GEOLOGY AND LANDSLIDE SUSCEPTIBILITY MAPPING USING GEOGRAPHICAL INFORMATION SYSYTEM (GIS) AT TEMANGAN, MACHANG , KELANTAN

by

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A report submitted in fulfillment of the requirements 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 Mapping Using Geographical Information System (GIS) At Temangan, Machang, Kelantan 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:...

Name :...

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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.

Signature :

____

Name of Supervisor :

Date :

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GEOLOGY AND LANDSLIDE SUSCEPTIBILITY MAPPING USING GEOGRAPHICAL INFORMATION SYSTEM (GIS) AT TEMANGAN, MACHANG KELANTAN

ABSTRACT

This research titled Geology And Landslide Susceptibility Mapping Using Geographical Information System (GIS) At Temangan, Machang, Kelantan .This study area was located at Temangan, Machang in area of of 25 km^2 . The purpose of this study is to update the geological map of the study area and to provide research on the landslide susceptibility map within the study area. The source that been used at the beginning of the research was through previous research and the literature review that has been conducted in the surrounding area . In addition, analysis of the structure such as fault and geomorphology of the study area is also done through data collected. Next, the method that been used in generating the landslide susceptibility map is by using the Geographical Information System (GIS) which used Analytical Hierarchy Process (AHP) and collected data from previous research. The parameter that triggered the occurence of landslide were analyzed and overlaid, in order to generated the landslide susceptibility map. The data Digital Elevation Model (DEM) had been used to extract the parameters. The results showed the landslide susceptibility map is divided into 5 classes very low, low, moderte, high and very high. The higher the classes, the more prone the region is to landsliding. Based on the result of Landslide Susceptibility Map, it can conclude that the study area consist of low susceptibility percentage and the probabiliy to landsliding occur is low.

PEMETAAN KERENTANAN GEOLOGI DAN TANAH RUNTUH MENGGUNAKAN SISTEM MAKLUMAT GEOGRAFI (GIS) DI TEMANGAN, MACHANG KELANTAN

ABSTRAK

Penyelidikan ini bertajuk Pemetaan Kerentanan Geologi Dan Tanah runtuh Menggunakan Sistem Maklumat Geografi (GIS) Di Temangan, Machang, Kelantan. Kawasan kajian ini terletak di Temangan, Machang di kawasan seluas 25 km^2. Tujuan kajian ini adalah untuk mengemas kini peta geologi kawasan kajian dan memberikan kajian mengenai peta kerentanan tanah runtuh di kawasan kajian. Sumber yang digunakan pada awal penyelidikan adalah melalui kajian sebelumnya dan tinjauan literatur yang telah dilakukan di daerah sekitarnya. Selain itu, analisis struktur seperti kesalahan dan geomorfologi kawasan kajian juga dilakukan melalui data yang dikumpulkan. Seterusnya, kaedah yang digunakan dalam menghasilkan peta kerentanan tanah runtuh adalah dengan menggunakan Sistem Maklumat Geografi (GIS) yang menggunakan Proses Hierarki Analitik (AHP) dan mengumpulkan data dari penyelidikan sebelumnya. Parameter yang memicu terjadinya tanah runtuh dianalisis dan dilapisi, untuk menghasilkan peta kerentanan tanah runtuh. Data Digital Elevation Model (DEM) telah digunakan untuk mengekstrak parameter. Hasil kajian menunjukkan peta kerentanan tanah runtuh dibahagikan kepada 3 kelas, sangat rendah, rendah, sederhana, tinggi dan sangat tinggi. Semakin tinggi kelas, semakin rawan wilayah ini terhadap tanah runtuh. Berdasarkan hasil Peta Kerentanan Tanah Longsor, dapat disimpulkan bahawa kawasan kajian terdiri dari peratusan kerentanan rendah dan kemungkinan terjadinya tanah runtuh rendah.

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LIST OF ABBREVIATION

AHP	Analytical Hierarchy Process
CI	Consistency index
CR	Concentration Ratio
DEM	Data Elevation Model
GIS	Geographical Information System
Km	Kilometer
L	Left
m	Meter
mm	Milimeter
NE	North-east
NW	North-west
R	Right
S	Shear
SFM	Structure From Motion
SMCE	Spatial Multi-Criteria Evaluation
USGS	United State Geological Survey
WLC	Weighted Linear Combination

LIST OF SYMBOL

%	Percentage
°	Degree
λ	Lambda
n	Count
∂	Sigma

CHAPTER 1

INTRODUCTION

1.1 Background of study

This study entitled “Geology and landslide susceptibility mapping using Geographical Information System (GIS) at Temangan, Kelantan”. Even though Malaysia is not a precipitous country which is mountains and hills are less than 25 percent of the terrain, slope failures or landslides are a frequently occured.

Landslide is a natural disaster. Landslide is the mass movement of rock, debris or earth (soil) down a hillside under gravitational influence (Akter et al., 2019). Rainfall, storm,water activities and poor slope management are the main factor that caused slopes failure or landslides at site in Malaysia's hillside development. Another cause of landslides can be due to the abuse prescriptive methods, inadequate study of past failures, design errors including insufficient site specific ground investigation. Landslides are a serious geologic hazard common in most countries of the world. Globally, landslides cause billions of dollars in damage and thousands of deaths and injuries each year (Akter et al., 2019). In Malaysia, Bukit Antarabangsa landslide was a landslide that occurred on 6 December 2008, in Bukit Antarabangsa, Ulu Klang, Selangor, Malaysia.The landslide, which is believed to have buried 14 bungalows in Taman Bukit Mewah and Taman Bukit Utama, occurred at about 4 a.m. MST, causing 15 casualties and 4 deaths. In Malaysia, In Bukit Antarabangsa tragedy, a landslide damaged the settlements and resulted in casualties . Altogether this landslide caused five casualties, buried fourteen bungalows, and forced approximately 2000 residents to evacuate their homes (Kazmi et al., 2017).

The destructive effects of landslides on human life and on the overall economic system of many nations around the globe are extremely severe. Landslide hazard assessment and risk reduction can be accomplished by providing easily accessible, continuous, and accurate information to risk managers regarding landslide occurrence. Precise mapping of susceptibility can therefore be key information for a wide range of users from both the private and public sectors, government departments and the scientific community at local and international level.

The usage of the Analytical Hierarchy Process (AHP) approach, produced by Saaty including Weighted Linear Combination (WLC) Spatial Multi-Criteria Evaluation (SMCE) method has also been applied to landslide susceptibility mapping (Shahabi & Hashim, 2015). Each of the approaches employed depends on different logical reasons .This approach is able to generate an objective mapping of the susceptibility to landslides, thereby reducing the subjective assessment of the experts. Thus, the primary distinction between earlier studies and present research is the integration of landslide susceptibility maps extracted using AHP, WLC, and SMCE methods for preparing landslide susceptibility mapping in Temangan area, Kelantan using GIS and remote sensing data.

This study aims to assess the landslide susceptibility mapping by using Geographic Information System (GIS) on the Temangan area. A GIS overlay and raster calculation will be applied to generate anticipated landslide susceptibility map results.

1.2 Study area

The study area is in Temagan, in the district of Machang, Kelantan (Figure 1.1), which is located in the east of Peninsular Malaysia, for this research on landslide susceptibility map. Based on the base map , the study area (Figure 1.2) The coordinates are 5°39'15.12"N 102° 7'36.54"E Machang is one of the sub-districts of Kelantan which was formed on 1 January 1979. The study area is located in the western part of the 25 Km^2 area of the Temangan town of Machang. Most of the streets in the area of study are tarred road and only a few streets have not been tarred. The research area also features the Tumpat-Gemas railway line. The main villages in the study area are Kg. Kuala Nal and Kg. Kuala Hau.

1.2.1 Location

The study area is located at Temangan, Kelantan. Area of the study area is about 25 km2 . The coordinate on the top left is 5°39'15.12"N 102° 7'36.54"E , on right is 5°39'14.98"N 102°10'19.99"E, on the bottom left 5°36'32.51"N 102° 7'36.56"E and on the bottom right 5°36'32.52"N 102°10'19.17"E. Within the area, there are villagers in the study area, 1 main river and a few high elevation area. Figure 1.1 refers to base map of study area.

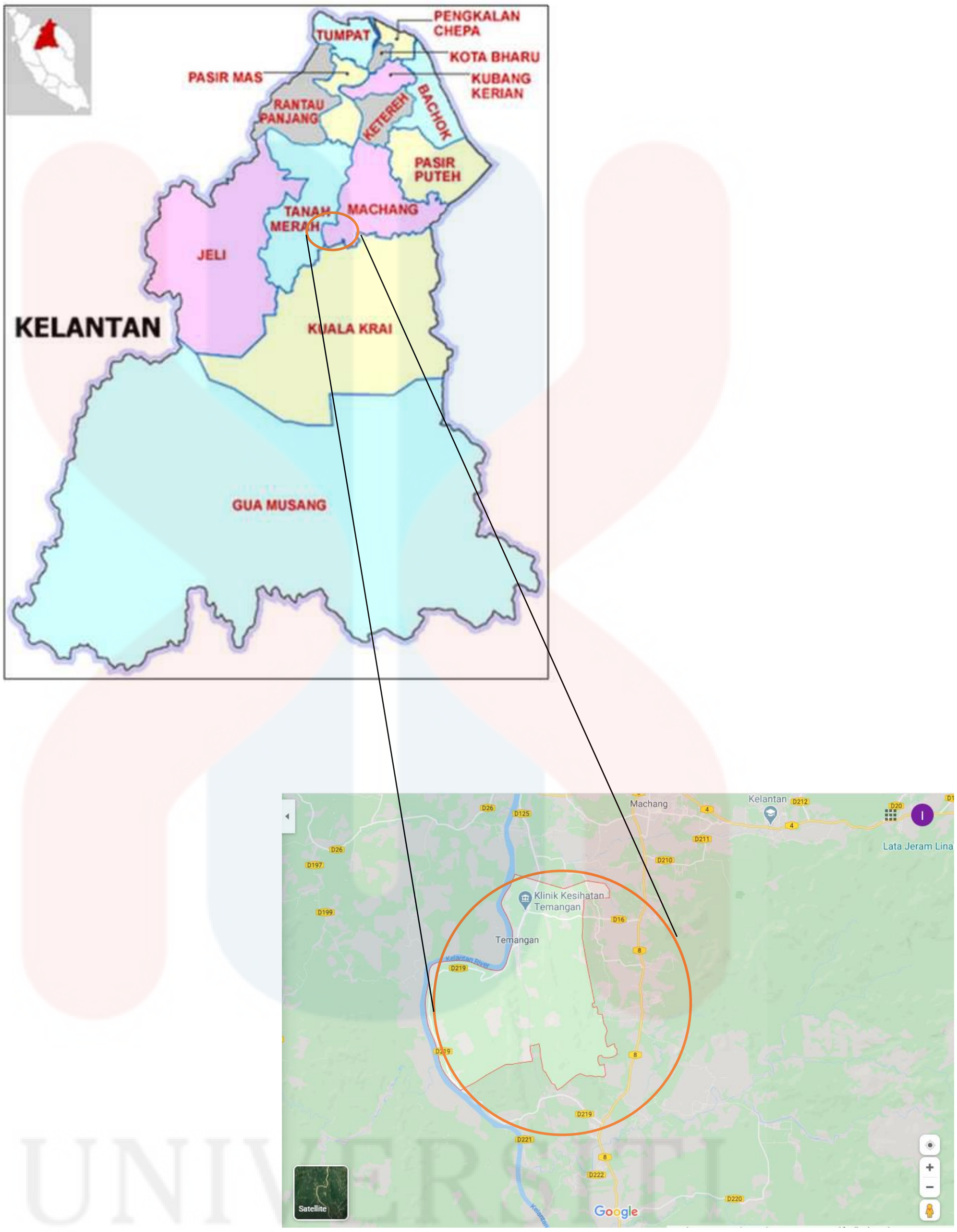


Figure 1.1 : Location of study area

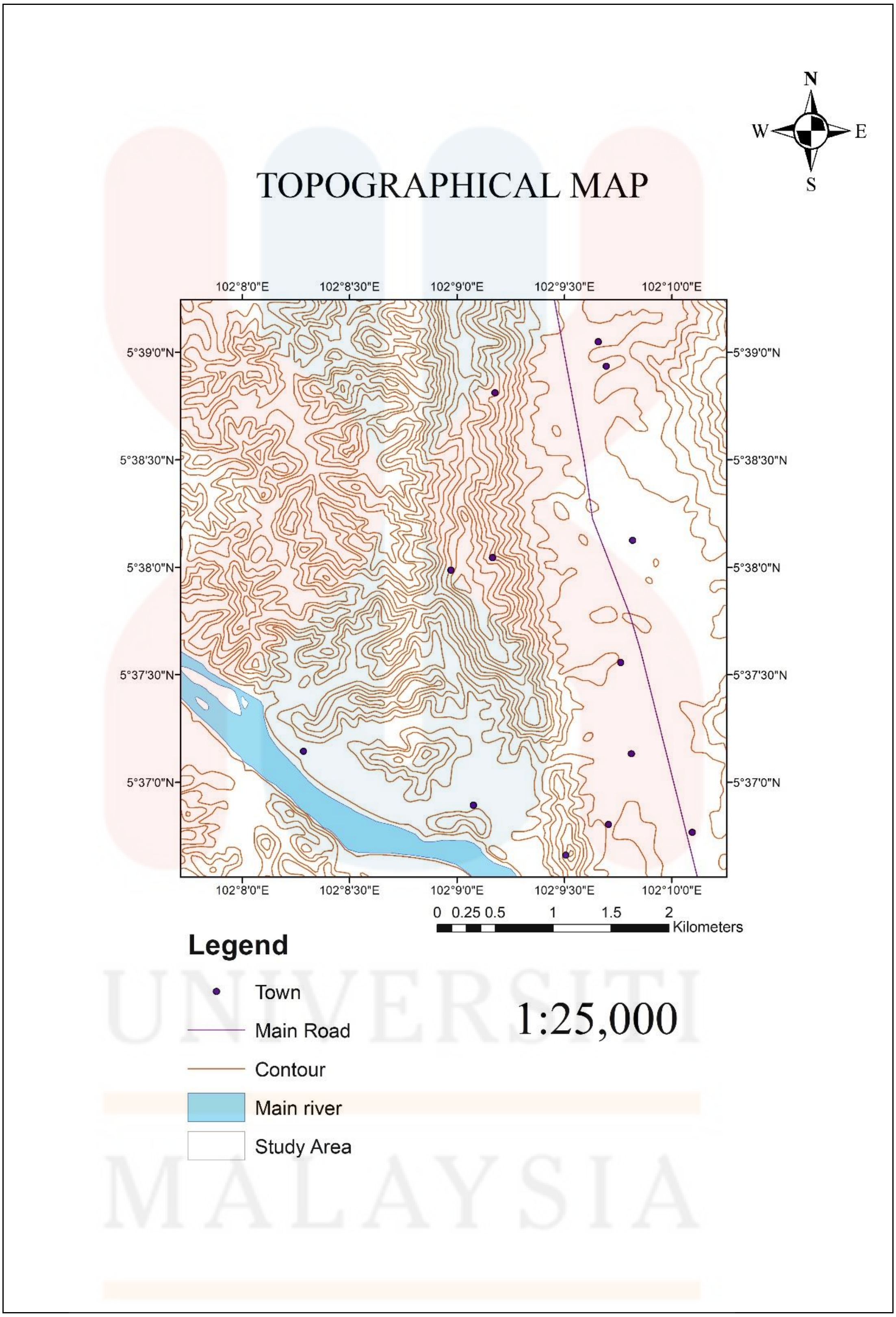


Figure 1.2 : Topographical map

1.2.2 Road connection and accessibility.

To reach Temangan, There are three main road that can be used to get to this area. The Batu 30 road, Paloh Raya road and Kg Bedal- Kuala Hau road is the three main road that can be reached by going through Machang to Kuala Krai road through Tanah Merah and Pasir Putih. Next, highway Kota Bahru to Gua Musang is a the main road in the constituency, going in the north-south direction. For west part, it goes to Jeli .

1.2.3 Demography

The study area is located in Temangan, which part of Machang district. In 2010, Machang has a population of 89,118 people. Table, 1.1, 1.2 and 1.3 shows the detailed people population based on ethnicity, in Machang by year 2010, and people population according to gender by year 2010

According to Table 1.1, people population according to ethnicity in Gua Musang is dominated by Malay people with the highest percentage, 85,300 people. Chinese second dominant ethnic , 2,462 people, meanwhile, Indian only occupied of the population, which is the second least ethnic in Machang by 394 people. Machang is only occupied by 64 people from other ethnic. Meanwhile, based on Table 1.2, Machang is dominated by female, 45,362 people. Others , male is only 43,756 people. Furthermore, the dominant age is also from those of age between 10 to 19 years, 25,687. The least population is 70 years and above, 3,766.

Table 1.1: The people population according to ethnicity in Machang for year 2010 (Department Of Statistic, 2020)

Ethnic group	**Population**
Malay	85,300
Chinese	2,462
Indian	394
Others	64

Table 1.2: The people population according to gender (Department Of Statistic, 2020)

Gender	**Population**
Male	43,756
Female	45,362

Table 1.3: The people population according to age (Department Of Statistic, 2020)

Age	**Population**
0-9 years	16,508
10-19 years	25,687
20-29 years	11,804
30-39 years	8,541
40-49 years	9,724
50-59 years	7,995
60-69 years	5,093
70 + years	3,766

1.2.4 Landuse

Most of the land in Kelantan is under alienated and another is under state land status, while others are under-reserved land.

Table 1.4: Category of land use in 2013 (Mahamud et al., 2019)

Category	**Area (km^2)**
Built up	142.34
Forest	91844.23
Oil palm	1522.34
Other agriculture	845.83
Paddy	762.97
Rubber	2349.04
Water body	215.78

Land use involves managing and modifying natural or wilderness environment into built environment such as settlements and semi-natural habitats. It was further defined as the total of arrangements, activities, and inputs that people undertake in a certain type of land cover.

Land use withal is land exploitation for agrarian, industrial , residential, recreational, or other purposes. The Temangan region's land use consists of about forty-seven percent (47 percent) of agriculture, about forty-five percent (45 percent) of environmental conservation, and eight percent (8 percent) of residential and industrial land use. In Temangan region agriculture type, rubber plantation, oil palm plantation and others are included. Temangan forest reserve and mangrove forest are the type of environment preserve for environmental preservation (Mahamud et al., 2019). The percentage of land used in Temangan, Machang, Kelantan is shown in figure 1.3.

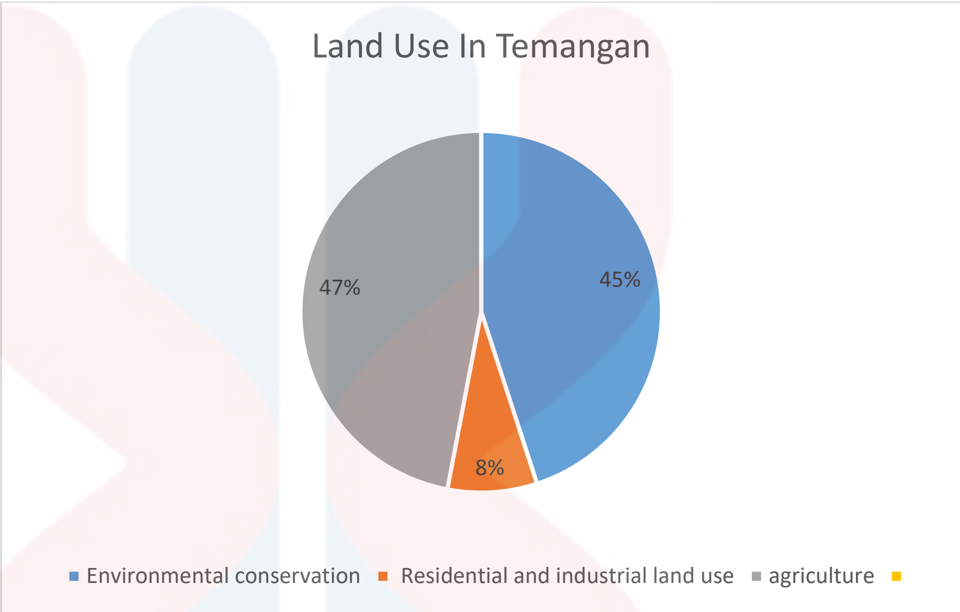


Figure 1.3 : Percentage of landuse in Temangan

1.2.5 Social economic

Most of the people in the study area carrying out work as plantation workers. However, there are also some local people that carrying out small business like grocery shop, small stall , selling out daily necessities for village people there. But, it can be said that most of the study area is dominated by the rubber plantation.

1.3 Problem statement

The geological data in the study area has fewer geomorphological information. The updated geologic maps of the study area can be produced through geological mapping and observation.

Landslide is an unpredictable hazard. It can occur anytime and make a huge destruction. Uncontrolled human actvities can cause landslides. These activities responsible for decreasing the environmental quality. Landslide studies are in needs for hilly and mountainous areas because of preparedness and mitigation activities are not running well in many regions even though it occur regularly in Malaysia, by doing this research, the lack of awareness of the villagers can be reduced as the potential susceptibility area will be predicted.

Due to annual high intensity of rainfall and flood in Temangan, Kuala Krai, the landslide susceptibility assessment can be conducted on this area. High vegetation, slope angle, rainfall intensity can affect the movemement of land that can cause landslide (Shahabi & Hashim, 2015).

1.4 Objectives

The objectives of this research:

1. To produce a geological map of Temangan, Kelantan with scale 1:25000 by using map interpretation.
2. To generate a landslide susceptibility map using Analytical Hierarchy Process (AHP) method using GIS approach

1.5 Scope of study

This research focuses on the production of the 25 Kilometre square of Temangan geological map. Geological mapping and observation must be done to acquire geological information from the study area in order to produce the geological map. In order to carry out the geological mapping secondary data is needed.

In addition, this study also provides a landslide susceptibility map of the study area. The susceptibility map of the landslide were be produced by raster based GIS using parameter such as lithology map, aspect map, landuse map, distance to fault, ditance to road, distance to stream and slope map . An overlay parameter process and raster calculation then be generated in GIS. Its included secondary data and data image of the satellite.

1.6 Significance of study

Geological mapping is one of the best ways to determine the geological characteristics in depth within the study area. This is because the geological features are able to do geological mapping with more details.

Next, the most potential place can be identified by producing a landslide susceptibility map. By providing easy, continuous and accurate information about the occurrence of a landslide is the key to estimate the landslide.The accuracy of landslide susceptibility maps is important and can reduce life and property losses that are important and can help disaster planners, local authorities and decision-makers. Otherwise, an accurate susceptibility mapping can be key information for a large variety of users from both private and public sectors, from governmental departments and the scientific community on both local and international levels (Shahabi & Hashim, 2015).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses the literature review of the past study that has been done in the surrounded of the study area, or similar study used by the previous researchers. The purpose of the literature review is to justify the methodology and procedure to be used for the purpose of this research. This chapter covered the regional geology including the Temangan area stratigraphy and structural geology with a specification.

2.2 Regional Geology and Tectonic Setting

Regional geology of Kelantan consists of a central zone of sedimentary and metasedimentary rocks, bordered by Main Range and Boundary Range granites on the west and east respectively. There are windows of granitic intrusives within the central zone, the more prominent of which are the batholith DIu Lalat (Senting), the Stong Igneous Complex and the pluton Kemahang. These granite and country rock belts have a north-south trend, and are essentially the northern continuation of northern regional geology of Pahang. In western and central Kelantan, the belts continue northward into southern Thailand but in the east, the alluvial coastal flat of Sungai Kelantan overlays the Boundary Range granite. Rare occurrences of amphibolite and serpentinite have been recorded (Khoo, 1983).

The state 's oldest rocks are of Lower Paleozoic age, outcropping as a northerly-trending belt bordering the Main Range foothills and extending eastward to Sungai Nenggiri. Most of them are metapelites with lesser volcanic fragmentation and lesser arenatic and calcareous intercalations. On the eastern side of the Lower Paleozoic sequence in southwest Kelantan, predominantly Permian volcanic-sedimentary rocks occur extensively and uncomfortably overlying. The Taku Schist dominates central north Kelantan, the age of which is still doubtful but defiantly pre-Triassic (Khoo, 1983).

Taku Schist Formation is a clastic Carboniferous-Permian rock in the southern part of the Transect region. The formations consist predominantly of schists that are wholly crystalline and generally schistoned to the full. Taku schist formation 's main rock type is mica schist which consists of quartz-mica schist, mica-garnet schist and quartz-mica-garnet schist. (McDonald, 1967) introduced the terms of Taku Schist to describe the metamorphic of rock that is cropping out in central Kelantan.

After the Sungai Taku, taku schist was designated where the good outcrop was observed. These formations comprise predominantly schist formations that are wholly crystalline and generally totally schistosa. Based on (Khoo, 1983) shows that the rocks of Taku Schist are majority Permo-Triassic but maybe some part also include strata of Carboniferous age. Surround the Taku Schist along both its western and eastern margins, as well as the strata of the same age but greenschist facies.

Temangan dykes have been mapped on the Geological Map of Malaya on 1963 as quartz phorphyry. It similarly known as volcanic character before it was found error by (Aw, 1967) which state that the Temangan dykes as an ignimbrite (Burton, 1967).

There is no pure lava characteristic, normal pyroclastic rock or middle rock of ignimbrite rock at Temangan mine (Aw, 1967). The track is thick mine of ignimbrite, like inserting a fractured old plug. It is extrusive igneous rock. Several investigations are under way at Temangan. It was formed as a result of transport during eastern granite intrusion, and named the Temangan dykes as rhyolite dykes.

2.2.1 Petrography

The study of minerals by using a microscope is petrography. Petrography was limited to identification of of rocks, minerals and ores to the characterization of properties such as cleavage, twining, reflectance, and so forth (Ahmad & Voort, 2015) . The solidification of the magma or lava are formed igneous rocks that presents beneath the earth surface (R, Gill, 2010).

Mineral crystallization and the magma cools down during the magma solidification process. Ignimbrite is the rock which existed at Temangan which is my area of study. Ignimbrite is the deposit of a pyroclastic density current which is a particle which has evolved hot suspension and the rapid flow of gasses from a volcano, and the density is greater than the surrounding atmosphere density.

Ignimbrite rock at Temangan does not have pure lava characteristics, normal pyroclastic rock, or middle rock (Aw, 1967). The track is thick mine of ignimbrite, like inserting a fractured old plug. Sillar ignimbrite formed as a flow of tuffs. Temangan dyke that found in in Temangan was named as rhyolite dyke by (Rosli, 1983). Temangan dyke was formed during the intrusion of eastern granite due to the major transportation.

The ash consists of crystal fragments. This rock may be loose, and may have been called lapili-tuff in shape. Since ignimbrite is present, this could involve the alteration. This is because when they tend to blanket wet soil and then bury all the watercourse and river, the large of hot ignimbrite can create some hydrothermal activity. In fumaroles and geysers, the water that comes from substrates will exit ignimbrite. When this water was in the process of boiling off, the ignimbrite will change and tend to form chimneys and pockets of kaolin-altered rock. There are also more igneous rocks in my study area that are felsic intrusive and basically pyroclastic volcanic. Figure 2.1 shows shows the general geological map in Kelantan (Mazlan Hashim, 2003).

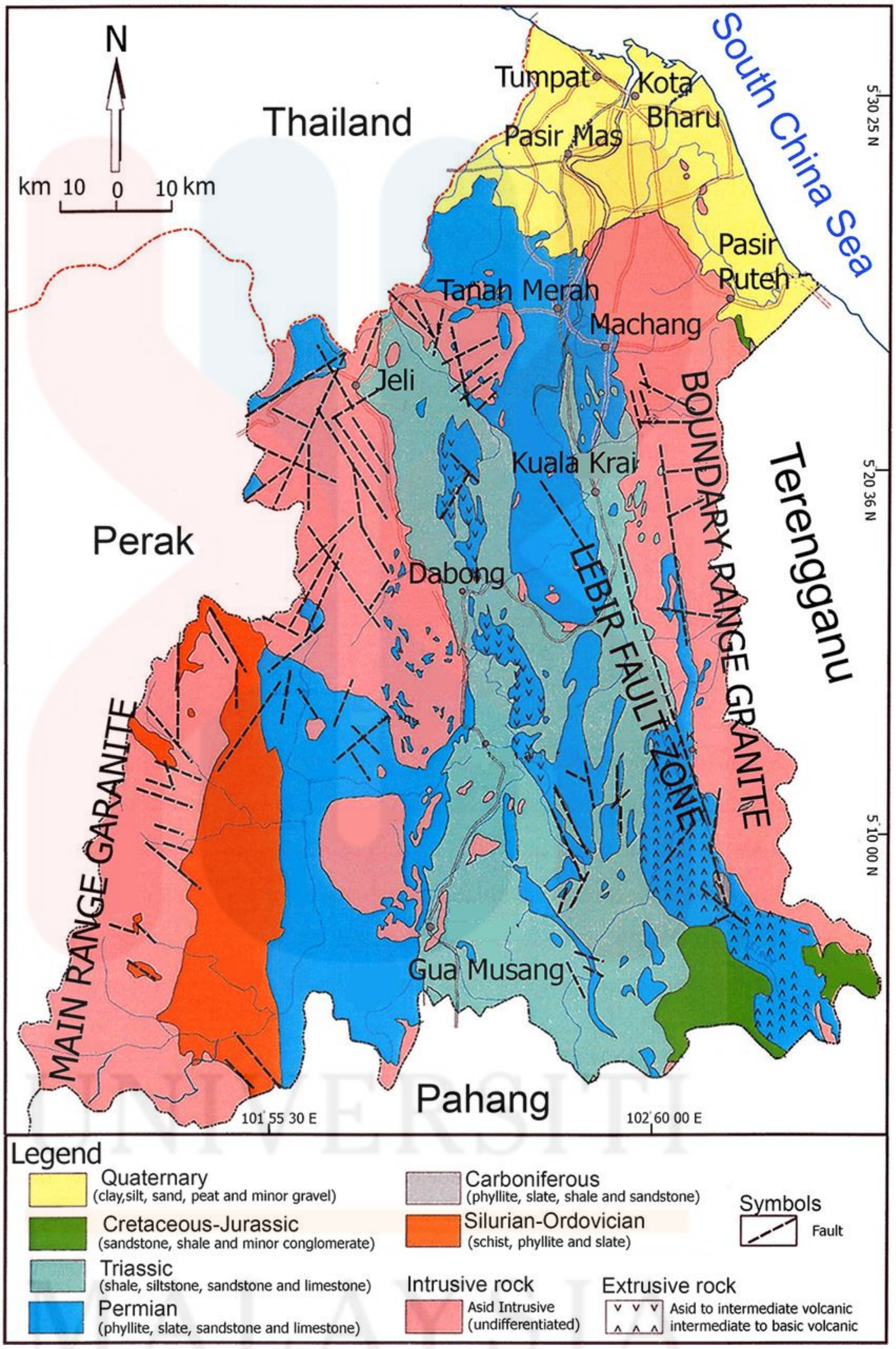


Figure 2.1 The Geological Map Of Kelantan

2.3 Stratigraphy

The Temangan area was located in Kelantan is presented with Telong Formation, Aring Formation and taku schist. The Telong Formation consists mainly of argillite, low-grade metasedimentary and metavolcanic rocks.

Telong formation are mainly argillite associated with some tuffs in southern Kelantan's Aring River area. It spreads westward into the Gua Musang Formation. Telong formation is confined in Malaysia to the central-south and central part of the Transect area, in Kampung Legeh, and extends eastward to the Tanah Merah area. The term was named after the rock sequence cropping out along part of the Sungai Telong in the Sungai Aring area, Kelantan by (Aw, 1990). The Telong formation consists primarily of metasementary rocks of argillite, low grade, and metavolcanic rocks.

It is believed that the iron ore deposit was first covered in 1921 and was prospected in the early 1930. The ore occurs in long , narrow belt along the contact of the schist and the sedimentary rock. The iron ore basically occurs on or near the crest of the north-south aligned ridges, and, where undisturbed by precious mining, takes the form of massive outcrops, large boulders, and nodules in the soil (MacDonald, 1967).

A probable age from Middle to Late Triassic (Carnian-Ladinian) is proposed from fossils that have not been identified in any way. It is uncomfortable to the east over the Aring Formation, and is probably also overlaid to the southeast and southwest by the Koh Formation. It is interpreted as being over 1,000 meters thick (Khoo, 1983).

Aring Formation are predominantly pyroclastic sequence in the river Lebir Valley, lower reaches of the river Aring and the river Relai in south Kelantan. Fossil evidence indicates an age which ranges from late Carboniferous to Early Triassic. The total formulation thickness is 3,000 meters and the top portion of about 1,000 meters is designated as the Paloh member, interbedded with slate , tuffaceous limestone, limestone. It is unconformingly overlaid by the Telong Formation, and by the Koh Formation, where this is absent. The type locality is tributaries of the Lebir River along the Relai River and Nuar River (Khoo, 1983).

2.4 Structural Geology

Structural geology is the study of any geological features formed during rock formation. There are many factors contributing to the formation of structural geology such as the tectonic process, the deposition of sediments and the stress caused by the earth's energy. The major structural can bring harm to human in faulting which can lead to natural disaster such as landslide. Temangan consist of ignimbrites. The Temangan ignimbrite presents a prominent ridge about 10 km long and 800 m wide This evidence suggests an intrusive nature for the ignimbrite which intruded along the Lebir Fault zone (Malaysian & Thailand Groups, 2006).

2.5 Historical Geology

Kelantan lies on Peninsular Malaysia 's Eastern Belt. The sediments range from Carboniferous to Permian age, and are distributed from east Kelantan through Terengganu and east Pahang to southeast Johor. The western boundary was formed by the central belt starting from Kelantan to Johor between east of the foothills from the main range, to its eastern boundary significant by Lebir Fault in the north down to the western boundary of Dohol Formation in the south. Carboniferous calcareous form Mesozoic sediments on both edges of the central and eastern belt belt belt. In the central of upper Paleozoic rock are Gua Musang and Aring Formation at south, while Taku schist at east, and south are the Raub group in west Pahang (Hutchison, 2014).

2.6 Landslide definition

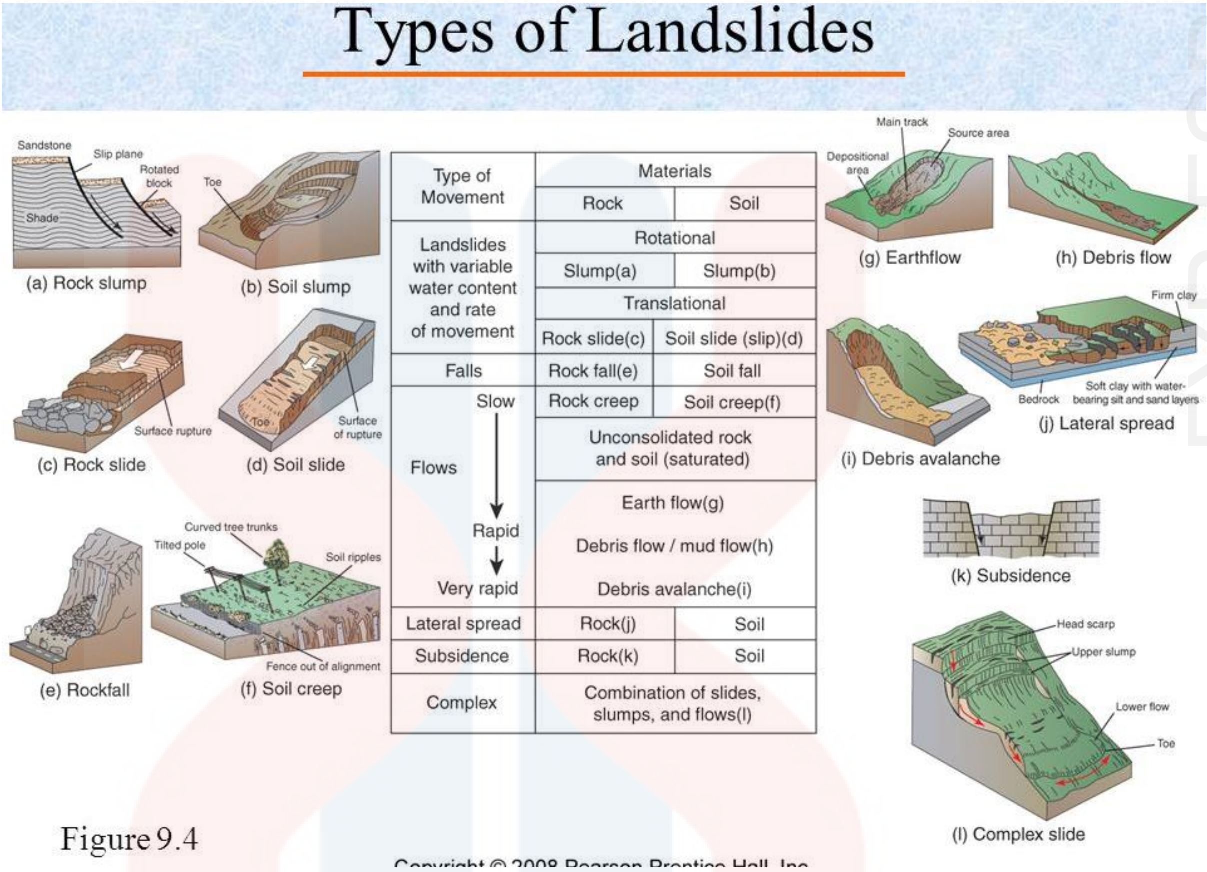
Landslide is a movement of earth's material, such as rock mass, debris, or earth down a slope. Landslide can be defined as a massive mass of soil and rock debris moving downhill due to the gravity action.The sheer mass of material involved and the speed at which they occur make them potentially disastrous as a consequence because of the existence damage they can cause to property and lives. (National Slope Master Plan, 2009)

2.7 Landslide in Malaysia

Landslide is a natural disaster that frequently occurs might cause loss of property and life. Malaysia faced numerous major and medium-sized landslide disasters that resulted in a total of up to 500 deaths as well as substantial property losses, collapse of multi-story buildings, road and highway damage and loss of environmental resource (Akter et al., 2019). Statistics show that there are an average of 2 to 8 landslides per year, of which 1 to 7 lead to deaths and property losses. More than 13.9% of mortalities were caused by landslides during the years of 1990-2014 (National Slope Master Plan, 2009). Malaysia's damages and losses from landslide are partly due to the country's rapid urbanization and economic development. Due to the scarcity of suitable low-lying areas available, people have expanded their economic activities into the highlands and hilly terrain areas. Cutting of mountain sides and hilly areas for construction of high-rise buildings increases the risk of landslide (Akter et al., 2019) .

2.8 Type of Landslide

Materials on the earth can fail and in several ways move or deform (Figure 2.2). Rotational slumps involve the sliding along a curved plain that produces blocks of slumps. Translational sliding is downward slope motion of earth materials along a slip plane like a bedding plane or fracture. Rock fall is the free fall of earth material from a cliff's open face. Flows are the downward slope movement of unconsolidated materials where particles move and mix inside the mass. Rock or soil flowing very slowly is called creep. Rapid flow may be a flow of earth, mud or debris. A debris avalanche is a flow of debris which is very fast to extremely fast. Large avalanche of debris can cause catastrophic damage and loss of life. Lateral spreading is a type of landslide often occurring on almost flat slopes or on very gentle slopes. It often starts suddenly, and then slowly and progressively gets larger. Subsidence may occur on slopes or on flat ground and invloves the sinking of a mass of earth material below the level of the surrounding surface. (Keller, 2008)



Type of Movement	Materials	
	Rock	Soil
Landslides with variable water content and rate of movement	Rotational	
	Slump(a)	Slump(b)
	Translational	
	Rock slide(c)	Soil slide (slip)(d)
Falls	Rock fall(e)	Soil fall
Flows: Slow	Rock creep	Soil creep(f)
	Unconsolidated rock and soil (saturated)	
Rapid	Earth flow(g)	
	Debris flow / mud flow(h)	
Very rapid	Debris avalanche(i)	
Lateral spread	Rock(j)	Soil
Subsidence	Rock(k)	Soil
Complex	Combination of slides, slumps, and flows(l)	

Figure 2.2 : Types Of Landslides

Landslide commonly occurs with complex sliding and flow combinations. When water-saturated, earth materials will flow from the lower part of the slope, which will undermine the upper part causing blocks of earth materials to slump. Suddenly, landslide can have caused numerous deaths and injuries to people living nearby.

2.9 GIS in Landslide Susceptibility Mapping

Geographic Information System (GIS) is a fundamental tool that exploits the spatial dimension and its links to other dimensions, enabling processes that are representative of the world to be modeled and represented (Salehi & Ahmadian, 2017). GIS is able to find its place in nearly every field of study. The need to consider location in slope and risk assessment is embedded in the very definitions of the terms. GIS however can do much more than provide distance measurements and mapping solutions.

Many approaches to make landslide susceptibility map generation can be used in GIS methods. The previous study used landslide inventory as it method. Landslide inventory maps show locations and also characteristics of past landslides, although its usually do not show the mechanism that triggered them. Inventory maps therefore provide useful information on the spatial distribution of existing landfill locations and the potential for future landfill slides (Shahabi & Hashim, 2015).

Landslide mapping in tropical mountainous environments is difficult as the dense growth of vegetation obscures landslides soon after they occur (Shahabi & Hashim, 2015). Due to insufficient and reliable landslide inventory map which hampers the assessment of landslide hazard and risk, mitigation measures are sometimes held back. The use of remote sensing data such as radar, optical satellite images, and aerial photography interpretation are primary methods for obtaining important, cost-effective landslide location information. The landslide information taken from remotely sensed images is particularly linked to the region's morphology, plant life, and hydrological conditions (Shahabi & Hashim, 2015)

2.10 Geographic Information System (GIS) Application

The primary instrument for the completion of this study in natural hazard assessment is the Geographical Information System. This tool has advantages and disadvantages based on the study. In order to systematically and efficiently analyse the risk of landslides, the use of the Geographical Information System is essential. It is possible to use the Geographical Information System to create thematic map layers based on several factors that contribute to the occurrence of landslides. The slope angle, lithology, land use, distance to road, distance to fault and distance of stream are included in the data. Then the GIS tool can store a lot of information. GIS is designed as a database management system for storing, organising, managing and querying data during the database query and analysis stage. The slope angle, lithology, land use, distance to road, distance to fault and distance of stream are included in the data.. The data can also be shown in maps, graphs, charts and tables. In addition, GIS data can also be combined for statistical analysis with Microsoft Excel data.

In addition, the various layers will be joined or integrated to create a map of susceptibility to landslides. For example, slope angle, lithology, land use, distance to road, distance to fault and distance of stream were combined and layered to produce landslide susceptibility maps. Then, as well as the ability to query attributes and evaluate the spatial relationship, the spatial data, colours and symbols will be selected. In addition, the various layers will be joined or integrated to create a map of susceptibility to landslides. Not only that the maps can also be created in vector or raster format. Because of the demand, the format allows conversion. In addition, in preparing the maps, the digitization process usually takes a long time to complete. In addition, the GIS method can also be used for the large area to conduct the study.

Besides, there also have disadvantage of using GIS during complete the landslide assessment study. In this study,there are three classes that can be read for low, moderate and high class. While the high landslide class occurs in the region of the study area,the data can be identified . Then a lot of time is needed through the use of GIS. This is because, to complete this research, the maps should be clipped, digitised, merged and intersected. Additionally, because of incomplete data, the database has to convert from raster format to vector format and the data cannot be integrated without conversion.

To produce the Landslide Susceptibility Map, there are various method that had been used by researcher while making the map. One of it is Analytic Hierarchy Process (AHP), which is been used on this study area. Basically, AHP is a way of breaking down into its components a complex, unstructured situation; organising these parts or variables into a hierarchical order; synthesising the judgments to determine which variables have the highest priority and should be used to influence the situation's outcome. In order to abstract, decompose, organise and control the complexity of decisions involving many attributes, it uses a hierarchical structure and uses informed judgement or expert opinion to measure and synthesise a solution to the relative value or contribution of these attributes (Shahabi & Hashim, 2015).

One of the most convenient methodologies for evaluating transportation problems is AHP. First of all, any issue of selection, priority and decision consists of different criteria. These criteria also frequently have sub-criteria. Criteria have to be taken into consideration quite a lot in this case. With the AHP technique, either objective or subjective considerations or either quantitative or qualitative information may be evaluated. In this technique, any level of information about the main focus can be listed or structured. The overview of the main focus or the problem can be very easily represented in this way.(Afshin, et all (2017)

In conclusion, the analysis was carried out in order to create a database for mapping the study area for landslide susceptibility. Database integration using a GIS framework. GIS is one of the technology implemented in this research, and GIS is an important desktop study method for landslide assessment. Finally, the research area's landslide vulnerability chart has been developed which indicates the magnitude of landslides that could occur in the future.

CHAPTER 3

MATERIAL AND METHOD

3.1 Introduction

Many types of materials and methodologies had been used to perform these this research and were been discussed in this section. Any information and data collection were been recorded.

3.2 Material

In order to carry out the research, it will be necessary to carry out by interpretation on secondary data. Other than that, several secondary data from the satellite image will be needed in order to generate the landslide susceptibilty.

- **Material for landslide susceptibility analysis area mapping**

  Secondary data such as topographical data, digital elevation model (DEM) and satellite image can be collected from USGS (United State Geological Survey), previous study and geology agencies, its also must show the causes of the factor, including the lithology map, aspect map, Landuse map, slope map, distance to road, distance to fault and distance to stream in order to assess the area susceptibility to landslide.

1) Lithology map

Lithology serves as the basis for the subdivision of rock sequences into individual lithostratigraphic units for mapping and correlation of areas. In some applications, for instance site investigations. The updated lthology section will be produced after data have been collected and recorded for the study area.

2) Aspect map

Aspect values indicate the orientations facing the physical slopes. Based on slope angle, the aspect direction with a descrptive direction can been. A raster of the output aspect typically results in several classes of the direction of the slope.

Aspect map was generated from satellite image data that will be downloaded from the website of the United States Geological Survey Resources Observation and Science Center (USGS). The different direction of lineament ,different geological features.

3) Landuse map

Landuse is a simple graphical indicator which can be used to analyze measurements of remote sensing and to assess whether or not the target to be observed contains live green vegetation. Landuse map will be produce to show the high and low vegetation. The high vegetation will had less probability to landslide because of the hold the soil.

4) Slope map

Slope is a measure of steepness or a degree of inclination relative to the horizontal plane of a feature. Slope is used interchangeably with gradient, grade, incline, and pitch. Typically slope is expressed as percentage, angle, or ratio. To find the slope of a feature, it is necessary to determine both the horizontal distance (run) and the vertical distance (rise) between two points in a line parallel to the feature. The slope is obtained through a division of the rise over run. To express slope as a percentage multiply this ratio by 100. The angle of slope expressed in degrees is discovered by taking the arctangent of the ratio between rise and run.

On a topograhic map the average slope of a terrain feature can be calculated conveniently from contour lines.The slope map will be extrated from the satellite image data. It will show the distribution of the slope based on its angle. The previous landslide in the study area is compared to the current susceptibility.

5) Distance to road

From previous research, (Tuan and dan ,2019) state that indicated that most of the landslides were distributed close to the road system. Discontinuity is produced in the soil and rock by cutting the slope hills for building roads in the slopes greater than 10 degrees. The area may therefore be prone to landslides.

6) Distance to fault

Active faults increase landslide susceptibility because rocks near a fault are weaker, due to intense shearing. Distance from faults increases the likelihood of occurrence of landslides (Pradhan and Lee 2010). Fault lines have been digitised from the region's geological map and updated through remote sensing and extensive field work.

7) Distance to stream

Slope stability is directly affected by the saturation levels of the materials. Streams may negatively affect stability by eroding or by saturating the toe materials of the slopes and hence reducing their shear resistance (Dai et al. 2001)

3.3 Methodology

In order to carry out this research, it is necessary to carry out a geological mapping and slope observation to complete the requirement and produce a good quality result. Secondary data of study area is needed to carry out a geological mapping, where the geological data will be collected in the Temangan area. The secondary data can be collected from USGS (United State Geological Survey), previous study and geology agencies.

In order to generate the landslide susceptibility map the intensity of rainfall,vegetation, slope angle are needed to be collected. The GIS raster-based analysis technique will be applied by using ArcGIS software to use the Analytical hierarchy process (AHP) method in order to establish an landslide susceptibility map.

3.3.1 Preliminary study

Before starting the research, all information on how to conduct the research must be obtained and fully understood by doing the preliminary study. Referring to articles and studies that been reviewing previous research on the study area related to the susceptibility of the lanslide in order to gain additional information through the research will be studied. It is important and crucial as it involves knowledge of what will be done in surface area. Therefore, the study area's structural history, lithology and formation are known.

a) Method for landslide susceptibility analysis area mapping

The method in susceptibility is the integrated method of remote sensing, fieldwork and GIS analysis in this study.The remote sensing was used to obtain the geological lineament and lithological boundaries, while the fieldwork was carried out to characterize the deposits of the outcrops and to identify the pattern of micro-fault, joint and fracture found in the outcrop. The GIS platform analyzed all data from remote sensing and fieldwork. The computing activities have focused primarily on the motion structure (SFM) procedure. Meanwhile, remote sensing and GIS focused mainly on the visual interpretation and the process of map generation.

For the lithology map, aspect map, landuse map, slope map, distance to road,distance to fault and distance to stream will be produced by using ArcGis software to determine the distribution from the parameter used. As for the final product, an area of susceptibility to landslide will be developed and evaluations will be carried out. Using ArcMap reclassify tool, a Analytical hierarchy process (AHP) method will be used from satellite image and data collection and converted into raster.

3.3.3 Data collection

There are two types of data, primary and secondary. Primary data refers to the data obtained from the field observation and interpretation geological mapping of the study area. Susceptibility map for the landslide has been conducted. The survey was conducted at the landslide prone area and based on the history of the landslide. Besides analytical hierarchy process method was one of the methods used to determine the influencing factors which contributed more to landslide.

The secondary data refer to the data obtain from various for example United State Geological Survey (USGS). The data includes Digital Elevation Model (DEM) data that covers slope information in terms of location elevation and steepness to help identify the factors that could lead to landslide hazard.

3.3.4 Data processing

The data collected from the secondary data is then transferred to the Geographical Information System (GIS) for the production of geological hazard maps and floods. Besides, that few maps that are geomorphological and lithological map needed to be produced. Then there are several steps to produce maps including the construction of databases, spatial analysis and spatial integrations. Data will be entered into GIS to update the topographical map and integration of data was useful in mapping.

3.3.5 Data analysis and interpretation

All data from the secondary data was analyzed by interpreting the geological features and also using the GIS to identify the susceptibility zones to landslides. Landslide susceptibility can be analyzed by slope steepness, elevation, and some geological factors. So the level of landslide susceptibility can be determined either in the low, medium , or high potential classes of prone area.

3.3.5.1 Rainfall Distribution

Based on the rainfall distribution data from the climate data, it shows that the amount of rainfall distribution increased significantly compared to the previous year in 1982-2012. Data from the month of January shows that the rainfall distribution in Temangan was 263 mm while the rainfall distribution in December was 491 mm (Department Of Statistic, 2020).

It can be observed that in the month of January to April, the rainfall distribution is became increase compare with the rainfall distribution in the month of June to October. But in the month of November to December, the rainfall distribution increase and the trend of the rainfall distribution are relatively the same in the year of 1982-2012. Table 1.3 shows the rainfall distribution of Temangan 1982-2012.

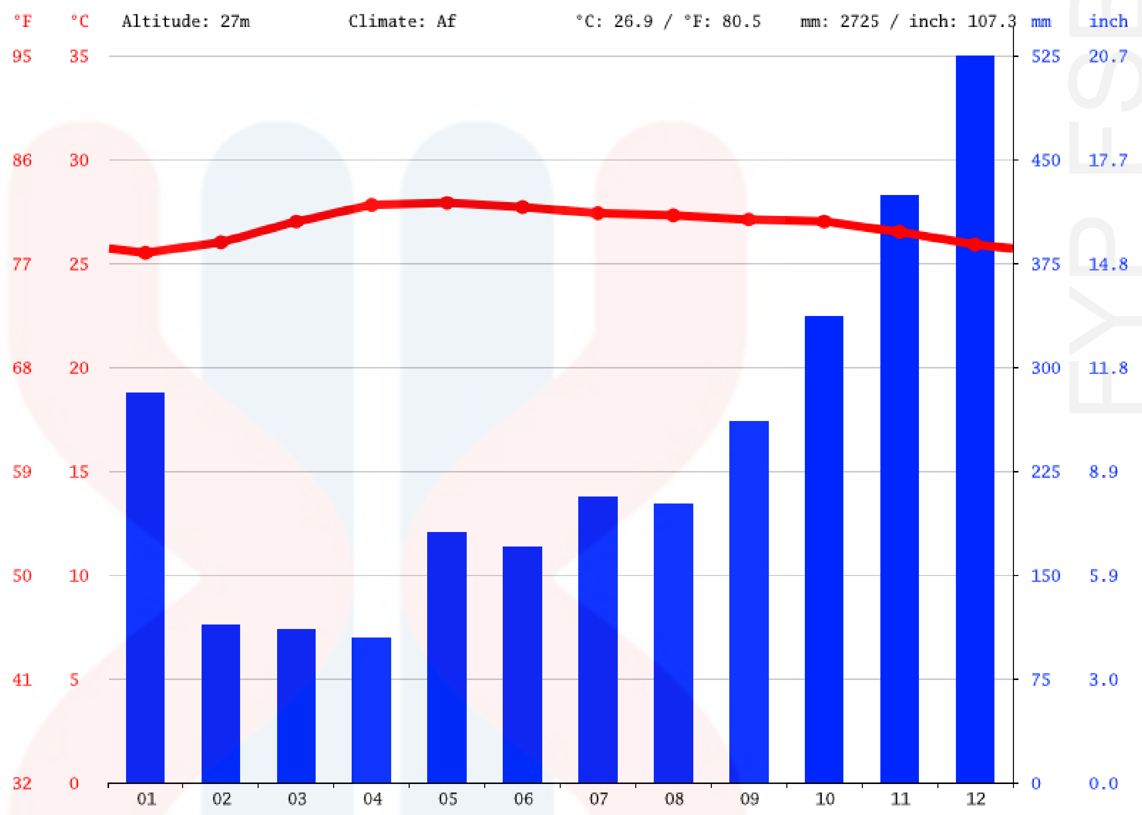


Figure 3.1 : Rainfall distribution

Table 3.1 : Average temperature and rainfall precipitation (Climate, 2020)

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	25.5	26	27	27.8	27.9	27.7	27.4	27.3	27.1	27	26.5	25.9
Min. Temperature (°C)	21.9	22	22.5	23.2	23.5	23.2	22.9	22.9	22.8	23	23.1	22.6
Max. Temperature (°C)	29.2	30.1	31.5	32.4	32.4	32.2	31.9	31.7	31.5	31	30	29.3
Avg. Temperature (°F)	77.9	78.8	80.6	82.0	82.2	81.9	81.3	81.1	80.8	80.6	79.7	78.6
Min. Temperature (°F)	71.4	71.6	72.5	73.8	74.3	73.8	73.2	73.2	73.0	73.4	73.6	72.7
Max. Temperature (°F)	84.6	86.2	88.7	90.3	90.3	90.0	89.4	89.1	88.7	87.8	86.0	84.7
Precipitation / Rainfall (mm)	263	106	103	98	169	159	193	188	244	315	396	491

Research Flowchart

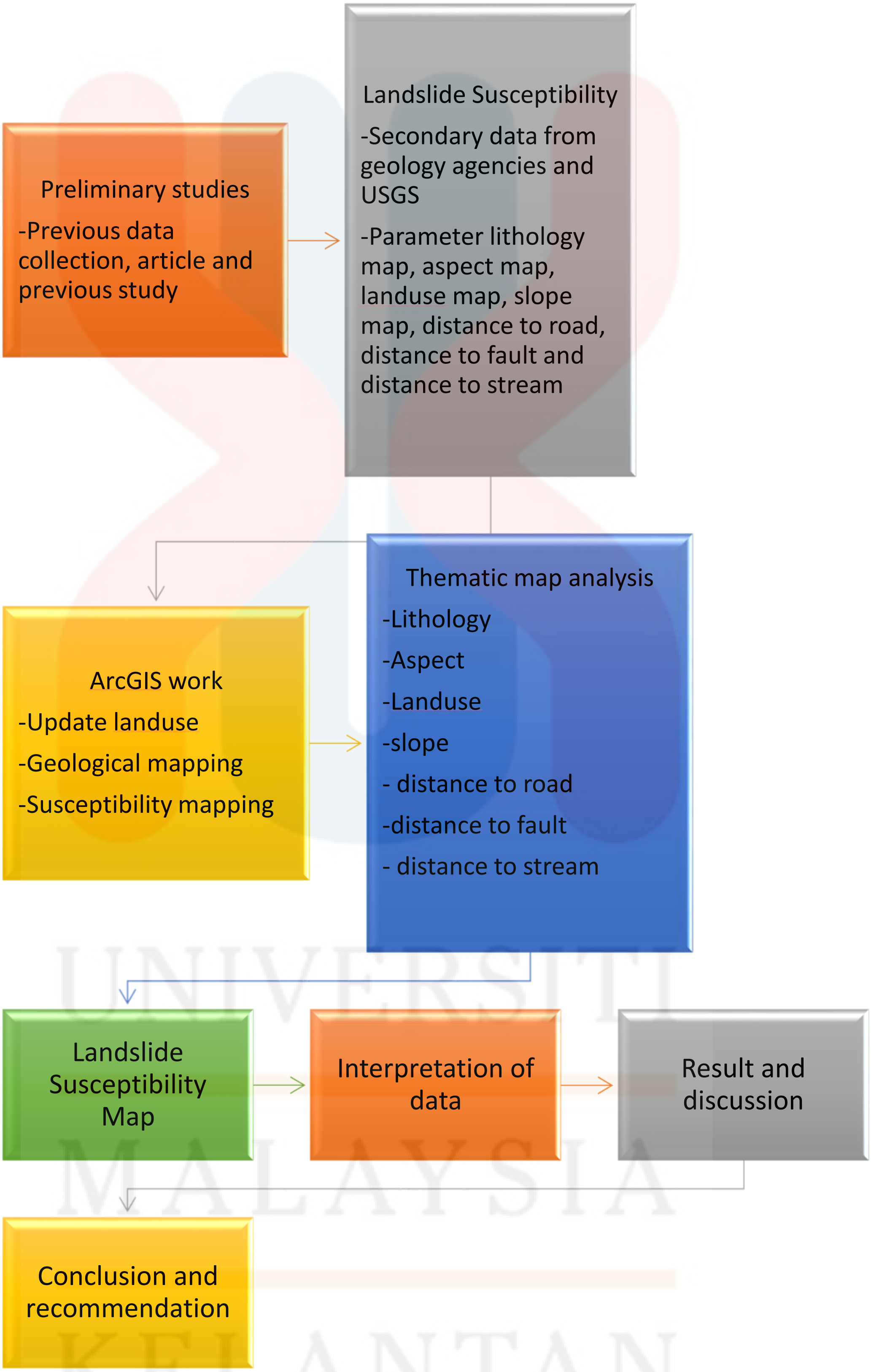


Figure 3.2 Flowchart

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

General geology is a survey of the many geological and earth science facets. From the creation of the universe and the solar system, to rocks and minerals, to geological and hazardous processes. Earth cycles, such as the rock cycle and the hydrological cycle, are based on general geology. The main study area at Temangan is located. This area of study is dissected by numerous elevations or contours. Some place is a very dangerous area so that since there is no accessibility, some of elevation cannot be explored.

4.1.1 Accessibility

In Temangan, roads are the main type of connection system. There are two kinds of roads that are paved and unpaved. The main road connection in this area is the Kuala Krai-Machang road. This route is used by most local people and outsiders as the main link. Other than that, the unpaved road and railway track were also used during the study as a road link.

4.1.2 Settlement

The study area is located in Temangan, which part of Machang district. In 2010, Machang has a population of 89,118 people. Table 4.1 shows the detailed people population based on ethnicity, in Machang by year 2010, and people population according to gender by year 2010.

Table 4.1: Population of ethnic group (Department Of Statistic, 2020)

Ethnic group	**Population**
Malay	85,300
Chinese	2,462
Indian	394
Others	64

4.1.3 Forestry (or vegetation)

The Temangan area consists of farming, quarry, paddy farming in the plantation area. Thus, agricultural and business sources are the main economic sources in the study area. The majority of people work as rubber tappers and farmers in Machang. Rubber planting and paddy cultivation are attracting people to work in the Temangan area.

4.2 Geomorphology

Geomorphology is the scientific study of the shape of the terrain (geometry) and of the formation and development processes involved. The exogenic (external) and endogenic processes affect terrain shape (internal). In order to understand the physical changes that occur on the earth's surface in the study area, geomorphological processes occurring in the study area are very important.

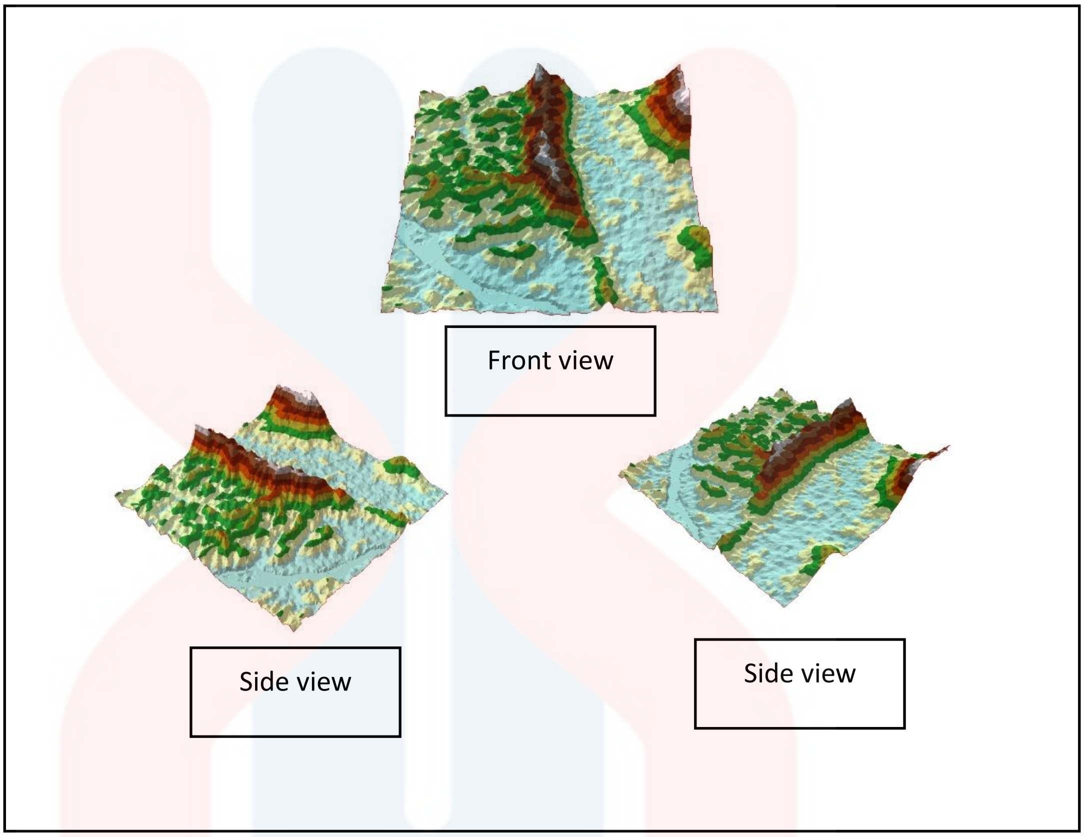


Figure 4.1 The 3D Map on the study area

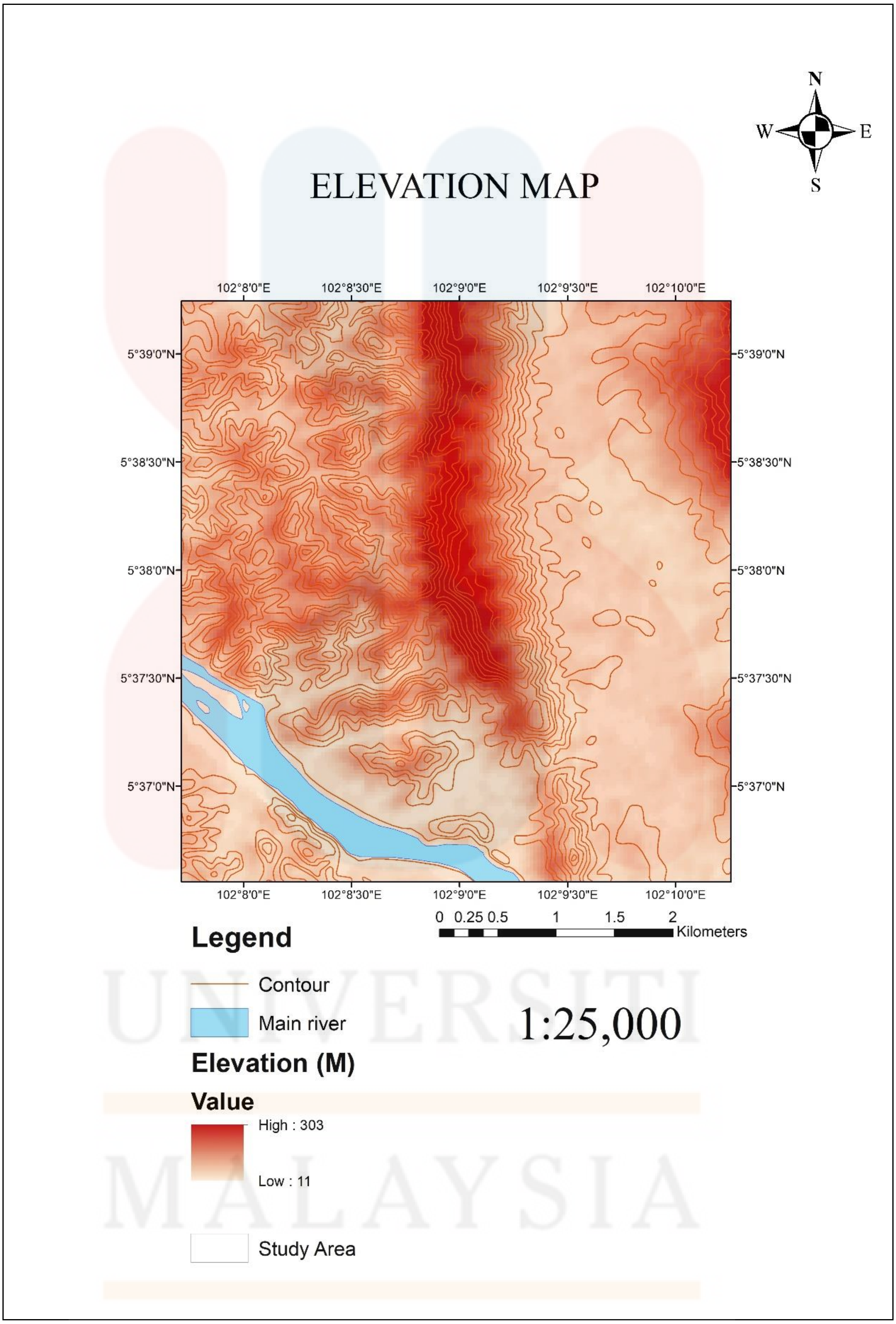


Figure 4.2 The elevation of the study area

4.2.1 Topography

Topography is a term used to describe the surface of the Earth that includes the various characteristics known as the landform. It is measured at the elevation of the difference across the surface of the Earth, where the difference is between high and low elevation. This is referred to as a relief modification. In the topographic unit, there are five types of classes that show differing elevations. The table 4.2 shows a summary of the topographic units.

Table 4.2 Landform (Van Zuidam, 1985)

Landform	
5 m – 100 m	Low lying plain
100 m – 200 m	Low hills
200 m – 500 m	Hills

4.2.2 Drainage Pattern

The drainage system is the pattern developed in a particular drainage basin that affects rivers, streams and lakes. The formation of the drainage pattern usually depends on the type of rock, rock distribution, and rock location on the surface. It is caused by the arrangement of the weakness of rock planes, such as planes for bedding, faults, joints, shape, and other variables. such as folding, amount of rainfalls and erosion. The main water flow channel for the river in the study area is the hills and basins surrounding the study area.

Based on the map in Figure 4.3, dendritic drainage patterns dominate the drainage pattern in the study area. The most common form is the dendritic drainage pattern and looks like the branching appearance of tree roots. They form when the channel of the river follows the terrain slope. This pattern allows the downhill stream to flow in the same direction and they meet on a large or main stream together.

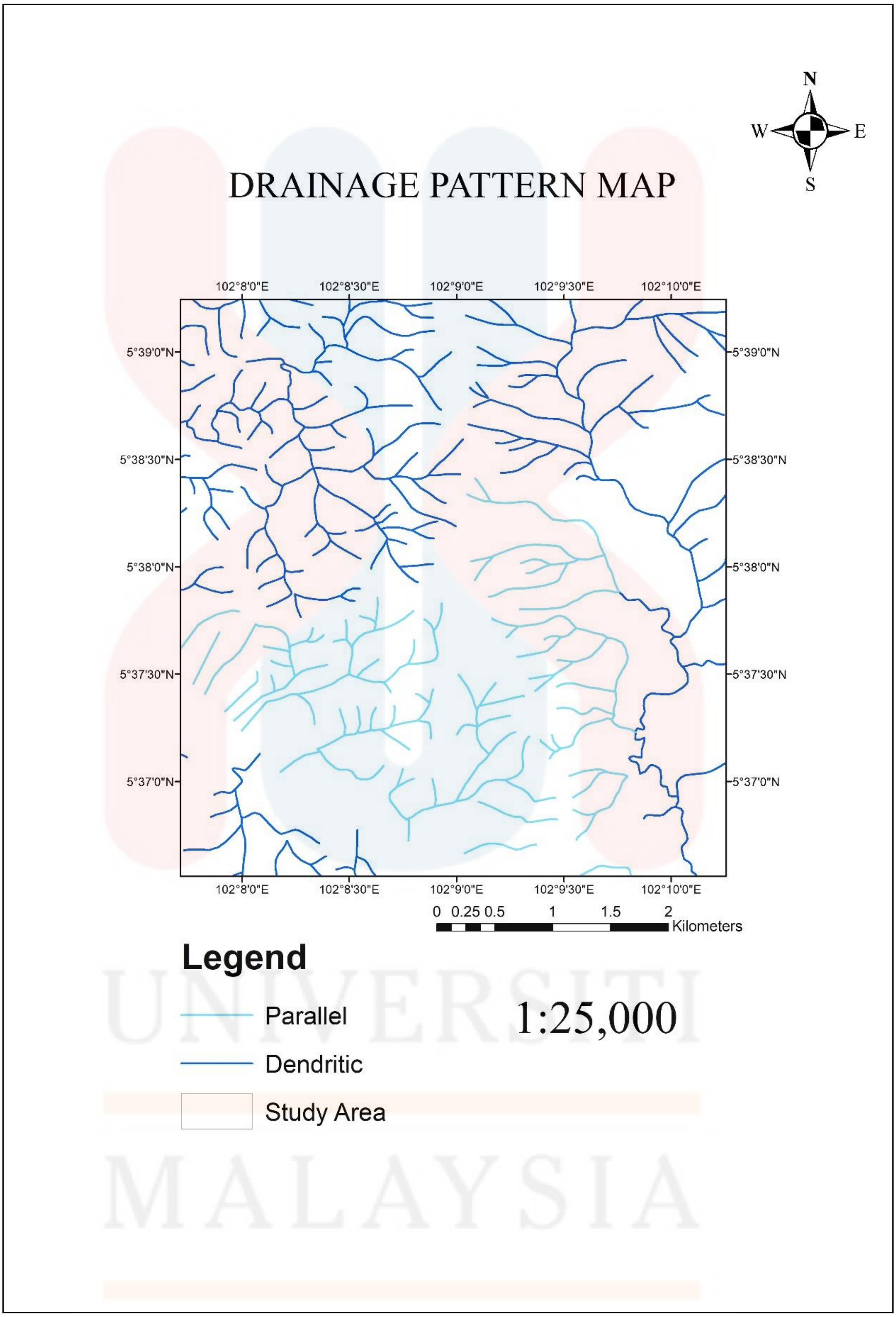


Figure 4.3 Drainage pattern

4.3 Lithostatigraphy

Lithostratigraphy is the sub-discipline of stratigraphy, the geological science of the study of layers of strata or rock. Geochronology, comparative geology, and petrology are major areas of focus. In general, the strata relating to how the rock was formed are primarily igneous or sedimentary. The age of the rocks will later be described by the layer that is first deposited and subsequently intruded. In this area of study, the oldest rock is Permian-age quartz mica schist, while the youngest rock is ignimbrite that was intruded in the Triassic age. The lithostatigraphy shows the lithology of the rocks that existed in Temangan, based on Table 4.3.

It can be concluded on the basis of the geological map in Figure 4.4 in Temangan that about 50 percent of the area covered by metamorphic rocks is quartz mica schist. It is about 25 percent of study area covered by magmatic rock, which is ignimbrite and andesite. Based on contour and v-rule, it can determine the rock boundary by using ArcGIS without going to the field.

Table 4.3: The lithostratigraphy column in Temangan.

Lithology	Description	Formation/Unit	Period	Era
	Alluvial consist mainly of sand, silt and clay. Widespread in the flat river valleys	Alluvium	Quartenary	Cenozoic
	Unconformity			
	Ignimbrite	Temanagan Ignimbrite	Triassic	Mesozoic
	Unconformity			
	Andesite	Interbedded Formation	Permian – Triassic	
	Shale and mudstone			
	Mainly politic schist consist mainly of quartz-mica schist	Taku schist	Permian	Paleozoic

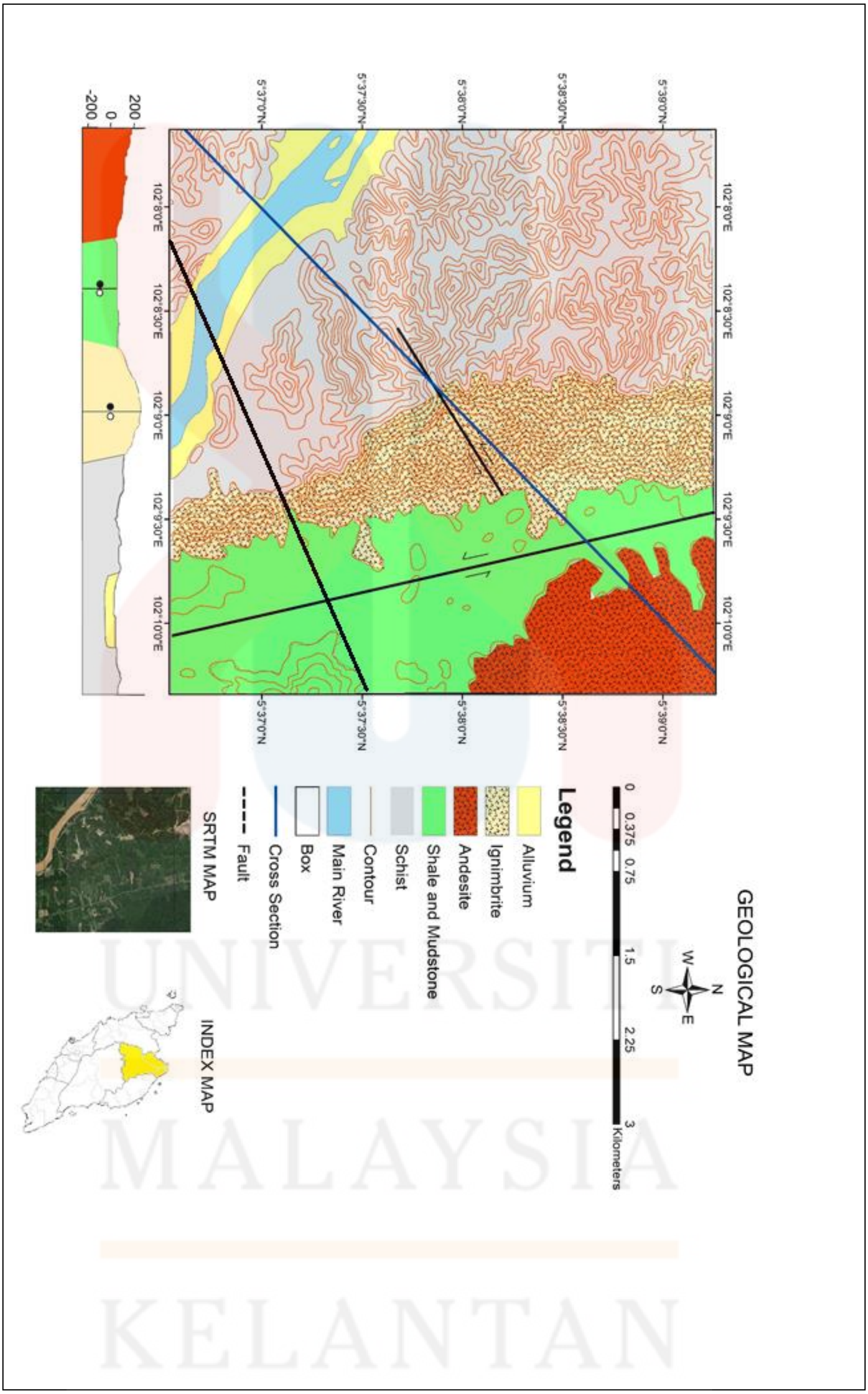


Figure 4.4: Geological map of study area

4.4 Structural Geology

In terms of their deformation histories, structural geology is the study of the three-dimensional distribution of rock units. It is also the processes that lead to geological structures being formed and how the rocks can be affected by these structures.

4.4.1 Fault

The fault process occurs when the rocks cause the movement of the earth's crust to break. Basically, this movement was carried out to create some earthquakes. The movements of the earth's crust affect the stress that can build up over a period of time before a huge amount of energy is released that can create an earthquake (Britannica, 2020).

Faults are divided by three which are normal fault, thrust fault and strike-slip fault. The fault moving towards the downthrown block is the normal fault, but still the youngest rocks remain in the oldest rock above. It differs from the thrust fault. This is because the fault is the break that will be placed above the youngest rocks affecting the oldest rocks and it is the type of fault that occurs in the vertical or horizontal of the fault plane for the strike-slip fault. It showed that because the fault occurred on ignimbrite rock, the ignimbrite rock is older than the fault (Britannica, 2020) .

From the map, the fault can easily been identify by lineament on the map. Other than that, contour and the rock boundary also can be indicator in observation of fault, as the definition of fault is a planar fracture.

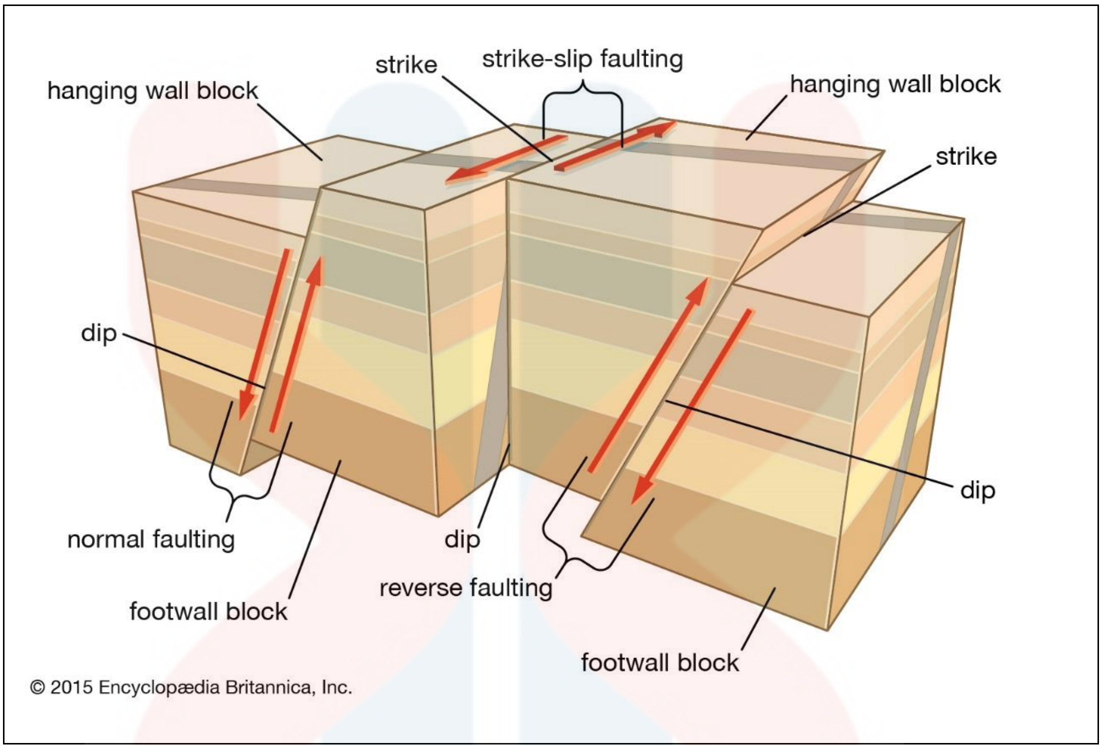


Figure 4.5 Type of fault (Britannica, 2020)

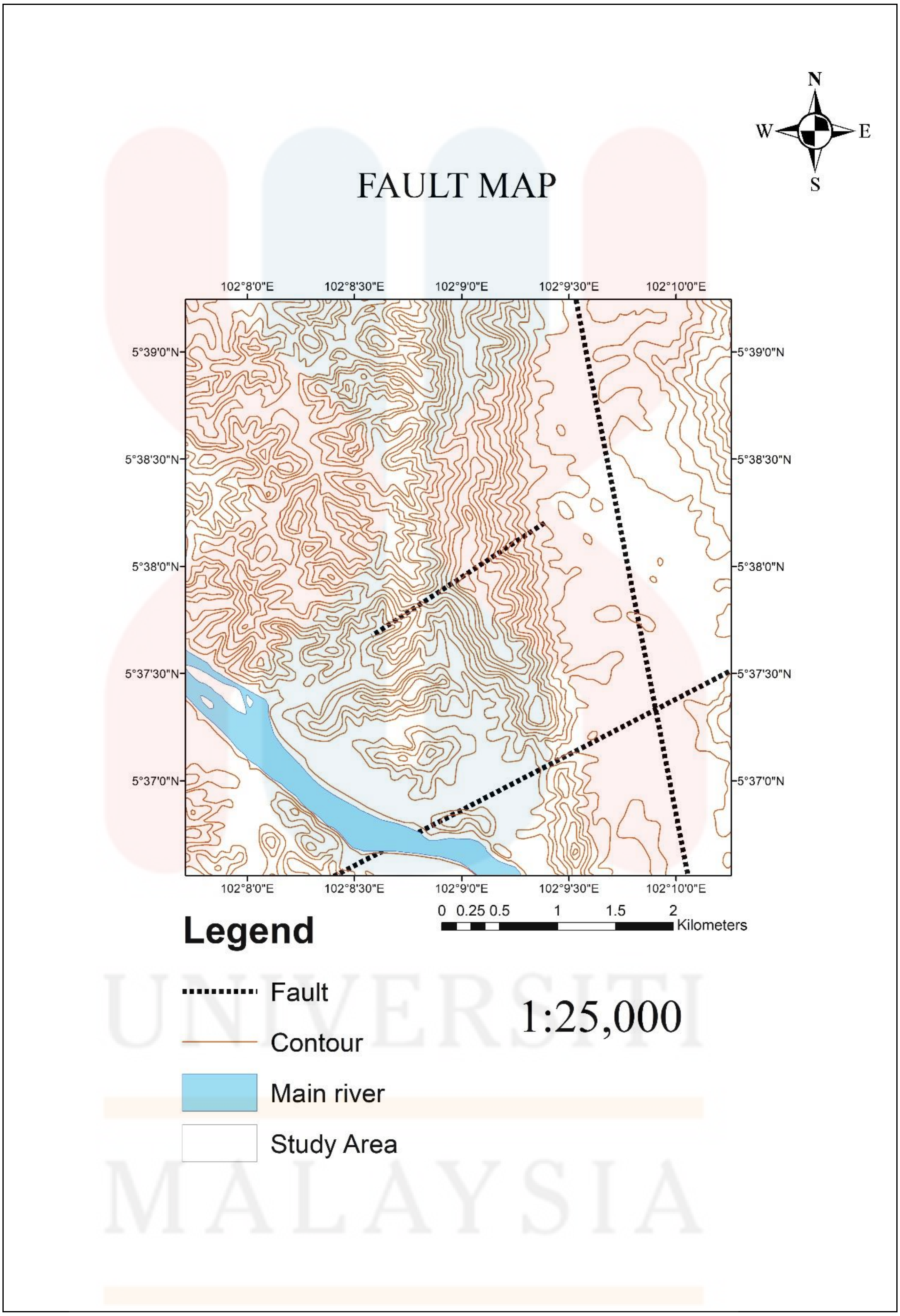


Figure 4.6 :Fault

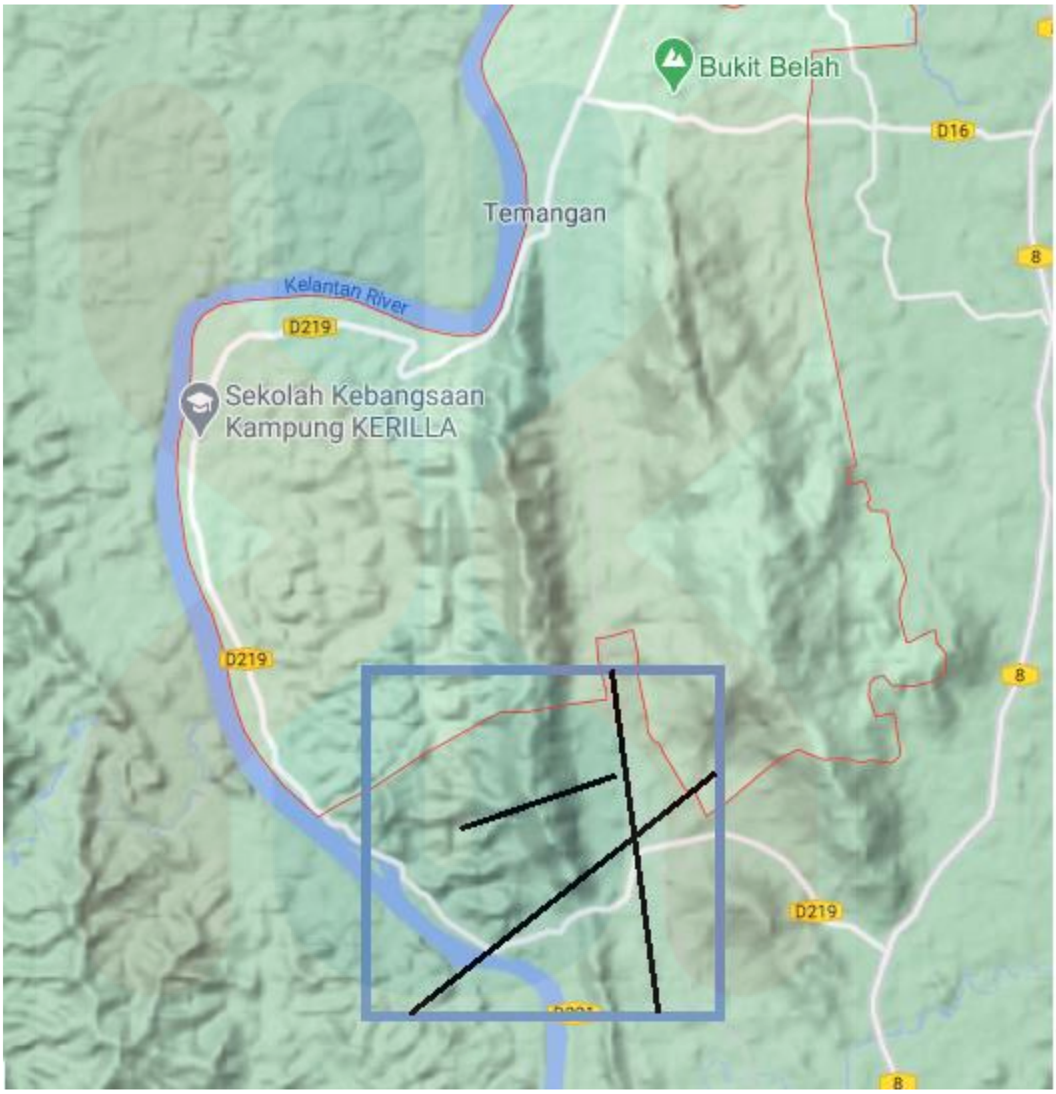


Figure 4.7: The terrain map of the study area in large scale

4.4.1 Mechanism of structure

A) Lineament analysis

Based on the ridge, the positive lineament analysis is defined and the negative lineament is based on the river. The rose diagram for both positive and negative lineament was plotted in order to get the direction, fault, force and joint. For analysis, lineament was calculated in the rose diagram.

i) Positive Lineament Analysis

As a result, the positive lineament on the ridge analysis Figure 4.8 and the rose diagram are plotted Figure 4.10. Based on the rose diagram, the tension from ridge came from Northeast and Southwest. So , the primary shear is to the left, which show the direction of deformation, Northeast and Southeast.

ii) Negative Lineament Analysis

As a result, the negative lineament on the ridge analysis Figure 4.9 and the rose diagram are plotted Figure 4.10. Based on the rose diagram, the direction of $\partial 1$ which the major force is came from North-east, so the primary shear to the left. Meanwhile, the direction of $\partial 3$ is came from north-west and secondary shear to the right. The direction of the main stress NE corresponds to the structural direction of peninsular Malaysia directed NNW-SSE (Hutchison, 2014)

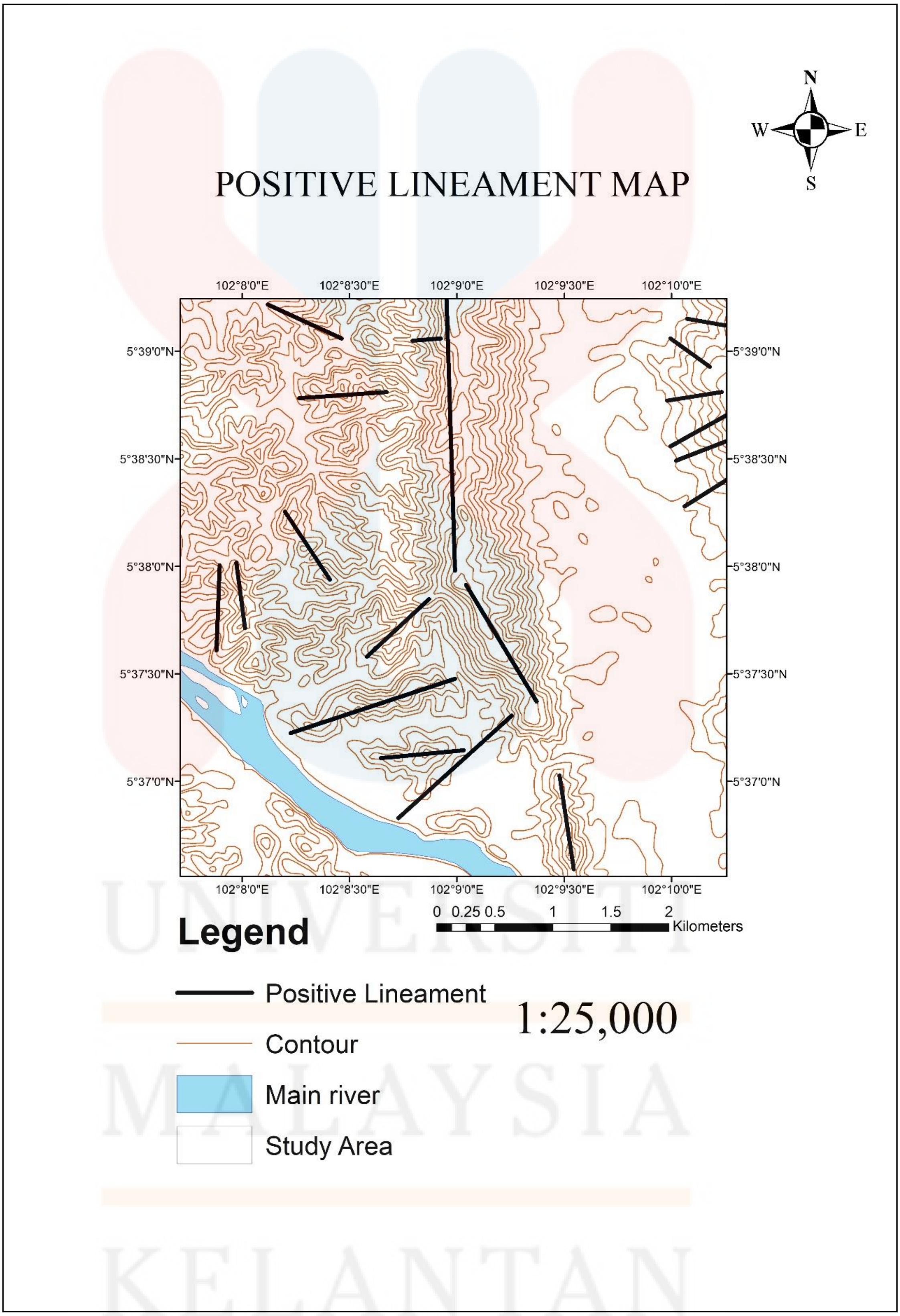


Figure 4.8 Positive Lineament

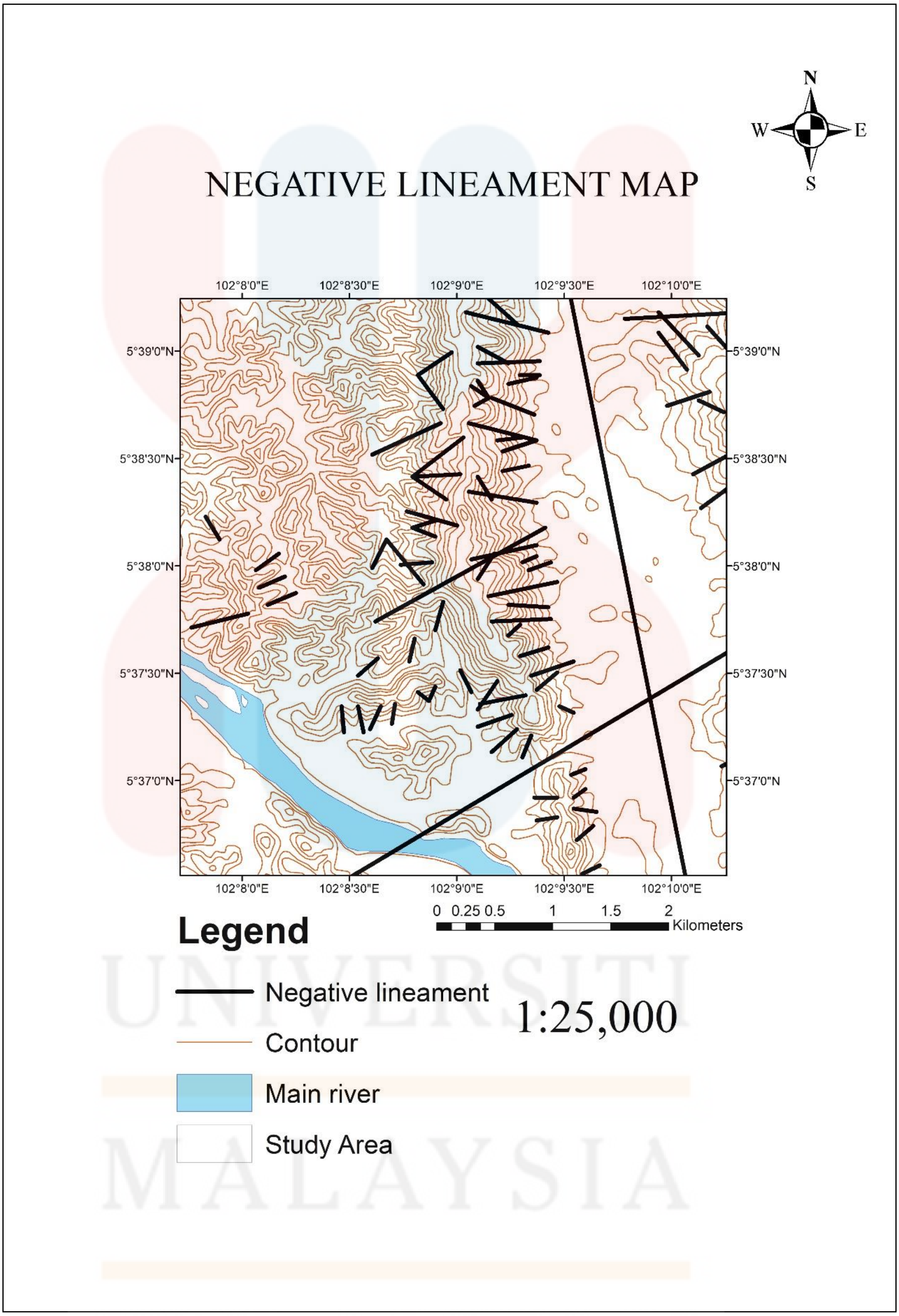
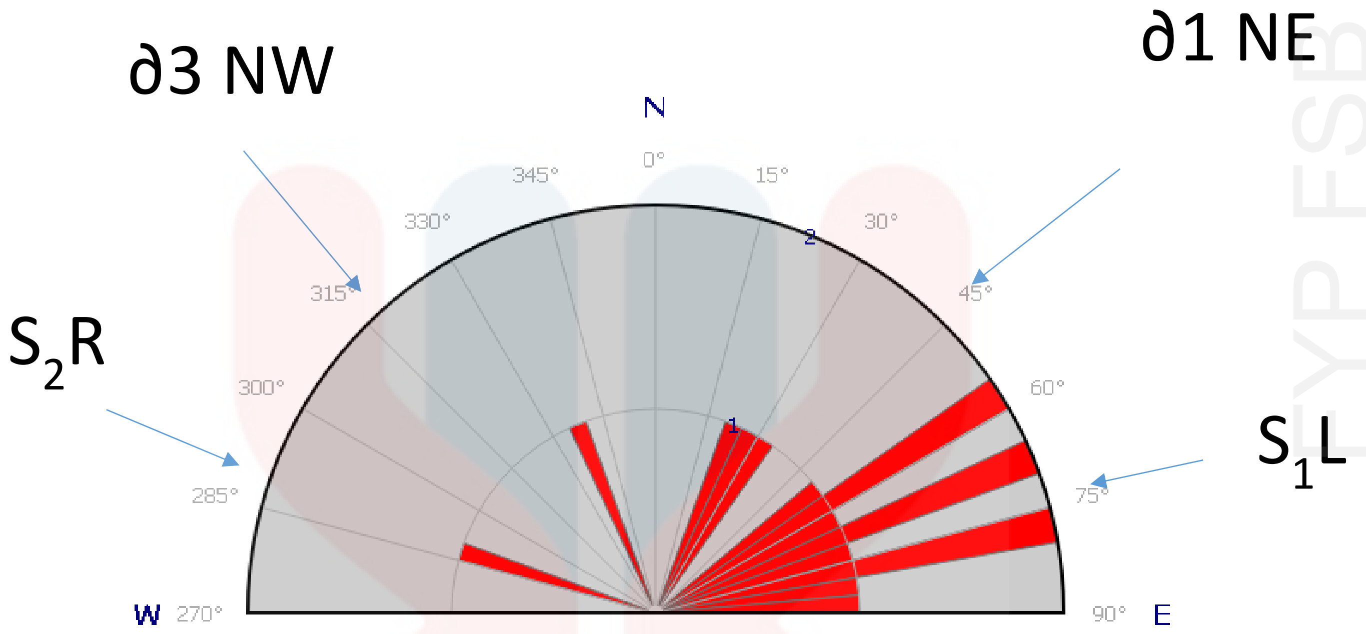
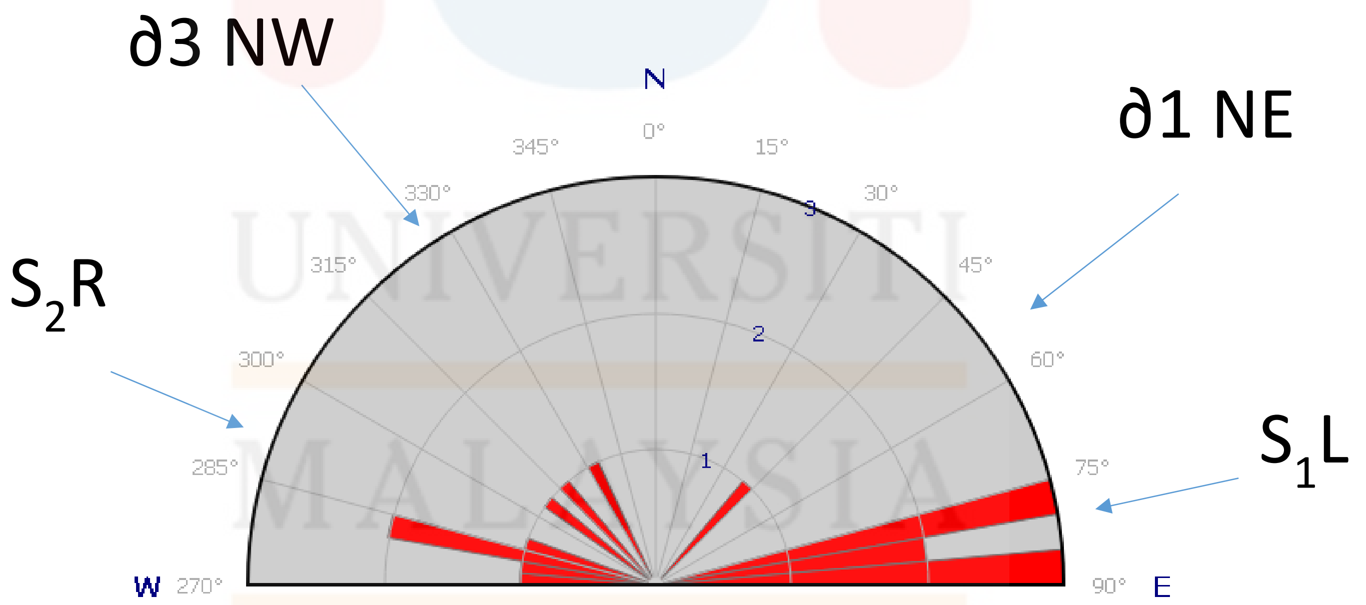


Figure 4.9 Negative Lineament



Rose diagram of positive lineament



Rose diagram of negative lineament

Figure 4.10 Rose diagram

4.5 Historical Geology

a) Taku schist Formation

Quartz mica schist found in study area. This type of rock is the highest percentage to be found in study area about 50 percent . Based on previous study, This rock undergoes weathering process with the presence of clay properties. The rock's colour is dark purple. This rock is a grain-like sheet that can be separated into layers.

b) Tanah Merah volcanic

Almost 25 percent of the research area covered was found andesite rocks. Based on previous study, Andesite rock on the study area is aphanitic which has small grain that hardly to be detected by using naked eyes. The structure of the andesite is phorphyritic because the matrix constitutes some of the pnenocrysts in smaller ones.

c) Temangan Ignimbrite

According to previous study, the ignimbrite stones found in different locations in the study area are pinkish to dark brown in colour (Aw, 1967). These rocks are volcanic rocks that have a pyroclastic texture and are composed of some phenocrysts in the fine grain matrix. Quartz, Muscovite, alkali feldspar and lithic fragments are the minerals found in this rock. The texture of the rocks is between tuff and rhyolite lava. This is proof that this rock was laid out as a stream of tuff.

d) Alluvial

The youngest rock types found in the study area are alluvial deposits. The Quaternary Age is the age of this rock. The loose, unconsolidated soil or sediments caused by the erosion of the riverbank are characterised as alluvial deposits. Alluvial consists essentially of a range of materials, including sand, silt and clay. In the flat valley of the Kelantan River, stream channels and floodplain deposits were widespread.

CHAPTER 5

GEOLOGY AND LANDSLIDE SUSCEPTIBILITY MAPPING USING GEOGRAPHICAL INFORMATION SYSTEM (GIS) AT TEMANGAN, MACHANG KELANTAN

5.1 Landslide susceptibility assessment

As a consequence of the urgent demand for slope instability mapping, many attempts have been carried out. There are various methods that can be used, either direct or indirect methods, to classify the slope stability factors. Geomorphological mapping normally consists of direct methods. Meanwhile, the heuristic methods and statistical methods are used on the indirect approach (Shahabi & Hashim, 2015). In this study, ArcGIS software was used to prepare the landslide susceptibility map. The Analytical Hierarchy Process (AHP) method was used in this study. When the relationship between landslides and causal factors was analysed, the Landslide Susceptibility Index (LSI) was used as an appropriate instrument.

The weight assigned to each parameter must reflect its importance in the occurrence of landslides in the index-base method and together with the rating values for the individual classes, then the degree of hazard they represent should be denoted. Eventually, the susceptibility map was divided into three levels of hazard and the levels were low, moderate and high. The landslide category depends on its parameters. This map was created using ArcGis 10.3 by overlaying maps of all parameters. Then in the data analysis stage, the statistical approach was implemented. This method is necessary to identify the landslide potential area and the percentage area. This statistical analysis was used to determine the area and the percentage of each parameter, as well as the overall susceptibility to landslides.

5.2 Parameter factors that influencing landslide

Landsliding can be influenced by many environmental variables such as lithology, aspect, land use and slope. There are a large number of sets of instability variables used to analyse the risk of landslides in literature. In this study area, the following four types of parameters are considered to influence parameters of landslide occurrence.

5.2.1 Lithology

It is well recognised in lithology that geology greatly influences the occurrence of landslides. This is because lithological and structural variations often lead to distinct rock and soil strength and permeability. In the study region, it consist of alluvial consist mainly of sand, silt and clay. While, ignimbrite and andesite is igneous rock,followed by interbedded shale and mudstone is sedimentary rock.On the study area also consist of metamorphic rock, quartz-mica schist. The map consists of various types of rock presented in figure 5.1 in the study area.

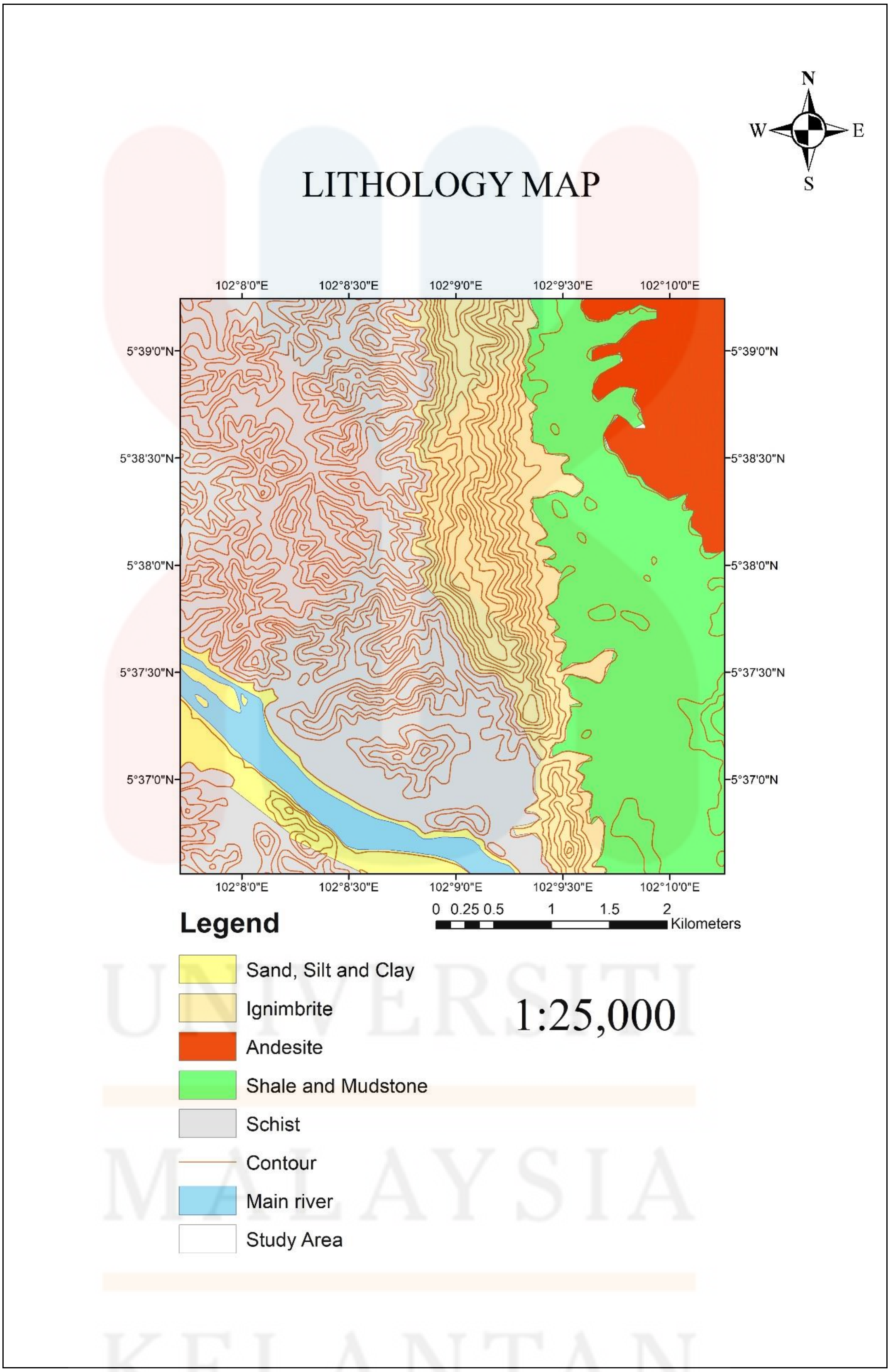


Figure 5.1: The lithology map

5.2.2 Aspect

An aspect that is also considered a conditioning factor for landslides. Some of the meteorological events such as the direction of the rainfall, amount of sunshine. However the hillside that received dense rainfall reaches saturation faster, this is also associated with the slope's infiltration capacity controlled by different parameters such as topographic slope, soil type, permeability, porosity, humidity, organic content, land cover and climate season.

The aspect map was developed to demonstrate the relationship between the occurrence of elements and landslides in the study area. Aspect values indicate the directions the physical slopes face.

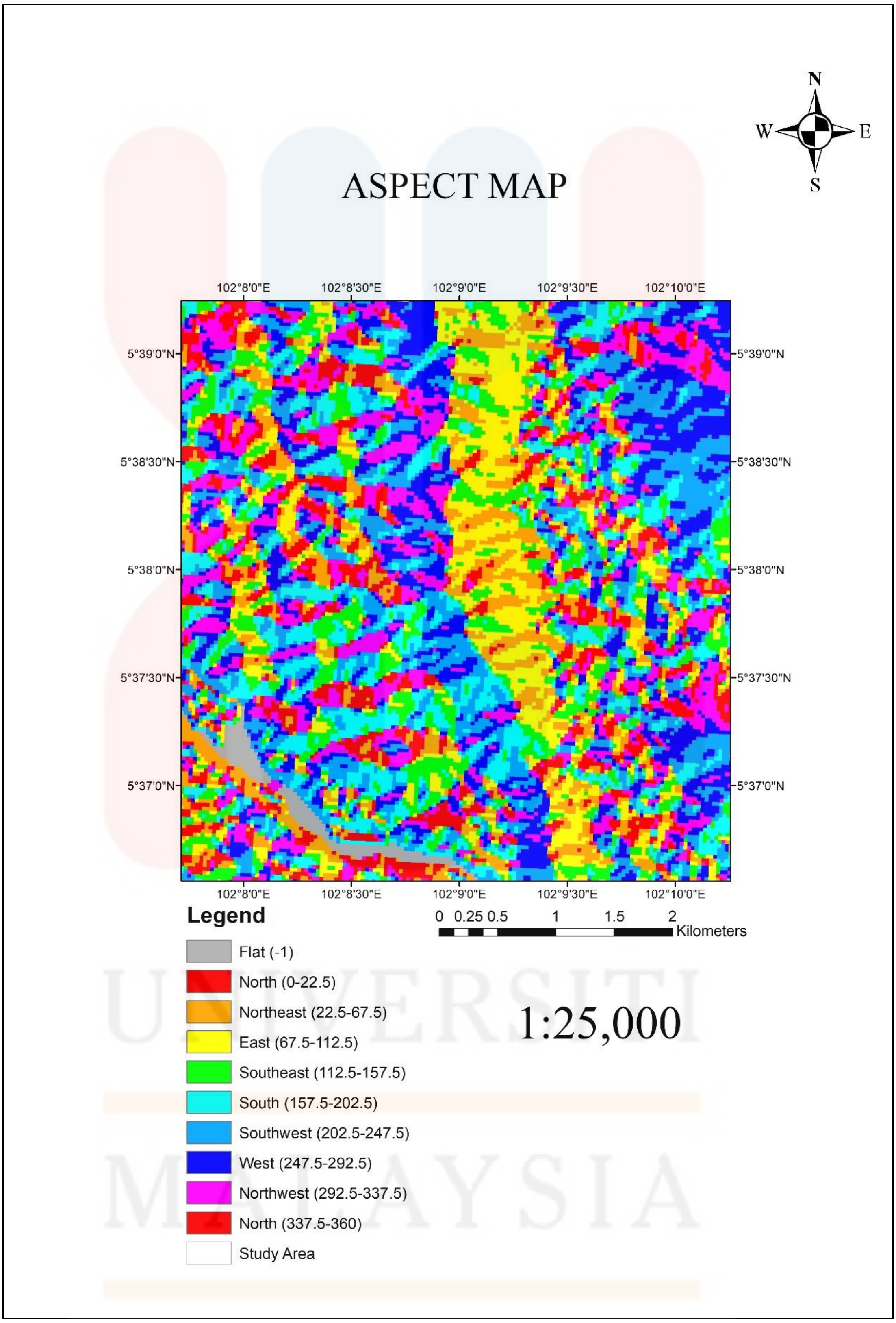


Figure 5.2: The aspect map

5.2.3 Land Use

Land use is the other indicator that causes landslides to occur. A number of hydrological and mechanical effects may clarify the effect of land use on slope stability. In this study, a map of land use was prepared from the information provided. The erosion and landslide of the soil depends on the land cover or land use. The area covered by thick forests, sparse forests, built-up areas, barren land, agricultural land and the body of water was found to be.

The lower class of the landslide has a higher percentage in thick forest areas compared to moderate, which are 51.79 percent and 48.21 percent respectively. Then it consists of an equal proportion of area with low and moderate landslide classes in the barren land area. Next, the low landslide class has a higher percentage range in agricultural land than the moderate class. The low landslide class noted that 81.63 percent and 18.37 percent were moderate. As a result, no landslides will occur in sparse forests and built-up areas.

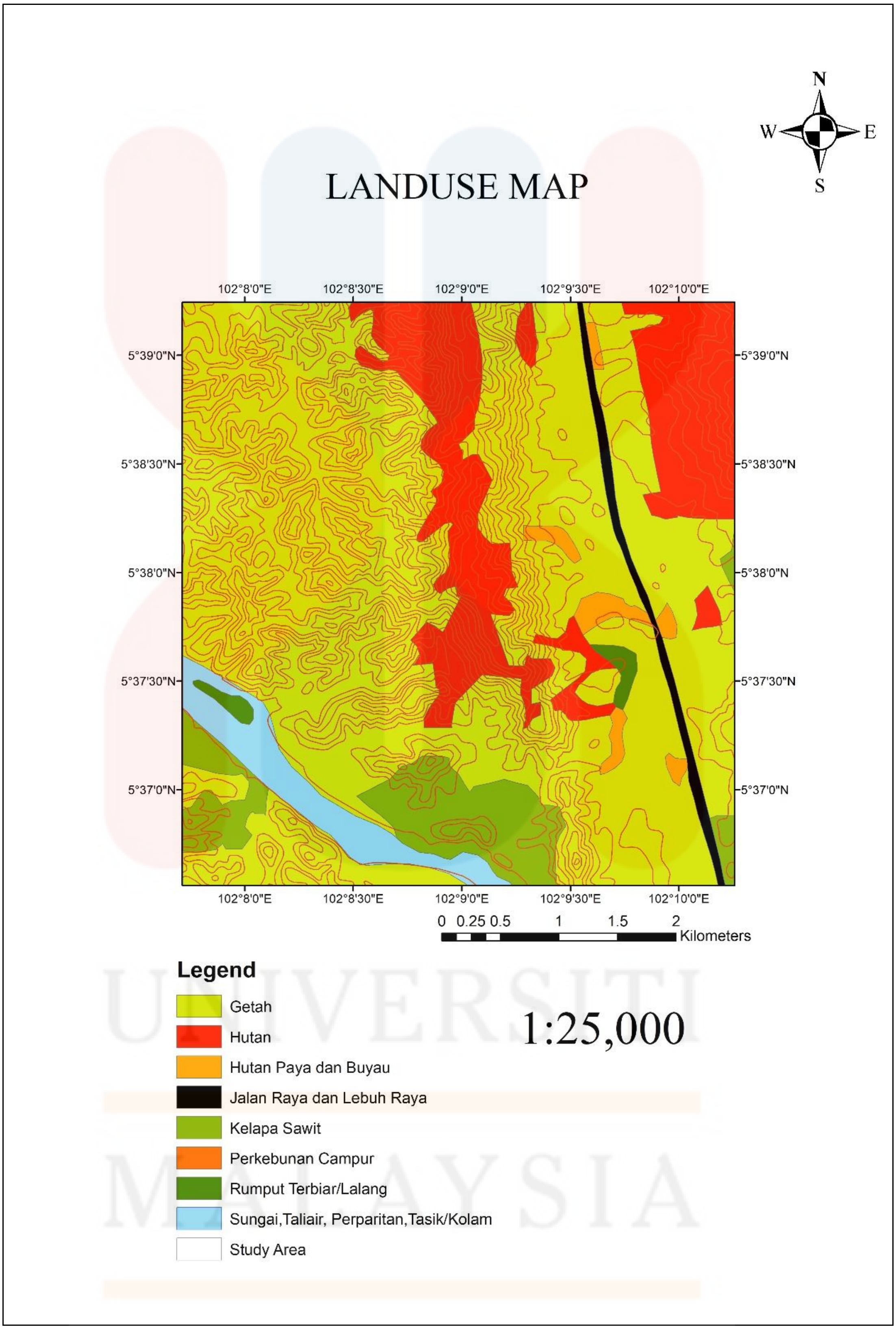


Figure 5.3 The landuse map

Table 5.1 Landuse

Landuse	Area (Km^2)
Rubber Tree	17.9
Forest	4
Swamp Forest	0.2
Roads and Highways	1.13
Palm Tree	0.5
Mixed Plantation	0.02
Idle Grass / Weed	0.002
River	1.03
Total	25 Km^2

5.2.4 Slope

The slope angle is the other slope stability analysis parameter. In landslide evaluation, slope angle is commonly used because land sliding is directly related to the angle of the slope. The slope map of the study area prepared. The steeper slope is usually highly susceptible to landslide. Based on the result,

Table 5.2: Slope

Slope		
Class	Area (Km^2)	Percentage (%)
Flat	6.8	28
Gentle	6	25
Moderate	4.8	19
Moderate	4	14
Steep	2.7	10
Very steep	0.7	4
Total	25	100

Table 5.3: Class of slope angle

Slope angle	Class
<10°	Flat
10° – 20°	Gentle
20° – 30°	Moderate
30° – 40°	Moderate
40° - 50°	steep

>50°	Very steep

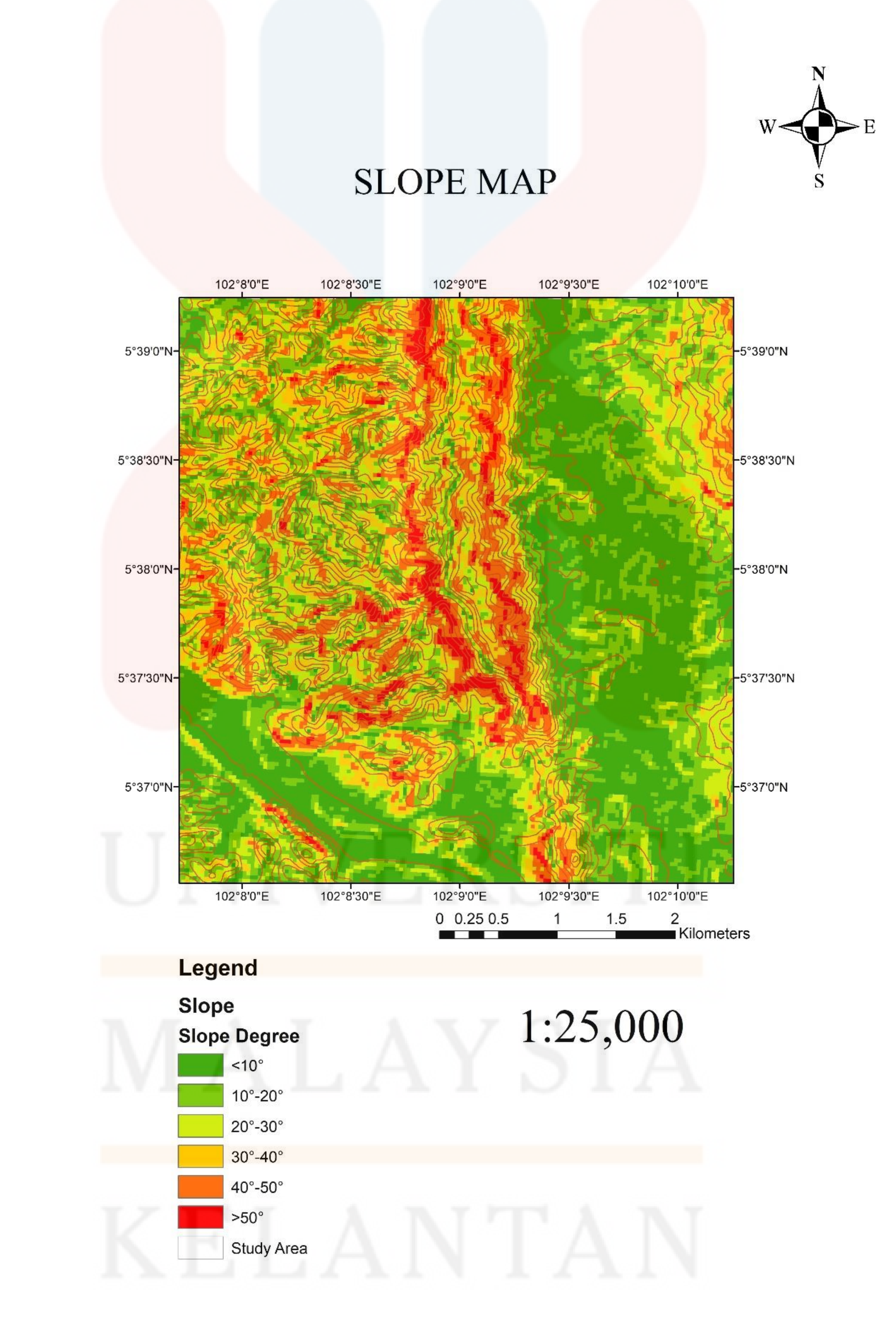


Figure 5.4 The slope map

5.2.5 Distance to road

The distance to road is one of the parameter in Analytical Hierarhcy Process (AHP). The opening of roads on the slopes causes both the topography and the slope base to decline. Changes in topography and load reduction trigger high stresses that eventually lead to cracking. Since the number of landslides occurring near the roads in the study area is high, this parameter should be taken into account. The value shows in the result is 0 m – 300 m near with the landslide zone or prone zone.

Table 5.4 : Distance to road

Distance to road (m)	Value
0 – 300	Near
300 – 600	
600 – 900	Moderate
900 – 1200	
1200 – 1500	Far
1500 – 1800	

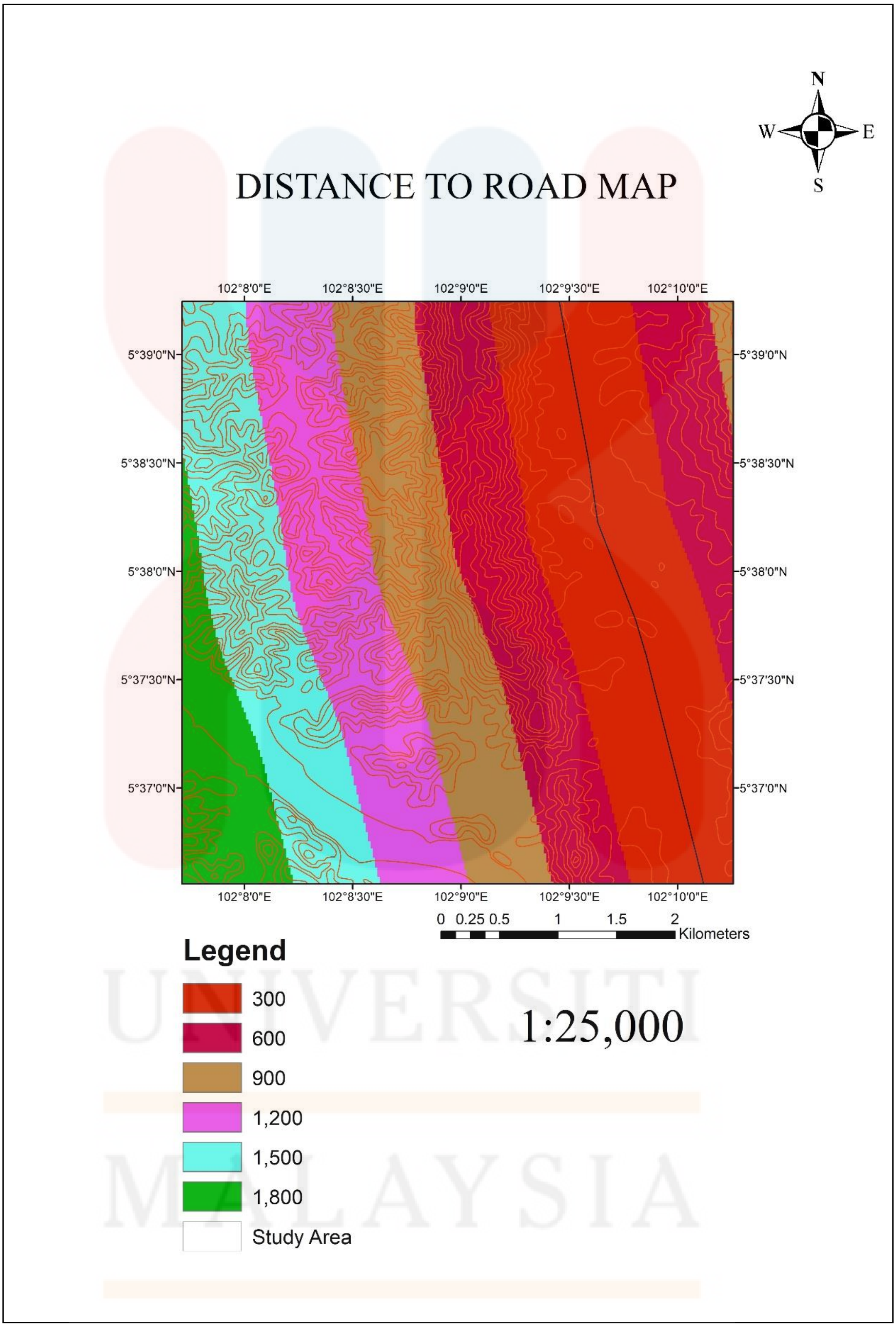


Figure 5.5 : The distance to road map

5.2.6 Distance to fault

If had major fault in the area, the area will consist minor fault (Pour & Hashim, 2017)) .Since the study area is located near with lebir fault, which acts as major fault, the fault parameter had to be included in the susceptibility analysis as well, because in the study area consist of minor fault that get from lineament analysis. When the relationship between landslide and fault lines is explored, it was seen that by 0-100 m, for the region close to fault. The ratio value is the same for a region that is 200-300 m away from a fault, while for distance values of more than 400 m, the frequency ratios will be even lower table 5.5.

Table 5.5 : The frequency ratio of factor Aykut, (2013)

Factor	Class (m)	Number of pixels landslide pixels	Percentage of lanslide pixels (%)	Frequency ratio
Distance to fault	0-100	3431	24.89	1.44
	100-200	4200	21.54	1.44
	200-300	3398	15.57	1.35
	300-400	2256	10.34	1.20

Table 5.6 : Distance to fault

Distance to fault (m)	Value
0 – 500	Near
500-1000	
1000-1200	Moderate

1200-1500	
1500-2000	Far
2000-3000	

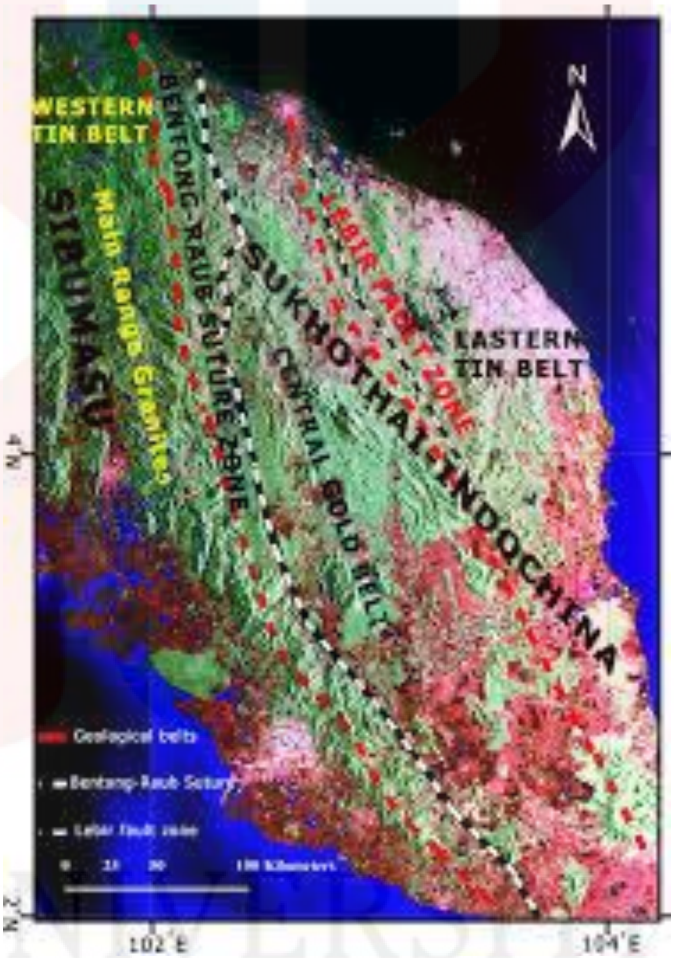


Figure 5.7 : RGB colour combination (HH, HV and HH+HV polarization channels) Of merged PALSAR-2 Scan SAR scenes covering Peninsular Malaysia(Pour & Hashim, 2016)

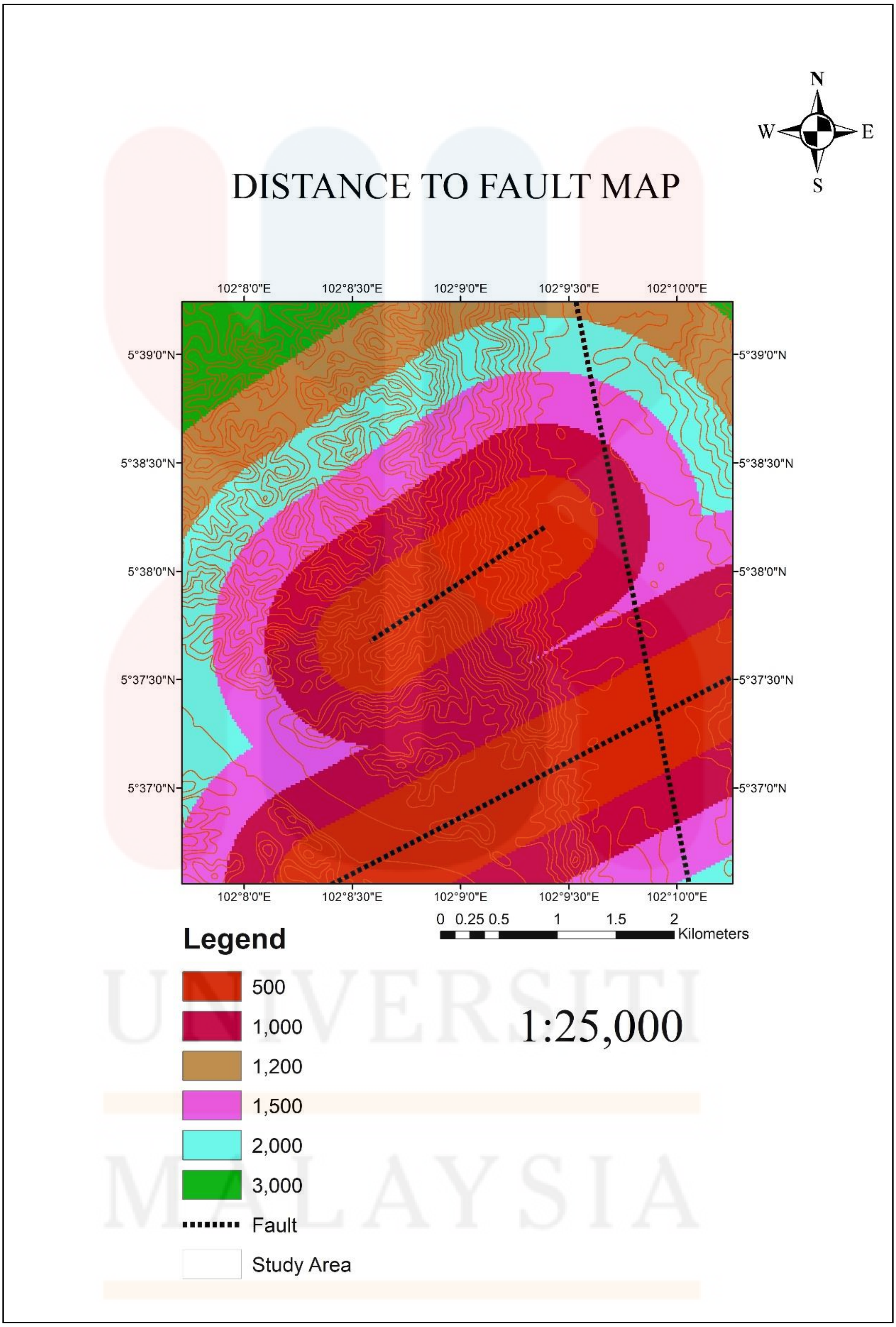


Figure 5.6 : The distance to fault map

5.2.7 Distance to stream

Another important factor in terms of stability is the slope's closeness to drainage structures. Drainage network rivers have adverse effects on the susceptibility of landslides as they abrade the slope base and saturate the underwater portion of the material forming the slope (Pradhan & Lee, 2010). From the table shows the result of distance to stream.

Table 5.7 Distance to stream

Distance to stream (m)	Value
0 – 200	Near
200 – 300	
300 – 400	Moderate
400 – 500	
500 – 600	Far
600 – 700	

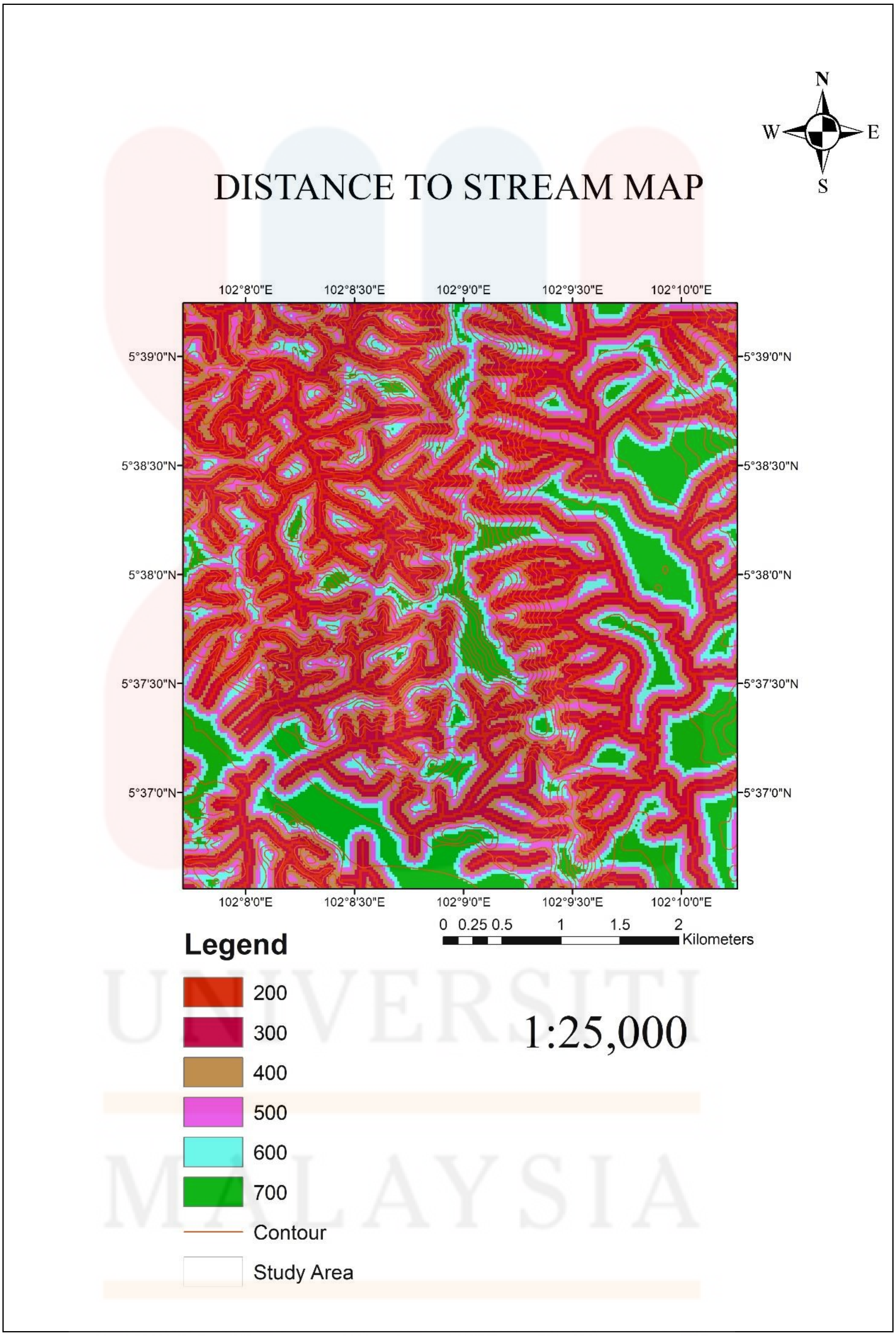


Figure 5.8 The distance to stream map

5.3 Landslide Susceptibility Map

The overall estimation of landslide susceptibility for an area results from the combination of susceptible levels of the individual factors. Figure 5.8 shows a Landslide susceptibility map with a scale of 1:25000. Five classes consist of the landslide susceptibility map: very low, low ,moderate, high and very high. The higher the LSI, the more prone the region is to landsliding. It can be observed that most landslides occur in the low susceptibility region, which is 27.2%, based on the outcome.With 19.2% of the area with a medium level of instability factors, the second classification performs better.

Based on the landslide susceptibility map, the high and very high class of landslide is only 16% and 14% , where it cannot been detected due to smale scale.

From the AHP table of seven factors, the most important factor in producing the Landslide Susceptibility Map is the slope, which giving the highest weightage, 0.34. Meanwhile, the less important factor in producing Landslide Susceptibility Map is distance to stream, where it give only 0.03 weightage.

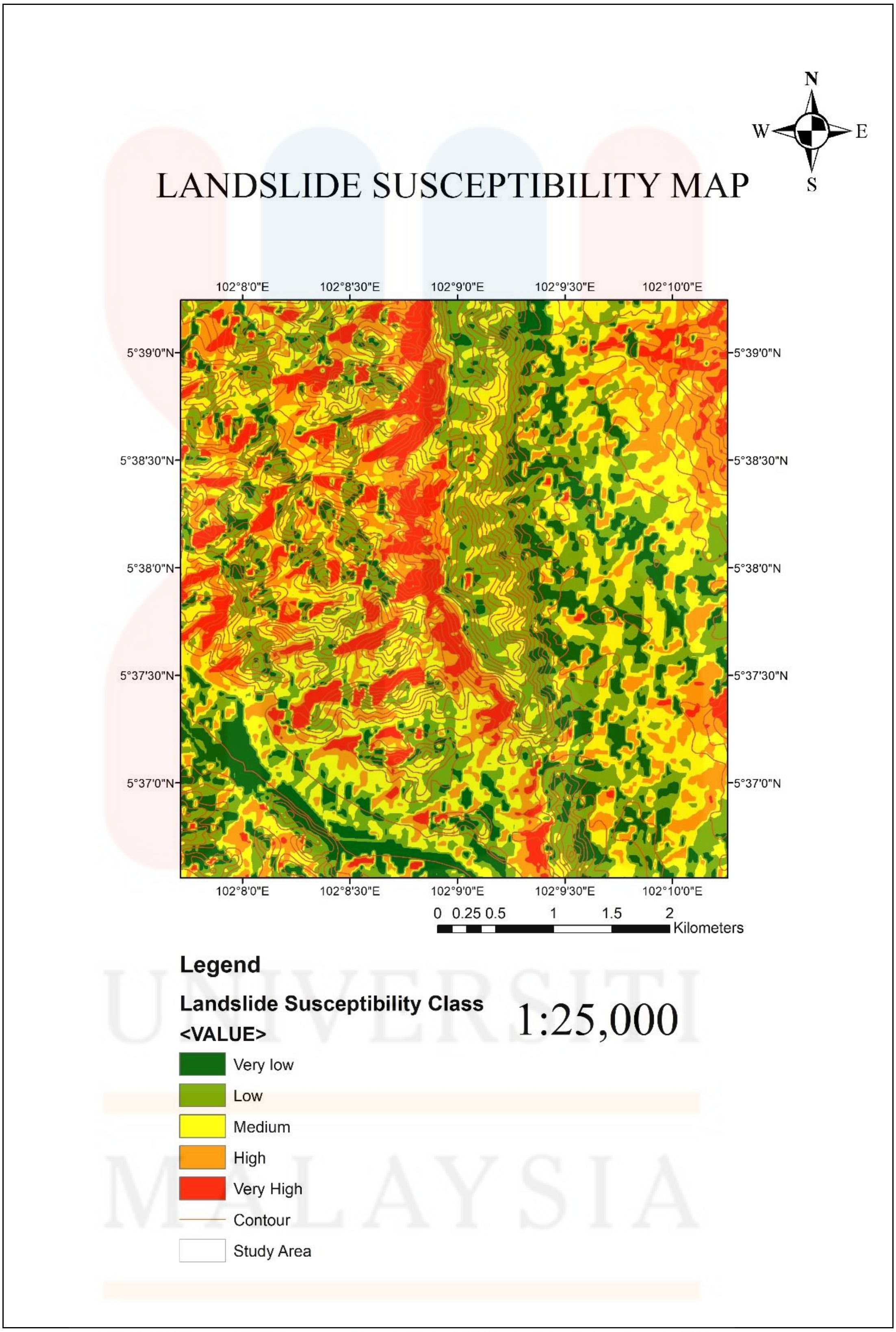


Figure 5.9 : The landslide susceptibility map

Table 5.8 : AHP table for seven factors

Factor	Slope	Lithology	Distance to fault	Distance to road	Landuse	Aspect	Distance to stream	Final weight
Slope	1	2	3	4	6	7	6	0.34
Lithology	1	1/2	3	5	4	6	5	0.26
Distance to fault	1/3	1/3	1	3	4	5	6	0.17
Distance to road	1/4	1/5	1/3	1	2	3	3	0.08
Landuse	1/6	1/4	1/4	1/2	1	5	4	0.08
Aspect	1/7	1/6	1/5	1/3	1/5	1	2	0.04
Distance to stream	1/6	1/5	1/6	1/3	1/4	1/2	1	0.03

Table 5.9 : Normalization of the comparison matrix and priority weighting.

	A	B	C	D	E	F	G
A	2.94	5.88	8.82	11.7	17.6	20.6	17.6
B	1.92	3.85	11.5	19.2	15.4	23.1	19.2
C	1.96	1.96	5.88	17.6	23.5	29.4	35.3
D	3.13	2.5	4.17	12.5	25	37.5	37.5
E	2.08	3.13	3.13	6.3	12.5	62.5	50
F	3.57	4.17	5	8.33	5	25	50
G	5.56	6.67	5.56	11.1	8.33	16.7	33.3

Information
Slope : A Lithology:B Distance to fault: C Distance to road: D Landuse: E Aspect: F Distance to stream: G

Table 5.10 : Eigen vector normalization

Information	Total	Eigen vector normalization
A	85.14	12.163
B	94.17	13.453
C	115.6	16.514
D	122.3	17.471
E	139.64	19.949
F	101.07	14.439
G	87.22	12.46

Calculating the consistency ratio:

Maximum eigenvalues (λ max)

λ= (0.34x12.163) + (0.26x13.453) + (0.17x16.514) + (0.08x17.471) + (0.08x19.949) + (0.04x14.439) + (0.03x12.46) = 14.39

Calculate the consistency index (CI)

CI = (λ maks – n)/ n-1

=0.10416

Consistency Ratio = CI / RI

The RI value for n-3 is 1.32

CR = 0.10416/1.32

=0.079

Since CR <0.100, the weighting preference is not consistent. So, the normalized eigen vectors (F) for each criterion are true, . This F value is then the weight of each criterion for calculating the Landslide Susceptibility Index (LSI).

$$LSI = \sum_{1} W1 \times F1$$

LSI = (12.163 x Slope) + (13.453 x Lithology) + (16.514 x distance to fault) + (17.471 x Distance to road) + (19.949 x Landuse) + (14.439 x Aspect) + (12.46 x Distance to stream)

Table 5.11 : Landslide Susceptibility classes and percentage

Landslide Susceptibility		
Class	Area (Km^2)	Percentage(%)
Very Low	6.8	27.2
Low	5.9	23.6
Moderate	4.8	19.2
High	3.5	14
Very High	4	16
Total	25	100

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 CONCLUSION

By using Geographical Information System (GIS) that carried out on this study area, it can be inferred that this region consist of three types of rock that are metamorphic rock, igneous rock and sedimentary rock. On the other hand, the metamorphic rock is represented by schist. While, ignimbrite and andesite representing igneous rock. The appearance of shale and mudstone is evidence of sedimentary rock. It is possible to find different structural characteristics, which are joint, fault and folding. Generally,the study area consist of low hills type of landform.

From the result of Landslide Susceptibility Map, it can conclude that the study area consist of low susceptibility area, which covered 27.2 % which is 6.8 km^2 . Only 16% is very high which is only covered 4 km^2. This showed that the study area had low chances to landslide.

6.2 SUGGESTION

The purpose of this research is to introduce the AHP method and to offer a benefit to urban planners' to avoid transport problems. This thesis, consist two main part . The first part consists of geological mapping and the second part consist of landslide susceptibility application.

This study can be improved by doing fieldwork and laboratory investigation in the future. By doing these it will increase the accuracy of the data and the results. In addition, it will also decrease the data collection.

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