo metamorphism process. On the northern part of the central belt there are also occupied with Taku Schist and it expose mainly schists, amphiboles and phyllites. The regional metamorphic rocks adjacent to the Taku Schists include the Triassic. Then, the rock assemblage inside the Taku Schists has some similarity to those of the Permian-Triassic outside and it is possible that they represent pre-Permian rocks. The Taku Schist and their adjacent areas during late Triassic suffered uplift, recumbent style folding and regional metamorphism. In the rest of the Central Belt, the orogenic uplift also terminated the marine sedimentation. The continental deposition begins and continued up to the early Cretaceous. During the Late Cretaceous, the continental deposits were uplifted and gently folded.

While, at the Eastern Belt is large underlay by Carboniferous and Permian clastics and volcanics. During late Paleozoic there are probably occur a phase of regional metamorphism, folding and uplift which followed by deposition of an older series of continental deposits such as the Murau and Redang conglomerates according to

(Khoo & Tan, 1983). In the Late Triassic orogenic event uplifted the Eastern Belt. After that, deposition of a younger series of continental deposits which are only gently dipping and probably they were uplifted in the late Cretaceous.

2.3 GEOLOGICAL SETTING OF FRASER HILL, PAHANG

Fraser Hill located at uplift of granite batholith of Main Range of Titiwangsa which is dominated with biotite granite and amphibole granite. This main range was integrated with two major fault which is Kuala Lumpur Fault and Bukit Tinggi Fault. Other than that, minor fault also can be seen at this range that the granite outcrop has been foliated and has long lineation and mylonite (Koopmans, 1974)

The earlier geology research has been conduct at Fraser Hill is the study that has been doing by (Roe, 1951)In that study it stated that Fraser Hill has a granite rock that has fined and coursed grain. It is said that, on the fined grain granite has more cracks compared to the coursed grain granite. Most of the granite found in Fraser Hill is formed in early Mesozoic or early Tertiary. According to Roe (1951) the coarse grain granite formed during the early formation of the rock. It is because the tin mineral that exists on the fine grain granite. Moreover, from this study it is reliable that the granite has undergoes crystallization of magma during the last phase.

Other than that, Roe (1951) has reported from its study, the Fraser Hill area formed by amphibole schist. This is supported also by (Koopmans, 1974) which is it has actinolite schist, tremolite schist and proxene schist (Goh, 2011) also reported that schist amphibole can be found KM15 Jalan Kuala Kubu Bharu – Bukit Fraser it is from the structure roof pendant on the granite rock.

2.4 ELECTRICAL RESISTIVITY SURVEY

2.4.1 INTRODUCTION

Geophysics is a branch of geoscience that use principles of physics to study about the earth. This method was expanding fast during this decade and it became one of the technology in earth subsurface survey. Geophysics also helps more researchers in order to understands about the earth tectonic theory (Samsudin, 2016).

Usually resistivity of rock is depends on the amount of groundwater present and based on the salts dissolved in the rocks. Besides that, the resistivity also decreased by the presence of many ore minerals and by high temperatures.

The main purpose of using this method are therefore for mapping the presence of rocks which has different porosity that particularly are connected to hydrogeology for detecting aquifers, contamination and for mineral prospecting. There are other uses such as investigate saline and other type of pollution, archaeological surveying and detecting hot rocks.

This resistivity surveying method use to investigate the subsurface by passing electric current through it by means of electrodes pushed into the ground. Before this, these techniques have been designed to determine the vertical structure of earth which known as vertical electrical sounding (VES), or lateral variation as electrical profiling. But then, the more sophisticated method is being improve use when there are both vertical and lateral variations.

Electrical resistivity is a study of geology that use geophysics theory that may be contracted in the context of flow of current through a subsurface medium that consist of layers of materials with different resistivity (Hermana, 2000).

Based on previous research found that there are several ways the current flow through the rock mass. There are electrolytes, electronic, dielectric conductivity (Reynolds, 1997). The movement of ions in the electrolyte is the study field of the electrolytic conductivity. Ion concentration and mobility of ion are depending and rely on the type of ion. The specific charges will be control the movement of the ions. For the weak conductor it just exists the dielectric conductivity. In research by (Reynolds, 1997), in every rock have their own conductivity and porosity. Later, the conductivity will be affected the porosity of the lithology. For rock such as graphite, pyrite, chalcopyrite, galena, and magnetite will have categorized and grouping as a good electrical conductor.

Induced polarization survey is a survey that measure the time for potential changes (voltage) decay in between two electrode that when the electric current are decided on top of the soil which first done by Schlumberger (1920). Soil characteristics that allow induced polarization when it contain clay minerals which make it to expand and shrink, this characteristics of soil often cause the damage on the engineering structure (Peters & Fowler, 2002).

2.4.2 RESISTIVITY ARRANGEMENT

There are three types of commonly and normally used electrode array which is Schlumberger arrays, Wenner arrays and also Dipole-dipole arrays.

I. Wenner Arrays

Wenner consist of four collinear with equally spaced electrodes. The arrangement of the Wenner arrays the spacing will be expand about the array midpoint while maintaining and equal spacing between each electrode. This array only can survey in moderate depth of investigation (Loke, 2018)Table 2.1 shows the advantages and disadvantage of Wenner Arrys.

Table 2.1 Advantages and Disadvantages of Wenner Arrays

Advantages	**Disadvantages**
a. Is good resolving vertical changes b. Can detect high background noise and can give true value of subsurface	a. Poorly in detecting horizontal changes

(Source: Loke, 2000)

II. Dipole-dipole Arrays

According to Loke (2000), this survey is approximately use because of the low electromagnetic connection between the current and potential circuits. This arrangement is involving of the potential electrodes, pair of electrodes and also currents. The dipole is a paired electrode set with the electrodes located closed to one another. Table 2.2 shows the advantage and disadvantages of dipole-dipole arrays

Table 2.2 Advantages and Disadvantages Dipole-Dipole Arrays

Advantages	Disadvantages
a. Good mapping for vertical structure, such as dykes and cavities	a. Poor in mapping horizontal structure b. The small signal strength for large value of the 'n' factor.

(Source: Loke, 2000)

III. Schlumberger Arrays

The four collinear electrodes electrodes were used in this Sclumberger array. The arrangement of this array was comprise by the current electrodes and the inner two electrodes. The potential electrodes were positioned at the same position while for the current electrode are increase to a greater separation. The expanding the current electrodes take place roughly six times per decade. Table 2.3 shows the advantage and disadvantages of Schlumberger arrays

Table 2.3 Advantages and Disadvantages of Schlumberger Arrays

Advantages	Disadvantages
a. Fewer electrodes need to be moved b. The cable length for potential electrodes is shorter c. Greater probing depth and less time-consuming then Wenner	a. Long current electrode cable b. Recording instrument need to be sensitive c. Array may be hard to coordinate in the field

(Source: Loke, 2000)

2.4.3 GEOPHYSICAL METHOD ANALYSIS

The geophysical electrical resistivity analysis is made by the data obtained from the fieldwork. The data are obtained when the ABEM Terrameter LS has been conducted in the field. The measuring taking a long time to obtain the final results. In the field we have to set up the ABEM Terrameter to choose the method. In this study Wenner – Schlumberger array has been choosen. Then the final result will be obtain and process in the field.

According to (Reynolds, 1997), the geo-electrical resistivity method is one the most flexible and important for the exploration of the research environment. Reynolds (1997) has highlighted that this method has been develop in year 1990. It has been use the general principle of the Ohm's law. By the time, this method can be used for detecting the properties underground and subsurface, geological structure and the resistivity of the subsurface of the earth in selecting of the geohazard such as landslide. The data that has been obtained from the ABEM Terrameter LS will be transfer to the flash USB. Then the data will be transfer to the software of Terrameter LS Toolbox. In that software, the topography data can be put in the software. Then, the all data in this software can be export to DAT file. The Terrameter LS Toolbox has its own functions and the main reason of using the Terameter LS Toolbox is to export and convert the data field to be DAT file.

After the fieldwork data has been converted to the DAT file, the data can be process by using the Res2DINv software. This software actually can give the better information that could lead the accurate interpretation of the resistivity pseudosection profile.

2.5 LANDSLIDES

2.5.1 INTRODUCTION

Landslides are important activities of hazard that occurs around the world, it is connected with other hazards such as volcanic activity or earthquakes (Keller, 2019). The majority of landslides are small and slow but it can be fast and catastrophic. Moreover, according to (Turner & Schuster, 1996) they are categorized landslides into five types which is fall, topple, slide, spread, and flow.

a. Fall – Rock or debris move rapidly and extreme in vertical movement. This type usually has low moisture (Gilchrist & Summerfield, 1991).
b. Topple – a process of rotation out of a mass of soil or rock about a point or axis below the center or gravity of the displaced mass.
c. Slide – movement of soil or rock through the downslope when there is a rupture on the surface. Slide has two types which is rotational or translational and the moisture is low to moderate (Gilchrist & Summerfield, 1991).

d. Spread – Movement of cohesive soil or rock mass over a material unstable. Due to the different material and water interaction the movement is complex.

e. Flow – movement of no consolidate materials and this movement can be fast or slow depends of the materials and the moisture (Gilchrist & Summerfield, 1991).

One of the reason landslides occur is the weather which is can be complex in different types of landslides. Extreme weather events such as high intensity rainfall or long periods of rain may produce landslides dangerous (Keller, 2019)

2.5.2 OLD-DORMANT LANDSLIDE

Normally landslides that hidden under thick and densely forested are called old-dormant landslides. It is in a large scale and deep-seated (Tajul Anuar, 2019). Due to increase of infrastructure damage and disruptions to human activities this type of landslide has been increasingly recognized as a serious natural terrain geohazard.

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

In this chapter the materials and methods used in the study of geological mapping and analysis of rock type which are igneous rock, metamorphic rock or sedimentary rock. Seismic refraction survey in this study. The methodology is including the data collection, data processing, data analysis and interpretation.

3.2 MATERIALS AND METHODS

3.2.1 GEOLOGICAL MAPPING

Materials

- **Computer Software**

  Computer software is used to get the geological data from previous research or studies.

- **Map**

  Many types of maps such as landuse map, landslide map, stream map, watershed map and other are use in this study for the interpretation part.

Methods

- **Preliminary Studies**

  Preliminary studies are conduct by referred to varies medium like books, journals, and source from internet. This reference medium is needs to have early information about our research study. From the related research material it is important to use in literature review that relate to study.

  Other than that, base map produce using ArcGIS software is used to have clear perspective for the research. Base map is important key for preliminary studies on lithology, access to study area, rock and general features of the study area.

  Next, a variety type of maps is needed in this studies which need to be done by interpretation of map such as terrain map, aspect map, landuse map, stream map, and others.

- **Field Studies**

  There are no fields studies in this research project, the studies will be based on the interpretation of map. The interpretation of map can be done by using computer software such as ArcGis, Envi, Terrameter Toolbox, Google Earth and many more.

  a) Interpretation Map Using Google Earth

  From the Google Earth interpretation we can know the landform of the study area and cross section of the area. The steps as follows,

- First step

Open the google earth pro software on your laptop.

- Second step

Use search tools for searching your study area in google earth.

- Third step

Once you have found your study area. You need to add placemark in your study area based on coordinates. Add 4 placemark (A, B, C, and D) to complete the placemark.

- 4th step
- You can add polygon on the google earth pro software by using the tools "add polygon"
- Add polygon followed the placemark you have sign earlier.
- Then, landform can be identified using following steps.
- 5th step,
- Identify the landform that exist at your study area such as hill, high hill, valley, and others.
- After you identified your landform, you need to digitize it in form of polygon.
- Add a new polygon layer, then make a polygon around your landform.
- After done digitize, you can change the colour of polygon as you wish.
- Then click "Ok"

- After digitize all the landform, in order to transfer all the layer to ArcGis software you need to save the layer in format KML.
- Right click on the layer you want to save, and select the "save place as"

b) Generate Map Using Arcgis Software.

A. Landform Map

One of the types of geomorphology is landform. Landform is a natural or artificial feature of the Earth's ground surface or some other celestial object. Landforms together shape a given surface, and are known as topography for their arrangement in the landscape. Landform extracted from a simulated elevation model using some automated techniques, where modern satellites and stereoscopic aerial surveillance collected the data

B. Landslide Susceptibility Map

Landslide or also known as landslip is the downward movement of a mass of rock, debris, earth or soil. Landslides occur when the shear strength of the materials that form the slope exceeds the gravitational and other types of shear stresses within a slope. Shear stresses can be built up by a number of processes within a slope. These include overgrazing the base of the slope, such as natural erosion or excavation, and loading the slope, such as a water inflow, a rise in the groundwater table or the accumulation of debris on the surface of the slope. Then, short-term stresses such as those imposed by earthquakes and rainstorms can contribute to landslide activation.

Landslides may also be enabled by processes that reduce the shear strength of a material in a slope. A map of landslide susceptibility will identify the areas that undergo landslides and are measured from low to high. The map of the landslides susceptibility takes into account where and what causes the landslides occur. The parameter that can be used in landslide susceptibility assessment such as slope/relief, aspect, vegetation, land use, soil, drainage density, distance from river/fault/lineament/road and lithology. For this landslides susceptibility map only use four parameter which is slope, aspect, drainage density and hill relief.

C. Fluvial System

Fluvial in term of geography and Earth science refer to the processes associated with the river and stream and the deposit and landform that created by them. When the stream, are associated with glacier, ice sheet or ice caps, the term change into glaciofluvial and fluvioglacial.

Fluvial processes include the motion of sediment and erosion or deposition on the river bed. Erosion by moving water can happen in two ways. Firstly, the movement of water across the stream bed exerts a shear stress directly onto the bed. However, if the river carries significant quantities of sediment, this material can act as tools to enhance wear of the bed. Sediment in rivers is transported as either bedload or suspended load. There is also a component carried as dissolved material.

Fluvial geomorphology contains a rich tradition of river evolution conceptual models. Fluvial geomorphology is the study of the form and function of streams and the interaction between streams and their surrounding landscape. 'Fluvial' refers to the running water processes, 'geo' refers to the earth and 'morphology' refers to the shape of the channel. Morphology of streams is dynamic and constantly changing.

D. Watershed Map

A watershed is an upslope area which contributes to the flow of water as concentrated drainage. Using the Spatial Analyst toolbox Hydrology toolset, this area can be delineated from a digital elevation model (DEM).

Data Processing

After map are produce and interpretation has be done, all the data need to be processed to make a Geological Map, this data processing can be done by using ArcMap.(Reynolds,1997)

3.2.2 ELECTRIC RESISITIVITY IMAGING METHOD (ERI)

In this part, a secondary data will be used which a data that get from the field study. The data need to be process using the software and produce a 2-D map of subsurface of landslide. From the subsurface map, the structure of the subsurface is investigate and also the type of rock is determine to relate all the characteristics with the potential of landslides hazard occur.

a) Data acquisition

Secondary data is acquired from previous researcher which is also my co-supervisor a lecturer from UKM. The data that acquired is a pseudosection from the electric resistivity method use.

At field survey line for electrical resistivity is around 100 meters length of cables with 21 electrodes. All the lines survey is using Wenner-Schlumberger array.

The reason of choosing 100 meters lines of survey is because the height of landslide location is not more than 100 meters. From the survey, the depth of subsurface data obtained around 10 -15 meters.

b) Data processing

The research is made by data obtained from the fieldwork study. Res2DINv software has been use to process the data that obtain from fieldwork. This software will provide information that could assist with more accurate interpretation. The processing in ABEM Terrameter LS also require long time to finish. This processing will be process in the field and then will continue after field work in Res2DINv software.

According to (Loke, 2018), to process the data from field, we have to convert the data into DAT file. Then after entering the DAT file into the Res2DINv, the bad data points must be removed to avoid the processing of the bad data points. The resist to remove the bad data points will give an inaccurate result in the final results. Before carrying the inversion, we must make sure that we have edited bad data points by clicking it with the mouse of the computer. Normally, the bad data points, cause of the problem of the poor ground contact of electrodes while we are doing in the field. It will give a result of the higher error reading in the final results.

After, remove the bad data points, bad data points can be checked using the " Edit File". Then, the data points that has been edit, it will be saved as a new file. The next step, the data has been saved will be proceed by inverse the data by using the “Inversion Option”. Then it will process until the error can be minimized. Finally to get the true resistivity model, the “Least- Square Inversion” has been clicked. Then the pseudosection profile has been produced with the minimum error.

b) Data analysis

The data that require in fieldwork and also in the laboratory will be interpret more to get more information about lithology, structure, mineral composition and moreover. Besides that, with using ArcMap 10.2, we can do analysis about the geological mapping and also cross section. From the map that we done by using ArcMap 10.2, we can interpret the type of lithology by interpreting the shape of contour. We also can study about the geomorphology of that area with focusing the elevation of the topography of the study area. Furthermore, in the laboratory we can interpret the shape of the mineral by using the microscope. From the shape and habitat of the minerals, we can interpret what kind of mineral in the rock in our study area.

CHAPTER 4

GENERAL GEOLOGY

This chapter explains the geological process that had been undergoes in the study area. The research on general geology will include the study on all aspect of geology such as geomorphology, petrology, lithology and structure. Other than that, the study can be broad to the study of stratigraphy, historical geology, and also paleontology. Geological process also will be highlighted in this chapter such as weathering process and drainage system that exists in the study area.

In this chapter all the information was described by obtain the data from literature review, and interpretation using secondary data. Geological mapping activity cannot be carried out due to pandemic situation. From that situation activity such as fieldwork for collecting data, measurement and make observation at study area cannot be done. The only option for obtain the data is from the interpretation using secondary data from internet and geology agencies.

4.1 Accessibility

The study area is cover by the forest and also palm plantation or farm. From Google Earth images we can see in the north-east of the study area there has plantation. It is located at low hill area of the study area. The other part of study area is covered by the forest. To arrive at the study area there are two main roads that can be used. The first main road is from the top of Fraser Hill- Raub District and the other road is Raub District at the east part of the stud area. There are lots of landslides that have been occurred or landslides is possible to happen at the study area because the road is constructed at hill area. Figure 4.1 shows the study area at Fraser Hill, Pahang.

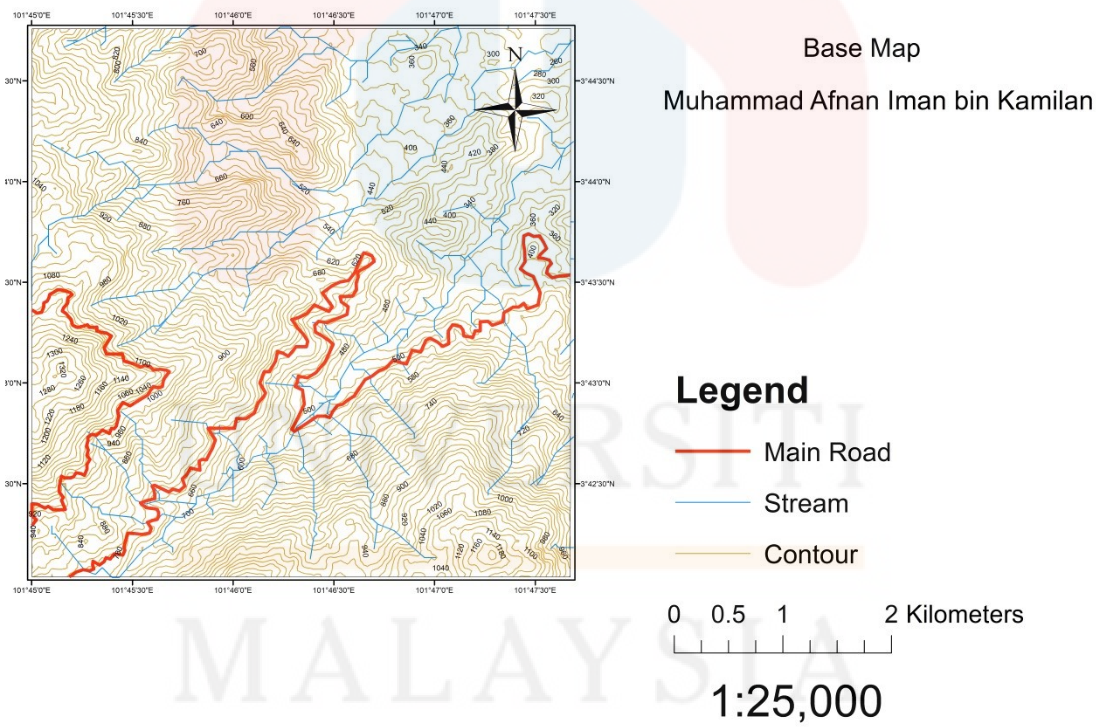

Figure 4.1 Main road in study area

4.2 Forestry

The study area is rich with the vegetation such as farm or oil palm plantation and also forest tree. These farm plantation and palm plantation mostly owned by the local people that gain their income from the activity done at that area. Other than that, the study area is also rich with the forest tree. There are two reserved forest at that area that covered most of the study area. The forestry of the study is shown in Figure 4.2.

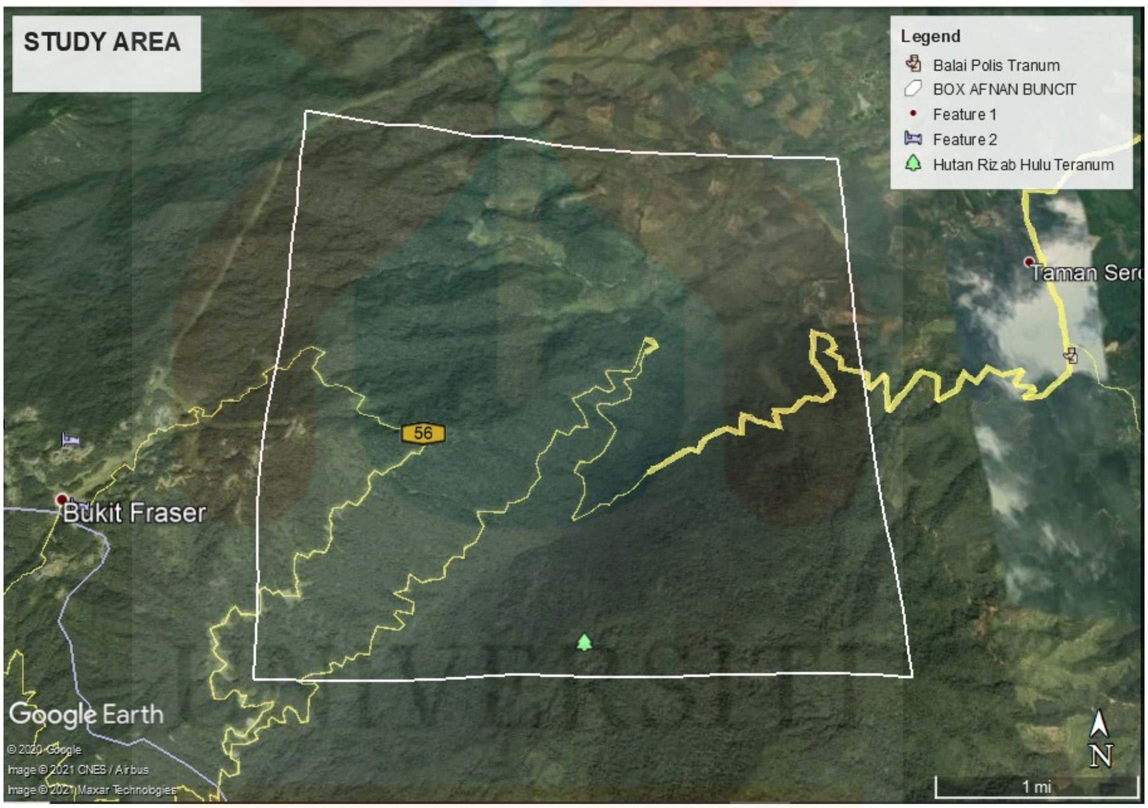

Figure 4.2 Forestry at study area

4.3 Geomorphology

4.3.1 Geomorphologic classification

There are several processes that formed a geomorphology that can be seen at some area such as tectonic setting, ecology, human activity, and also climate. This study is defining by the influence of the processes that will shape the formation of the geological structure and also lithology. Moreover, from the geomorphology we can determine the drainage system, the steepness of contour, the slope area and also weathering process. From that we also can determine and study the shape of landform, plateau, and hill. This part also will discuss about topography, drainage system, landform, hill slopes, watershed, contour pattern and also weathering process.

4.3.2 Topography

Topography can be used in determining the position of any feature or more generally any points in terms of both of a horizontal coordinate system such as latitude, longitude and altitude. As refer to Figure 4.3, the lowest elevation in the study area is 260m while the highest elevation is 1360m. In the study area are majority covered by the forest. There are also land covers by the farm and palm plantation. Since the study area are located at the forest and also farm and palm plantation, the accessibility only by using the unpaved road and the main road at study area.

The top elevation in the study area is located at western part of study area. The study area is located at mountain ridge which is located at central belt of Peninsular Malaysia.

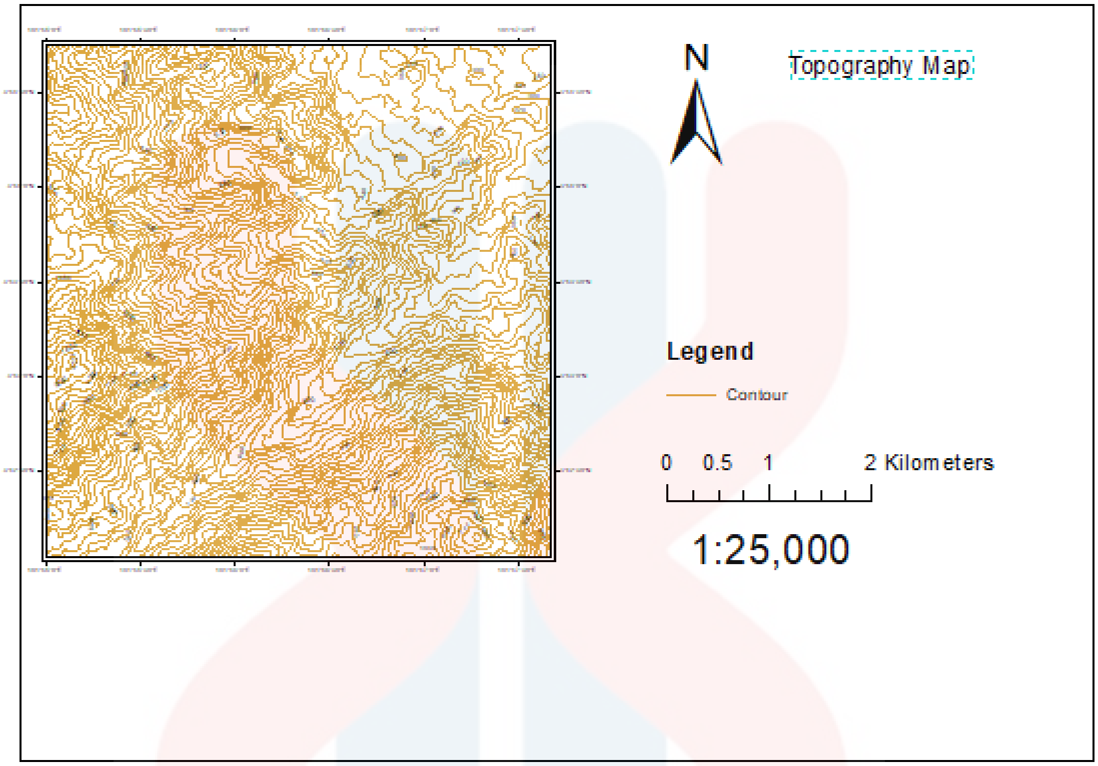

Figure 4.3 Topography map

4.3.3 Drainage Pattern

Drainage system is mean by system that related to river, lake, and stream's pattern that formed in the formation of valley, channel and others. Some of geological structure formed affected due to drainage pattern such as fold, fault, and joint. There are many types of drainage pattern such as parallel, rectangular, radial, angular and deranged.

The drainage pattern formation also can be formed due to the topography of the land either that area was covered by hard rock or soft rock and as well as the gradient of the area itself. Moreover, topography and geology of the study area also one of the important factor in formation of the drainage system. In geology studies recognize the drainage pattern can help us to define the rock types, recharge area and potential, and also its general hydrologic condition. The Figure 4.4 shows the map of the drainage of the study area and Table 4.1 shows the characteristics of drainage pattern.

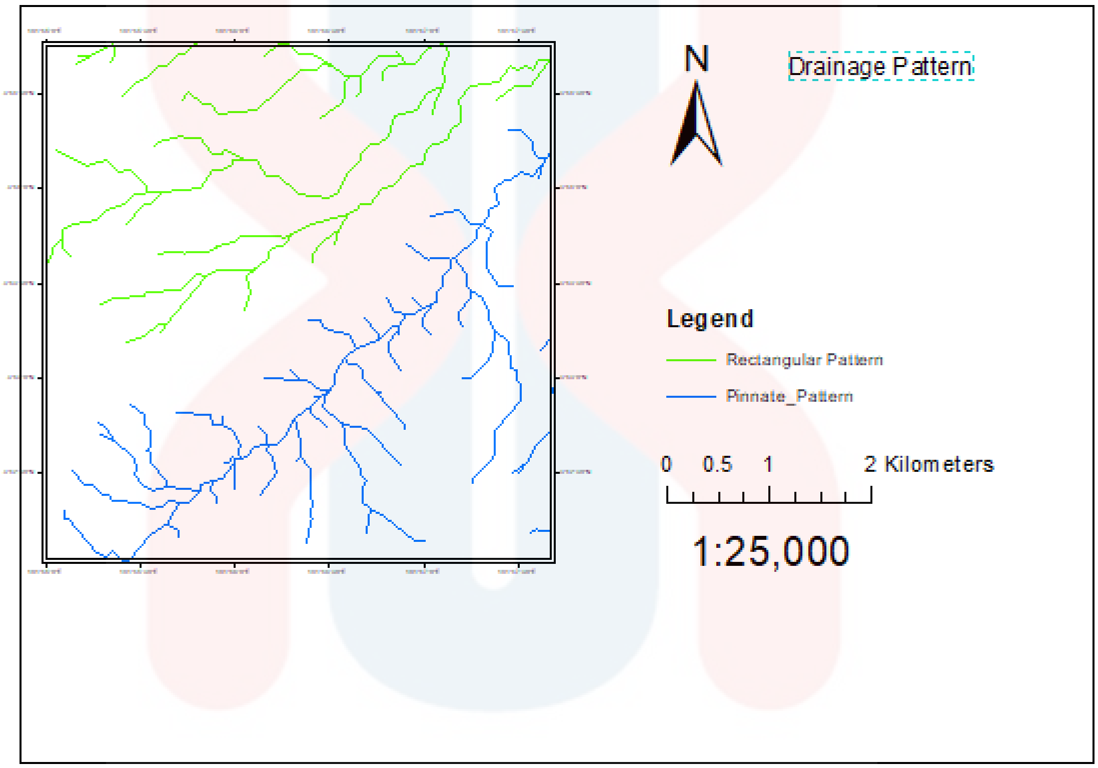

Figure 4.4 Drainage pattern of study area

Table 4.1 Classification of drainage pattern

Rectangular Pattern	Pinnate Pattern
Drainage Pattern that have rivers with right-angle bends. It forms where the bedrock is faulted and jointed	Pinnate Pattern develops at a narrow valley flanked by steep ranges. The tributaries originate from steep sides and join to valley at acute angle

4.3.4 Watershed

This part is explains about the watershed which means the place where all of water will flow and will be accumulate. From the map that has been produced, the watershed has been flowing from the hilly area to tributaries and will accumulate at the river. The main river that the watershed will accumulate in the study area is Sungai Teranum. The watershed of the study area is shown in Figure 4.5

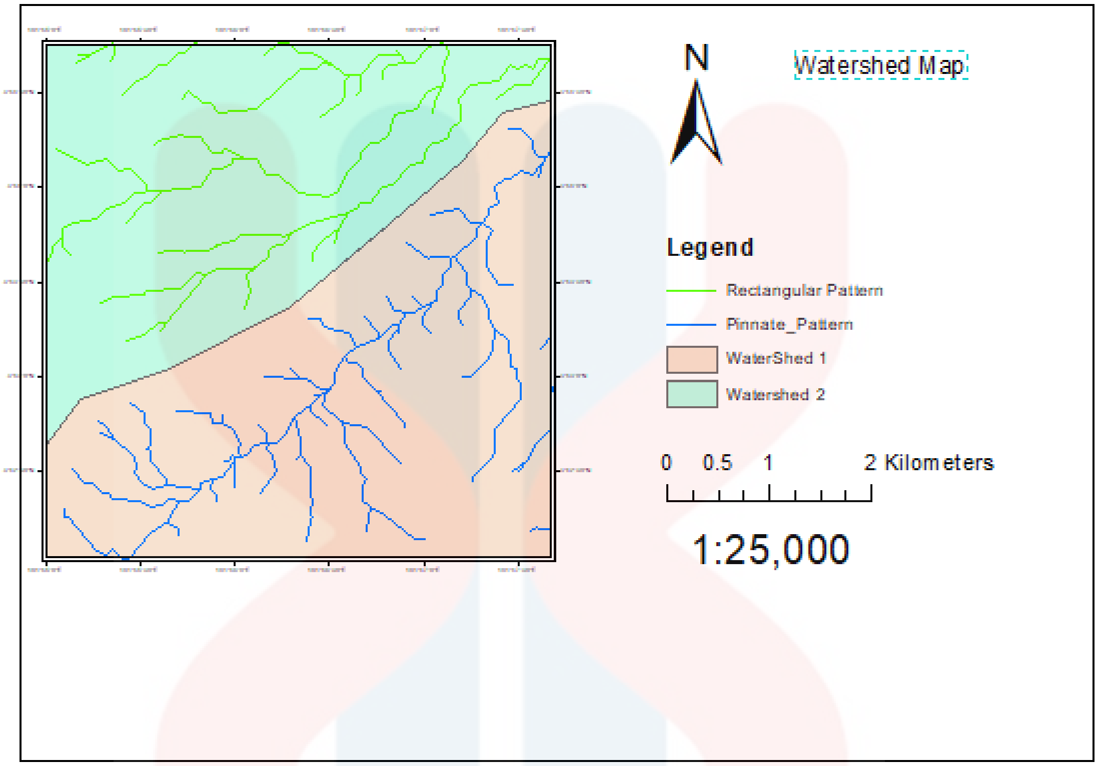

Figure 4.5 Watershed map

4.3.5 Landform

Landform is one of the geological features that exist in the earth surfaces, it is part of the terrain. Some of the landforms that exists are canyon, valley, ridge, and basin. The landform formation usually created by tectonic plate movement under the earth. Other than that, erosion process that affected by agent such as water and wind also can create new landforms like valleys.

In the study area at Fraser Hill, Pahang the landform mostly covered by the high hill slopes geomorphology and also hill geomorphology. Some of the area is also covered by tributaries type. This landform has been influenced the position of the research area which it lies to the central belt of the peninsular Malaysia which due to the tectonic plate movement. Figure 4.6 shows the landform map in the study area.

Most of the landscape at the study area is covered by hillslopes. Most of the hillslopes are steep. This condition has occured due to the natural condition such as water, sediments and rock move down slope under natural condition due elevation and gravity. The present topography and soil thickness reflect the geology process such as weathering, erosion, and also depositional activity.

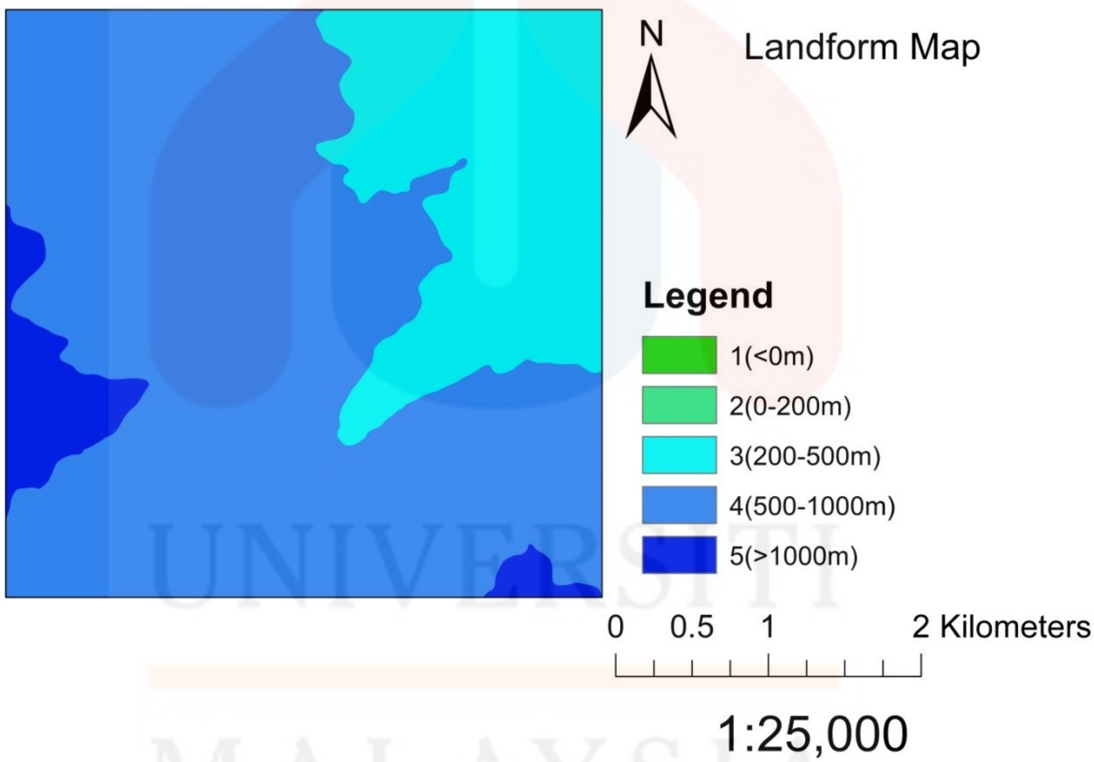

Figure 4.6 Landform map

4.4 Stratigraphy

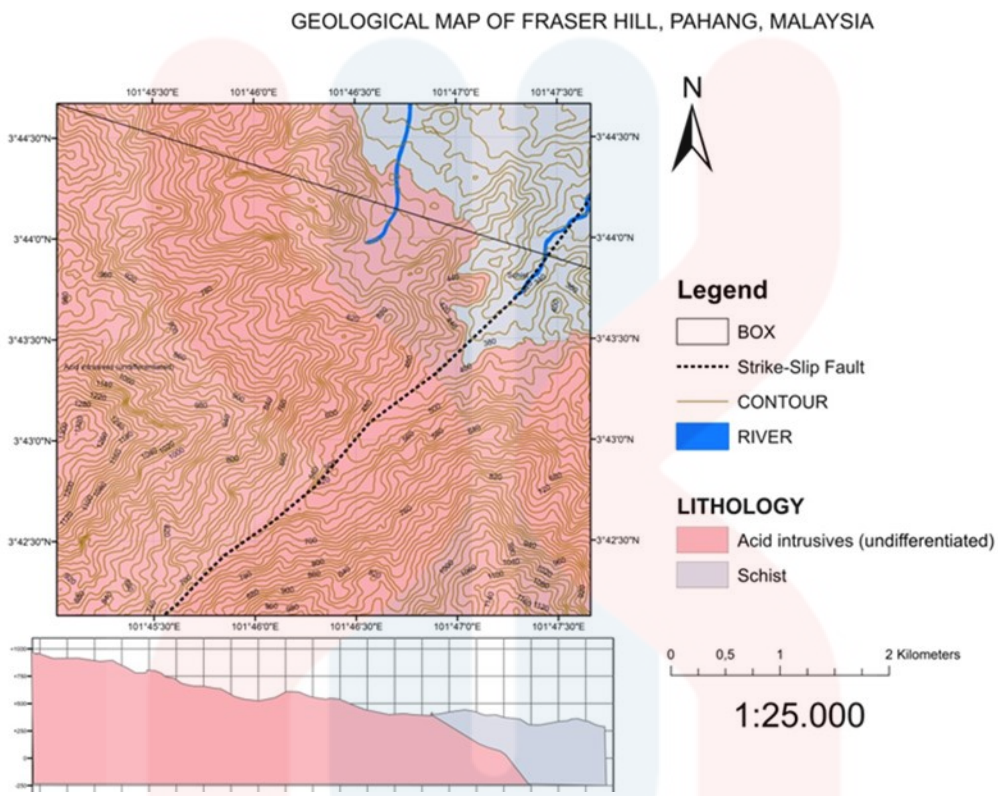

Figure 4.7 Geological Map of Study Area

Stratigraphy is the field of geology that concerned with the study of rock layers which is known as strata and layering. In this study it needed to interpret the history represented by these rock layers. Lithostratigraphy is the arrangement of rock according to their age which the oldest rock unit lies at the bottom and the youngest unit of rock lies at the top. The lithostratigraphy of study area is shown in Table 4.2

The formation of study area is main range granite on central belt of peninsular Malaysia and also Bentong-Raub Suture. The age of main range granite is around Mesozoic and Early Tertiary while the Bentong-Raub Suture is on the Silurian or Ordovician age. This statement can be proved by the previous research which is done by

(Hutchison, 1977) and also (Roe, 1951)reported the area of Fraser Hill formed by amphibole schist.

For the main range granite the rock unit can be found in the study area are biotite and amphibole granite. While for the other rock unit in the study area are interpreted as schist. There are several type of schist may be found in the study area such as amphibole schist, actinolite schist and tremolite schist.

Table 4.2 Stratigraphy column of study area

Age	Lithology	Description
Mesozoic/ Early Tertiary	Biotite and amphibole granite	Fine grain, coarse grain. The granite intrudes the schist unit.
Silurian/ Ordovician	Amphibole schist, actinolite schist, tremolite schist	Foliated minerals There are evidence of the schist has been intruded by the roof pendant at the top of the Fraser Hill.

4.5 Lithostratigraphy

4.5.1 Schist unit

Schist is a foliated metamorphic rock. The texture of the rock usually a medium to coarse grained, it is also strongly foliated rock which rich in platy or elongated minerals. The formation of schist occurs during regional metamorphism. The parent rock for schist is can be either siltstone or shale, when the metamorphism caused the rock change due to high pressure and temperature and formed schist unit.

From the previous research it stated that the schists of the Foothills Range are predominantly quartz-mica schists with variety of politic such as quartz-graphite schist and subordinate lenses of amphibole schist. According to (Haile, 1977)in the Cheroh area which nearby the study area the schist contains biotite as well as muscovite, sericite, chlorite, and carboniferous matter. It is also considered that the rocks are belong to epidote-biotite sub facies of the greenschist facies.

It is said that the schists are strongly folded and also shows a micro-folding and crenulation that indicate the rock already folded at least twice. The intensity of folding and schistosity shows that obviously to their position on the flanks of the granite intrusion. The schist units are separated because there are overlying chert or argillite by a major unconformity. Between the schist and the overlying bed there are no discordancy in general strike even though there are difference in metamorphic grade and tectonism. It is said that the schist outcrop extends 37 km along a north-north westerly trend and both end is truncate by the granite.

4.5.2 Granite unit

Granite is a volcanic rock that intrudes the earth surface to form a batholith. It is phaneritic rock which shows a light colored. The primary mineral that usually exists in granite is quartz, feldspar, and plagioclase. Granite can be both either fine grain or coarse grain, it is according to the cooling process that occur on that rock itself either slow or fast cooling. Fine grained granite has more discontinuities compared to coarse grain granite. It is because there has difference in their rock materials and rock mass.

Based on my readings and interpretation using aerial image, most of the study area in Fraser Hill is covered by the granite intrusion. This feature can be seen obviously from the geomorphology and landform of the study area by using terrain map, landform map, and others. There are several types of granite that can be found in Fraser Hill such as biotite and amphibole granite.

Other than that, from my interpretation based on contour at the study area there are noticeable changes in contour pattern that indicate the changes in type of rock. There are area that has gentle slope and also steep slope. It interpreted as contour that has steep slope is the granite unit. It is because we can see the forms of intrusion in that area.

Then, based on previous research done by (Roe, 1951)reported that rock unit that exist at Fraser Hill are fine grain and coarse grain granite. Granite found is believed to be in Carbon age and its likely to form during early Mesozoic or early Tertiary. On the same study its reported that coarse grain granite appear during early formation and based on the tin mineral on the granite it is reliable that granite undergo final phase of magma crystallization.

4.6 Structural Geology

Structural geology is the study about the discontinuities such as deformation, structure, and also arrangement of the rock which affected by the movement of plate tectonic. The example of the geological structure is fault, fold, cleavage, vein, and joint. In this chapter the analysis of geological structure done by interpretation the terrain map, landform map, and others. From that several map we can do lineament analysis at the study area. Figure 4.8 Shows the lineament map of Fraser Hill, Pahang and figure 4.9 Shows the rose diagram analysis of lineament at Fraser Hill, Pahang

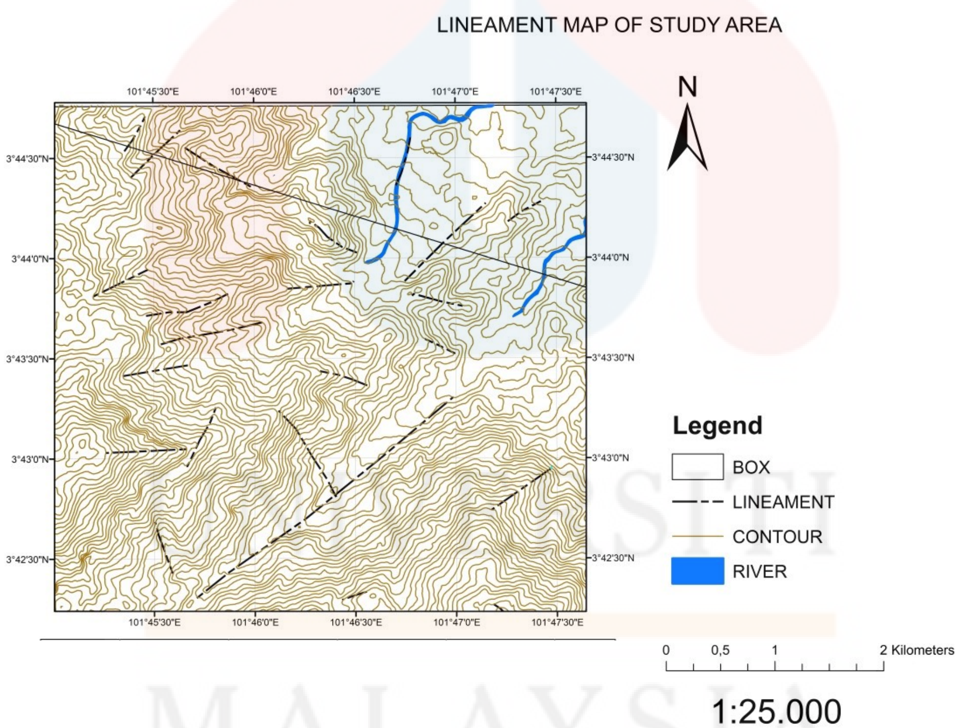

Figure 4.8 Lineament map

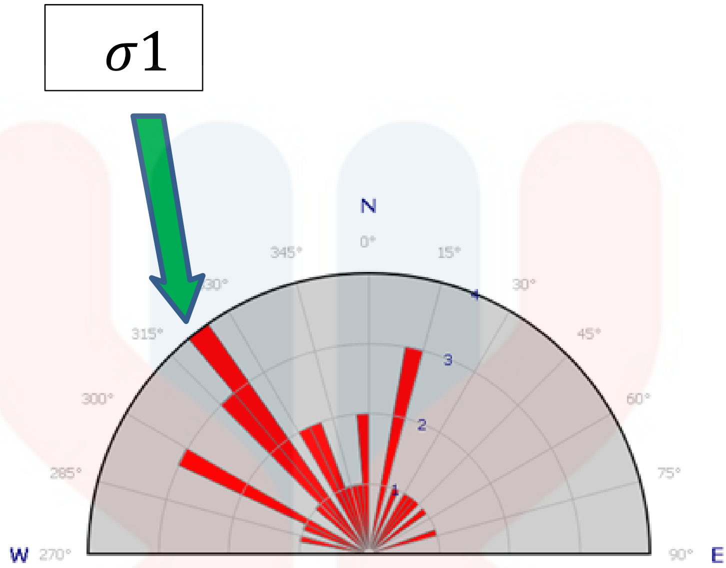

Figure 4.9 Rose diagram for lineament map

Correspond to the lineament analysis has shown that the major force is at W 330º N which shows the most lineament is strike to WN. While, the minimum force is at N 80º E which trending to NE. From this lineament most of the structure analysis can be studied according this lineament.

4.6.1 Faulting

Fault is a geological structure that has a fracture or zone of fractures that occured between two blocks of rock. Movement of block of rock is relative to each other. This faulting process can occur in two ways either fast or slow movement which is due to earthquake and creep respectively. Other than that, the length of fault may range from a few millimeters to thousands of kilometers. Along the geological time faults it can produce repeated displacement at the same place.

Based on the interpretation, at the study area there are major faults that can be seen through the aerial imagery. The faulting forms the valley at the study area continuous to the river. Valley and a straight pattern of river usually can form from the faulting itself. Then, from the interpretation the type of faults that exist in the study area is strike-slip fault. That fault moves towards from south west to north east direction and the length of the fault line is about 1km.

Next, from the previous research it has been said that this Main Range is bounded with two major fault which is Kuala Lumpur Fault and Bukit Tinggi Fault. Other than that, minor fault also can be found in the range by seeing the shape of the granite outcrop that has foliation, mylonite and long lineation (Koopmans, 1974)

4.7 Historical geology

The formation of study area can be divided into two formation which is Main Range Granite and Bentong Group. The geological age for the Main Range Granite is Mesozoic or Early Tertiary. While the Bentong Group is at Silurian or Ordovician age based on the previous research.

For the Bentong Group, whereas the Foothills Range, mostly 600m high or less, are extend from Karak north-northwest through Bentong and passing at west of Raub. This formation is composed of various sedimentary and metasedimentary rocks which have same direction of trending with general steep easterly dips. Based on Richardson (1939) it is considered the schist and amphibole schist along the west side of the Foothills Range in the Raub area to be the metamorphic equivalent of the Calcareous Formation

The Main Range Granite is said to be formed during early Mesozoic or early Tertiary. Research done by (Roe, 1951)said during the early formation coarse grain granite has been forms. Crystallization of magma occurs during the last phase of the granite intrusion. During the intrusion of granite, the process regional metamorphism occurs at the area of Fraser Hill.

CHAPTER 5

ELECTRICAL RESISTIVITY SURVEY FOR LANDSLIDE AT FRASER HILL, PAHANG

Occurrence of landslide usually influenced by the rock material and also rock mass. Rock material is the distribution of rock and mineral compositions of the rock bodies. Other than that, there are others factor that influence the stability of the landslide such as weathering. Weathering of the rock are the main reason for strength of the rock and stability decreasing. Weathering of the rock can be divided into six classes that have different explanation. Weathering is the process of deterioration of a rock mass to a soil and comprises the effect of both chemicals decomposition and mechanical disintegration. Besides that, presence of the substance such as clay and also water should be the major highlights as it give a factor of the influence of the landslide's stability. All of these factors can be detected by using the electrical resistivity survey which also known as ERI.

The study of electrical resistivity survey has been done in three different localities. Each locality has been conducted one line of electrical resistivity to obtain the pseudo section of subsurface. Since it has been choosing three landslide locations so it will produce three lines in three landslides.

The survey line for electrical resistivity is around 100 meters length of cables with 21 electrodes. All the lines survey is using Wenner-Schlumberger array. The reason of choosing 100 meters lines of survey is because the height of landslide location is not more than 100 meters. From the survey, the depth of subsurface data obtained around 10 -15 meters.

5.1 Geophysical Method Analysis

The geophysical electrical resistivity analysis is made by the data obtained from the fieldwork. The data are obtained when the ABEM Terrameter LS has been conducted in the field. The measuring taking a long time to obtain the final results. In the field we have to set up the ABEM Terrameter to choose the method. In this study Wenner – Schlumberger array has been choosen. Then the final result will be obtain and process in the field.

According to (Reynolds, 1997), the geo-electrical resistivity method is one the most flexible and important for the exploration of the research environment. Reynolds (1997) has highlighted that this method has been develop in year 1990. It has been use the general principle of the Ohm's law. By the time, this method can be used for detecting the properties underground and subsurface, geological structure and the resistivity of the subsurface of the earth in selecting of the geohazard such as landslide. The data that has been obtained from the ABEM Terrameter LS will be transfer to the flash USB. Then the data will be transfer to the software of Terrameter LS Toolbox. In that software, the topography data can be put in the software. Then, the all data in this software can be export to DAT file. The Terrameter LS Toolbox has its own functions and the main reason of using the Terameter LS Toolbox is to export and convert the data field to be DAT file.

After the fieldwork data has been converted to the DAT file, the data can be process by using the Res2DINv software. This software actually can give the better information that could lead the accurate interpretation of the resistivity pseudosection profile.

5.2 Res2DINv Software Program

According to (Loke, 2018), to process the data from field, we have to convert the data into DAT file. Then after entering the DAT file into the Res2DINv, the bad data points must be removed to avoid the processing of the bad data points. The resist to remove the bad data points will give an inaccurate result in the final results. Before carrying the inversion, we must make sure that we have edited bad data points by clicking it with the mouse of the computer. Normally, the bad data points, cause of the problem of the poor ground contact of electrodes while we are doing in the field. It will give a result of the higher error reading in the final results.

After, remove the bad data points, bad data points can be checked using the " Edit File". Then, the data points that has been edit, it will be saved as a new file. The next step, the data has been saved will be proceed by inverse the data by using the "Inversion Option". Then it will process until the error can be minimized. Finally to get the true resistivity model, the “Least- Square Inversion” has been clicked. Then the pseudosection profile has been produced with the minimum error.

5.3 Data Interpretation

The geophysical properties of rock can be interpreted by using several chart or classification. In this study, classification that has been used is resistivity values for different lithological sections by (Srinivas, 2013). Other than that, representative chart by (Palacky, 1990) also been used in this study which in most texts on applied geophysics. Besides that, in order to strengthen the interpretation of pseudosection profile there are some references that have been used to interpret the data as shown in Figure 5.3.

Lithology	Resistivity Range [Ωm]	Linguistic Output variables
Clay	8–70	C
Topsoil	50–100	TS
Weathered Gneisses	10–60	WG
Groundwater	0.5–100	GW
Gravel	100–1000	G
Fine Sand/Silt	5–500	FS
Medium Grain Sand	600–6000	MGS
Sand Stone	$1–1 \times 10^8$	SS
Limestone	$50–1 \times 10^7$	L
Basalt	$500–1 \times 10^5$	B
Quartzite	$500–8 \times 10^5$	Q
Granite	$5 \times 10^3–1 \times 10^6$	Gr
Topsoil/Clay	8–100	TS/C
Topsoil/Clay/Gravel	5–1500	TS/C/G
Topsoil/Clay/Fine sand/Silt 50-500	TS/C/FS/S	
Weathered Gneiss/ Groundwater/ Medium Grain Sand	10–6000	WG/GW/MGS
Groundwater/ Medium Grain Sand/ Sand stone	$0.5–1 \times 10^8$	GW/MGS/SS
Quartzite/ Granite	$500–1 \times 10^6$	Q/Gr
Basalt/Limestone	$500–1 \times 10^7$	B/L
Weathered/ Fractured Granite	60–800	W/FGr

Figure 5.1 Resistivity value for different lithology

(Source:(Srinivas et al., 2013))

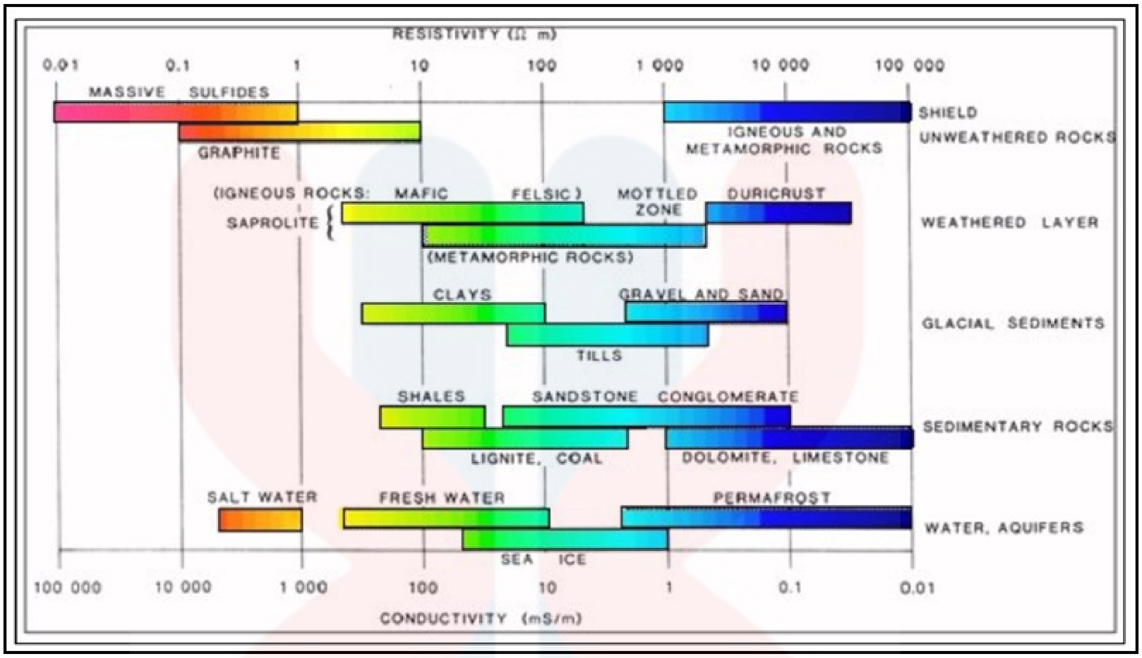

Figure 5.2 Chart of using electrical resistivity

(Source: (Palacky et al., 1990)

References	Type of granite	Electric resistivity (Ω m)
Ebert (1952)	Weathered granite (Bodetal/Harz)	160
	Weathered granite (Lindenfels/Odenwald)	1150
	Highly weathered granites (Bensheim/Odenwald)	490
	Fresh granite (Thale/Harz)	4300
Heiland (1963)	Granites in Washington DC	5×10^3
Telford et al. (1976)	Fresh granites	300 to 10^6
	Wet granitic porphyry	4.5×10^3
	Dry granitic porphyry	1.3×10^6
Reynolds (1997)	Fresh granites	300 to 10^6
	Weathered granites	30 to 500
Clausthal University of Technology	Falkenberg Granite (Bavaria)	310–3465

Figure 5.3 Resistivity value use in ERI survey

Source (Giao et al., 2008)

Besides that, this survey also using Induced Polarization (IP) method. According to (Ayolabi, 2013), this method is created on the study of potential measurement observed in geological formations when direct current is sent into them. This mechanism will operate when the current is suddenly switched off, then the potential difference will be observed between the measuring electrodes that does not vanished instantaneously but gradually dies down in course of a few seconds or minute. This is the chargeability measure in millisecond (msec) or in mV/V. Table 5.1 shows the chargeability of the lithology unit.

Table 5.1: Chargeability of the materials

Materials	**Chargeability (MS)**
Groundwater	0
Alluvium	1-4
Gravels	3-9
Precambrian Volcanics	8-20
Precambrian Gneisses	6-30
Schists	5-20
Sandstone	3-12
rightArgillites	3-10
Quarzite	5-12

(Source: (Elijah A. Ayolabi & Oyelayo, 2005))

Resistivity data is interpreting after getting the results. Table 5.2, 5.3, and 5.4 show the geo-electrical resistivity results for each line survey. While, Figure 5.3, 5.4, and 5.5 shows the pseudosection profile of each survey line.

5.4 Discussion

In this research there are three locality of landslides that has been studied. The three locations are located at the center of Fraser Hill town. Each landslide has been conducted with one survey lines of electrical resistivity imaging (ERI). The data is obtained from this method and interpreted for the landslide possibility to occur at that specific area.

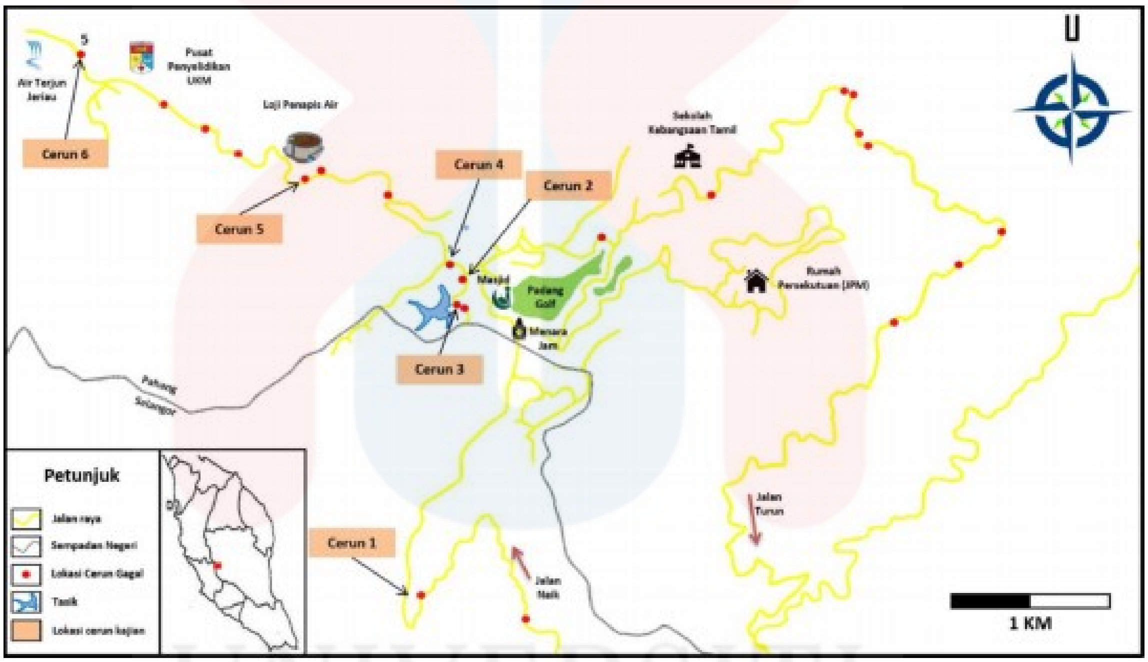

Figure 5.4 Location map of landslide survey

Source: (Arifin et al, 2020)

Figure 5.5 Landslide Hazard at Fraser Hill

Source : (Arifin et al, 2020)

Geo-electrical in slope 1

Table 5.2 Data interpretation for slope 1 in resistivity

Description	Value (Ωm)	Distance (m)
Topsoil clay/silt	0 - 800	27 – 40
Topsoil gravel (weathered granite)	800 – 1700	8 – 13, 14 – 16, 17 – 26
Fresh Rock (granite)	1700 – 3000	2 – 34

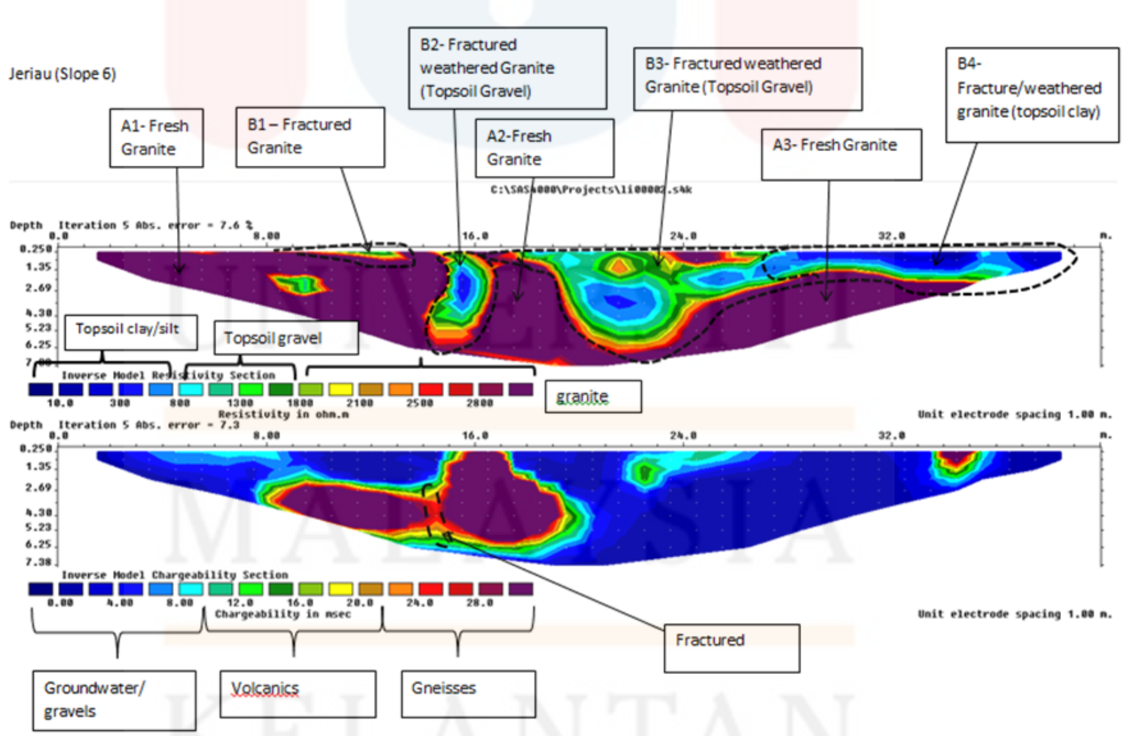

Figure 5.6 Pseudosection for slope 1 (Jeriau)

The data is obtained from this survey line is shown in Figure 5.4. From the pseudosection profile the survey line is 50 meter in length and the electrode spacing used in this survey is 1 meter. This survey is using Wenner-Schlumberger array and the depth of subsurface that we can get from this method is 8 meter.

From the Figure 5.6, this area has a high value of resistivity. The high value of resistivity is estimate to be hard rock. From the geological studies at this place the hard rock that exist in this area is igneous rock which is granite. In the pseudosection profile of this area was represented by green to purple color. The range of resistivity value is 1000 Ωm to 3000 Ωm. This type of rock can be seen dominated at the bottom layer of the pseudosection profile.

Next, from the pseudosection profile of the area that has intermediate value of resistivity is shown in turquoise to green color. The resistivity value for this part is ranged from the 800 Ωm to 1500 Ωm and is known as fractured zone that consists of weathered granite. This fractured zone mostly can be seen at the center of pseudosection profile which is between 15 m to 17m and from 18m to 24m. Then, the lowest resistivity value that is obtained from the pseudosection profile is in range from 0 Ωm to 800 Ωm. This resistivity value indicates the topsoil of the slope which is clay or silt.

This area was represented as the location that has a weak zone. The appearance of water saturated is the reason why the landslide is occured. In addition, the sliding plane of the landslide was along the line. The pseudosection has shown that the sliding plane was dominated by the weathered rock. The distance of sliding plane is ranged between 16 m to 40 m that shown it has the deposit by the water saturated zone. This zone trendily makes the weathered granite to move at the downward area.

Other than that, lithology of the fractured zone of granite can be one of the reasons for landslides to occur. This is because at that area there are weathering process that occured such as chemical and biological weathering. The rock material may react with water from the rain or may weathered because of the vegetation that existed at that area. Because of that, with the season rain at this area can affect the weakness of the subsoil and affected the fractured zone. So, the slightest movement or extreme weather will cause a landslide.

Geo-electrical in slope 2

Table 5.3 Data interpretation for slope 2 in resistivity

Description	Value (Ωm)	Distance (m)
Topsoil clay/silt	0 - 800	35 – 43
Topsoil gravel (weathered granite)	800 – 1700	3 – 30
Fresh Rock (granite)	1700 – 3000	7 – 10 , 10 – 17, 20 – 37

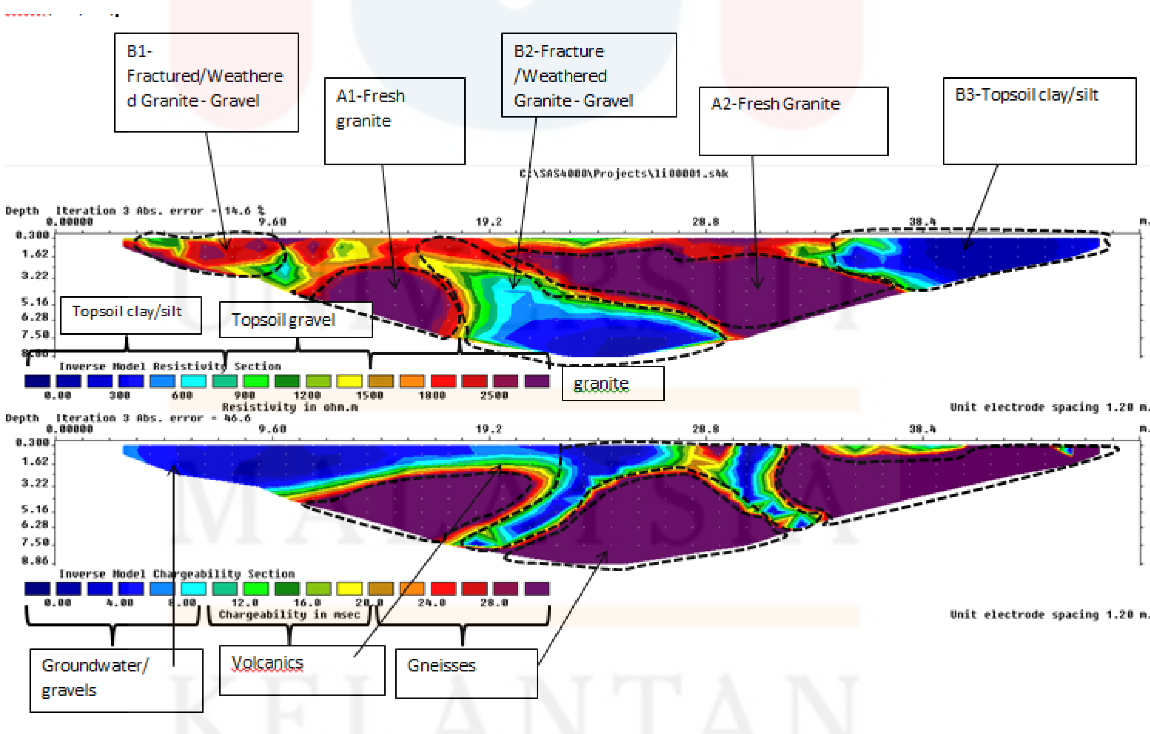

Figure 5.7 Pseudosection for slope 2 (Tasik)

The data is obtained from this line of research is shown in Figure 5.7. The survey line is 50 meters in length from the pseudo-section profile and the electrode spacing used in this analysis is 1 meter. This research uses the Wenner-Schlumberger array and the subsurface depth is 8 meters.

From the Figure 5.7, this area has a high value of resistivity. The high resistivity value is calculated to be hard rock. The hard rock that occurs in this region is igneous rock and interpreted as granite from geological studies at this site. This region was represented in the brown to purple color shown in pseudosection profile. The resistivity value ranged is 1500 Ωm to 3000 Ωm. In the bottom layer of the pseudo section, this type of rock can be seen dominating.

Next the region that has an intermediate value of resistivity is shown in green to yellow color from the pseudo segment. For this section, the resistivity value is ranged from 800 Ωm to 1500 Ωm, and this portion is known as the weathered granite fracture zone. At the middle of the pseudosection, which is between 10 m to 12 m and 20 m to 24 m, this fractured zone is most evident. Then the lowest resistivity value that can be derived from the pseudo-section varies from 0 to 800 m. This resistivity value is interpreted as the slope's topsoil, which is clay or silt.

This region has been described as a weak zone. The appearance of saturated water is the explanation for the landslide occurring. Additionally, along the axis was the slipping plane of the landslide. The pseudo-section showed that the weathered rock is dominated the sliding plane. The width of the sliding plane between 34 m to 50 m has been shown by the water saturated zone to have the deposit. The weathered granite is typically shifted to the downward zone.

Other than that, one of the factors for landslides to occur is the lithology of the granite fracture zone. This is occurred because of the weathering processes, such as chemical and biological weathering. The material of the rock may respond to rain water or may be weathered because of the vegetation that existed in that region. Therefore, with the rainy season at this area can affect the subsoil and the fracture zone. So the slightest movement or extreme weather will cause a landslide.

Geo-electrical in slope 3

Table 5.4 Data interpretation for slope 3 in resistivity

Description	Value (Ωm)	Distance (m)
Groundwater	0 – 100	4 – 34
Topsoil (Clay/ Silt, Gravel)	100 - 1000	0 – 40

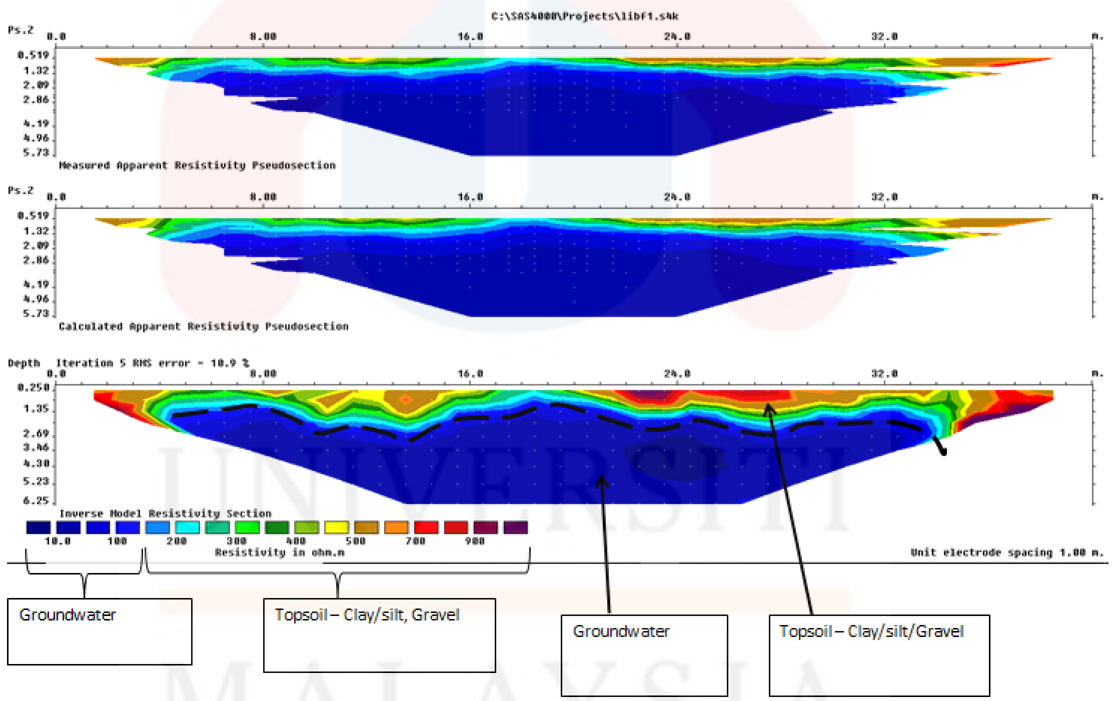

Figure 5.8 Pseudosection for slope 3 (Masjid)

Figure 5.8 indicates the data collected from this line survey. The length of the survey line from the pseudo-section is 50 meters and the electrode separation used in this study is 1 meter. This study utilizes the technique of Wenner-Schlumberger array and the depth of the subsurface is 7 meters.

In the pseudosection profile, this area was dominated with blue color at the bottom layer and at the upper represented is light blue to purple color. The blue color represents low resistivity value while range from light blue to purple color is high resistivity value. In this pseudosection, there is two lithologies that were interpreted to be groundwater and topsoil that consist of clay, silt and gravel.

The range of the resistivity value for groundwater is ranged from 0 Ωm until 100 Ωm. This position was located at depth 0.5 m to 6.25 m at distance from 4 m to 34 m. Besides that, another range of resistivity value is from 100 Ωm to 900 Ωm. This resistivity value can be observed at depth 0 m to 2.70 m and at distance 1.25 m until 38.5 m.

This area is dominated with fractured zone and topsoil area. This appearance of fracture zone and water saturated zone are the reason for the landslides to occur. Plus, landslides can occur in any area that contains fractured materials near the top of a steep slope. Also, with the rainy season at this area can affect it weakness of the sub soil making it weaker. So the slightest movement or extreme weather will cause a landslide.

In addition the sliding plane of the landslide was along the line. The pseudosection profile has shown that the sliding plane was dominated by the weathered rock. The distance from 0m until 100m has shown it has the deposit by the water saturated zone. This zone tenderly makes the weathered andesite to move at the downward area. The weakens of the cohesion force of the rock make it easier to move downward along the sliding plane.

In a conclusion, all three location has the potential for landslide to occur based on the material that exist at sliding plane of the slope. Most of the rock material that exist at the slope are in form of topsoil and has high water content. This can be one of the factor for landslide to occur.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Based on the geological studies, the study area is located at Central Belt of Peninsular Malaysia. The study area consists of two formation which is Main Range Granite and Bentong Group. The lithology exist in study area is granite and schist with different type of minerals. Other than that, the geomorphology classification at this study area can be divided into three classes. The first class of geomorphology is class 3 which the elevation ranging from 200 meter to 500 meter. Then, at elevation 500 – 1000 meter the geomorphology was classified with value of 4. Lastly, the value of class is 5 which include the elevation more than 1000 meter. In the study area there are also has many geohazard such as landslide. Next, through the study of drainage map, the drainage pattern is rectangular and pinnate pattern.

The formation of study area can be classified into two formation or groups which is Main Range Granite and also Bentong Group. The geological age for Main Range Granite is ranging from Mesozoic to Early Tertiary while for the Bentong Group the geological age is ranging from Silurian to Ordovician. This statement proved by many previous research such as (Hutchison, 1977) (Sulaiman & Rosli, 2010).

Next, for the Bentong Group the geological age is ranging from Silurian to Ordovician. The rock unit that has in the study area specifically is schist, but there are another type of schist that exists such as amphibole schist, actinolite schist, and tremolite schist. This rock unit is much oldest than the Main Range Granite. The Main Range Granite intrude the area of schist that cause regional metamorphism. All this information supported by previous research done by (Haile et al., 1977).

Electrical resistivity imaging is the most used method for landslide and groundwater monitoring investigation. This method used because by obtain and analysis the data we can know the resistivity value and the lithology of the subsurface at the study area. For this research, electrical resistivity imaging methods were done at three locations with three lines survey. This survey is important to know the potential for landslide to occur.

In slope 1, the rock unit that dominated in the pseudosection is granite which most of the rock lies at the bottom layer. Other than that, fracture zone that consists of weathered granite also exists at the slope. This fracture zone can be the main reason for landslide to occur at that specific slope. At this area of slope there are also have high vegetation which can be the reason for biological weathering. Then, because of this two parameters process of the weathering might be happening in the beneath of the subsurface. Also, with the season rain at this area can affect it weakens the sub soil making it weak.

In slope 2, the rock unit that exists in the pseudosection is granite which most of the rock lies at the bottom layer. Other than that, fracture zone that consists of weathered granite also exists at the slope and this lithology is dominate most of the pseudosection. Most of the fracture zone is located at the top of the slope that can be the main reason for the residue to move downwards the slope. This fracture zone can be the main reason for landslide to occur at that specific slope. There are also lithology of topsoil that consists of clay or silt at this slope. At this area of slope there are also have high vegetation which can be the reason for biological weathering. Then, because of this two parameters process of the weathering might be happening in the beneath of the subsurface. Also, with the season rain at this area can affect it weakens the sub soil making it weak.

In slope 3, from the pseudosection can be observed that most of the subsurface area is dominate by groundwater, clay, and silt at the bottom layer. Then at the upper layer gravel can be observed through the pseudosection. It can be said that this slope is consists of loose material that can be the reason for landslide to occur. Other than that, weathering can be said as one of the reason for landslide to occur. The presence of groundwater may be because of the existence of lake nearby the slope. Also, with the season rain at this area can affect it weakens the sub soil making it weak.

6.2 Recommendation

In geological part for this research mapping has been done through aerial imaging method and studies from previous research. This method cannot give the actual views of the study area. Then, the data that we obtain from the previous research is not up to date. Most of the data used in this research are from five years ago and below. To get the actual views and to update the data obtain for the geological part, geological mapping should be done at this study area. From the geological mapping, there are more specific data can be obtain such as rock unit, weathering, geomorphology, and other parts in geology studies.

Then, the fieldwork is conducted by using geo-electrical resistivity, but there are other methods that can give accurate result such as borehole technique and also seismic refraction method. For seismic method, it can give high degree of precision data display. This method also allows mapping the thickness of the landslide and identification of rock. The borehole technique should also be applied at the study area to get the exact data in underground. With the combination of boreholes data and geophysical survey, the investigation of landslide can be done more effectively.

REFERENCE

Akter, A., Noor, M. J. M. M., Goto, M., Khanam, S., Parvez, A., & Rasheduzzaman, M. (2019). Landslide Disaster in Malaysia: An Overview. *International Journal of Innovative Research and Development*.

Jeong, S., Kassim, A., Hong, M., & Saadatkhah, N. (2018). Susceptibility assessments of landslides in Hulu Kelang area using a geographic information system-based prediction model. *Sustainability (Switzerland)*.

Psomiadis, E., Papazachariou, A., Soulis, K. X., Alexiou, D. S., & Charalampopoulos, I. (2020). Landslide mapping and susceptibility assessment using geospatial analysis and earth observation data. *Land*.

Pardeshi, S. D., Autade, S. E., & Pardeshi, S. S. (2013). Landslide hazard assessment: Recent trends and techniques. In *SpringerPlus*.

Turner, A. K., & Schuster, R. L. (1996). Landslides investigation and mitigation. Special Report 247/ Transportation Research Board, National research Council. *Transportation Research Board, Us National Research Council, Chap Landslides Types and Processes*.

Giao, P. H., Weller, A., Hien, D. H., & Adisornsupawat, K. (2008). An approach to construct the weathering profile in a hilly granitic terrain based on electrical imaging. *Journal of Applied Geophysics*.

Gilchrist, A. R., & Summerfield, M. A. (1991). Denudation, isostasy and landscape evolution. *Earth Surface Processes and Landforms*.

Loke, M. H., Wilkinson, P. B., Chambers, J. E., & Meldrum, P. I. (2018). Rapid inversion of data from 2D resistivity surveys with electrode displacements. *Geophysical Prospecting*.

Arifin, M. H., Nazer, N. S. M., & Jalal, A. Q. (2020). Identification of the main mechanism of shallow landslides in bukit fraser, Pahang. *Bulletin of the Geological Society of Malaysia*.

Ayolabi, E. A., & Adigun, A. O. (2013). The Use of Seismic Attributes to Enhance Structural Interpretation of Z-Field, Onshore Niger Delta. *Earth Science Research*.

Palacky, G. J., Holladay, J. S., & Walker, P. W. (1990). Use of inversion techniques in interpretation of helicopter electromagnetic data for mapping quaternary sediments near Kapuskasing, Ontario, Canada. *1990 SEG Annual Meeting*.

Ayolabi, E. A., & Oyelayo, F. J. (2005). Geophysical and hydrochemical assessment of groundwater pollution due to a dumpsite in Lagos State, Nigeria. *Journal of the Geological Society of India*.

Haile, N. S., Stauffer, P. H., Krishnan, D., & Lim, T. P. (1977). Palaeozoic redbeds and radiolarian chert: reinterpretation of their relationship in the Bentong and Raub areas, West Pahang, Peninsular Malaysia. *Bulletin of the Geological Society of Malaysia*.

Srinivas, Y., Raj, S. A., Hudson, O. D., Muthuraj, D., & Chandrasekar, N. (2013). Geoelectrical inversion and evaluation of lithology based on optimized Adaptive Neuro Fuzzy Inference System (ANFIS). *Studia Geophysica et Geodaetica*.

Koopmans, B. N. (1974). Geology of the Malay Peninsula, West Malaysia and Singapore. *Earth-Science Reviews*.

Hutchison, C. S. (1977). Granite emplacement and tectonic subdivision of Peninsular Malaysia. *Bulletin of the Geological Society of Malaysia*.

Mussett, A. E., Khan, M. A., & Button, S. (2000). Looking into the Earth: An introduction to geological geophysics. In *Magnetic surveying*.

Samsudin, A. R. (2016). Utilizations of geophysical methods in hydrogeology. *ResearchGate*.

Tajul Anuar, J. (2019). Tanah Runtuh Pendam-Lama dalam Terain Perbukitan Tropika. (Old Dormant Landslides in Tropical Hilly Terrain - From Geohazards to Geodisasters). *Geological Society of Malaysia, Technical Talk.*

Ridd, M. F. (1991). Geological evolution of South-east Asia. *Marine and Petroleum Geology*.

Tajul Anuar, J. (2019). Pengecaman geobahaya tanah runtuh pendam di tanah tinggi tropika – Beberapa contoh dari Cameron Highland dan Kundasang, Malaysia. *NATIONAL GEOSCIENCE CONFERENCE 2019*.

Khalil, A. E., Nawawi, M., & Kamel, R. (2015). Seismic reflection survey at Ayer Hangat site to investigate shallow subsurface structures. *Electronic Journal of Geotechnical Engineering*.

Koopmans, B. N. (1965). Structural Evidence for a Palaeozoic Orogeny in North-west Malaya. *Geological Magazine*.

Hussin, H., Ghani, S. A. A., Jamaluddin, T. A., & Razab, M. K. A. A. (2015). Tanah runtuh di Malaysia: "Geobencana" atau "geobahaya." *Jurnal Teknologi*.

W. R. J. (1951). The Geology and Mineral Resources of the Fraser's Hill Area, Selangor, Perak, And Pahang, Federation of Malaya, with an Account of the Mineral Resources. By DrF. W. Roe. pp. ix + 138, with coloured map. Geol. Survey (Federation of Malaya) Memoir 5. 1951. . *Geological Magazine*.

Khoo, T. T., & Tan, B. K. (1983). Geological Evolution of Peninsular Malaysia. *Workshop on Stratigraphic Correlation of Thailand and Malaysia*.

Goh, T. L., Samsudin, A. R., & Rafek, A. G. (2011). Application of spectral analysis of surface waves (SASW) method: Rock mass characterization. *Sains Malaysiana*.

Z., W., L., C., Y., W., Z., Y., H., W., & X., W. (2011). Potential health risk of arsenic and cadmium in groundwater near Xiangjiang River, China: A case study for risk assessment and management of toxic substances. In *Environmental Monitoring and Assessment* (Vol. 175, Issues 1–4, pp. 167–173). Springer Netherlands (Van Godewijckstraat 30, Dordrecht 3311 GZ, Netherlands).

Reynolds, J. M. (1997). An introduction to applied and environmental geophysics. In *An introduction to applied and environmental geophysics*.

Sulaiman, W. N. A., & Rosli, M. H. (2010). Susceptibility of shallow landslide in fraser hill catchment, Pahang Malaysia. *EnvironmentAsia*.

Samsudin, A. R. (2016). Utilizations of geophysical methods in hydrogeology. *ResearchGate*.

Peters, K. E., & Fowler, M. G. (2002). Applications of petroleum geochemistry to exploration and reservoir management. *Organic Geochemistry*.

Park, S., Yi, M. J., Kim, J. H., & Shin, S. W. (2016). Electrical resistivity imaging (ERI) monitoring for groundwater contamination in an uncontrolled landfill, South Korea. *Journal of Applied Geophysics*.

Keller, E. A., DeVecchio, D. E., Blodgett, R. H., Keller, E. A., & DeVecchio, D. E. (2019). Internal Structure of Earth and Plate Tectonics. In *Natural Hazards*.

. P. C. L., . M. Z., . A. N. A. G., & . A. M. (2004). Valuing the Opportunities of Wildlife-based Recreation in Fraser`s Hill as Support for Nature Conservation. *Journal of Biological Sciences*.

APPENDIX

A) Steps to generate map using ArcGis

A. Landform Map

1. Add data from folder in the computer, choose DEM data and click to insert to the layers.

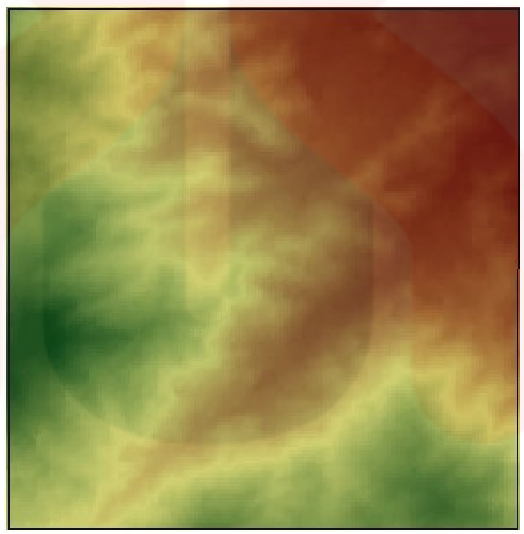

Figure Data Elevation Model of Study Area

2. Add basemap features like study area, river and street.

3. Go to arctoolbox select spatial analyst tool and choose contour.

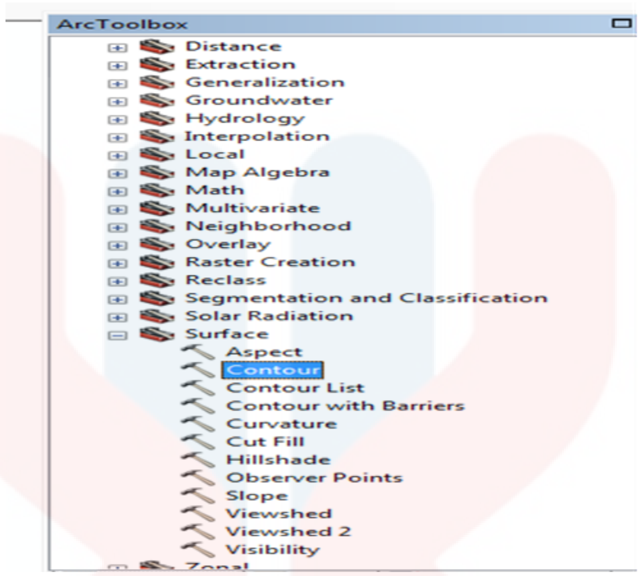

Figure Arctoolbox in ArcGis

4. Then , add DEM data to convert to contour with 20m interval.

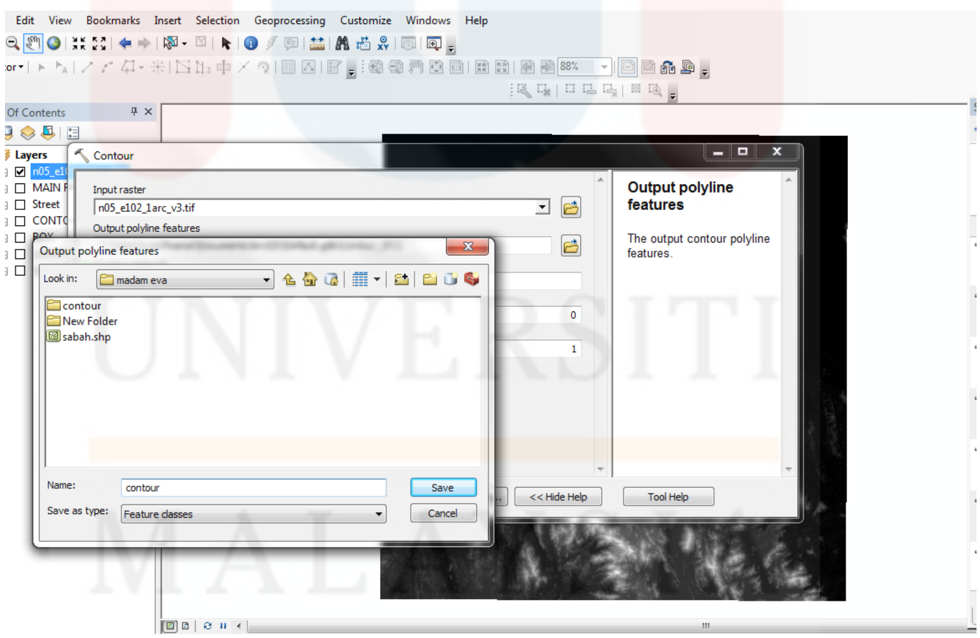

Figure Steps to Convert DEM to Contour

5. Then, go to processing then choose clip. Clip the contour and box.

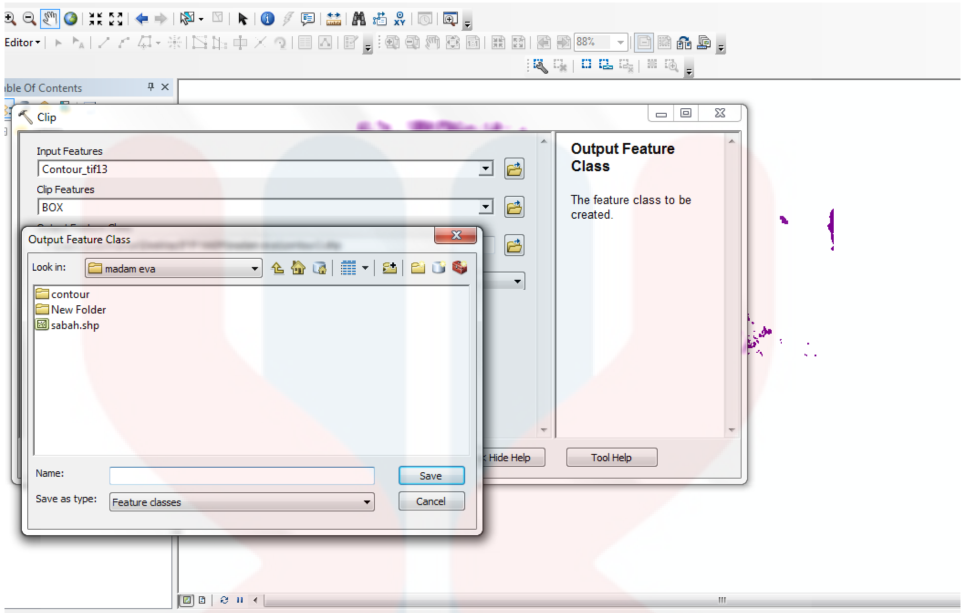

Figure Steps to Clip the layer

6. Then go to spatial analyst tool and search topo to raster. Then add data contour.

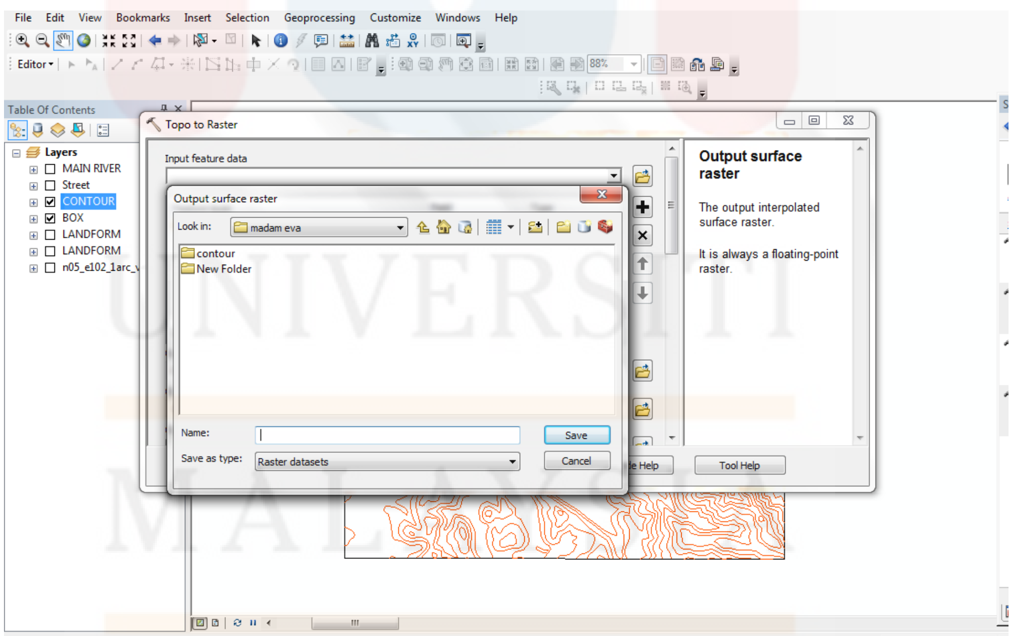

Figure Steps to Convert from Contour to Raster

7.Then go to properties and classified it as 3.

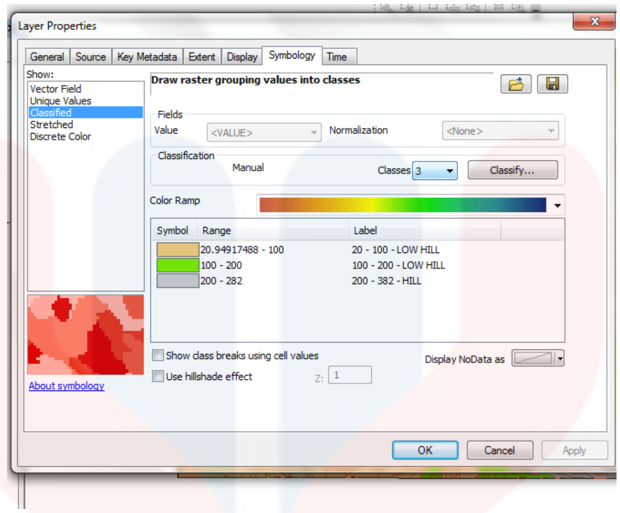

Figure Layer Properties of Raster

B. Landslide Susceptibility Map

1. Slope map

- The layer is right clicked to select properties, in order to select coordinate system for the map. Geographic Coordinate System is choosing, followed by World > WGS 1984.
- Add data from folder in the computer, choose DEM data and click to insert to the layers.
- Add box data and do the clip feature from geoprocessing at DEM data into the box area only.
- Navigate to System Toolboxes, choose Spatial Analyst Tools > Surface > Slope.
- Select the input surface raster and insert the clip DEM layer.
- Specify the location of the output raster and select the output measurement.

- Click OK. The slope map is created from the DEM layer

2. Drainage density

- The layer is right clicked to select properties, in order to select coordinate system for the map. Geographic Coordinate System is choosing, followed by World > WGS 1984.
- Add data from folder in the computer, choose DEM data and click to insert to the layers.
- Add box data and do the clip feature from geoprocessing at DEM data into the box area only.
- Navigate to System Toolboxes, choose Spatial Analyst Tools > Hydrology > Fill.
- Select the input surface raster and insert the clip DEM layer.
- Navigate to System Toolboxes, choose Spatial Analyst Tools > Hydrology > Flow direction.
- Select the input surface raster and insert the clip Fill dem layer.
- Navigate to System Toolboxes, choose Spatial Analyst Tools > Hydrology > Flow accumulation.
- Select the input surface raster and insert the clip Flow direction dem layer.
- Navigate to System Toolboxes, choose Spatial Analyst Tools > Hydrology > Stream order.
- Select the input stream raster and insert the clip stream order dem layer, then insert flow direction dem layers into input flow direction raster.

- Navigate to System Toolboxes, choose Spatial Analyst Tools > Hydrology > Stream to feature.
- Select the input stream raster and insert the clip stream order dem layer, then insert stream order dem layers into input flow direction raster.
- At layers, click the stream order dem layers properties and change the line colour and each size.
- Navigate to System Toolboxes, choose Spatial Analyst Tools > Density > Line density.
- Select the input polyline raster and insert the clip stream order dem layer, then for population field choose grid code.
- Click OK. The density map is created from the stream order layer.

3. Aspect map

- The layer is right clicked to select properties, in order to select coordinate system for the map. Geographic Coordinate System is choosing, followed by World > WGS 1984.
- Add data from folder in the computer, choose DEM data and click to insert to the layers.
- Add box data and do the clip feature from geoprocessing at DEM data into the box area only.
- Navigate to System Toolboxes, choose Spatial Analyst Tools > Surface > Aspect.
- Select the input surface raster and insert the clip DEM layer.

- Specify the location of the output raster and select the output measurement.
- Click OK. The aspect map is created from the DEM layer.

4. Hill relief map

- The layer is right clicked to select properties, in order to select coordinate system for the map. Geographic Coordinate System is choosing, followed by World > WGS 1984.
- Add data from folder in the computer, choose DEM data and click to insert to the layers.
- Add box data and do the clip feature from geoprocessing at DEM data into the box area only.
- Click the Image Analysis Options button Options, click the Hillshade tab, then adjust the illumination properties to be applied.
- Click the Shaded Relief button Shaded Relief in the Processing section of the window.
- To change the color ramp, click the newly added layer in the Image Analysis window, then click the color ramp drop-down arrow in the Processing section and select a different color ramp.
- Right-click the raster layer in the table of contents and click Properties.
- Click the Functions tab.
- Right-click Shaded Relief Function and click Properties.
- Click the Shaded Relief tab and edit the properties.

- Click OK to close the Raster Properties Function dialog box and click OK again to close the Layer Properties dialog box.

5. Landslide susceptibility map

   - The layer is right clicked to select properties, in order to select coordinate system for the map. Geographic Coordinate System is choosing, followed by World > WGS 1984.
   - Add data from folder in the computer, choose DEM data and click to insert to the layers.
   - Add box data and do the clip feature from geoprocessing at DEM data into the box area only.
   - Add the aspect, slope, drainage density and hillshade layers into map.
   - Navigate to System Toolboxes, choose Spatial Analyst Tools > Reclass > Reclassify.
   - Do the reclassify at the aspect, slope, drainage density and hillshade layers.
   - Then, navigate to System Toolboxes, choose Spatial Analyst Tools > Overlay > Put all the reclass layer.
   - Click OK. The landslide suscepbility map is created from the all reclass layer.

C. Fluvial System

1. Stream Order Map

- • The first stage of any hydrology processing is to fill any pit in the DEM using a filling tool to ensure that water will flow over the surface without being 'stuck' in the DEM's erroneous void.

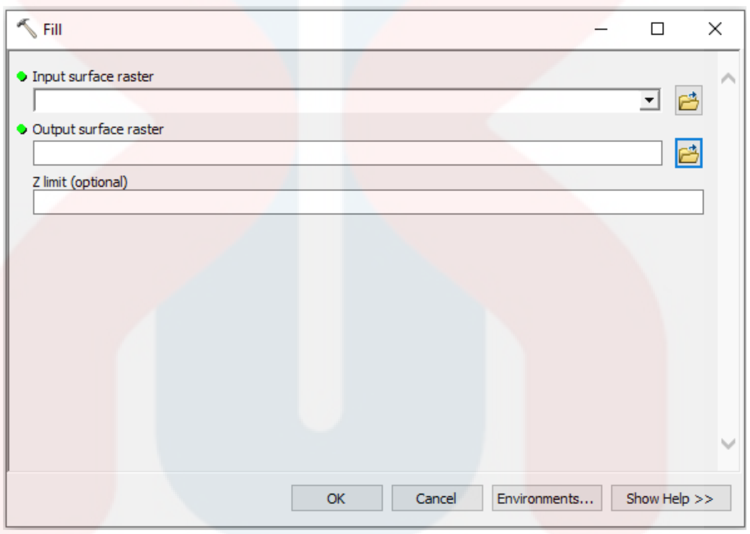

Figure Steps to Insert Raster Data

- Input surface raster > DEM data
- Then click OK.

Figure DEM data of Study Area

- Once this filled DEM has been created, the flow direction can be calculated using the elevation to determine which direction water flows in each cell using the D8 method where all water flows into one of the eight surrounding cells.

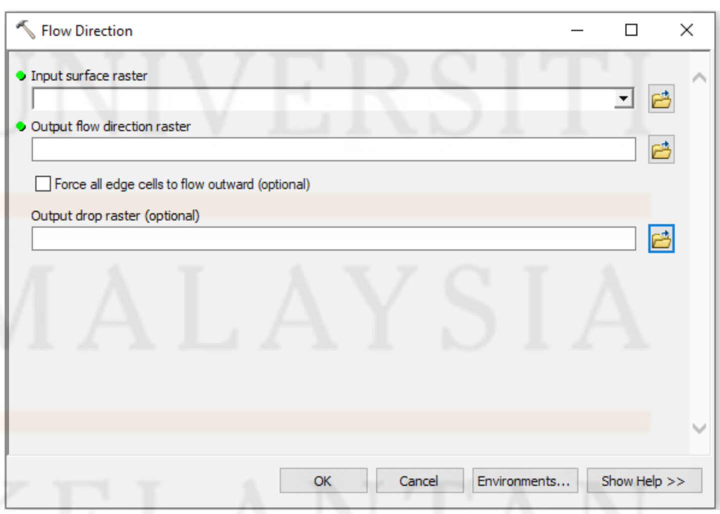

Figure Input Flow Direction

- Input surface raster > DEM Fill
- Then Click OK

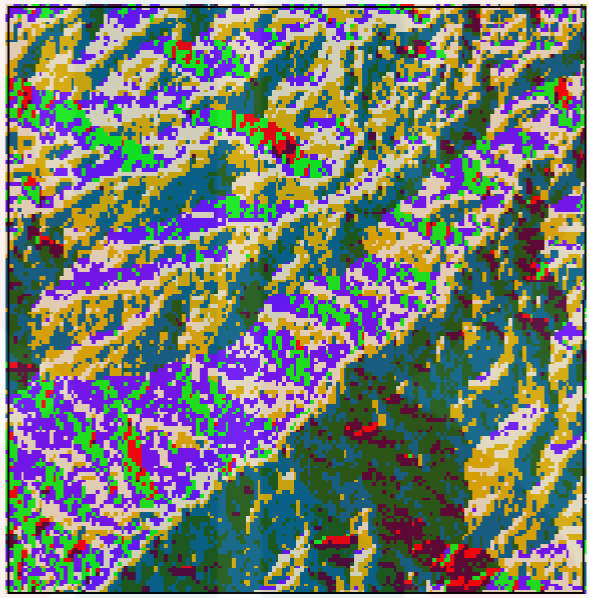

Figure DEM Fill

- The flow direction can then be used to create the flow accumulation, a measure of the number of cells which flow into each cell in the raster.

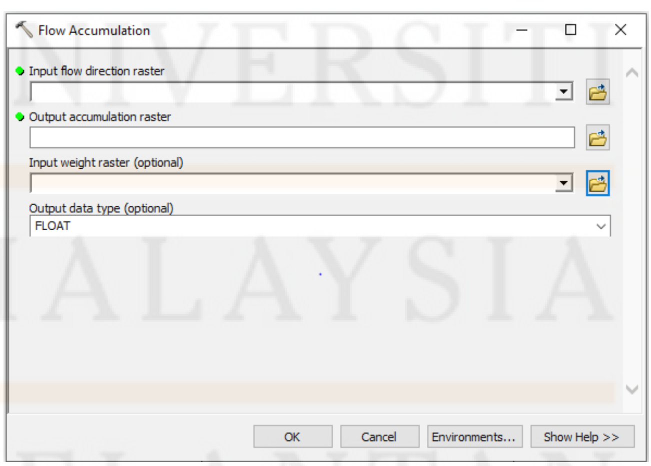

Figure Input Flow Accumulation

- Input flow direction raster > FlowDir
- Output Data Type change to INTEGER
- Then click OK

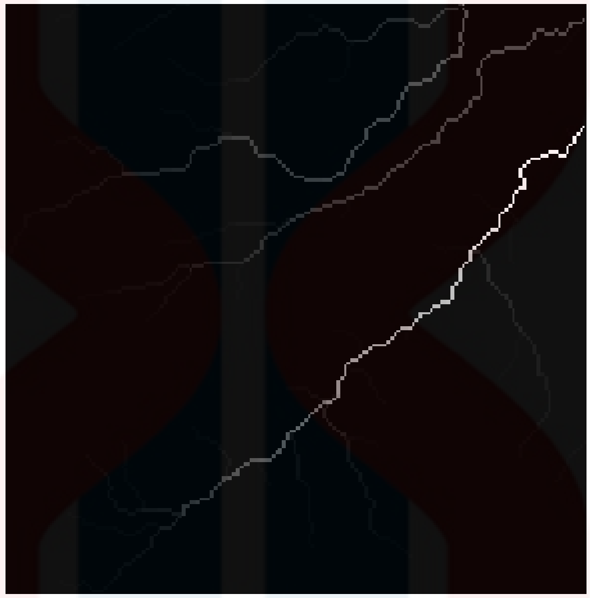

Figure Flow Direction Raster

- Then using raster calculator

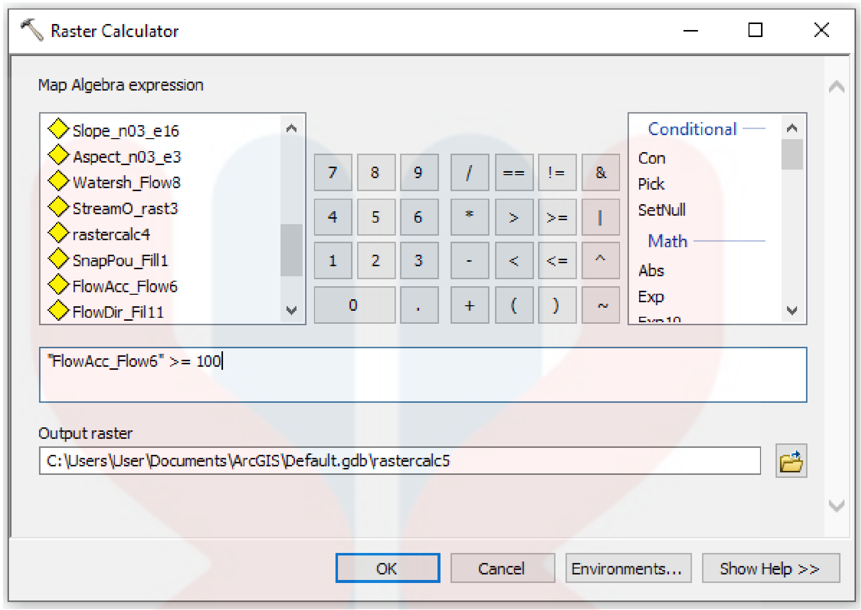

Figure Raster Calculator in ArcToolbox

- FlowAcc raster >= 100
- Then click OK

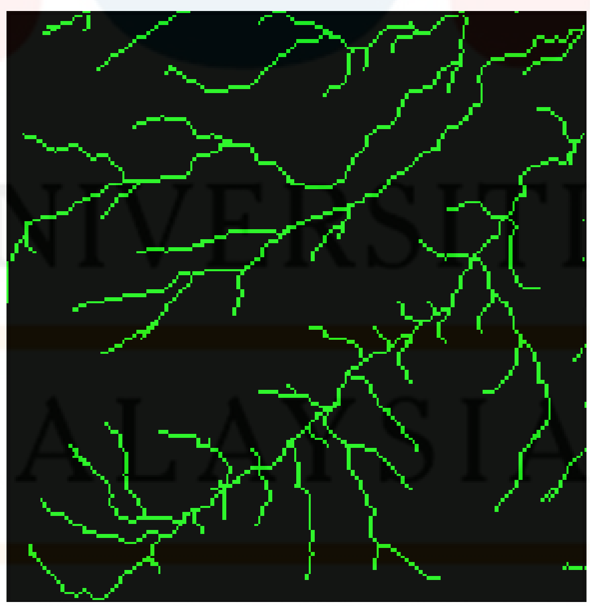

Figure Flow Accumulation Raster

- This is example of stream after raster calculate process.

- Use stream order tool.

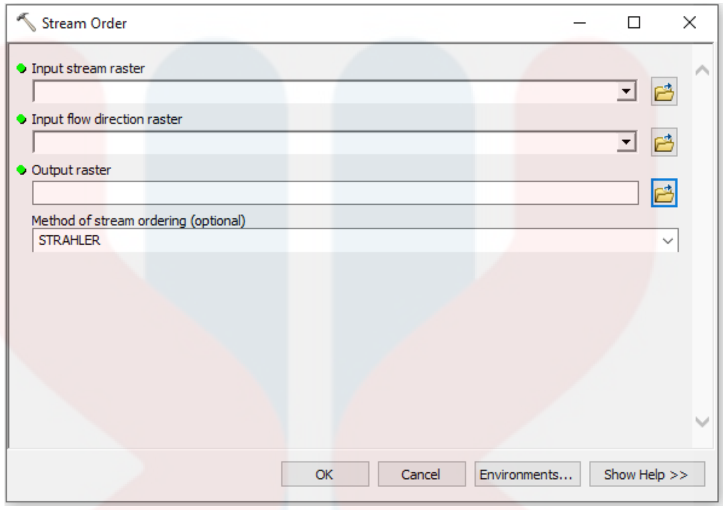

Figure Input Stream Order

- Input Stream raster > raster calculate layer
- Input flow direction raster > FlowDIr raster
- Use Strahler method for the stream order
- Then Click OK.

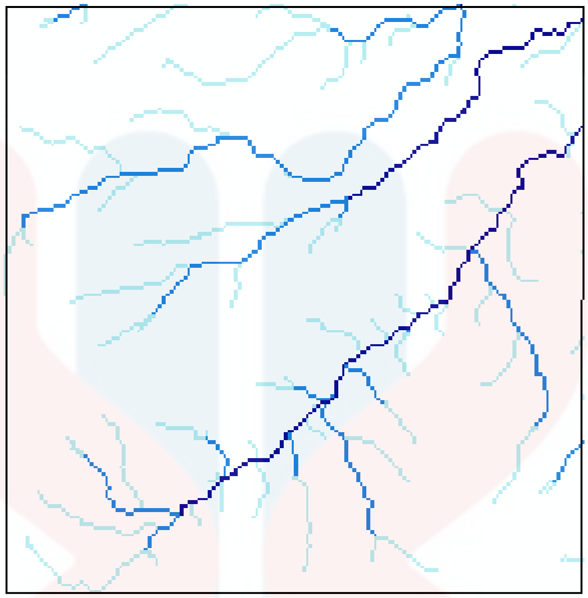

Figure Stream Order of Study Area

- Stream order raster need to be converted as the final step, it need to be convert into a vector which is simply that shows the stream to feature command

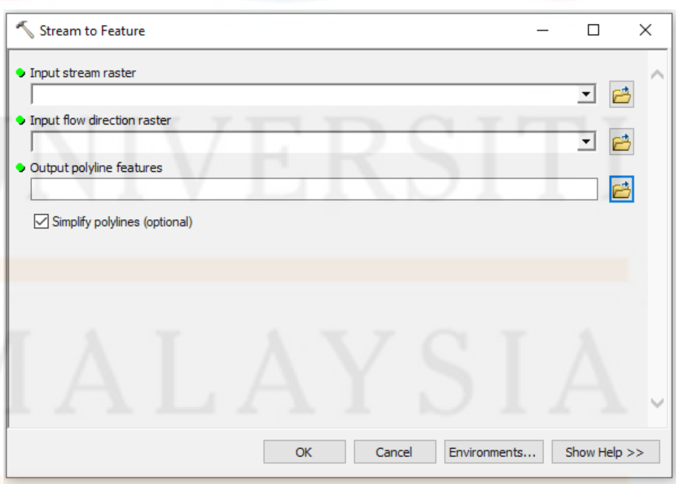

Figure Input Stream to Feature

- Input stream raster > stream order layer

- Input flow direction > FlowDir raster
- Then click OK
- Complete the step.

For other maps use in fluvial system is also the same as in landslide susceptibility map such as aspect map, slope map, drainage density.

D. Watershed Map

- Fill tool is run in the Arccatalog.
- In ArcCatalog, Toolboxes > System Toolboxes > Spatial Analyst Tools > Hydrology > Fill this step used to navigate
- Digital elevation model (DEM) is used as the 'Input surface raster'
- Then, at the 'Output surface raster' the path name need to be verify
- If necessary, put the Z-limit.
- Button OK needed to be clicked.
- Flow Direction tool is run
- In ArcCatalog, use this navigation to get the Flow Direction, Toolboxes > System Toolboxes > Spatial Analyst Tools > Hydrology > Flow Direction.
- DEM is used as the output in the 'Input surface raster'.
- The path name for ' Output flow direction raster' need to be verify.
- Click OK.
- The Flow Direction tool specifies the flow direction from each cell to its steepest downhill neighbour.
- Flow accumulation tool is run.

- In ArcCatalog, this steps is used to navigate the flow direction, Toolboxes > System Toolboxes > Spatial Analyst Tools > Hydrology > Flow Accumulation.
- Then, output raster at step 2 is used as the ‘input flow direction raster’.
- Path name for the ‘output accumulation raster’ needed to be verify.
- Click OK.
- The Flow Accumulation method measures each cell 's cumulative flow as determined by the aggregate weight of all cells flowing into each downslope cell.
- Run the Snap Pour Point tool to locate high accumulated flow cells at the pour points.
- Navigate to Toolboxes in ArcCatalog > Device Toolboxes > Spatial Analyst Software Hydrology > Snap For Points.
- • Either input a point class feature or a raster as the 'Input raster or the pour point data feature.'
- Output raster from Step 3 is used as the 'Input accumulation raster'.
- Path name for the 'Output raster' needed to be verify
- Click OK.
- Watershed tool is run in the software.
- In ArcCatalog, Toolboxes > System Toolboxes > Spatial Analyst Tools > Hydrology > Watershed are navigated to get the output
- Output raster from Step 2 is used as the 'Input flow direction raster'.
- Output from Step 4 is used as the 'Input raster or feature pour point data'.

- Path name for the 'Output raster' need to be verified.
- Click OK.
- Then, 'Raster to Polygon' tool is used to create polygon features from the watershed raster.
- In ArcCatalog, to navigate the polygon this step is used Toolboxes > System Toolboxes > Conversion Tools > From Raster > Raster to Polygon.
- Output from Step 5 is used as the 'Input raster'.
- Path name for the 'Output polygon features' need to verify.
- Click OK.