GEOLOGY AND LANDSLIDE SUSCEPTIBILITY ON TOP OF FRASER HILL, PAHANG USING GEOGRAPHIC INFORMATION SYSTEM (GIS)

by

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A thesis submitted in fulfilment of the requirement for the degree of Bachelor of Applied Science (Geoscience) with Honours

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DECLARATION

I declare that this thesis entitled **"GEOLOGY AND LANDSLIDE SUSCEPTIBILITY ON TOP OF FRASER HILL, PAHANG USING GEOGRAPHIC INFORMATION SYSTEM (GIS)"** 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.

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APPROVAL

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

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ABSTRACT

Fraser Hill is located in Raub, Pahang, Malaysia which are vulnerable to geological hazard such as landslide which contribute to damage and loss. The study is located on top of Fraser Hill with the area covered of 5km² which aligned along latitude 3° 44’ 22.00” N - 3° 41’ 40.00” N and 101° 43’ 14.58” E - 101° 45’ 59.00” E. This research aims to update a geological map of Fraser Hill with scale 1:25000 and to produce a landslide susceptibility map. The factors that triggered the landslide on top of Fraser Hill were also analysed. The research on geological mapping which includes study of geomorphology, stratigraphy, structural geology and historical geology of the study area. Based on geological map identified two types of lithology which is granite rock and schist. The study is composed of two formation which is intrusion of Central Belt and Bentong Group. The parameters that caused the occurrence of landslide were determined and the landslide susceptibility map was produced using Weightage Overlay Method (WOM) in ArcGIS software. The results showed that the susceptibility map was classified into three zones which is low, moderate and high zone. The factor that triggered the landslide were identified which is heavy rainfall intensity. As a conclusion, the ability to detect landslide susceptibility leads to a better understanding of landslide mechanisms for the research area, thus leading to an enhanced identification of the most likely failure sites within a landslide-prone area.

Keywords: GIS, Landslide Susceptibility, Weightage Overlay Model, Fraser Hill

GEOLOGI DAN KERENTANAN TANAH RUNTUH DI KAWASAN BUKIT FRASER, PAHANG MENGGUNAKAN APLIKASI SISTEM MAKLUMAT GEOGRAFI

ABSTRAK

Bukit Fraser terletak di Raub, Pahang, Malaysia yang terdedah dengan bencana geologi seperti tanah runtuh. Namun, kerentanan tanah runtuh di beberapa kawasan di Bukit Fraser yang berlaku telah menyebabkan kerosakan dan kerugian. Kajian ini terletak di puncak Bukit Fraser dengan kawasan seluas $5km^2$ yang sejajar dengan garis lintang3^{o} 44’ 22.00” N - 3^{o} 41’ 40.00” N and 101^{o} 43’ 14.58” E - 101^{o} 45’ 59.00” E. Penyelidikan ini bertujuan untuk mengemas kini peta geologi Bukit Fraser dengan skala 1: 25000 dan menghasilkan peta kerentanan tanah runtuh. Faktor-faktor yang menyebabkan tanah runtuh di atas Bukit Fraser juga telah dianalisis. Penyelidikan ini melibatkan kajian geomorfologi, stratigrafi, geologi struktur dan geologi sejarah kawasan kajian. Kajian ini terdiri daripada dua formasi iaitu kumpulan intrusi Jalur Tengah dan Kumpulan Bentong iaitu granit dan syis. Parameter yang menyebabkan berlakunya tanah runtuh ditentukan dan peta kerentanan tanah runtuh dihasilkan menggunakan Kaedah Perlapisan Berwajaran (WOM) dalam perisian ArcGIS. Hasil kajian menunjukkan bahawa peta kerentanan dikelaskan kepada tiga zon iaitu zon rendah, sederhana dan tinggi. Faktor yang menyebabkan tanah runtuh dikenal pasti adalah intensiti hujan lebat. Sebagai kesimpulan, kemampuan untuk mengesan kerentanan tanah runtuh menyebabkan pemahaman yang lebih baik mengenai mekanisme tanah runtuh untuk kawasan penyelidikan, sehingga membawa kepada peningkatan pengenalpastian lokasi kegagalan yang paling mungkin di kawasan rentan tanah runtuh.

Kata kunci: GIS, Kaedah Perlapisan Berwajaran, Kerentanan Tanah Runtuh, Bukit Fraser

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LIST OF ABBRIVIATIONS

DEM	Digital Elevation Model
GIS	Geographical Information System
GPS	Global Positioning System
USGS	US Geological Survey Earth Resources and Science Centre
WOM	Weighted Overlay Methods

LIST OF SYMBOLS

%	Percentage
>	Greater than
<	Less than
ºC	Degree Celsius
º	Degree
×	Multiplication
Σ	Sum
Ϭ	Sigma

CHAPTER 1

INTRODUCTION

1.1 General Background

Geohazard is a geological phenomenon that may lead to worst damage and risk. This phenomenon can be occurred and involve in the environment conditions in long-term and short-term geological process. Geohazard can be relate with small features and also can be in big dimension such as submarine and surface landslide. Landslide is a movement of a mass rock, debris or earth down a slope. Commonly all the landslide occurs as the result of the failure of the soil and the rock materials that forming the slope hills and driven by the gravity downing. This landslide can be simple as a single bolder until a huge rock falls or topple to tens of millions of cubic meters of materials in a debris avalanche. According to Geoscience Australia and Emergency Management Australia in February 2013, landslide can be triggered by the natural causes and also can be caused by the human activity. Human activity such as drilling through the overpressure zonation that could drive to risky situation.

Landslide can be considered as the normal natural disaster or hazard around the world. United States Geological Survey (USGS) once stated in average about 25-50 people killed resulting of the landslide hazard. According to Kazmi (2016), in Malaysia most of the landslide happened as the consequence of handicapped design, improper construction and non-maintenance of slopes which correlates with the human being failure. Instability at the rock slope is primarily due to discontinuities including objects joints, stratigraphy, foliation, cracks, bedding, fractures and faults according to Tan (1986) and Othman et al (2010) referred are treacherous, and hard to identify.

In tropical countries, landside incidences often occur during the monsoon season, when precipitation during that time is heavier and intense compared to another period. Climate conditions in the tropical areas are the main factor responsible for the stability of the slopes or landslides in the hilly areas. Malaysia is one of tropical country that facing this landslide problem. One way to reduce the after-effect of landslide occurrence is by delineating the potential area by producing a landslide susceptibility area map. Throughout this, developers and planners are well informed about the spatial location of the potential slide area. Consequently, any developments in the potential slide area can be avoided and safety measures will be implemented. Back in the old days, landslide susceptibility map was produced by geologists or landslide experts using manual in situ interpretation based on their experience. Then, they will draw up a landslide susceptibility map based on their observation over the specific area. Landslide susceptibility analysis is one of the most important analysis that need to be done in every developing country especially the Asia country because it will give a bad effect and catastrophe if geological hazard such as an earthquake.

Geomorphology is the study of landforms on the Earth's surface, their structures, forms, and sediments. The study involves looking at landscapes to find out how the earth's surface processes, such as air, water and ice, can shape the landscape. Geomorphology can also be described as an analysis of the origin and development of topographic and bathymetric characteristics produced by physical, chemical or biological processes that operate on or near the surface of the Earth. Erosion or deposition produces landforms, as rock and sediment are worn away by these earth-surface processes and transported and deposited to various locations. Geomorphologists seek to understand why landscapes look the way they do, through a combination of field observations, physical experiments, to understand landform history and dynamics and to predict changes. Geomorphologists aim to understand why ecosystems look the way they do, understand the past and evolution of landforms, and forecast changes by integrating field observations and physical experiments. A combination of surface processes that form ecosystems and geological processes that cause tectonic uplift and subsidence, and form the coastal geography and the surface of the Earth.

1.2 Study Area

1.2.1 Location

This study area is located at Fraser Hill, Pahang with coordinate A (3° 44’ 22.00” N , 101° 43’ 14.58” E), B (3° 44’ 22.00” N , 101° 45’ 59.00” E), C (3° 41’ 40.00” N , 101° 45’ 59.00” E), D (3° 41’ 40.00” N , 101° 43’ 14.58” E). All these four points will cover 25km^2 wide. The dimension of the study area is about 5x5 km wide and length. Figure 1.1 shows the location of the study area from Google Earth Pro while Figure 1.2 shows the base map of the study area with contours, coordinates, stream and road connection.

Fraser Hill in the state of Pahang, above the Titiwangsa Range, Malaysia. It is an attractive mountain tourism area with a cool temperature of 17-24 Celsius. The summit of Fraser Hill is 1,310 meters above sea level. About 104 kilometer from the city of Kuala Lumpur, the hill is located in Tras District in Raub Pahang District. According to Cheong (2013) Fraser Hill is named after the adventures of a Scotland citizen, Louis James Fraser, who conducted a tin ore trade and the impact of an ore mine remains a golf course in the middle of a Fraser hillside today. The area covers 2829 hectares and known as one of the high-altitude tourist areas in the peninsula Malaysia. Its position is about 65 km from north-east of Kuala Lumpur makes it one of the focal points of focus not far from the capital. Fraser hill is on the main range of Peninsular Malaysia which is Himalaya range or Central Belt.

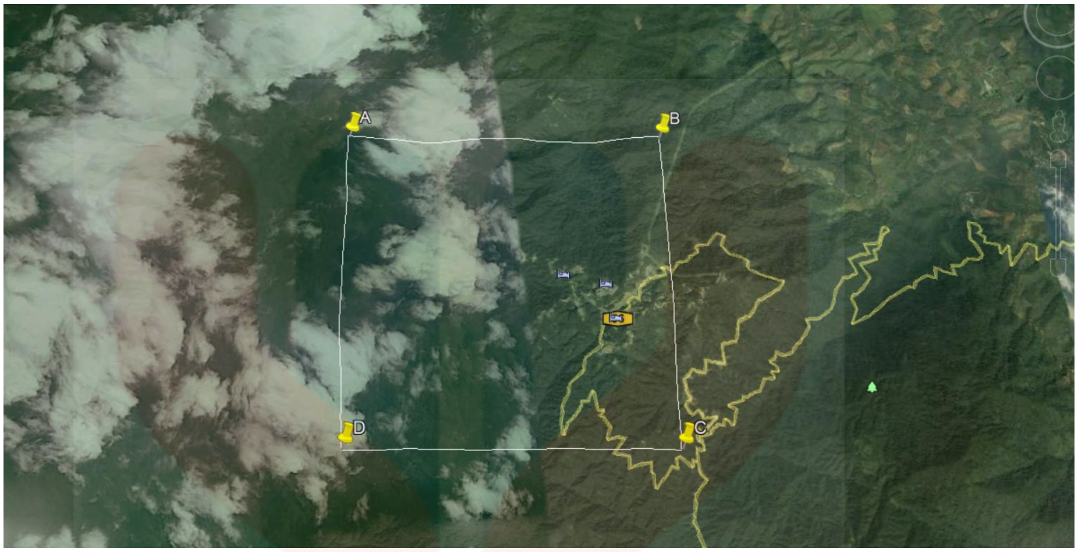


Figure 1.1: View of the study area in Fraser Hill.

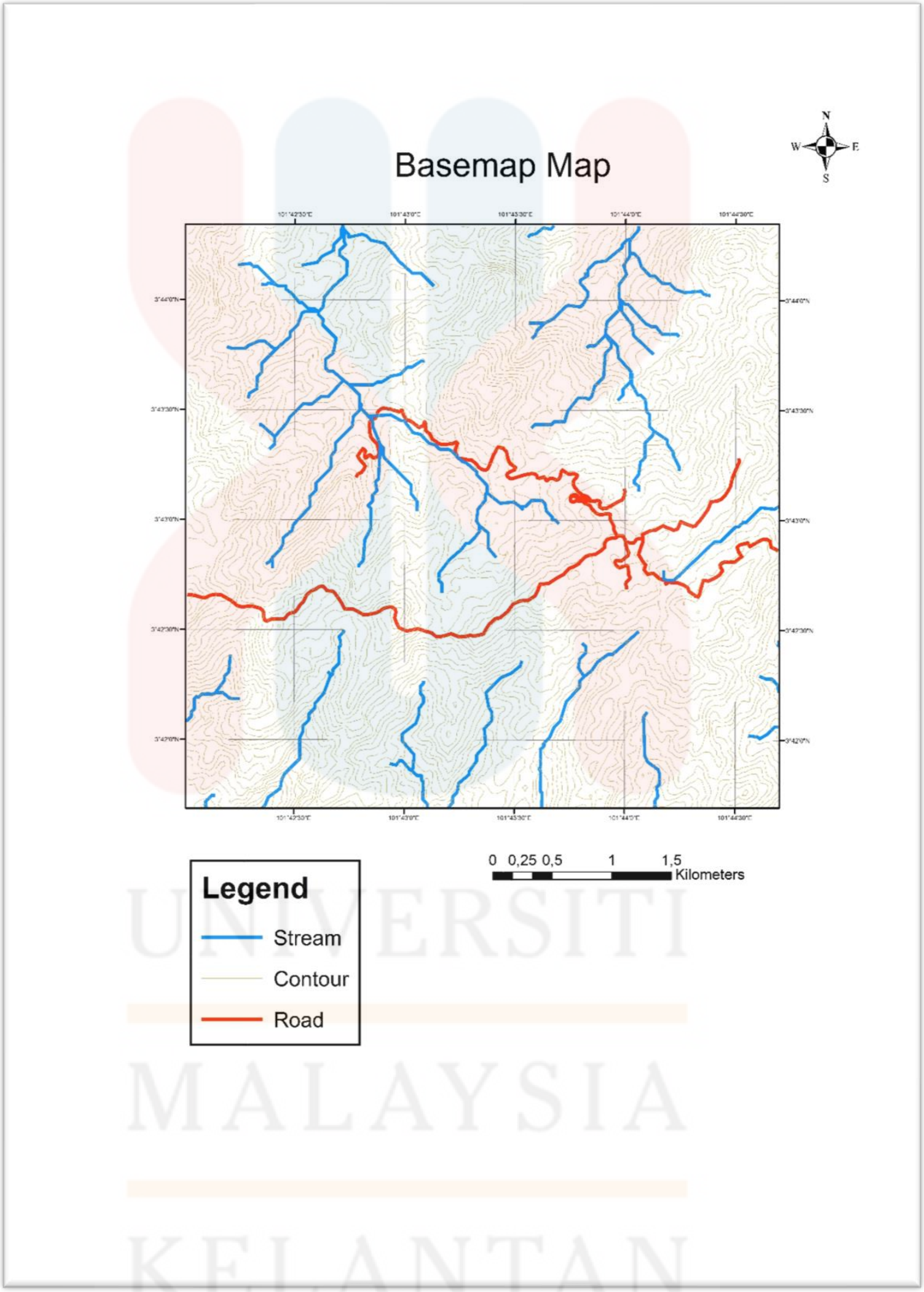


Figure 1.2: Base map of the study area.

1.2.2 Accessibility

There is a main road that connected the study area. Then, few roads can be used to access to the study area that mainly in the town of Fraser Hill. Next, there are a lot of village road, housing area road and unpaved road that reach the study area. All these roads can be accessed by car, motorcycle and also by walking. It can easier the researcher to reach the study area to conduct the research.

1.2.3 Demography

The investigation of human population in certain territory is called demography it is incorporated births, passing and relocation of human. Demography is valuable for understanding the social monetary issues. Simultaneously the demography empowers individuals to take arrangement in regards to specific issues. According to government of Pahang state, the population in Pahang is about 178 000 and only 1000 population stated in Fraser Hill. The Table 1.1 shows the population in Raub, Pahang. Table 1.2, Table 1.3 and Table 1.4 shows the division by gender, ages and ethnic in Raub, Pahang.

Table 1.1: The population in Raub, Pahang.

Name	**Status**	**Population** Census 2000-07-05	**Population** Census 2010-07-06
Raub	District	83,363	95,506

(Source: citypopulation.de)

Table 1.2: Division by gender in Raub, Pahang.

Gender (C 2010)	
Males	47,897
Females	43,834

(Source: citypopulation.de)

Table 1.3: Division by ages in Raub, Pahang.

Age Groups (C 2010)	
0-14 years	27,809
15-64 years	57,072
65+ years	6,850

(Source: citypopulation.de)

Table 1.4: The ethnic group in Raub, Pahang.

Ethnic Group (C 2010)	
Malay & other indigenous (Bumiputera)	55,787
Chinese	26,728
Indian	5,682
Others	272

(Source: citypopulation.de)

1.2.4 Land use

Fraser Hill can be categorised as a tourism spot that attract many tourists from local and overseas. Most of the town covered by infrastructure that use for the community to survive. Besides, there were also others land use at the foothill which is oil palm plantation and permanent forest reserve. In the study area, 50% of the study area located in the forest and agriculture area.

1.2.5 Social Economic

Fraser Hill is a tourism area that gained economic income from the sector. The community surrounding use the opportunity to generate income for them through the tourism service. Besides, the agriculture such as the oil palm plantation gained income to the state gross domestic product.

1.3 Problem Statement

The rising in number of landslides happened in Malaysia due to increase the process of urbanization and development in landslide-prone areas including the road and building development and deforestation. The landslide may affect the economic including damages on habitats and property and resources and injuries. The increase of regional precipitation caused by the change of climate pattern also needed to be study.

The study area is located at Fraser Hill, Pahang is a potential area that may lead into landslide hazard. The slope located there is heavily influenced with the climate area. This situation is endangered slope stability and induce landslide.

1.4 Research Objectives

The main objectives of the study are:

a) To update geological map of the lithology in the study area with the scale of 1:25000.

b) To analyse the landslide susceptibility analysis in the study area using the ArcGIS software.

1.5 Scope of Study

The study was held in 25km^2 wide on top of Fraser Hill. Geological map from the interpretation of previous data will be conduct in the area to have overlook for geological features at the study area to produce geological map as the result. The data gained from others agencies collected interpreted and produce a geological map to observe the geological features such as structure, vegetation and others. The GIS specification method such as landslide susceptibility analysis is conducted in order to determine the probability in the occurrences of landslide in the study area. The study is limited to due to the sources of secondary data. Others, the field mapping can not be done because the mapping process was not done.

1.6 Significant of Study

By This study, develop updated geological database of an area with different aspect such as drainage pattern, type of lithology, and structure and that maps will be beneficial to enhance previous researches, geologist, government and to conserve and protect the natural resources at the study area.

This research is important due to the previous outdated geological map so an updated geological map of the area was be produced at the end result of this research proposal that is believe to be beneficial to enhance previous research. The result of the landslide susceptibility analysis then will be obtained by using the ArcGIS software. This map will useful for the geologist, government and etc to conserve and protect the natural resources at the study area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will represent the result of the research based on the literature review and previous research such as thesis, journal and past report about the study area. This literature review needed to be done to understand the geological features of Fraser Hill, Pahang. All the previous study will be part of the references to this research. This chapter is very important as the starting point to ensure the working or the flow of the research can be done in the right ways, smoothly and accurate.

2.2 Regional Geology and Tectonic Setting

Southeast Asia is a complex geological region with many combinations of micro continent due to the collision of the tectonic plate since 500 million years ago. Southeast Asia consists of Early Tertiary continental terraces called Sunda stage which overlapped with the western part of Myanmar to south of Borneo.

Peninsular Malaysia is divided into three north-south part of belt that follow the different in terms of stratigraphy, structure, lithology and the age of the period time. This belt or zone named as Western Belt, Bentong-Raub Suture Zone (Central Belt) and Eastern Belt. The Wastern Belt form as the part of Sibumasu terrane that derived from the NW

Australian Gondwana margin during the late Early Permian era. Bentong-Raub Suture Zone can be assumed as the collision zone between Indochina and Sibumasu terranes.

Central Belt (Bentong-Raub Suture Zone) is including some state in Peninsular Malaysia such as Kelantan, Terengganu, Pahang, Negeri Sembilan and Johor. The rocks in this formation can be classify as Permian until Triassic period. Sedimentary rocks in this location are most consist of clastic volcanic rock and carbonate rock. Igneous rock also located in some part of this Central Belt.

Fraser Hill is in the middle of Peninsular Malaysia which is Bentong-Raub Suture Zone in Pahang state. Bentong-Raub Suture Zone is the tectonic between boundary Western Belt and Eastern Belt and also known as Bentong-Raub ophiolite line based on Hutchison (1975). Fraser Hill located in the Main Range which is Batholith Granite that dominated by Biotite Granite and amphibole granite. According to Gobbert & Hutchison (1973), Main Range is bounded by two fault which is Kuala Lumpur Fault and Bukit Tinggi Fault. Some minor fault can be identified through mylonite zone that discovered and can be seen clearly by the lineament observation.

The research in Fraser Hill started by Roe (1951). According to Roe (1951), the lithology in Fraser Hill is fined-grain Granite and coursed-grain Granite. Fined-grain Granite have more fractures than coursed-grain Granite. Granite that founded is in Carbonate period and maybe form during early Mesozoic or early Tertiary. Roe (1951) also stated that coursed-grain Granite as the first during the formation. This is based on the properties of tin in fined-grain Granite. Roe believe that this Granite had magma crystallization process during the last phase.

2.3 Stratigraphy

Fraser Hill is located on the granite rock of the Main Range dominated by biotite granite, the Range is co-opted by two major fault, Kuala Lumpur Fault and Bukit Tinggi fault. Minor faults detected in this range by looking at the elongated forms of granite mylonite zone and foliated (Gobbett & Hutchison, 1973). The earliest geological studies around Fraser Hill are those of Roe (1951). Roe reports that the rocks at Fraser Hill are fine-grained granite and coarse-grained granite and more likely fine-grained compared to coarse-grained. The found of granite is believed to be in Carbonate and most likely formed during the early Mesozoic or Lower Tertiary.

Previous Bentong Group used for Bentong area by Alexander (1955) has expanded further, its use for the whole Lower Paleozoic rocks available east of Granite. Along the path leading almost northwest of this area, many studies have been done. between area where detailed study was performed in BentongRaub area, Karak, Kuala Kelawang, Durian Tipus, and Kuala Pilah. North area of Bentong has no detailed study done. In those areas, the Bentong Group rocks have been divided or known by some formation names. Partly than these formations can be correlate with each other.

Alexander (1968) is divided Bentong group into two units which is Arenite series and Schist series. The Schist consists of quartz schist and graphite together with phyllite, slate and hornfels. In addition, there are garnet schist and amphibole. This sequence has been having a strong folded. The Arenite consists of layers flysch-type sediments. There is many lithology in this series which is conglomerate, quartzite and sub ridges, shale, phyllite, schist and carbonated chert.

Abdul Ghani Rafek and Goh Thian Lai (2012) have done a research on Joint Roughness Coefficient (JRC) at KM15 Jalan Kuala Kubu Baru to Fraser Hill and stated that shist amphibole rock sample had found as the roof pendant above the granite body. Roe (1951) also reported that the location formed from shist amphibole. This rock is made up of schist actinolite, schist tremolite and schist pyroxene and had been agreed by Hutchinson (1973).

2.4 Structural Geology

A lineament is a linear feature of a landscape which is used to express an underlying geological structure such as fault. It is any extensive linear surface as a fault line or a fracture line. Lineament is often apparent in geological or topographic maps.

The term lineament first used by Hobbs (1904) to define a significant line of landscape of basement rocks. Lineament can be described as a linear topographical or tonal feature on the terrain that representing zones of structural weakness (William,1983). Then, Gupta (1991) concluded that the lineament defined in different geological features, such as shear zones or faults, rift valleys, truncation of outcrops, fold axial traces, joint and fracture traces, topographic, vegetation, soil tonal changes alignment and others.

Using PALSAR ScanSAR data, major structural lineaments such as the Bentong-Raub Suture Zone and Lebir Fault Zone, ductile deformation associated with crustal shortening, fragile disjunctive structures (faults and fractures) and collisional mountain range (Main Range granites) were identified and mapped on a regional scale. The BRSZ's major geological structure directions were N-S, NNE-SSW, NE-SW and NW-SE, which were derived from PALSAR fine and polarimetric data from directional filtering analysis.

2.5 Historical Geology

The Bentong-Raub Silk Zone is considered as zone of infringement between the Sibumasu terrain and the eastern Malaya terrain (Indochina). Sibumasu is part of the Cimmeria plate still associated with Gondwana during Carbon. The East Malaya terrain is also associated with the Indochina Sheet. From Devon to Perm Sibumasu and East Malaya are separated by an ocean known as the Palaeo-Tethys. The closing of the Palaeo-Tethys expired in Trias time. Most of the history of the Palaeo-Tethys has been destroyed, only a small portion of it is preserved in rock seaweed like chert.

In the Late Palaeozoic and Triassic collisions of the Sibumasu terrane with and underthrusting of, Indochina, the suture zone is the result of the northward subduction of the Palaeo-Tethys ocean beneath Indochina. Tectonostratigraphic, palaeobiogeographic and palaeomagnetic data show that during the Permian-Triassic, the Sibumasu Terrane separated from Gondwana in the late Sakmarian, and then dropped rapidly northward. The East Malaya volcano-plutonic arc, with I-Type granitoids and intermediate to acidic volcanism, was developed at the margin of Indochina during the Permian subduction phase. The main structural discontinuity between Palaeozoic and Triassic rocks occurs in Peninsular Malaysia, and orogenic deformation appears to have been initiated when Sibumasu began to collide with Indochina in the Upper Permian to Lower Triassic. A-Type subduction and crustal thickening generated the Main Range syn-to post-orogenic granites during the Early to Middle Triassic, which were located in the Late Triassic-Early

Jurassic. In front of the uplifted accretionary complex in which the Semanggol "Formation" rocks accumulated, a foredeep basin developed on the depressed margin of Sibumasu. A recent Triassic, Jurassic and Cretaceous, primarily continental, red bed overlap sequence, covers the suture zone. From Figure 2.1, it shows the summary for the movement formation.

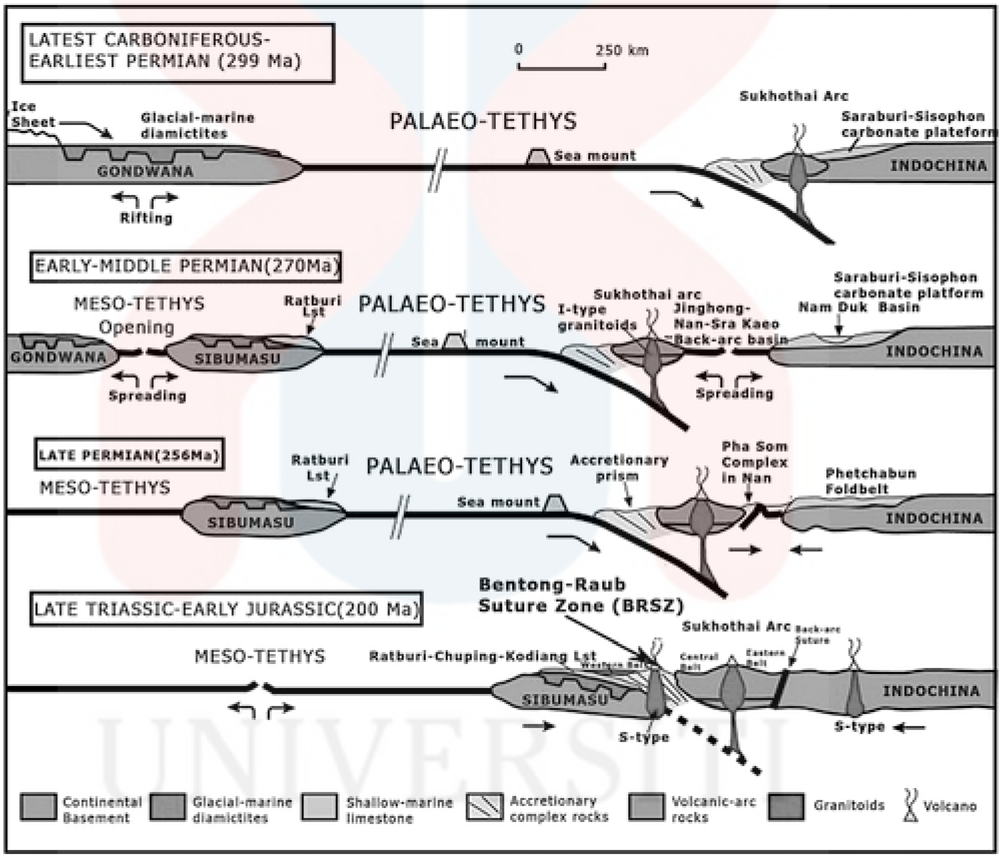


Figure 2.1: The formation of Central Belt. (source: Pour A. B. 2016)

2.6 Landslide Factors

Landslide influence by six common factors such as rainfall, soil, slope length and stability, slope gradient, covering system and soil conservation system said by Roslan (2004). Between these factors, rainfall and soil factor is the most important factors that always influence and trigger soil erosion or landslide. By identifying this factor, the prediction of soil risk reliability can be determined for any further study. According to Department of Mineral and Geoscience & Komoo (2003), landslide occurred in Taman Hillview were caused by the continuous heavy rainfall and human activity such as land reclamation and thrusting slopes to prevent the original flow of water from flowing as the main factor for the failure.

According to Jamaluddin (2006)**,** Malaysia is not a rash country. The slope failure always happens because of the monopoly of the rainfall. Abdullah (2013), found that Malaysia always experiences frequent flooding and also landslides. About more than USD 1 billion has been estimated and appraised during case losses of landslide since year 1973. In Table 2.1 shows the example of landslides occurring in Kuala Lumpur city center.

Table 2.1: Example of landslides occurring close to Kuala Lumpur city centre.

Date	Location	Type of Landslide	Number of Death	Notes
December 1993	Ulu Klang,	Shallow rotational slide. Heavy rain triggered makeds the failure of cut slope behind the Highland Tower	48	Cut slope in granitic formation
June 1995	Karak Highway – Genting Highland slip road, Selangor – Pahang border, 20 km to Kuala Lumpur City	Debris flow. 'Snowball effect' debris avalanche triggered the failure of upstream natural dam during heavy rain triggered.	22	Natural slope in meta-sediment formation

January 1999	Squatters settlement, Sandakan Town, Sabah	Shallow rotational slide. Heavy rain triggered landslide – buried a number of houses	13	Natural slope in meta-sediment formation
November 2002	Hillview, Ulu Kelang, outskirt of Kuala Lumpur city	Debris flow. Sliding of debris soil of abandoned projects during heavy rain.	8	Dumping area of abandoned project in granitic formation
November 2004	Taman Harmonis, Gombak, outskirt of Kuala Lumpur City	Debris flow. Sliding/ flowing of debris soil from uphill bungalow project.	1	Dumping area of project ongoing project in meta-sediment formation

December 2004	Bercham, Ipoh City, Perak	Rock fall	2	Natural limestone cliff in karsts formation

(Source: Abdullah, 2013)

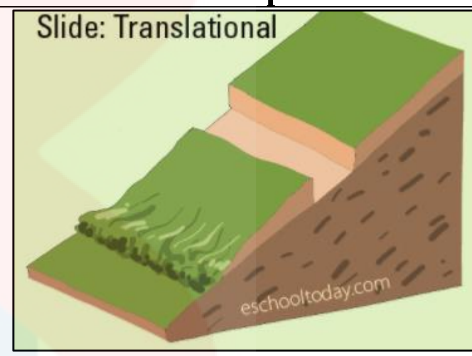
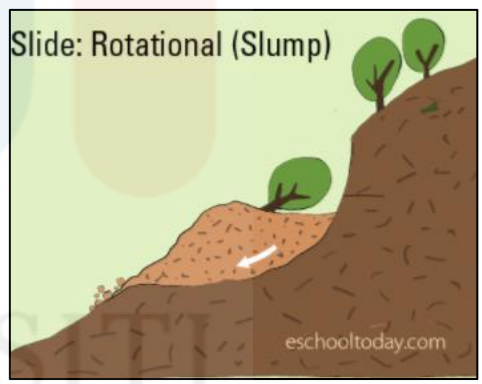
According Ibrahim Komoo and Lim (2003), the landslide occured at the Athenaeum Tower in Bukit Antarabangsa in year 1999 has investigated and studied. The area is consisting of hills from Great Range granite lithology and was highly weathered and the condition has been to be a residual land. This incident has caused in property damages and the location of the area was totally tough to access. This incident also involves the interruption of water supply, transmission and psychological by the society in that area.

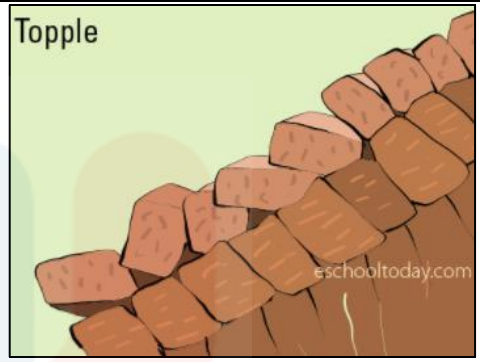
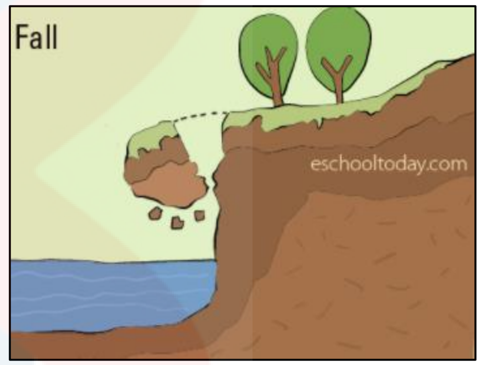
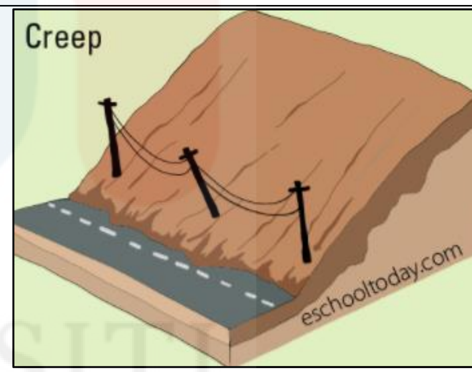
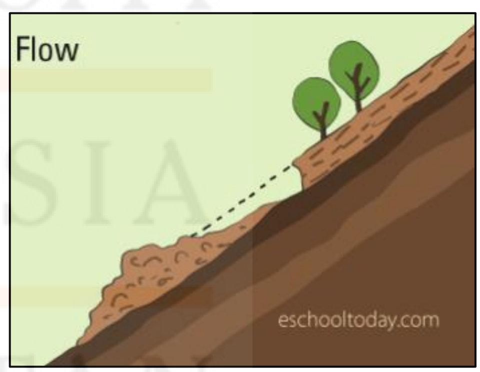
In study Tan (1986), found that a landslide take place at the Ipoh-Changkat Jering highway. He stated that this area consists of lithology of granite residual soil that has already have a slope failure about 150 m in range. This slope has been digging up for the construction of two tunnels. Slippage that occurred is due to slope conditions that is cut slope and also because of from rock blasting.

2.7 Type of Landslide

The types of landslides can be differentiated by observing their movement and earth material involved in that scene, according to eschooltoday.com website. Table 2.2 show the types of landslide.

Table 2.2: The types of landslide.

Type of landslide	Description	Example
Slide	Slides can be occurred in translational or rotational. In a translational slide, its mechanism has moved the earth mass than it has place after it slides downhill on a plane preface. In a rotational slide, the movement of the earth material is rotational and rotate. It is also well known as slump	 

Topple	The earth mass rotates and goes forward in toppling motion. The result is that the rock tilts without collapse. This is normally caused by crack or fracture phenomenon in the bedrocks.	 
Flow	Flows come in many types of movement, such as Debris flow, Debris avalanche, Mudflow, Creep and Earth flow.	 

(Source: eschooltoday.com, 2008)

2.8 GIS in Landslide Susceptibility

A Geographical Information System (GIS) is computer software system that used for mapping and analysing the events occur above the Earth surface. The geographical implies the locations of the data items which is in the form of coordinates systems. The data can be shown with coloured maps, graphics, tables, models and others. System refers to how the data manage and organized. How the component that made up GIS perform their works (Xie,2014).

In GIS methods, many approaches can be used to generate landslide susceptibility maps. From the previous study, the spatial data were organized in GIS SPRING software (Câmara *et al*., 1996) and calculations related to the computation of probabilistic methods performed using MATLAB software (MATLAB, 2016). By performing both methods, it is possible to determine the slope failure by producing a study area slope inclination map.

Shahabi & Hashim (2015) used the GIS-based statistical model in their study area to generate landslide susceptibility mapping using GIS and remote sensing data. Their study area located at Cameron Highlands and use parameter such as fault, SPOT 5, WorldView-1image and distance between roads that was extracted using SAR data. The maps are then constructed between variables defined using multiple models after calculation and determination including hierarchy process (AHP), weighted linear combination (WLC) and multi-criteria spatial evaluation (SMCE) models.

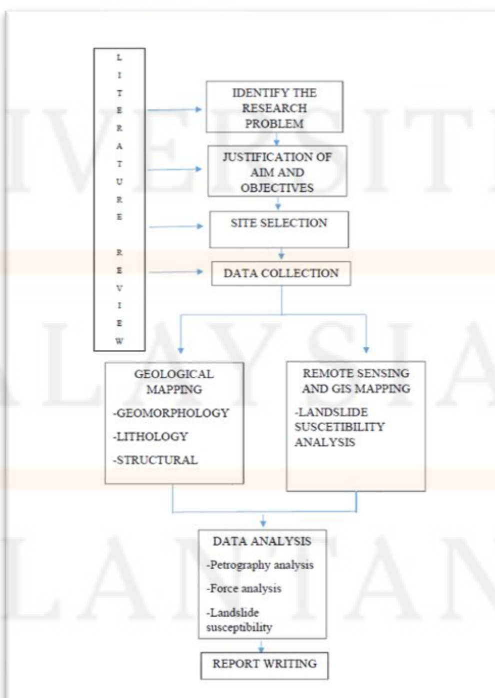
Using the Weightage Overlay Method (WOM) and Landslide Susceptibility Level (LSL) map, Rodeano et al. (2017) produced a landslide hazard zoning map from Genting Sempah to Bentong, Pahang. The most causative factors such as land use, drainage, line distance, soil lithology and geomorphology are weighted by the study. These parameters were collected from the topographic database and classified from very low to high levels of susceptibility to landslides, reflecting the possible occurrence of landslides in the study area. Heavy rainfall triggered the landslide by changing the land and soil intensity. From all the data, layering method by raster input was weighted.

CHAPTER 3

MATERIAL AND METHODOLOGY

3.1 Introduction

In this part it will clarified in subtleties how the examination was completed. It will give scientist a rule to follow the materials and technique that be use in this exploration. Moreover, it likewise will give an entrance to others to proceed with this examination by utilizing the rule given. Materials and methodologies initially being decide to run the exploration. It will assist the examination with obtaining information just as investigate information.



3.2 Materials

In order to obtain and analyse the data, material and method is most important to sustain the research. In this part, several different phases that include in the method process that involve from pre-field study, data analysis and interpretation. The materials that be use are identified by the type of method that will be conduct during this research as important and plays a major part of the method.

Computer software is very needed to complete this study in order to run the interpretation of the data and for the other previous research. The previous map is needed to produce the current geological map by interpretation and observation. This includes the digital data from other source such as LIDAR, PALSAR and USGS.

Global Positioning System (GPS) is very needed to identify the coordinates and to mark the location. The location will be mark and create a box in the GPS then help the researcher to know the exact location of the study area. During the sample collection, the coordinate of the location needed to be mark and noted in the field note book for further reference. GPS device is one of the best with highly sensitive and received an information faster from the satellites and will easier the researcher to know the location during traversing.

To produce the maps, the software that will be used are ArcGIS software. This is a software that used to create, edit and analyse the collected data and build a perfect map. By using ARCGIS, all of the maps are created before and during the programme. The maps that need to provide by the researcher in order to do the mapping is base map, contour map, drainage map, watershed map, lineament map, tin map, rock boundary map, landform map and land use map. Besides that, Google Earth Pro software also will be integrating with ArcGIS to form the maps in order to get more precise and correct location of the study area. These maps contain detailed information about the area itself including the spatial relationship that exists between objects, structures and more.

To produce the landslide susceptibility map, the secondary data collection of topographical data, Digital Elevation Model (DEM), and satellite images are essential. The maps of causative factor such as lithology map, soil map, drainage map, land use map, slope map, aspect map and NDVI map are extracted from secondary data gain from agencies and geological mapping.

a) Lithology map

The lithologies of the study area were collected during the geological mapping. By observing the rocks and its boundaries, the lithology was identified. As the observation was done, the data that was recorded in the field are mapped out and formed lithology map.

b) Slope map

By calculating the slope during geological mapping or extract it from the satellite imaginary data, the slope degree can be identified. It shows the distributions of the slope based on its angle. The slope is classified using Zuidam classification, 1985.

c) Aspect map

An aspect maps is a map that shows direction and degree of steepness of the slope for a terrain. It was generated in ArcGIS from the USGS website as well.

d) Lineament density map

Lineament density of the study area can be mapped out from geological mapping and derived from the satellite image. The data is derived from USGS portal.

e) Drainage density map

The drainage density map was design from the USGS satellite image from the USGS websites. It is very important as the drainage density is proportional to the mean erosion rate. Hill slope transported the sediment affect the process of runoff erosion.

The uses of remote sensing are to identify prominent rock landforms or any features in the map. The image properties and features that were obtain were delineate rock lithologies. The remote sensing also can be used to note any observable faults, contours and select the accessible traverse routes for closer field study of the lithologies and also the faults. Remote sensing data could be used to detect geological structures linked to suture zones between Gondwana-derived terranes, particularly for large inaccessible regions where field work is limited or non-existent. According to Raharimahefa & Kusky (2006, 2009), structural analysis and remote sensing studies have been used to spot the suture zone between Eastern and Western Gondwana in Madagascar.

3.3 Methodologies

3.3.1 Preliminary Study

The general knowledge about the study area and research can be known by the preliminary study. The literature review about the study area can be found in the previous article, journal and report. This preliminary study may overview the researcher about the geological setting, drainage pattern and morphology of the study area. It cleared the researcher imagination to interpret the geological mapping and the way to study electrical resistivity data and the best method to finish the project. A review from Google Earth (internet) Department of Survey and Mapping Malaysia (JUPEM) and the Department of Mineral and Geoscience Malaysia (JMG) has been study. These maps are important and helpful in making initial overview or interpretation of the study area. The discussion with supervisors also made to obtain the required information about the study area.

Research problem and creating the research question is the most important to complete this research. This is because the research is divided into two study which is general geology and landslide susceptibility. After knows the problem and research question have been created, proceed with the collection of literature review. It may come from journal, books or previous research thesis. Observation from topographic map and the satellite image also had been done

3.3.2 Data Processing

a. Evaluation of causative factors that triggered landslide to occur

In the assessment of causative factors that cause landslides to occur, six parameters such as lithology, slope, drainage density, land use, aspect and vegetation were considered. The occurrence of landslides usually occurs because of these variables, so all kinds of data in the study area such as dimension and past landslides were collected during the geological mapping.

b. Landslide susceptibility map

The Weighting Overlay Method was used for landslide susceptibility map production. Satellite data and data collection from geological mapping as well as the parameter involved have been mapped. It was then converted to raster-based data. Raster was weighted and rated using the rating scheme, in which all these factors and their classes were set as numerical values. The landslide was assessed with a scale of 1 to 5. Scale 1 is the least prone to landslides, while Scale 5 is the very high potential landslides, as shown in Table 3.1. All raster-based data were weighted as a percentage based on their importance. The total influence of the raster must be 100 %.

Table 3.1: The landslide susceptibility classes with its percentage.

Landslide Susceptibility classes	Percentage of landslide pixels	Percentage of class area
Very low	4.65	18.28
Low	7.31	19.04
Moderate	15.09	25.63
High	34.86	25.66
Very high	38.09	11.39
Total	100.00	100.00

(Sources: Champati P. R. and Santosh K. S., 2007)

3.3.3 Analysis and Interpretation

For the geological mapping, the researcher needs to perform information about the study area from the data taken. A geological map should be form to update and shows the prove of the project. The report should be concluded about the laboratory results, drainage pattern, geomorphology, lithology and stratigraphy of the study area. Geospatial Information System (GIS) is used to perform the geological map include traverse, geological map and stratigraphy column. The researcher should be able to use GIS to complete the research.

For the creation of Landslide Susceptibility inventory, the specific parameters that was identified during the analysis such as the slope geometry, the drainage density analysis, the lineament density analysis, the watershed analysis and also the topographical analysis. All of these parameters were important in determining the weightage of landslide susceptibility in the study area.

The raster layer of parameters used such as slope, vegetation, drainage density and aspect, were generated by using the DEM. From all the data, layering techniques were weighted by raster input. The weight assessment was carried out using reclassifying tool in ArcMap based on the reclassified weight. The landslide susceptibility map was generated as a consequence.

Results from the methods of weighted overlay show the most susceptible area to landslides with a scale of 1 to 5 and susceptibility classes. The landslide assessment was performed to show that the distribution of high potential to low landslide potential was most likely to occur. In order to avoid any construction of infrastructure or houses near the high susceptibility area, the landslide susceptibility map can be used as an indicator.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

General geology is one of the most important chapter that will includes about geomorphology, structural geology, stratigraphy and historical geology of the study area. All the data were obtained from the secondary data that had been analysed.

Geomorphology is the study of the landform and its processes related to the origin of the Earth and about the evolution of the Earth. Geomorphology includes the study from topography, drainage pattern and the weathering process occur in the study area. Stratigraphy is another part of geology that concerned with the order and relative position of strata and for sure their relationship with the geological timescale.

Stratigraphy involved the lithostratigraphy, biostratigraphy, chrono stratigraphy, sequence stratigraphy, seismic stratigraphy and also magneto stratigraphy but the most concerned part in this paper is on the lithostratigraphy part.

Structural geology is carried out by the analysis of structure found on the outcrops such as fault, joint, fracture and fold. The structural mechanism was done to determine the major forces that deformed in the study area. Part of the historical geology also discussed about the historical formation of the study area. In this part covered the sequence of the lithology found and also the history of deformation during the formation of the area.

The geological mapping is very important in geology to describe in detailed the process that had occurred in the study area, the type and also the formation of the rocks.

4.2 Geomorphology

Geomorphology is the scientific study of the origin and evolution of the topographic and bathymetric features that created by physical and chemical processes operating at or near the Earth's surfaces. The major type of landforms included mountains, hills, plateaus and plain. The geomorphology of the Earth can be made up by either endogenic or exogenic processes. The endogenic process that can create landforms is related to volcanism, diastrophism and earthquake while exogenic processes referred to the aggradation.

Mountain is the large landform in form of a peak that rises high to its surrounding area. Plain is a landform that has flat area commonly occurs as lowland. Fluvial is a morphology formed by the processes and deposits of rivers and streams. From this, it can seek the understands about why landscapes look the way they do, understand landform history and dynamics and also can predicts changes through a combination of the secondary data analysis. Figure 4.1 show the hilly landform in present in the study area. Figure 4.2 shows the landform at the study area mostly composed of undulating and hilly area. In this chapter, geomorphology consist of observation and analysed topography map of landform, and drainage pattern.

Figure 4.1: Hilly landform of the study area.

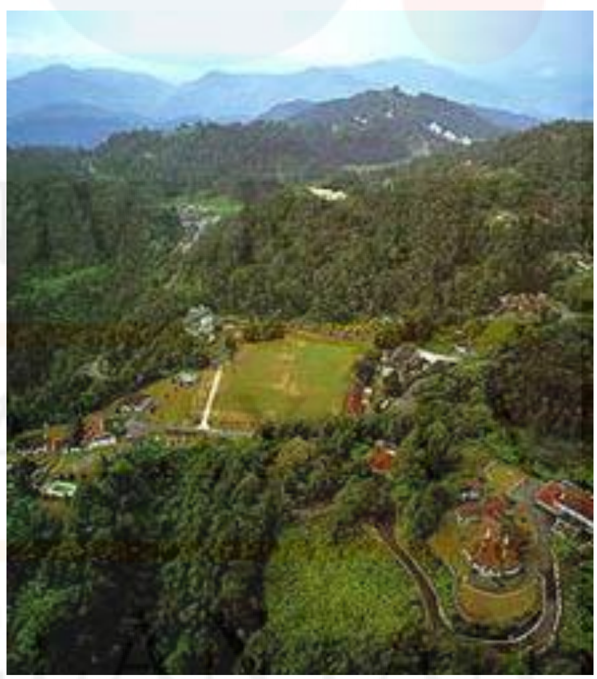


Figure 4.2: Undulating and hilly area landform.

4.2.1 Topography

Topography is the arrangement of the physical distribution of the Earth's surface such as shape and elevation. The topography of a particular area can show by the topographic map which included the elevation of the area. The topography in the study area high hill based on Van Zuidam (1985) classification. Table 4.1 shows the landform classification. Based on the Figure 4.3, the map shows the landform of the study area.

Table 4.1: The landform classification

Relief/Landform	Elevation (m)
Low hill	100 – 200
Hill	200 – 500
High hill	500 – 1500

(Sources: Van Zuidam, 1985)

The elevation of the study area ranging from the lowest that is from 800 meter to the highest elevation of 1340 meter. The pattern of topography that shows the lines of the contour is very close means the topography is high and steep. However, the line of the contour that far away means the topography is low area. The highest elevation of the study area can be seen at the middle of the study area where the highest elevation is 1340 meters. The study area is 100% covered by high hill according to Van Zuidam classification. Geomorphology analysis is done at the study area.

The type of rocks that found in the area are known based on contour pattern and from the secondary data. For the study area, the high hill area has the characteristic of igneous rock and some sedimentary rocks.

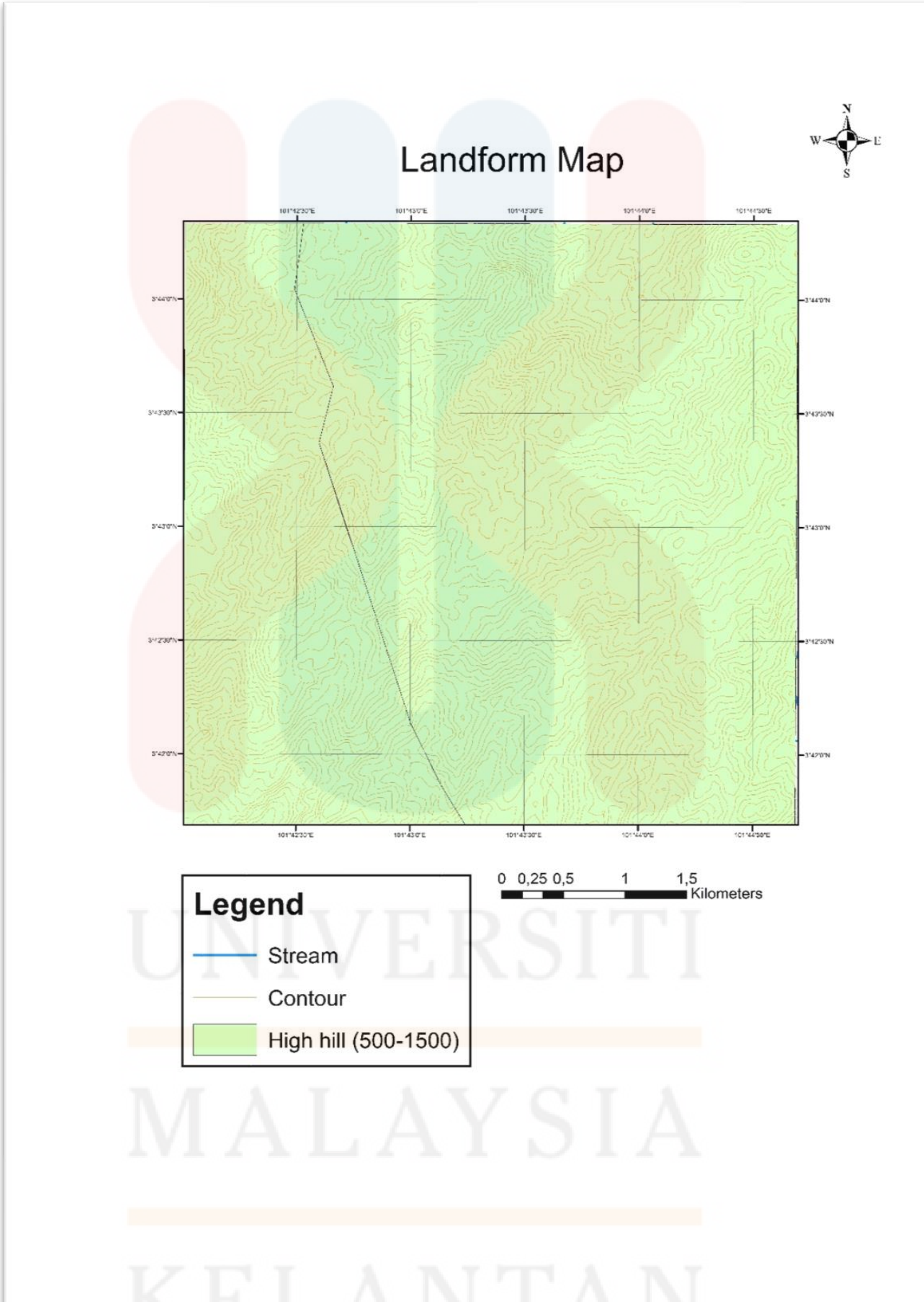


Figure 4.3: Topographical map of the study area.

4.2.2 Drainage pattern

Drainage pattern is the arrangement of streams on the surface of Earth by drainage system. Geologic and topographic factors of the rock beneath the Earth reflected the drainage pattern as well. The drainage pattern included dendritic, parallel, trellis, rectangular, radial, centripetal and deranged pattern. Dendritic drainage pattern is the most common drainage pattern found on the surface of Earth.

There are two types of drainage pattern that can be observed from the study area such as parallel and dendritic pattern. Parallel drainage pattern is a river pattern that caused by steep slopes with only some relief. This type of pattern frequently developed on uniformly sloping and dipping rocks beds. It is also developed in the regions of parallel elongated landforms for examples like the outcropping resistant rock bands.

Dendritic drainage pattern is one of the most common drainage patterns that develop in the area where the rock in the area beneath the stream can be eroded easily in all direction. The shape of the dendritic drainage pattern looks like branching shape of tree roots. Ritter (2006) stated that the dendritic drainage pattern develops in areas underlain by homogeneous material. The tributaries join to the larger streams at acute angle (less than 90 degrees). This dendritic pattern can be found at the steep area with the lithology of igneous rock.

Watershed can be defined as the area or ridge of land that separates the waters to flow to different basins, rivers or seas. Ridges and hills that separate two watersheds called as the drainage divide because of its character. The watershed also consists of streams, reservoirs, lakes and wetlands and all the underlying groundwater. Figure 4.4 shows the drainage pattern map of the study area.

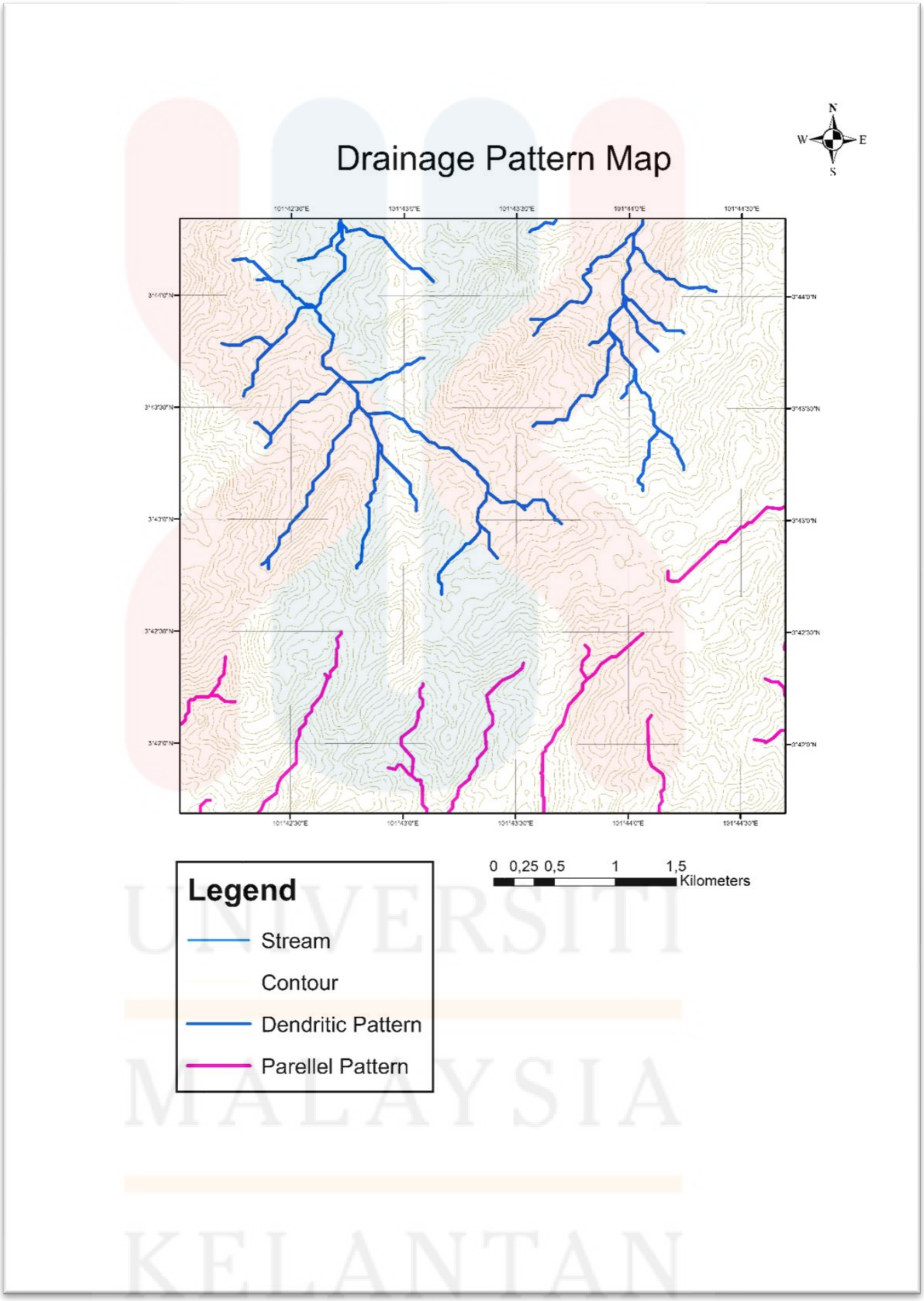


Figure 4.4: Drainage pattern map of the study area.

4.2.3 Contour Pattern

A contour line is a curve with constant value that indicates the resistance of rock in the study area. The resistance pattern was measured by analyses the resistant of rock to the erosion. Based on the map, the middle part of the study area has the highest elevation with steep contour line and northern part of the study area have two valleys with the lowest elevation. From there, middle area of the study area has the highest resistance.

4.3 Stratigraphy

Stratigraphy is the study of the characteristics of layered rocks, relationships between the layered rocks and the relative and absolute ages of the rocks. Lithostratigraphy is one of the sub-topics of stratigraphy which concern on the of the study of the rock layer. It usually uses to describe the relationships between the formations of igneous or sedimentary rocks.

4.3.1 Lithology

Lithology refers to the study and description of the physical characteristics of rocks, particularly in hand specimens and outcrop (Bates and Jackson, 1980). The characteristic of the lithology including the colour, gain size, type of rock and mineral contain. There are two main lithologies in the study area which are igneous rock unit and schist unit. These lithologies can be divided into Bentong Group and intrusions of Main Range Granite.

Bentong group is the oldest formation in the study area with Silurian or Ordovician with the schist consist of quartz and graphite together with phyllite, slate and hornfels. The youngest lithology in the study area is Middle range formation (Bentong-Raub suture) during Mesozoic until Lower Tertiary age with Batholith granite, Biotite granite and Amphibole granite. Figure 4.5 shows the lithological map while Figure 4.6 shows the stratigraphic and lithology column if the study area respectively.

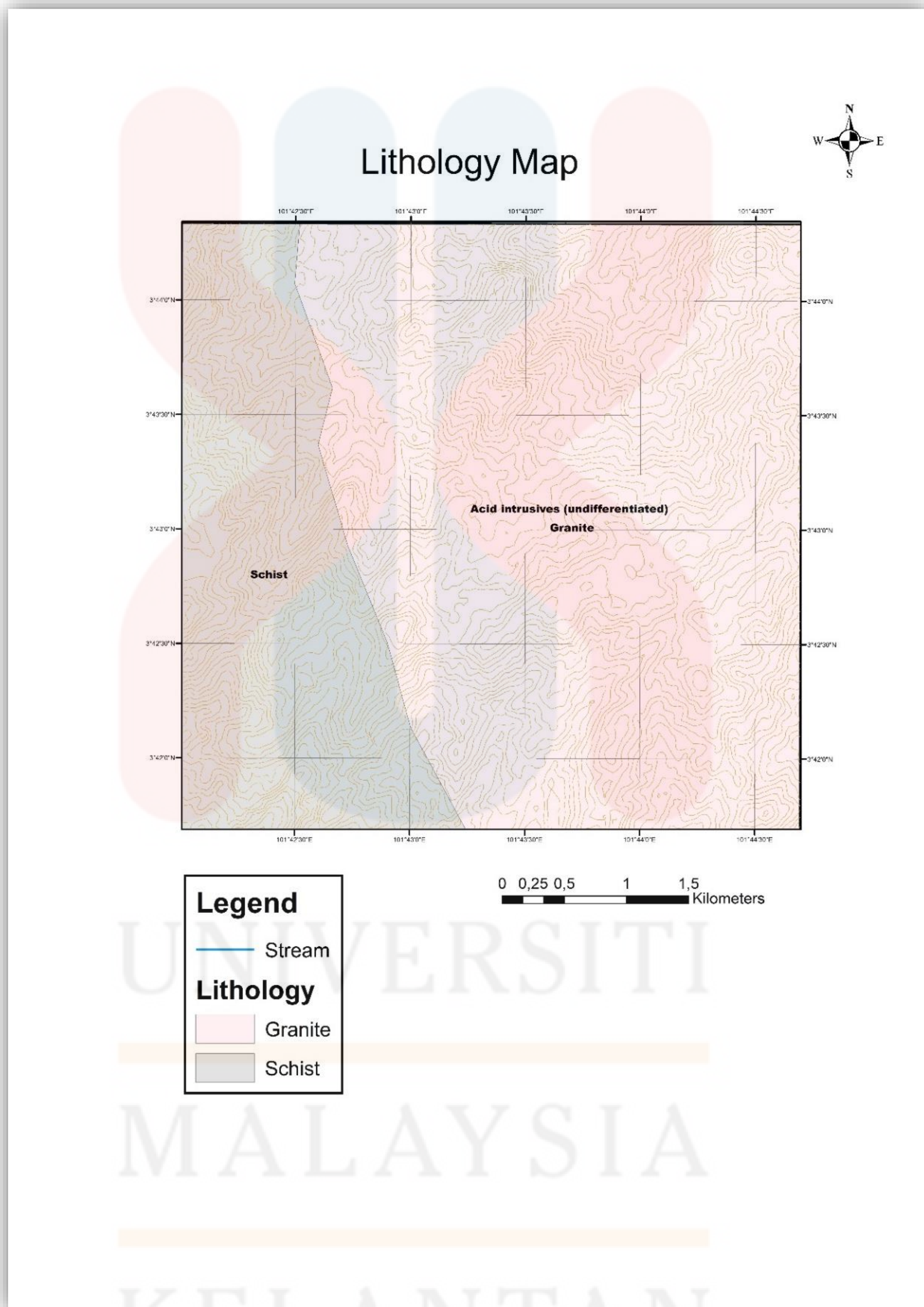


Figure 4.5: Lithological map of the study area.

AGE	LITHOLOGY	DESCRIPTION
Mesozoic / Lower Tertiary		**Bentong-Raub Suture.** Batholith Granite, Bio-tite Granite and amphi-bole granite.
Silurian / Ordovician		**Bentong Group.** The Schist consists of quartz schist and graph-ite together with phyllite, slate and hornfels.

Figure 4.6: Stratigraphy column of the study area.

4.4 Structural Geology

Structural geology concern on the geological features formed due to tectonic movement that cause deformation to occur. It is important to analyse the geometries and investigate the Earth tectonic activities as well as the stress and strain of the rock. By knowing the structural geology, the history of the Earth can be revealed. Deformation cause fault, fold, joint, bedding and veins to occurred. The deformation of Earth can be detected through geological mapping and lineament analysis using terrain map.

4.4.1 Lineament Analysis

Lineaments provide information about the geological structure lying on the Earth though linear or straight line. By using satellite image or aerial photograph, the terrain surface expresses the faulting and other structure in large scale. Caran et al. (1981) defined lineament as a pattern in a photograph, map or model of earth's surface or subsurface of earth which is stratigraphically, structurally or geophysically defined that must be linear, continuous, well expressed and related to features of the solid earth. Fault zones, igneous intrusions, shear zones, valley, fault or fold-aligned hills, streams and coastlines contributed to lineaments.

Lineament were divided into two categorize which is positive and negative lineament. Positive lineament was presented by ridge and range while negative lineament showing streams, faults and valleys. Lineament analysis was done before geological mapping to locate the geological structure such as strike slip fault, faulting, folding and joint. Figure 4.7 shows the lineament maps and Figure 4.8 shows the rose diagram of the study area.

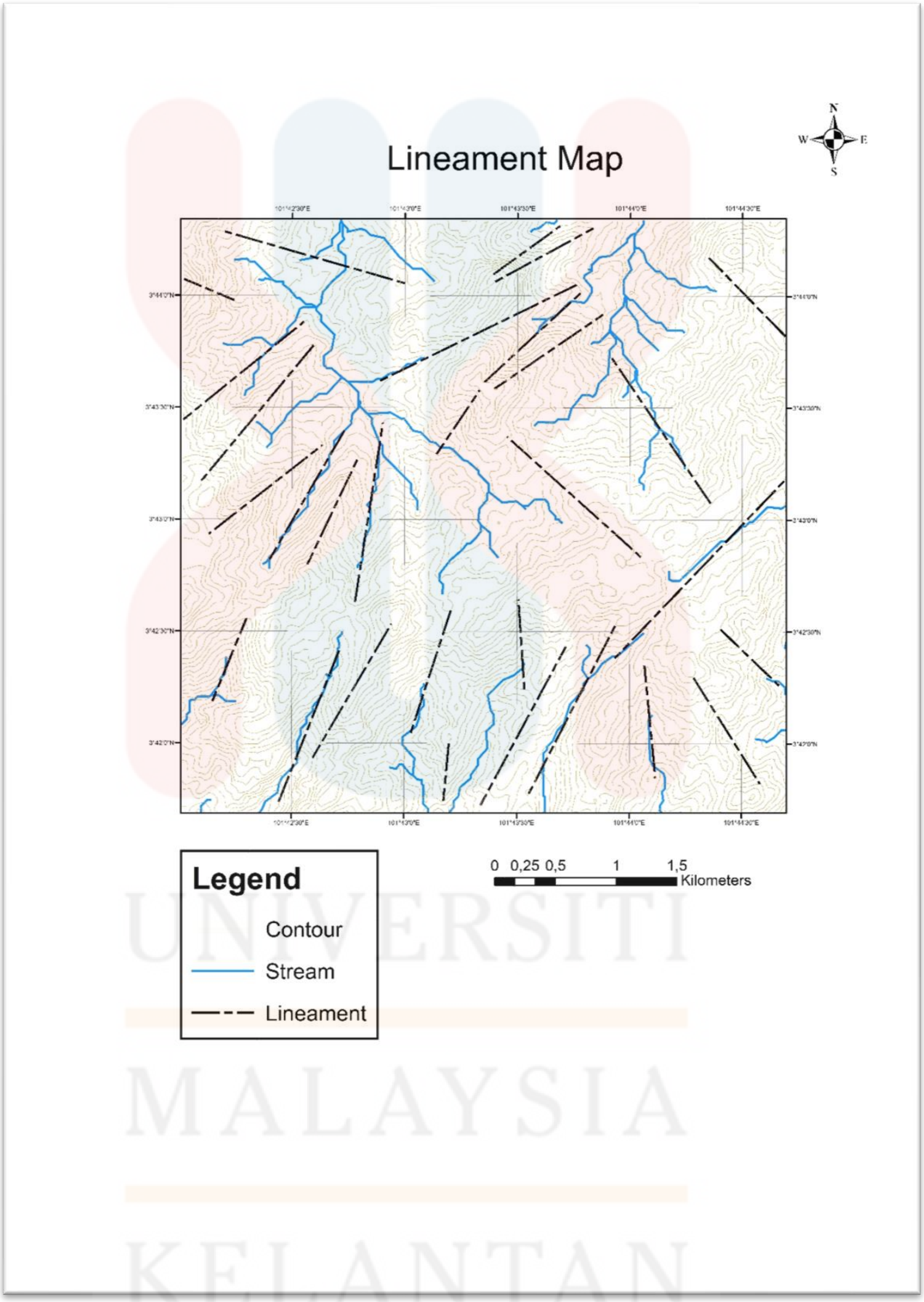


Figure 4.7: Lineament map of the study area.

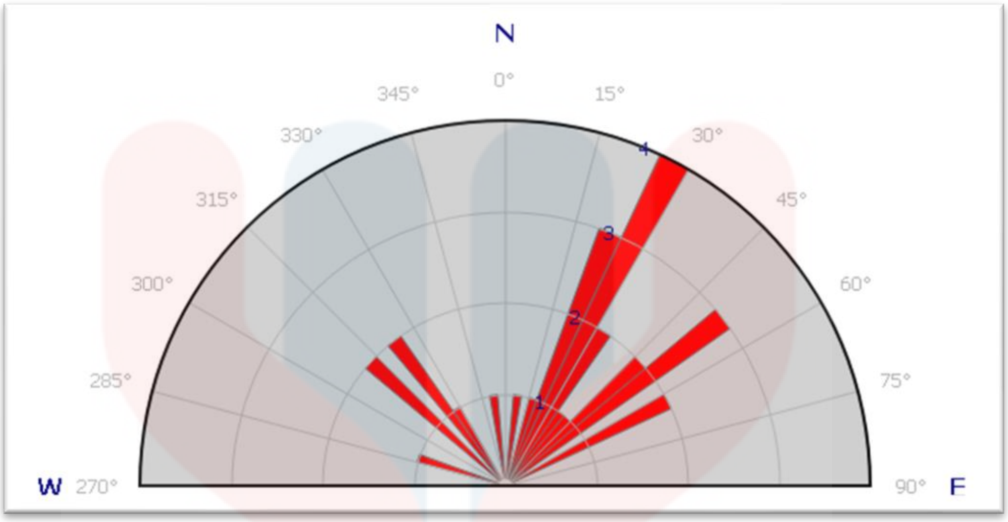


Figure 4.8: Rose diagram based on lineament analysis.

4.4.2 Faulting

Fault is defined as the fracture zone between the rocks. Fault allowed the blocks to move in relative to each other. The occurrences of fault may occur rapidly or it may occur in the form of earthquake. It can be classified into several types included dip-slip fault, strike-slip fault, oblique-slip fault, normal fault, reverse fault, and thrust fault. Fault can be formed at all types of rocks due to the deformation. The type of fault that can be found in the study area is normal fault and also the strike slip fault. The strike and dip of the fault is taken.

Strike-slip fault is the vertical fractures where most of the blocks have moved horizontally. There are two types of strike-slip fault that is called sinistral and dextral. Sinistral strike-slip fault is when the far sides of the blocks move to the left while dextral strike-slip fault is when the far sides of the blocks move to the right. In the study area, the type of the strike-slip fault is the sinistral strike-slip fault as the as the far sides of the blocks move to the left.

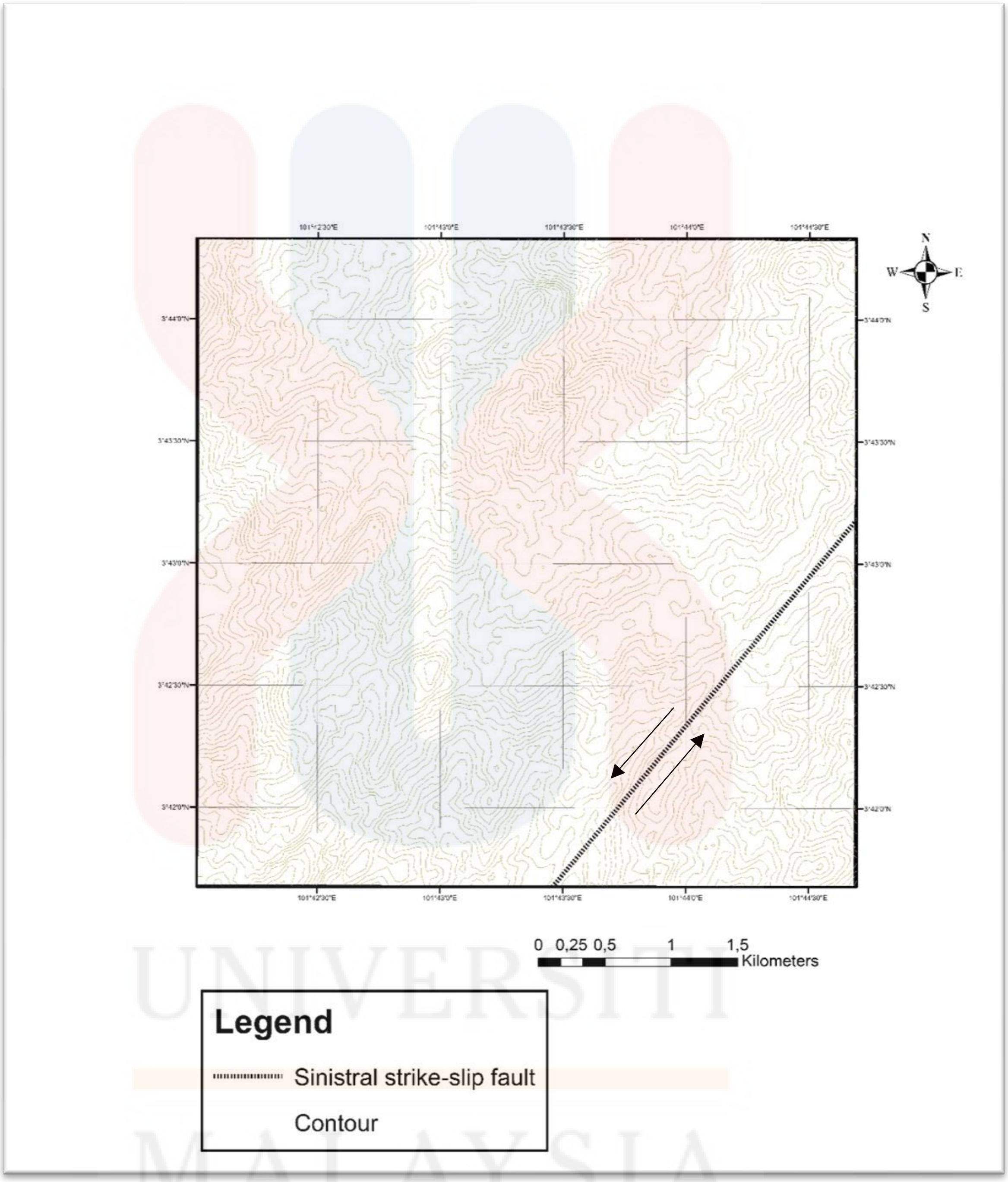


Figure 4.9: Sinistral strike-slip fault of the study area.

4.5 Historical Geology

In the Late Palaeozoic and Triassic collisions of the Sibumasu terrane with and below Indochina, the suture zone is the result of the northward subduction of the Palaeo-Tethys ocean below Indochina. Tectonostratigraphic, palaeobiogeographic and palaeomagnetic data show that, during the Permian-Triassic period, the Sibumasu Terrane separated from Gondwana in the late Sakmarian and then sank rapidly to the north.

The Bentong-Raub Silk Zone is considered as zone of infringement between the Sibumasu terrain and the eastern Malaya terrain (Indochina). Sibumasu is part of the Cimmeria plate still associated with Gondwana during the Carbon period. The volcano-plutonic arc of East Malaya, with I-Type granitoids and intermediate to acid volcanoes, was developed at the margin of Indochina during the Permian subduction phase.

The main structural discontinuity between the Palaeozoic and the Triassic rocks occurs in Peninsular Malaysia, and orogenic deformation appears to have begun when Sibumasu began colliding with Indochina in the Upper Permian to the Lower Triassic. A-Type subduction and crustal thickening produced the main range of syn-to post-orogenic granites during the Early to Middle Triassic period, which were located in the Late Triassic-Early Jurassic.

Bentong group into two units of the Arenite series and the Schist series. The Schist is made up of quartz and graphite, together with phyllite, slate and hornfels. In addition, the grenade and the amphibole are in place. This sequence was having a very strong fold. Arenite consists of layers of flysch-type sediments. There is a great deal of lithology in this series that is conglomerate, quartzite and sub-ridge, shale, phyllite, schist and carbonate chert.

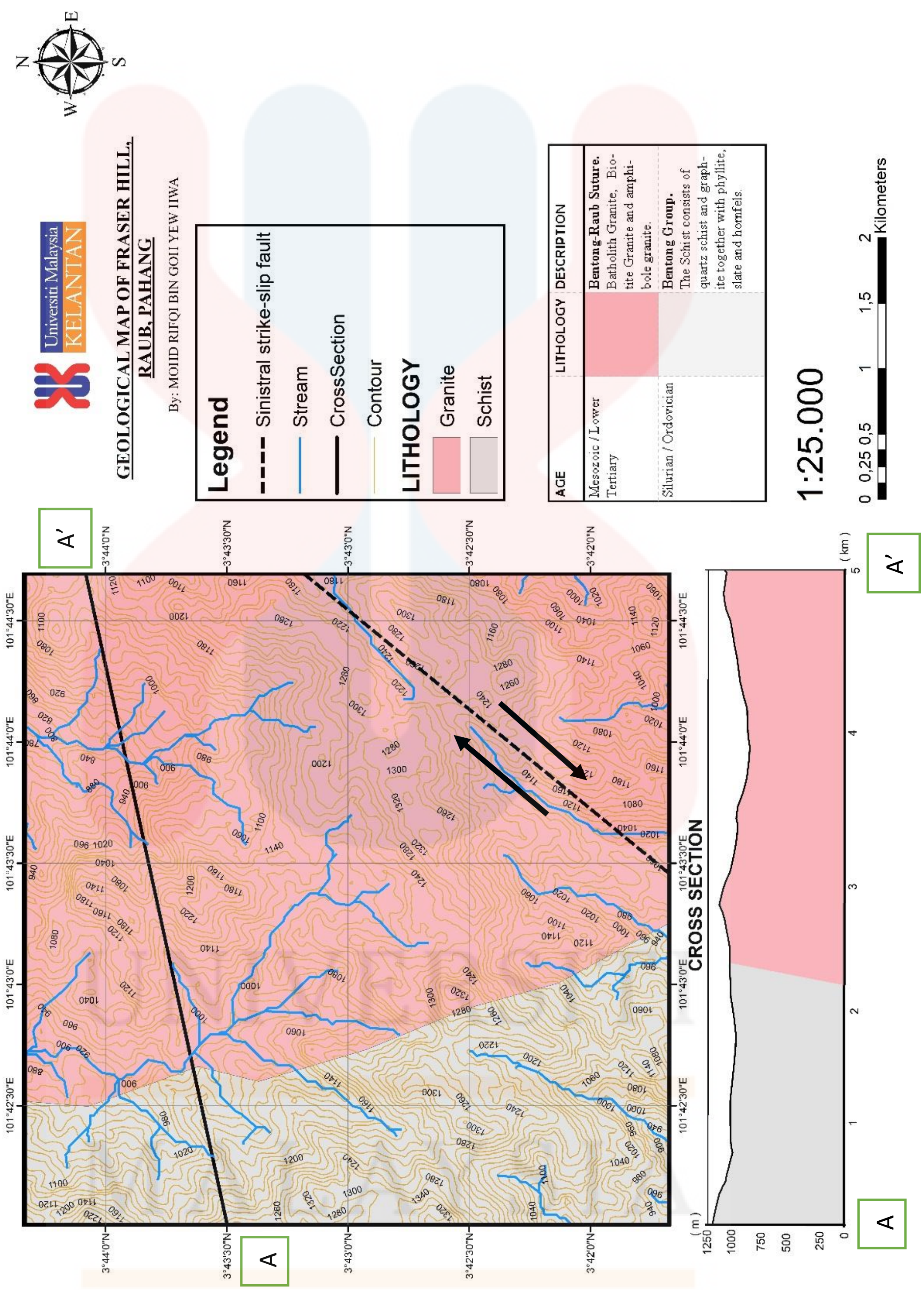


Figure 4.10: Geological map of the study area.

CHAPTER 5

LANDSLIDE SUSCEPTIBILITY ASSESSMENT

5.1 Introduction

In this chapter, the landslide susceptibility assessment was analysed and determined. Based on the study area of Fraser Hill, Pahang, four parameters were used in determining the landslide causative factor such as lithology, slope, aspect, vegetation, land use and drainage density. The parameters were generated from DEM data of year 2018. The average weightage score of each parameter were selected to determine the landslide susceptibility area. Table 5.1 shows the weightage of the parameters that have been selected in determining the landslide susceptibility.

Table 5.1: Weightage of landslide causative- factors

No	Parameter	Weightage (Wi)
1	Lithology	7
2	Slope	10
3	Aspect	8
4	Drainage density	5
5	Lineament density	9

5.2 Result and Discussion

5.2.1 Lithology

Lithology map were the parameter used in determining the susceptibility of landslide occurrence in the study area. The differences in lithology played an important role where the area is prone or low vulnerability to landslide. The lithologic condition and formation differentiate the characteristics of rock and soil.

Geologically, the lithologies in the study area are divided into two lithologies which is granite unit and schist unit and they were assigned to the score 5 and 6 respectively. The weightage for lithology had been assigned as 7 due to the influenced of it to the landslide susceptibility. Table 5.2 and Figure 5.1 shows the weightage and score of the types of lithology and the lithological map respectively.

Table 5.2: Weightage and score (lithology)

No	Lithology Class	Weightage (Wi)	Score (Sij)	Weightage x Score (Wi x Sij)
1	Granite	7	5	35
2	Schist	7	6	42

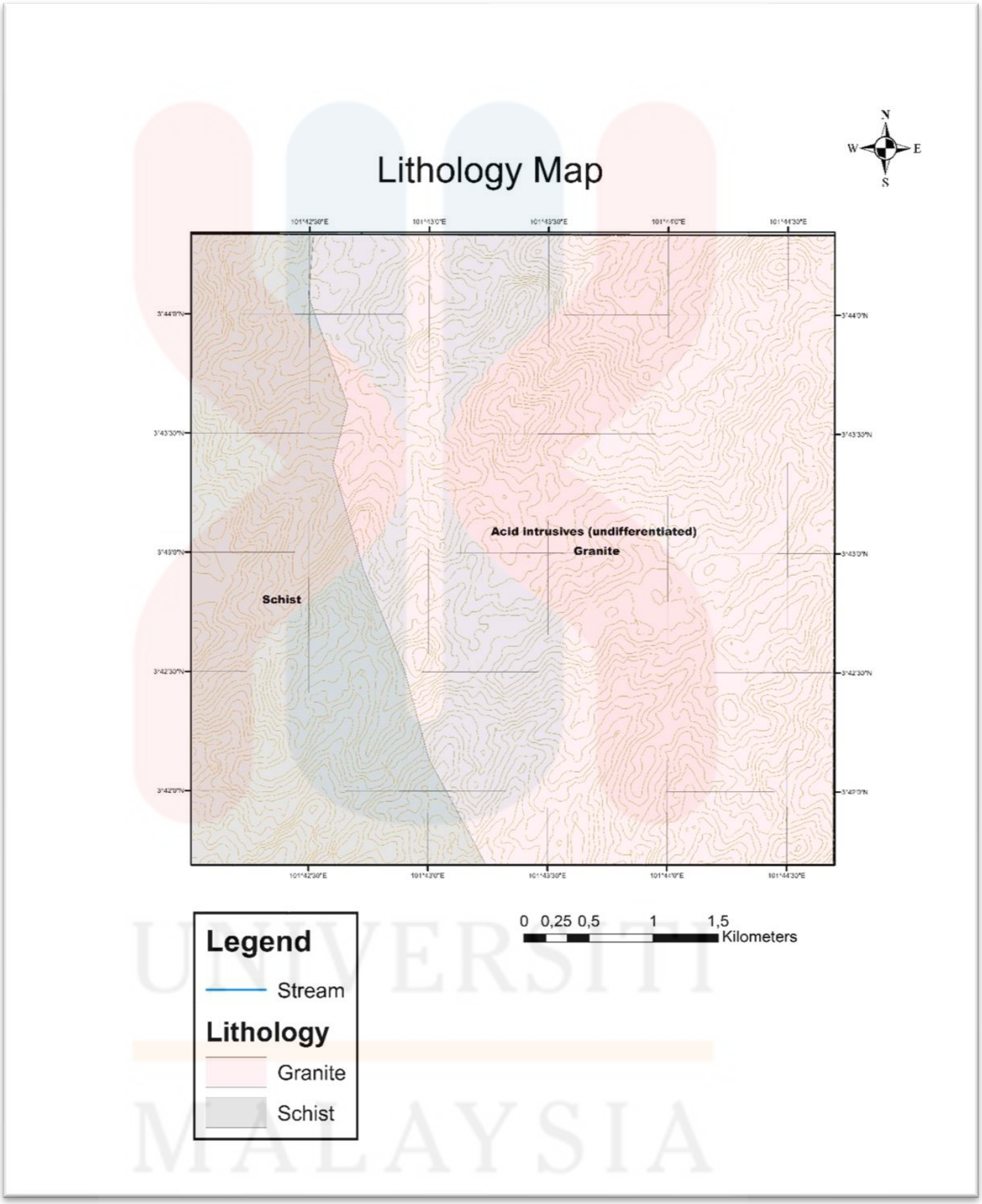


Figure 5.1: Lithology map of the study area.

5.2.2 Aspect

Aspect map were generated from DEM data. The aspect map was divided into 8 classification of slope direction that due to the North. The parameter was used to observe the direction of slope which resulting the differences in gravitational force. The instability and orientation of slope can be identified. It is measured counter clockwise in degrees from 0 (North) to 360 degree (due to North). Table 5.3 shows the slope direction of aspect and Figure 5.2 shows the aspect map of the study area.

Table 5.3: The slope direction of aspect.

No	Slope direction	Weightage (Wi)	Score (Sij)	Weightage x Score (Wi x Sij)
1	North-Facing (337.5 – 22.5)	8	1	8
2	North-East (22.5 – 67.5)	8	3	24
3	East-facing (67.5 – 112.5)	8	5	40
4	South-East (112.5 – 157.5)	8	6	48
5	South-facing (157.5 – 202.5)	8	9	72
6	Southwest-facing (202.5 – 247.5)	8	6	48
7	West-facing (247.5 – 292.5)	8	5	40
8	North-West (292.5 – 337.5)	8	2	16

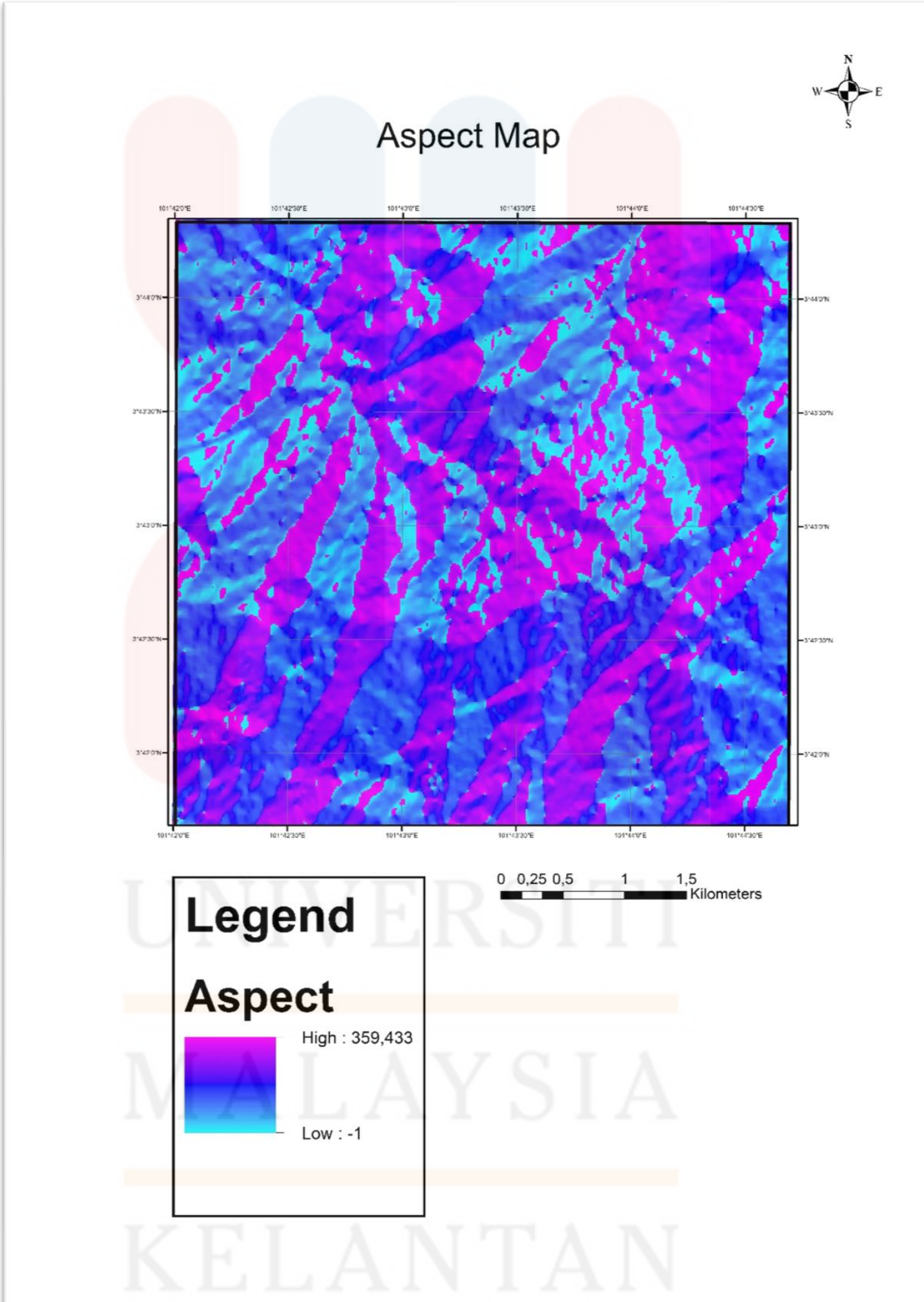


Figure 5.2: Aspect map of the study area.

5.2.3 Slope

Landslide is the movement of mass of rock, debris or earth down a slope. The soil and rock down-slope movement were influenced by gravity. The effect of down-slope forces contributes to low or reduce strength. Slope is an important parameter in determining the landslide susceptibility in the study area. The slope is classified into six categories based on Malaysia Slope Classification by Geology Society Malaysia as shown in Table 5.4. Figure 5.3 shows the slope map of the study area.

Table 5.4: Slope classification.

No	Class	Description
1.	0 – 5º	Very gentle
2.	5 – 10º	Gentle
3.	10 – 15º	Moderate
4.	15 – 25º	Moderately steep
5.	25 – 35º	Steep
6.	> 35º	Very steep

(Sources: Geology Society Malaysia, 2004)

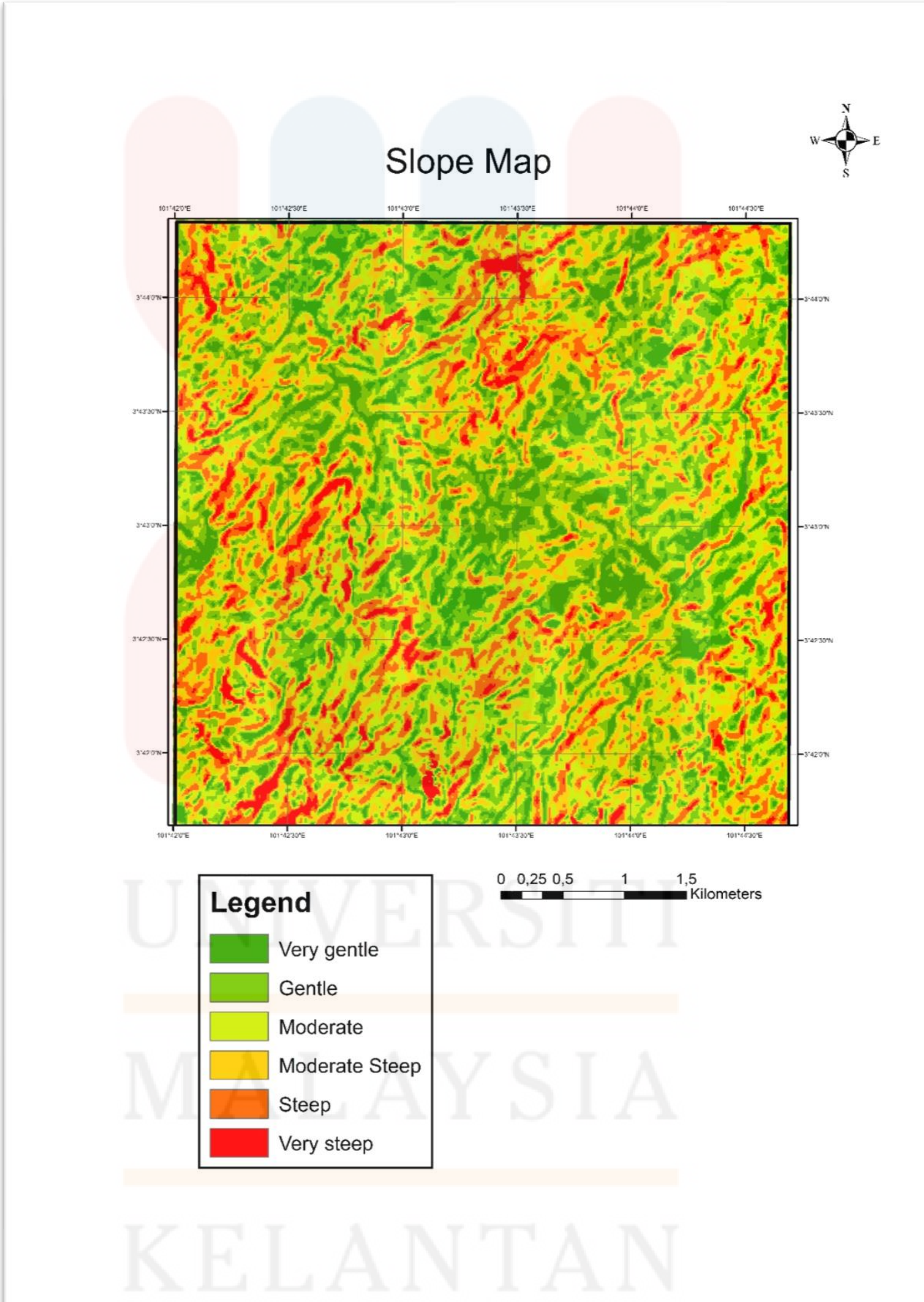


Figure 5.3: Slope map of the study area.

The weightage and score for the slope is divided into six using the slope classification by Geology Society Malaysia (GSM) with 10 scores for weightage. This is because, the slope factor gives high influence to landslide occurrence. The scores increase with the increasing of degree of slope. However, during the geological mapping, the past landslide shows that the landslide not only occurred on a very steep slope, but also landslide occurred on a moderate slope. This was probably related to another selected parameter. Table 5.5 shows the weightage and score for slope.

Table 5.5: Weightage and score for slope

No	Class	Weightage (Wi)	Score (Si)	Weightage x Score (Wi x Sij)
1	0 – 5º	10	1	10
2	5 – 10º	10	2	20
3	10 – 15º	10	3	30
4	15 – 25º	10	4	40
5	25 – 35º	10	5	50
6	> 35º	10	6	60

5.2.4 Drainage Density

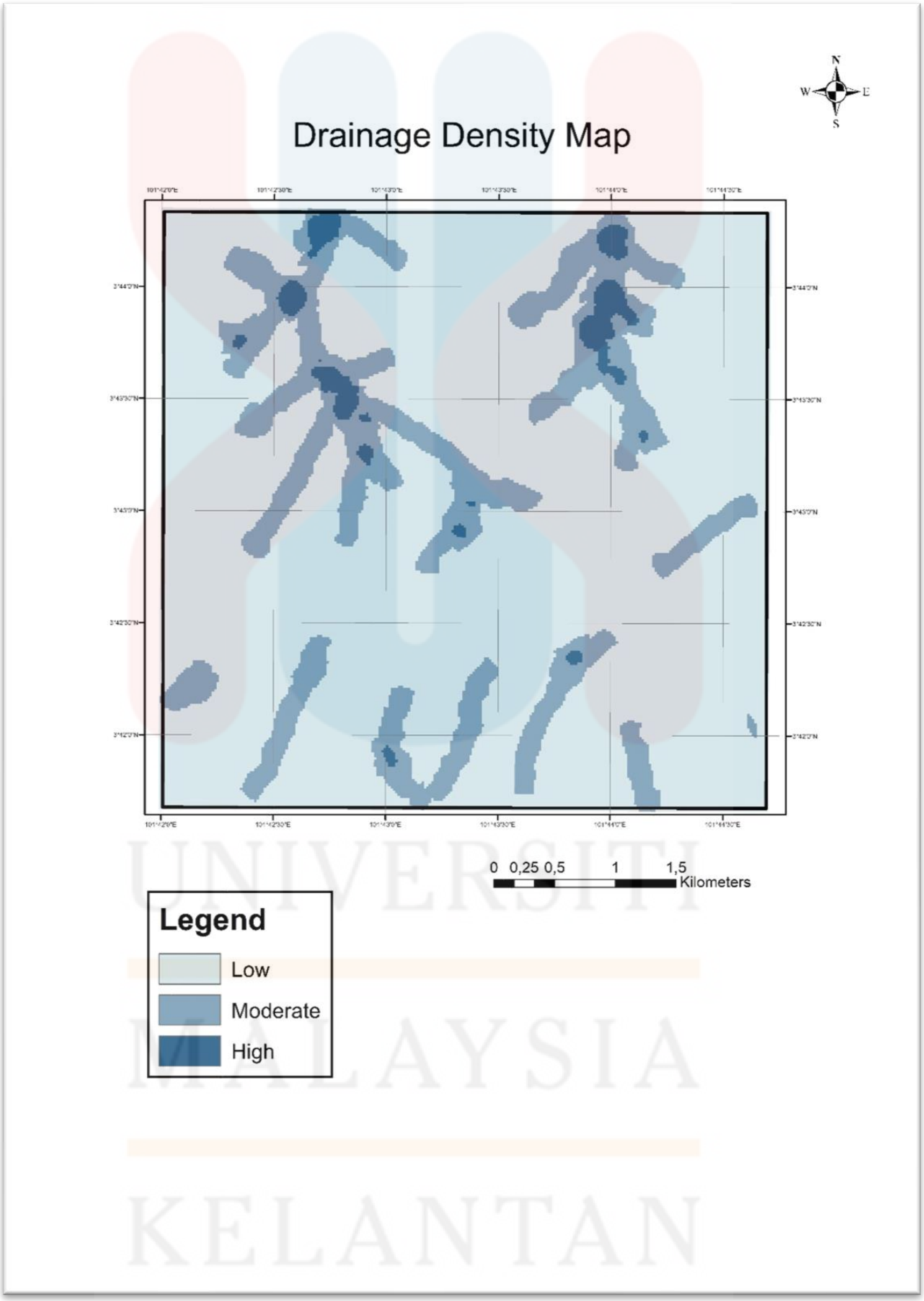
Drainage density refers to total length of the streams and river in a drainage basin divided by the total area of the drainage basin. Drainage variation was influenced by climate, topography, soil infiltration, vegetation, and flux density. It is essential in determining the fluvial network in the study area. The vulnerable area of landslide to occur can be determined in extent of debris flow and seepage due to rainfall infiltration.

Drainage density map were extracted from DEM data in ArcGIS. Drainage density is the stream length divided by area. The drainage density was classified into three categories which is low, moderate and high. High drainage density indicates the high possibilities of the landslide occurrence. This is because, the surface runoff is high. Table 5.6 shows the weightage and score for drainage density, while the Figure 5.4 shows the drainage density map of the study area.

$$Drainage\ Density = Stream\ Length\ /\ Area \qquad (5.1)$$

Table 5.6: Weightage and score for drainage density

No	Drainage Density	Weightage (Wi)		Score (Sij)	Weightage x Score (Wi x Sij)
1	Low	0 – 455	9	4	36
2	Moderate	455 – 911	9	6	54
3	High	911 – 1367	9	8	72



Drainage Density Map
N
S
W
E
0 0,25 0,5 1 1,5
Kilometers
Legend
Low
Moderate
High

Figure 5.4: Drainage density map of the study area.

5.2.5 Lineament density

Lineaments is the structurally controlled linear features that can be identified by the relatively linear alignments. Lineaments indicates that there are the presence of the faulting and fracturing that resulting in the increased of the secondary permeability and porosity. By measuring the density of the lineament, the susceptibility of landslides hazard can be determined.

There are 3 groups of lineaments that are recognized in the study area that is low group, moderate group, and also the high group. The low group is the lowest influence to the landslide susceptibility while the high group influenced the most to the landslide occurrences. The weightage of lineament density is 9 and will be multiply by the score that is shown in the Table 5.7 below. Figure 5.5 shows the lineament density of the study area.

Table 5.7: Weightage and Score (Lineament Density)

No.	Lineament Density		Weightage (Wi)	Score (Sij)	(Wi x Sij)
1	Low	0-270	9	8	72
2	Moderate	270-540	9	6	54
3	High	540-810	9	4	36

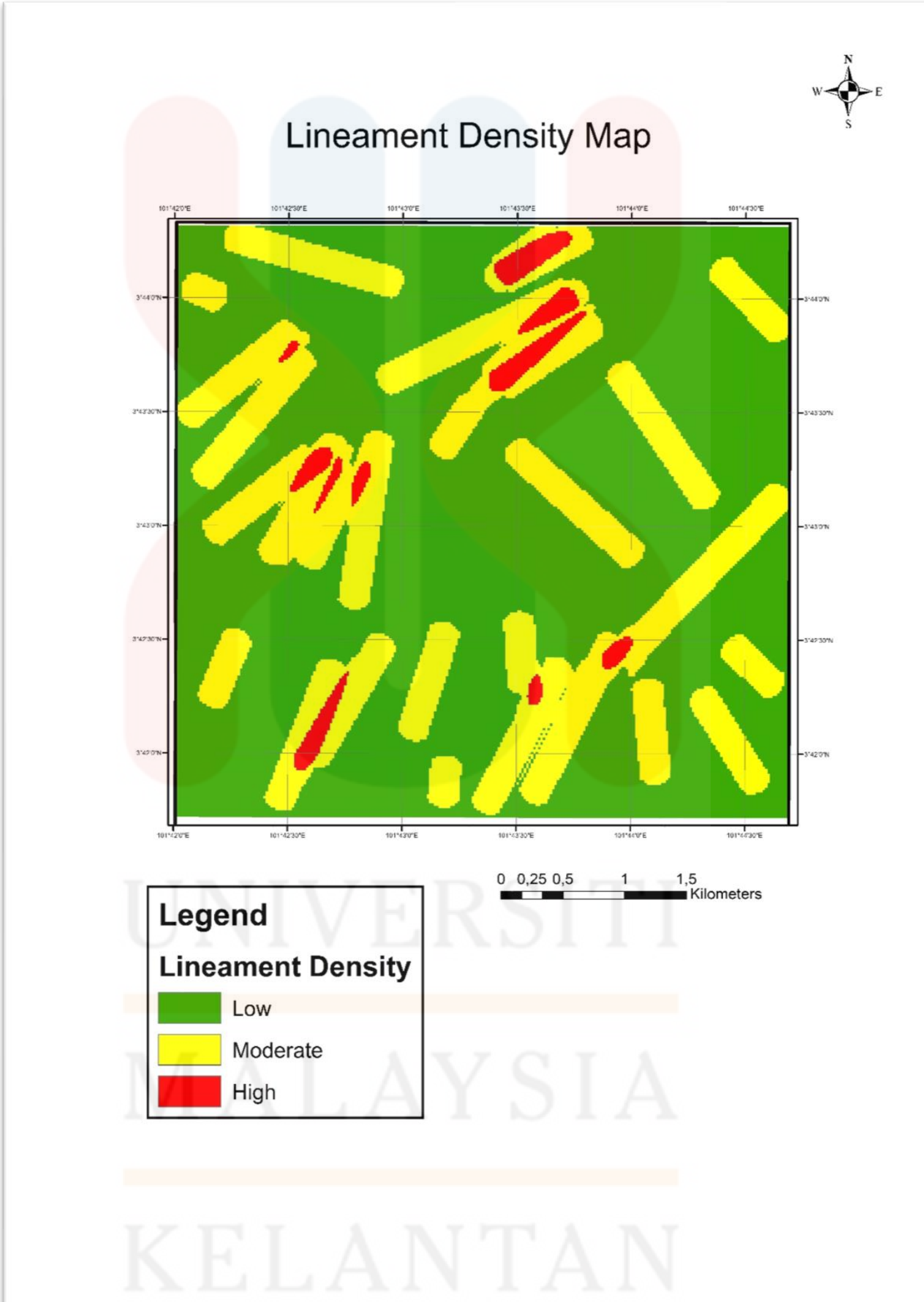


Figure 5.5: Lineament Density of the study area.

5.3 Rain Intensity

Fraser Hill lies at 1131m above sea level. Fraser Hill has a tropical climate. Fraser Hill is a city with heavy rainfall. There is a lot of rain even in the driest month. The climate classification of Köppen-Geiger is Af. The average temperature here is 20.0 °C | 68.0 °F. The precipitation here is approximately 2665 mm | 104.9 inch per year. Figure 5.6 shows the climate graph of rainfall distribution of Fraser Hill of year 2019 while Figure 5.7 shows the average weather by month of Fraser Hill in 2019.

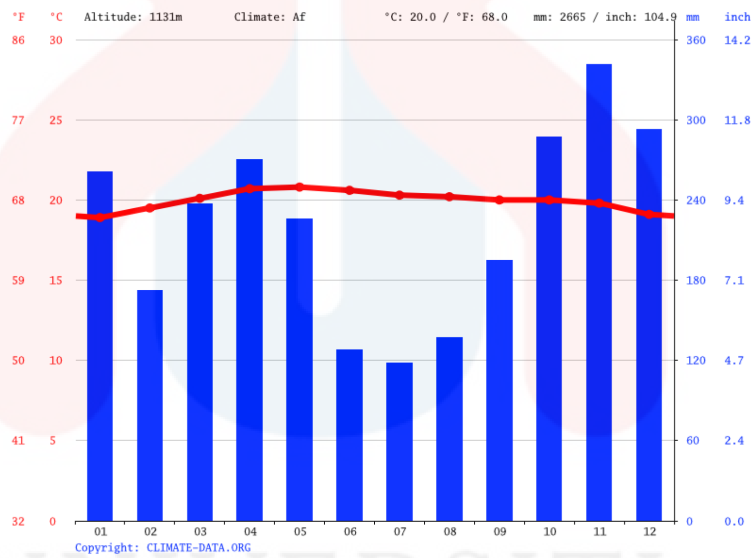


Figure 5.6: Climate graph by month of Fraser Hill. (source: https://en.climate-data.org, 2019)

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	18.9	19.5	20.1	20.7	20.8	20.6	20.3	20.2	20	20	19.8	19.1
Min. Temperature (°C)	14.5	14.9	15.2	16	16.2	15.9	15.5	15.5	15.5	15.6	15.6	14.9
Max. Temperature (°C)	23.3	24.1	25.1	25.4	25.5	25.3	25.1	24.9	24.6	24.4	24.1	23.4
Avg. Temperature (°F)	66.0	67.1	68.2	69.3	69.4	69.1	68.5	68.4	68.0	68.0	67.6	66.4
Min. Temperature (°F)	58.1	58.8	59.4	60.8	61.2	60.6	59.9	59.9	59.9	60.1	60.1	58.8
Max. Temperature (°F)	73.9	75.4	77.2	77.7	77.9	77.5	77.2	76.8	76.3	75.9	75.4	74.1
Precipitation / Rainfall (mm)	261	172	237	270	226	128	118	137	195	287	341	293

Figure 5.7: Average weather by month of Fraser Hill (source: https://en.climate-data.org, 2019)

Table 5.8: Rainfall distribution in Fraser Hill (2015-2019)

Month	Rain Distribution (mm)				
	2015	2016	2017	2018	2019
January	215.0	26.0	315.8	254.4	99.0
February	23.0	77.0	81.4	12.5	104.0
March	47.0	1.5	270.8	200.5	57.0
April	126.5	28.5	220.1	128.0	86.0
May	207.0	81.4	347.9	57.5	194.2
June	43.5	48.6	121.0	66.5	158.8
July	41.0	118.0	85.5	68.2	147.5
August	83.0	66.0	198.0	47.3	37.5
September	33.5	26.5	116.5	114.0	222.0
October	52.9	76.4	116.5	210.5	234.4
November	286.6	204.6	199.5	290.5	226.6
December	142.0	78.5	171.1	326.0	195.5

(Sources:*Jabatan Pengairan dan Saliran Malaysia*)

Table 5.8 shows the rainfall distribution data collected from Jabatan Pengairan dan Saliran Malaysia. It can be observed that in five years, the rainfall distribution is higher in August until January annually. In February to July the rain distribution lesser that other months. Landslide may occur because Malaysia has tropical climate, so weathering process may occur rapidly, and rainwater can reach the pores of rocks or soils, raising the mass of the rock or soil (Prihutama et.al, 2018).

5.4 Landslide Susceptibility Analysis

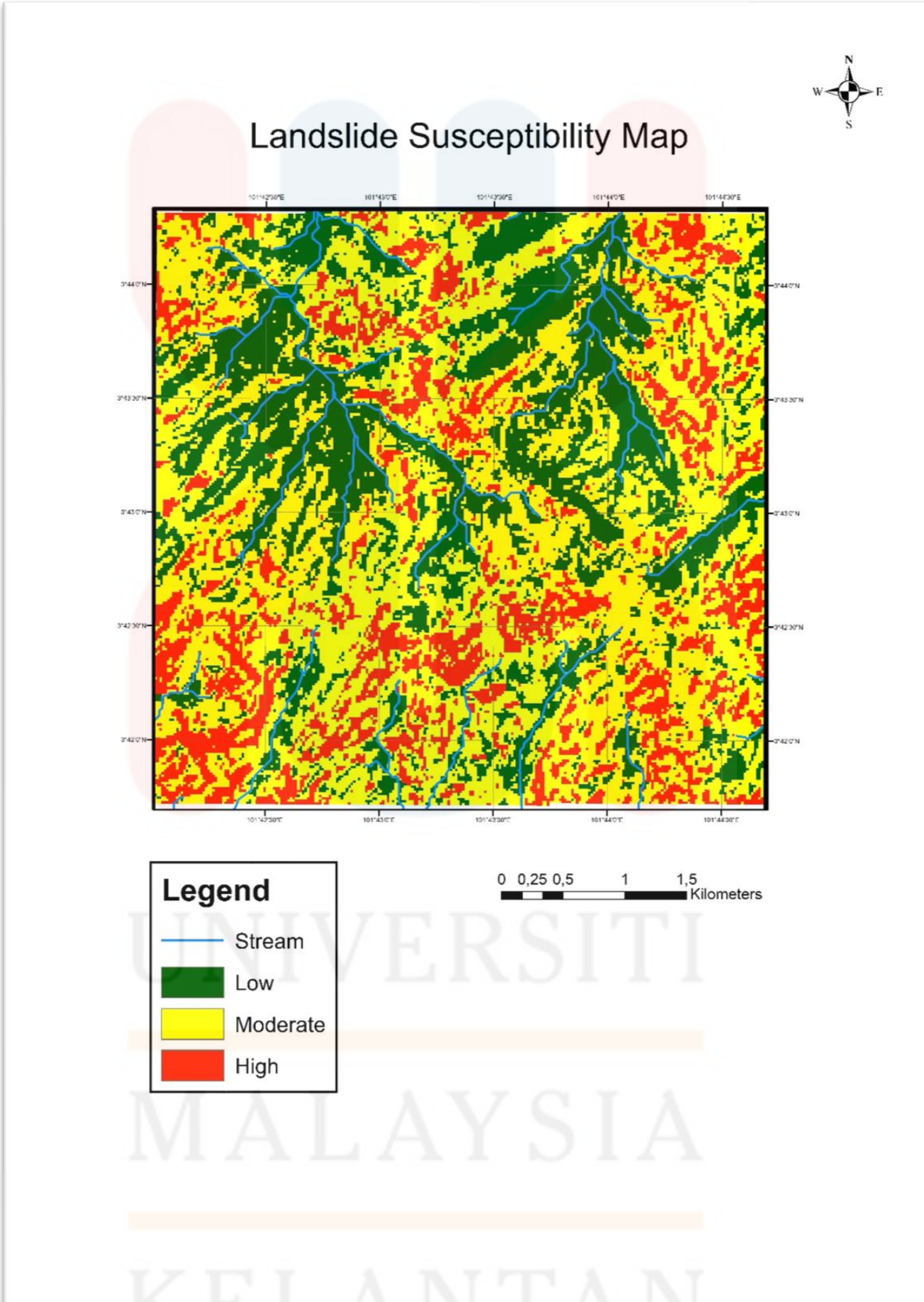
The susceptibility of the landslide hazard was prepared by using weighted overlay index method on the GIS platform. Five parameters of the landslide causative - factors have been chosen by referring to the previous study that is slope, lineament density, lithology, drainage density and also type of soil.

$$S = \frac{\Sigma wisij}{\Sigma wi} \quad \text{.. (5.2)}$$

Each of the parameters have been assigned of each weightage respectively and it is later calculated by using the equations that was shown in the above 5.1 equation.

Generally, with the decrease in the drainage density and also the line density, the level of landslides increased. In the landslide susceptibility analysis, slope is one of the most important parameters, since the stability of the slope is the basis for the frequency and intensity of landslide occurrences. Based on the Figure 5.8, it can be observed that the majority of the study area has a moderate susceptibility of landslide that covers around

35% of the study area and the 35% of the study area is consist of lo susceptibility of landslide hazard while 30% more is high susceptibility to landslides.


N
W
E
S
Landslide Susceptibility Map
Legend
Stream
Low
Moderate
High
0 0,25 0,5 1 1,5
Kilometers

No table of figures entries found.It is important to reclassify the data in order to generate the landslide susceptibility map using the weightage overlay method. Table 5.9 shows the reclassify data sets.

Table 5.9: The reclassify data with influence

No	Raster Datasets	Influence (%)
1	**Lithology :** Granite Schist	25
2	**Slope :** 0 - 5 º 5 - 10 º 10 - 15 º 15 - 25 º 25 - 35 º > 35 º	25
3	**Aspect :** North-Facing (337.5 – 22.5) North-East (22.5 – 67.5) East-facing (67.5 – 112.5) South-East (112.5 – 157.5) South-facing (157.5 – 202.5) Southwest-facing (202.5 – 247.5) West-facing (247.5 – 292.5) North-West (292.5 – 337.5)	10
4	**Drainage density :** Low (0 – 455) Moderate (455 – 911) High (911 – 1367)	10
5	**Lineament analysis :** Low (0-270) Moderate (270-540) High (540-810)	20
TOTAL		100

Slope, lithology and drainage density plays an important role and becoming the parameters that highly influence in landslide susceptibility analysis. Slope with steeper rate has higher the tendency for landslide to occur. The lithology also influences the landslide as the rock and soil that formed in the area have different porosity and void. Bentong group has weathered lithology by the intrusion of the Main range granite. The intensity of drainage density shows that the hydrological factor can cause landslide as most of the high tendency to occur landslide occurs along the river and stream.

Lineament density and aspect moderately influence the landslide phenomenon. But, with respect to other parameters and factor triggered, it simultaneously important in landslide analysis in the study area. Table 5.10 shows the susceptibility class for the landslide hazard in the study area.

Table 5.10: Susceptibility of landslide hazard in the study area

Susceptibility Class	Risk	Area Percentage (%)
Low	0 – 50%	15
Moderate	50 – 75%	75
High	> 75%	10

By referring to the landslide susceptibility map, the landslide is more vulnerable along the stream and river. This is probably due to the moderate to high stream density.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

As the conclusion, after the research was finished, the geological map of Fraser Hill area was updated in the scale of 1:25000. The lithology was divided into two units of lithologies that is Granite unit and Schist unit. Structural analysis, geomorphology form, drainage pattern and stratigraphy of the study area were obtained through the secondary data and imagery dataset.

In the specification part that is the landslide susceptibility mapping of the study area, a map had been generated that is the map of landslide zonation map of Fraser Hill area. It has been divided into three class of zone which is low class zone, moderate class zone and also high-class zone. By using the weightage overlay method in GIS platform, five parameters had been used that is slope, lineament density, lithology, drainage density and aspect.

Generally, the study area has been divided into three class of that susceptible to the landslides hazard that is low susceptibility of landslide, moderate susceptibility of landslide hazard and also high susceptibility of landslide hazard. The area also had been divided into percentages that is the low and moderate susceptibility mutual with 35% each. The high susceptibility of the study area included in 35% of the study area respectively.

Based on the five parameters that been selected, slope is the highest influenced towards the landslide hazard because the stability of slope formed the basic frequency for the occurrences of landslide hazard. The location of the study area that is on a mountainous and hilly area make it more prone to the occurrences of landslide hazard.

6.2 Recommendation

Based on the current research, the recommendations for the next study is that in the geological mapping itself, it should be start earlier so that the problem such as the insufficient in the collection of data can be avoided. The general knowledge in mapping also need to be improved that is in the mapping knowledge and also in another field of the geological knowledge such as the structural geology and also the lithologies of the study area.

In the specification part, it is advised in the next study to use different type of parameters such as the type of vegetation, the slope aspect and also the geomorphology of the study area. It is because the different type of parameters used may give different result then the result can be compared to know what parameters influenced most to the landslide susceptibility to the study area.

The landslide susceptibility analysis was recommended to be done by using the ArcGIS software because it is a simple software that can determined the landslide susceptibility in a study area. As for the result of the landslide susceptibility, it is advisable to the construction in the study area to be done properly as the area have a high probability of occurrences in landslide hazard. It is for the safety of the people and also to prevent life and property lost.

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