GEOLOGY AND LANDSLIDE SUSCEPTIBILITY MAPPING OF KAMPUNG LONG USING GEOGRAPHIC INFORMATION SYSTEM (GIS) IN JELI, KELANTAN

by

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DECLARATION

I declare that, this thesis entitled "General Geology and Landslide Susceptibility Mapping of Kampung Long, Jeli, Kelantan" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and not concurrently submitted in candidature of any other degree.

Signature :

Name :

Date :

Acknowledgement

Thanks to my parents for giving me financial and moral support for accomplishing this final year project report and expressing my highest gratitude to both of my parents and love for supporting me throughout this thesis accomplishment. I would like to express my gratitude to my supervisor Sir IR Patrick and Sir Arham Muchtar Bahar for their supervision in guiding me to accomplish this thesis. I also would like to thank my friends for their kindness for sharing their knowledge to complete my project. Never forget to all my friends who involved directly or indirectly in this thesis accomplishment, being companion for fieldwork and being able to encourage me to finish the task required by university.

Abstract

The study is about the general geology and landslide susceptibility mapping by using the Geographic Information System of Kampung Kuala Long. The coordinate of study area is located at (5° 43’ 24.42” –5° 40’ 46.05”) N and (101° 44’ 54.09” –101° 47'37.26”) E. The purpose of the study is to update the geological map of study area and determine the landslide prone area within the study area. Geological map is produced by geological mapping, fieldwork observation and collecting the rock sample. The rock sample is collected then cut for thin section for petrography analysis. The potential of landslide susceptibility is detected by the data collected from certain parameter such as land cover/use map, lithology map, slope morphometry and rain distribution data in order to produce a geohazard map using Geographical Information System (GIS). The data collected and map produced is important to contribute for the understanding of study area and may assist for developer in future development.

Abstrak

Kajian ini mengenai geologi am dan pengetahuan tentang kecenderungan tanah runtuh dengan menggunakan Geographic Information System (GIS). Lokasi kawasan kajian terletak di koordinate (5° 43’ 24.42” –5° 40’ 46.05”) N and (101° 44’ 54.09” –101° 47' 37.26”) E.. Tujuan kajian ini dijalankan adalah untuk menghasilkan sebuah peta geologi kawasan kajian dan untuk mengetahui potensi geobencana batu kapur dalam kawasasn kajian. Peta geologi ini dihasilkan menerusi pemetaan geologi, pemerhatian kerja lapangan dan pengumpulan sampel batuan di dalam kawasan kajian. Pengumpulan smapel batuan digunakan untuk proses keratan nipis untuk analisis petrografi

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CHAPTER 1

INTRODUCTION

Background of Study

1.1 Introduction

Landslide is a natural geohazard that occurs due to natural and also man-made activities. Landslides are one of the most dominant natural disasters which occurs throughout the world and the landslide hazard assessment has become a major concern for the hill station or mountain area development. Due to the increasing human populations the urbanization activities increases tremendously and mountainous and coastal areas are developed. This increasing development near the faults, hilly areas and flood plains indicates the increasing number of peoples at risk from natural hazards.

Landslides have caused serious damages to the victims and huge economic losses in hilly areas in the world. It is approximately stated that lanslides kills almost 600 people per annum as a consequence of slope failure. 90% of the recorded deaths are from the pacific ring of fire where plate tectonics are active (Aleotti P, 1999)

1.1.1 Geology

The Jeli highway runs amidst a different type of rock types and lithologic units. Based on the Geological Map of Peninsular Malaysia (Santokh Singh, 1985), Jones (1970) and detailed engineering geologic mapping by Tajul Anuar Jamaluddin (1991) the western segment of the study area is under-lain by a shale-sand-stone sequence intercalated with minor tuffs and cherts belonging to the Baling Formation. These rocks have undergone both low grade regional and dynamic metamorphism to phyllites, slates, schists, metatuffs and quartzites. The entire sequence has been complexly folded and faulted. Phyllite beds are either intact or occur as friable layers exhibiting distinctive brown and red brown hues. The beds have different in thickness up to 0.5 metres and have a well-developed clevage oriented subparallel to bedding. Clay layers which are very thin can be found between phyllite beds. Some bedding surfaces are slickensided.

The Main Range Granite outcrops at the center of the highway. It consists predominantly of fine to medium grained biotite granite and medium to coarse-grained porphyritic granite. The Cretaceous hornblend biotite granite (Santokh et. al., 1984) is exposed near Batu Melintang on the eastern end. Sandwiched between the granites are exposures of lowgrade greenschist facies to amphibolite facies rocks such as quartz mica schist, mica schists, phyllites, slates, amphibole schists, quatzites and gneisses.

The rocks are heavily influenced by faulting which dates to the Palaeozoic and Mesozoic to the Tertiary. The most major fault directions are NW-SE and N-S, and NE-SW. The surface of many found faults are slickensided. A considerable amount of schistosity is developed in the metasedimentary and metamorphic rocks which may occurred due to regional metamorphism long time ago. Normally 4 to 5 well-defined sets of joints are found in the rocks at many local places in the area.

1.1.2 Landslides in Malaysian History

In Malaysia, there were two tragic landslides incidences that directly involved Orang Asli. These tragedies were the Pos Dipang tragedy at Kampar, Perak and the Sg. Riul tragedy at Cameron Highland, Pahang. Both incidences have left a black mark on the country‟s history after the much coveted Highland Tower tragedy.

1.1.3 Basic concepts

1.1.3.1 Types of landslides

There are few types of landslides according to their rate of slope movement. According to Cruden and Varnes (1992) there are 5 types of landslides a) falling b) toppling c) sliding d) spreading e) flowing. Each type of landslide triggered at certain modes. Toppling and falling occurs commonly occurs at rock slopes, whereas the other three occurs at soil slopes.

Table 1.1 Classification of landslides according to type of material and movement after Varnes

Type of movement		Type of material		
		Bedrock	Engineering soils	
			Predominantly coarse	Predominantly fine
Falls		Rock fall	Debris fall	Earth fall
Topples		Rock topple	Debris topple	Earth topple
Slides	Rotational	Rock slide	Debris slide	Earth slide
	Translational			
Lateral spreads		Rock spread	Debris spread	Earth spread
Flows		Rock flow (deep creep)	Debris spread	Earth spread
			(soil creep)	
Complex		Combination of two or more principal types of movement		

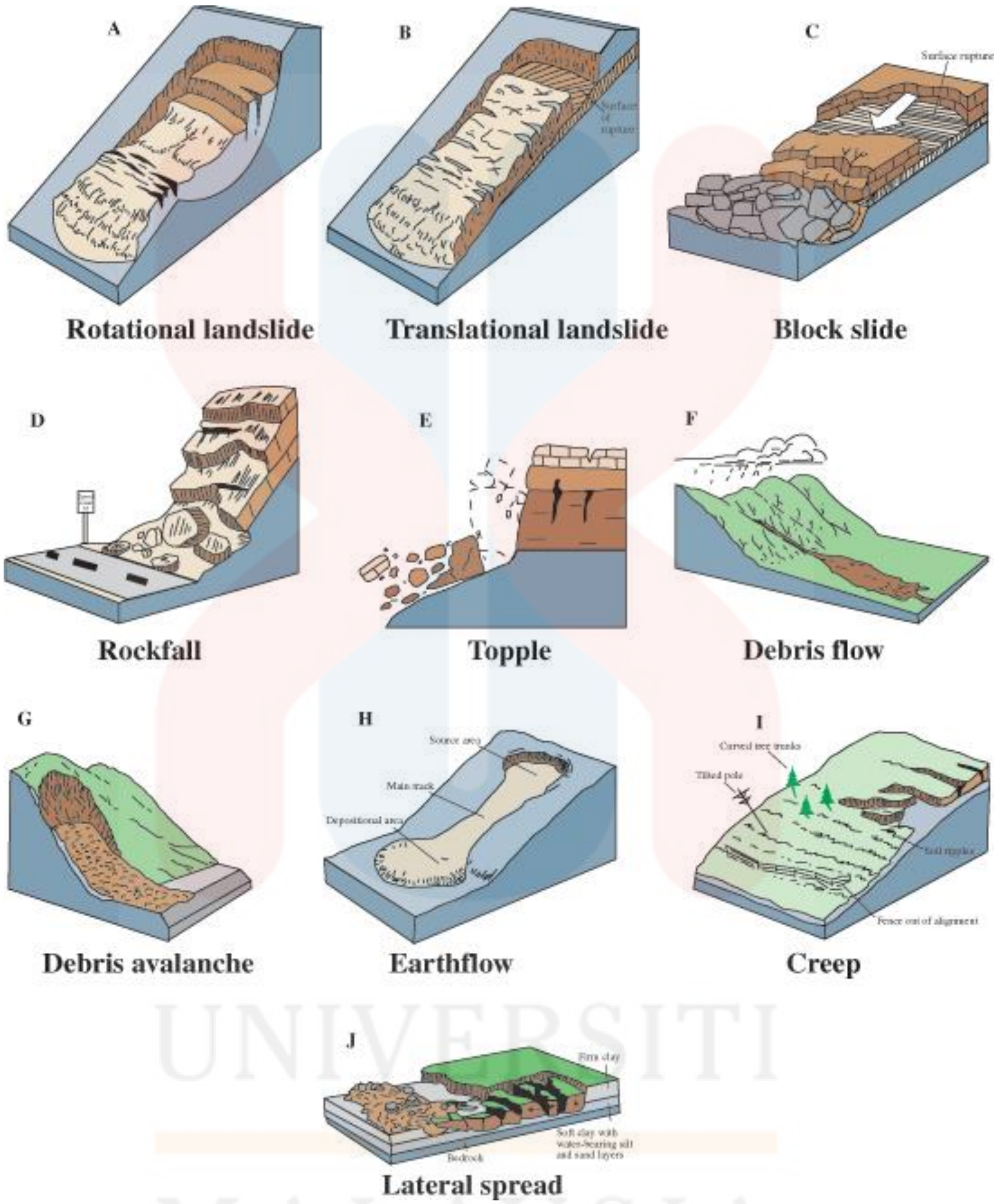


Figure 1.1 Types of landslides (Source: https://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html)

1.2 Aim

The aim of the study is to update the landslide susceptibility map of the Jeli area.

1.3 Problem Statement

The East-West (Phase 1) Highway Gerik–Jeli Highway which was built as a part of Security and Development Program of Malaysian Government in 1970 was opened to public officially in 1 July 1982. This highway is built in mountainous area and prone to landslides during heavy rain seasons. The study area Kampung Kuala Long falls amidst the highway which is prone to landslide during heavy rain season. This causes economic disruptions as transportation and urban activities are disturbed. The locals are also affected as their daily activities and lives are in threat in such areas.

The slope behavior in the study area is raveling and erosional failures usually develop preferentially in the slope areas, where the materials are relatively loose, friable, very weak, less durable which may be due to heavy weathering as the area is exposed to heavy rainfall and heat continuously.

Previously studies have been done by Farah Syuhada (2013) stated that there was lack of data as little research was done in that area. Most probably little research was done in the study area as the area covered by dense vegetation and image obtained from the satellite imagery are unclear as the landslides are covered by vegetation. The research gap found from the previous researcher is that that the previous researcher considered only one causative factor that is amount rainfall (annual precipitation) to produce the landslide susceptibility map of that area.

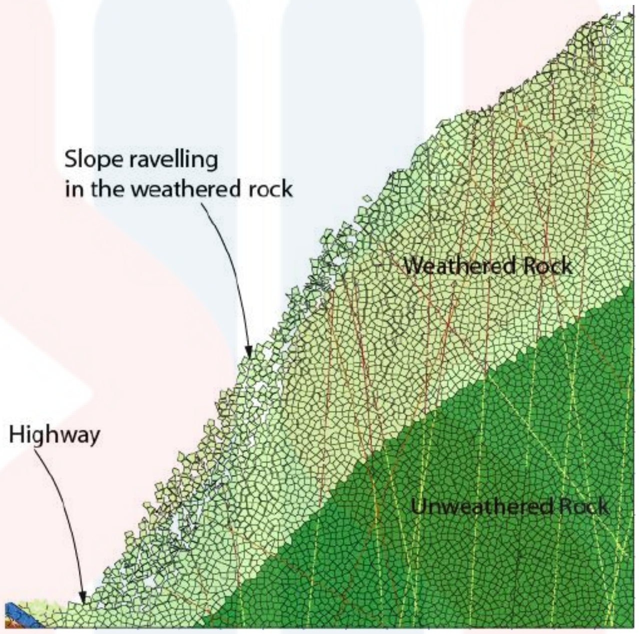


Figure 1.2 Slope raveling observed along the study area. (Derek Martin, 2011)

1.4 Research Significance

This study is important to locate the areas that have different potential of landslides. For the areas that indicate high risk to landslide, any activities related to the causes of it should be monitored. Deep physical study about the area should be done before proceeding with any development activities.

Besides that, this study also important in developing the database map on studied parameters such as soil types, rock types, land use, slope morphometry, elevation which will contribute to the making of landslide susceptibility map.

From the database the severity caused by the potential landslide can be predicted. Major landslide will cause adverse impact to the local people and environment. The database can be used for further reference on landslide in Jeli area.

1.5 Objectives

1. To study and investigate the landslides occurring in the study area.
2. To produce potential landslide susceptibility map using Geographical Information System (GIS) Analysis

1.6 Scope of Study

In the proposed study I will only investigate the places which are prone to landslide and update the landslide susceptibility map of the study area. Geological mapping will be conducted in the Jeli area. This activity was conducted to study the interrelationship between lithology and general geology of the study area. The study area covers an area of 5km by 5km related to their essential mapping. This study area conducted in order to obtain information about the general geology in the study area. The basic geomorphology, geomorphic process and its structure are part of the geological mapping.

Besides, the references and information about the geological data of the study are obtained from the Department of Minerals and Geosciences, Kelantan. Then the basic mapping in the study area is gained from primary data collections and fieldwork investigation.

1.7 Significant of Study

The significance of doing this study is producing a landslide susceptibility map of the study area. The map produced can be used for landslide prevention and mitigation when planning to develop or involve urbanization activities in the area. Before carrying out a development activity such as building or agriculture the authorities can use the landslide susceptibility map as a guidance.

The information gathered and the updated data from geological mapping of the area is used for future reference as an alternative of geological map. The map with scale of 1:33,000 may give more details. The geological map from previous map had been reviewed and it is only stated the previous landmark such as drainage pattern and land use. The previous unseen lithology is needed to be update in the study area for further review.

Using the Geographical Information System software can help to provide the detailed map by converting the 3D model of georeference to identify the geohazard potential of landslide. As the map will be published, it is very useful for the future references and guideline to the developers.

1.8 Study Area

Kampung Long is located at the latitude between 5º 36' 30" N and 5º 48' 30" N and longitude between 101º 46' 0" E and 101º 59' 30" E in Kelantan. Jeli is known as the gateway for people from West Coast of Peninsular Malaysia especially from northern part of Malaysia. Jeli is the main road for transportation connecting the northern part of Malaysia and the eastern part of Malaysia through Jeli-Dabong highway. Jeli has hilly and mountainous topography and hill cut is done for the transportation purpose. Jeli consist of 3 main districts which are Jeli (10.981km^2). Kuala Balah (621.59km^2) and Batu Melintang (152.52km^2). The study area is located in the town of Jeli as stated in the box of figure 1.1

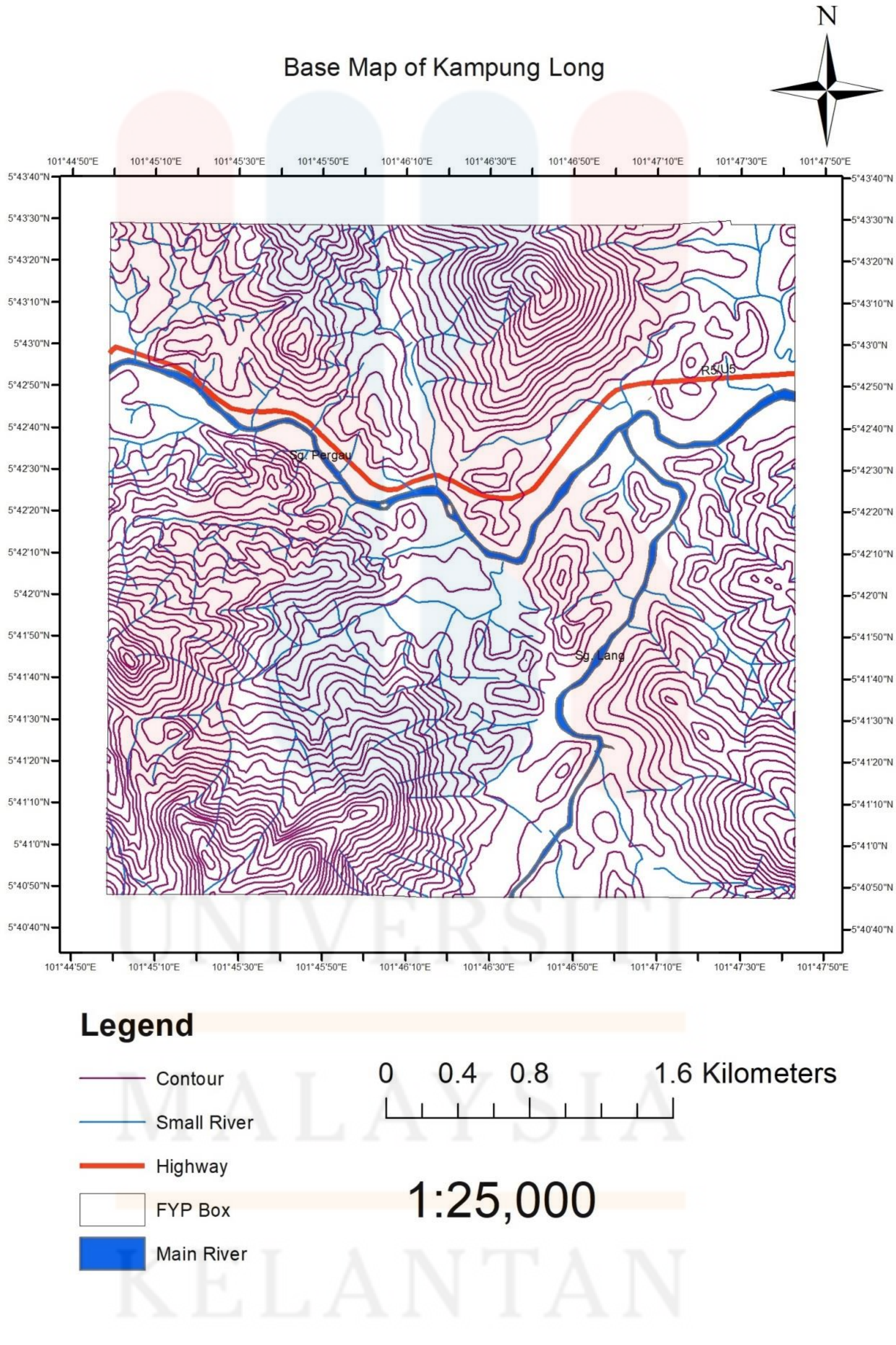


Figure 1.3: Base map of study area

CHAPTER 2

LITERATURE REVIEW

2.1 Geological Review

The formations in Kelantan are very similar to the rest of Peninsular in every aspects which was determined by Mr. J. B. Serivenor as follows: The sediments in the Kelantan area categorized into two groups that is the Raub Series (calcareous), and the Quartzite and Shale Series. The age of former is Carboniferous to Permian and the latter is Triassic. The relation cherts between these two series are still undecided. Although it was assumed that they were a different series forming between the Raubs and Quartzite and separated from the latter by an unconformity, it seems quite possible that they formed a passage from the calcareous to the sedimentary rocks. The Pahang volcanic series being found in both Raub and Quartzite and Shale series, ranges from Carboniferous to Triassic in age. The granite in the area is determined as Mesozoic and younger than the Quartzite and Shale series. (Savage, 1925)

The structural development of the late Palaeozoic metamorphic rocks in the study area has become weak since Cretaceous deformations due to presence of discontinuity planes. Because of long exposure, the climatic factors and weathering process have caused the crop out of these rocks and have experienced failure and movements. The aim of this study is to determine direction of slope failures of the rocks based on structural interpretation. The geology of study area is dominated by low-grade metamorphic rocks, consisting of interbedded phyllite, schist and quartzite.

2.2 Landslide

2.2.1 Landslide Definition

Varnes (1984) proposed that landslide hazard is "the probability of occurrence of potentially damaging landslide phenomenon within a given area and in a given period of time". K.G Avinash (2008) defined landslide as movement of mass rock, debris, or earth down a slope resulting geomorphic makeover of earth surface and this constant process leads to erosion and landscape evolution.

Landslides also can be defined as a massive mass of soil and rock debris that move downhill because of the action of gravity. The shear mass of material involved and the speed at which they occur made them potentially disastrous as a consequence because of the extensive damage they can cause to property and lives (Pierson et. Al., 1991; Van Wester, C.J, 2000)

According to British Geological Survey (2011), a landslide is a relatively rapid outward and downward movement of a mass of rock or soil on a slope due to the force of the gravity. A slope is under stress due to the force of gravity but will not move if its strength is greater than this stress. If the balance is altered so that the stress exceeds the strength, then movement will occur.

Meanwhile, spatial prediction of landslides is termed as landslide susceptibility, which is a function of landslide and landslide related internal factors. The aim is to identify places of landslides occurrence over a region on the basis of a set of internal causative factors. This is specifically known as landslide susceptibility zonation (LSZ).

According to D.P. Kanungo (2009), landslide susceptibility can formally defined as the division of land surface into near-homogenous zones and then ranking these according to the degrees of actual or potential hazard due to landslides.

2.2.2 Landslide problems in Malaysia

From 1973 onwards, a considerable number of landslides were reported in the local newspapers. Figure 2.1 shows reported landslides and fatalities from 1973 to 2007, indicates an increase in the number of fatalities with an increase in the number of landslides according to the National Slope Meter Plan in 2009.

During the last two decades landslides events have increased in Malaysia. From 1993-2004 there were 13 major landslides reported in Malaysia, involving both cut and natural slopes with a total loss of more than 100 lives.

Landslides have posed serious threats to settlement and structures that support transportation, natural resources management and tourism. More than 100 hill slopes had been identified by Malaysia Public Works Departments (PWD) as a risky for possible landslides.

2.2.3 Types of Landslides

Landslides are among the most costly natural damaging hazards in the mountainous terrains of tropical and subtropical environments, which cause loss of life and property and damage to the infrastructure.

Therefore, mountainous and steep hilly areas have been subjected to landslide susceptibility assessment to know scientifically the potential sites that are particularly susceptible to landslides in order to mitigate in advance any possible damage caused by them.

Malaysia is one of the country located in the tropical region where the annual rainfall is very high, and it can be reached as high as 4500mm yearly. This high level of rainfall together with the temperature around the year cause intense weathering of rocks producing thick residual soil profile in which landslide can occur during the rainy season.

The most common type of landslides in Malaysia is the shallow slide where the slide surface is usually less than 4m deep and occurs during or immediately after intense rainfall.

According to the two field studies conducted by Abdul Ghani *et al* (1989) and Tajul Annuar (1990) a total of 128 and 117 landslides respectively have been identified and described along E-W highway. The common types of landslides identified in the area were rock slumps, rock falls, wedge slopes, toppling, soil slides and soil slump.

2.2.4 Contribute factors of landslide

Landslides are the results of the effect of the conditioning factors which govern the stability conditions of the slope and the triggering factor. The triggering factor is nature of anthropogenic, intense and short term, irreversibly altering the slope causing landslide.

According to K.G Avinash (2008) landslides are also triggered by temporal conjunction of several factors such as quasi-static variables and the dynamic variable. The quasi-static variables which contribute to the landslide susceptibility, such as geology, lithology (rock soil), slope characteristics (gradient, slope aspect and elevation), geotechnical properties and long term drainage patterns.

Landslides can be also produced by tectonic factors such as earthquakes or fault but to do so, there should be a common climate factor such as precipitation on unstable slopes. Climate factors play an important role in making landslide. They can increase or decrease landslides on unstable slopes.

Besides that, most of the landslides emerge on manmade slopes and this is in essence the upshot of uncertainties related to human factors like insufficiency in design, failing in construction or wretched maintenance also declares that along with poor designing, incompetency, casualness, raw input data are also contributing in this frequent fact of landslides.

Over the last two decades, many governments and international research institutes in the world have invested considerable resources in assessing landslide hazards and constructing maps portraying their spatial distribution.

It is therefore necessary to understand the landslides process to assess the factors that contribute to instability, analyze the hazard and predict the future landslides to combat the damages caused due to landslide and evolve suitable mitigation measures.

Landslide susceptibility map provides such a document that portrays the likelihood or possibility of new landslides occurring in area and therefore helping to reduce future damages.

2.2.5 Landslide susceptibility zonation (LSZ)

Various project have focused on assessing risks from rapid, large volume landslides (van Western et al. 2006; Melchiorre et al 2006) and highlight the importance of multidisciplinary studies (eg.Geology and geomorphology, remote sensing, geodesy, fluid dynamics, computational analysis and social profiling) for landslide prediction.

For extensive areas mapped at a small scale (e.g., regional/country levels) it is possible to make general predictions over specific areas based on the number of landslides that have occurred in the past, within a specific land unit (Hong et al., 2007). However, this map inventory approach requires information about the previous landslides that are well-documented.

In areas currently free of landslides, process-based, stochastic, or heuristics models based on the assumptions that landslides are more likely to occur in place where a combination of condition that led to landslides in the past exist, appear more suitable (Kopackova and Sebesrta 2007).

This requires knowledge of causative factors, the ability to represents these on a map (or geographic information system (GIS) layer), and detailed knowledge of past mass movements (Piantanakulchai 2006). The handling of such large volume of information is best suited for an automated system.

The various steps and functions that experts perform to arrive at a solution for the problem of LSZ, can be accomplished through the different functional modules such as input, understanding, expert and output modules. Although a KBS for landslide hazard assessment exist (Ghosh an Suri 2005), a map understanding system for landslide assessment has yet to be presented. An integration of all these modules needs to be attempted, in order to achieve the objective of this study.

2.3 Geographic Information System (GIS)

GIS is a system in computers which is capable of storing, capturing, retrieving, managing, displaying and analyzing the types of various geographic and spatial data. This software system is designated to visualize the spatial data or analyze the geographic data. The features in GIS can be categorized into points, lines or raster image. For an example the data of city and data of roads can be stored as points or lines; the raster image stored as scanned map and it is obtained from the aerial photo. (Tarum Kumar Raghuvanshi, 2015)

GIS can analyze geographic data and spatial data. Geographic analysis tools aids in analyzing the geographic components present in the data. The image server supports the Google Earth map which is helpful to be used as base map in the GIS software. (Tarum Kumar Raghuvanshi, 2015)

The database is used to modify the addition and removal of records, filter the records, apply the table coding. Databases in GIS software can be aggregate and not aggregate. Topology layers like points or lines in editing tools are used in digitizing, merging, splitting the feature, add or erase features, clipping and masking the geographical data by region and redo the edits. The coordinate system also supports the import and export the map. (Tarum Kumar Raghuvanshi, 2015)

2.3.1 GIS in landslide hazard assessment

GIS have reached a amazing height in a short span of time due to its excellent spatial data processing capacity and aids in landslide hazard assessment. The GIS have three roles in landslide analysis namely data or analysis results expression, data handling and data analyses or modeling. The most famous feature of GIS is its ability to present data and analyze result in the form of a map. (Xie, 2013)

GIS is unique as it can capture, store and manage spatial referenced data like points, lines and polygons (vector data model) or as continuous fields (raster data model). The initial step to taken in every assessment is collecting all available data and information in study area. This is undoubtedly a very troublesome task in hazard assessment. Moreover hazard assessment should be continuous process which should be updated frequently as required. Researchers estimate that the cost of data collection and management uses 70%-80% of the total cost which includes reviewing and updating. (Leroi, 1996)

GIS consist of facilities to construct and import digital elevation models (DEMs) and triangulated irregular networks (TINs) using software specific functions. Such details are the foundation on which many models, including slope stability and surface runoff models are based. GIS provides a framework in which model spatially resident landslide phenomena. Distributed models can take advantage of implicit topology of geographic entities in the vector model or can consider the effects of surrounding cells in a raster-based model

Santacana and Corminas (2002) performed shallow landslide susceptibility analysis for data organized in vector GIS by multivariate statistical analysis. Data applicable for relative landslide density and for prediction performance curve were overtaken from GIS for chosen sample, number of observed slope failures, and their areas. The methodology used by Iwao (2002) used only GIS for evaluation and results, The methodology based on contours and their distances is a typical task whose analysis is possible to perform easily reliable in GIS. As a recent one Esaki *et al.* (2005) developed a GIS based statistical prediction model to identify and quantify the most influential geological and geomorphological variables and their relative contributions in terms of the statistical probabilities of sampling units. The prediction model has demonstrated the capability of GIS for covering large areas.

CHAPTER 3

METHODOLOGY

3.1 Materials And Methods

This chapter discuss on the process and methods on conducting the research. These research progresses were including preliminary study, literature review, mapping, sampling, data collection and identification of potential hazard within the study area, laboratory work, data interpretation and discussion and lastly thesis submission. The flow of research is shown in Figure 3.2 The field information is gathered, whereas the petrography analysis and structural analysis were conducted.

3.1.1 Materials

Instruments that were used for the research project can be categorized into 2 parts; fieldwork and software.

A) Fieldwork instruments

Fieldwork equipment's were geological hammer, Brunton compass, Geological Positioning System (GPS), hydrochloric acid (HCl), hand specimen plastic bag and hand lens.

B) Software instruments

Software works were done using ArcGIS version 10.2 It is used to digitize the map of study area and which is aided by the data of satellite imagery SPOT 5. The satellite imagery will provide the information and facilitated the process of field investigation especially monitoring the potential of slope failure, landslide, rock falls. The other used of software in research is rose diagram. Rose diagram is used to identify the internal forces from the movement of tectonic activity. The data needs for the software is structural features such as joints or fractures of the structure.

3.1.2 Methodology

Quantitative research method will be used to conduct the research. In general quantitative research is the systematic empirical investigation of observable phenomena via statistical, mathematical or computational techniques. The LHEF

A. Data Collection

There are two types of data collection involved which is primary data collection and secondary data collection. Primary data collection is the data gather based on this study while secondary data collection will be the data collected from other resources and also the data from previous studies.

i) Primary Data Collection

Site studies were done by taking the pictures of high potential area. The location prone to landslide will be recorded using Global Positioning System (GPS) to mark the coordinate and marking the route. During the site study the physical and geological characteristics like soil type and vegetation covers will be observed and recorded.

ii) Secondary Data Collection

Four parameters rock type, soil type, slope morphometry, land used and land cover were considered. The data were collected from previous researchers and from the department of survey and mapping.

B. Data Preparation

There were two main steps in data preparation which is thematic map preparation and weightage.

GIS Database was developed using the latest version of ArcGIS software. The landslide prone area in the researched study area and the factors of instability of slope was recorded and saved in different layers in the database.

3.4 Field Study

Research study is divided into 2 part which are geological mapping and the specification study, which specified in Geographical Information System (GIS) by using its software.

Geological mapping was done in study area to collect the new data and review the previous map for updates. Geological mapping was done by traversing throughout the study area. Fieldwork was conducted to identify the type of lithologies and the changes in drainage system in study area. The dip and strike data were collected for fracture analysis and joint analysis occured in the study area. The traverse routes throughout the study area are tracked by using the GPS.

After mapping was done, the information is gathered and the routes tracked by the GPS was transferred into the ArcGIS 10.2 software to allocate the potential of geohazard into the map.

3.5 Laboratory Investigation

Laboratory investigation is commonly a process of laboratory work where thin section is taken part in the laboratory. However, the geological map of study area was updated by using the software of ArcGIS.

3.5.1 Thin Section Preparation

Thin section is one of a process to obtain for petrography analysis. The rock samples were included in a vacuum in polyster resin. As the resin polymerised, it will harden the compact blocks and conserve the structure without alteration. Main steps of thin section preparation are including:

i. Preparing sample

The commercial resin is used to fix the sample. Firstly, the sample need to be dry with freeze drying.

ii. Cutting

A suitable size slab is used for mounting on the slide which is cut from a piece of rock or drill core with a diamond saw.

iii. Polishing

Section is placed in a holder and spin into a polishing machine using nylon cloth and diamond paste until a suitable polish is achieved under microscope observation.

iv. Final Cutting

Final cutting is done either the remaining of the slide is needed to be cut or extra polish.

3.5.2 Updating Geological Map

Geological map of study area was updated for several purposes such as development planning, environmental assessment or landuse. Information of geological map is important to ensure the study area can be a strategic development site in the future.

3.5.3 GIS Data Development

GIS data is important as it will give an accurate data. Several ways to interpret the spatial data into GIS. However, there are several factors that will lead to difference of projection. Global Positioning System (GPS) is needed to gather the accurate linear and point location data. GPS is a rapid and accurate method for data collection as it can record the traversing information in study area. Digitizing also one of a method to derived the database into an initial digital image. Image processing had a process which called as supervised classification which user can use a sampling pixel to identify the type of vegetation or landuse.

3.6 Analyses

Analysis and interpretation was conducted as the data and information is gathered from fieldwork. In this research, data analysis and interpretation including petrography analysis, structural analysis and GIS analysis. The raw data of strike and dip or rock samples are needed to proceed with structural analyses.

3.6.1 Petrography Analysis

Petrography analysis is an essential tool to evaluate or determine the minerals contain, rock's texture and characteristic inside the rocks. Petrographic analysis is an examination of microstructural of rock by optical microscope.

3.6.2 GIS Analysis

Geographic Information System (GIS) analysis is a process to create and export the updated information in study area. The GIS analysis can interpret the data in study area into a 2D or 3D model.

3.7 Report Writing and Thesis Submission

In this part, all the chapters in the thesis from chapter 1 until chapter 6 were written and submitted to the University to fulfill the requirement of the University.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

Study area is located in Kampung Long, Jeli where it is accessible by traversing and transportation by main road. Study area is mainly covered with palm tree plantation, rubber plantations. The residential area consist of people who is actively involved in agriculture (rubber plantation and palm tree plantation).Some residents were involved in collecting the food from the jungle and sells to in the main road where it is accessible to pass byers of Gerik highway. Other than that, the study area also covered by forest and there cleared land area which may intended for crops or housing plans. The landuse map is shown in Figure 4.1.

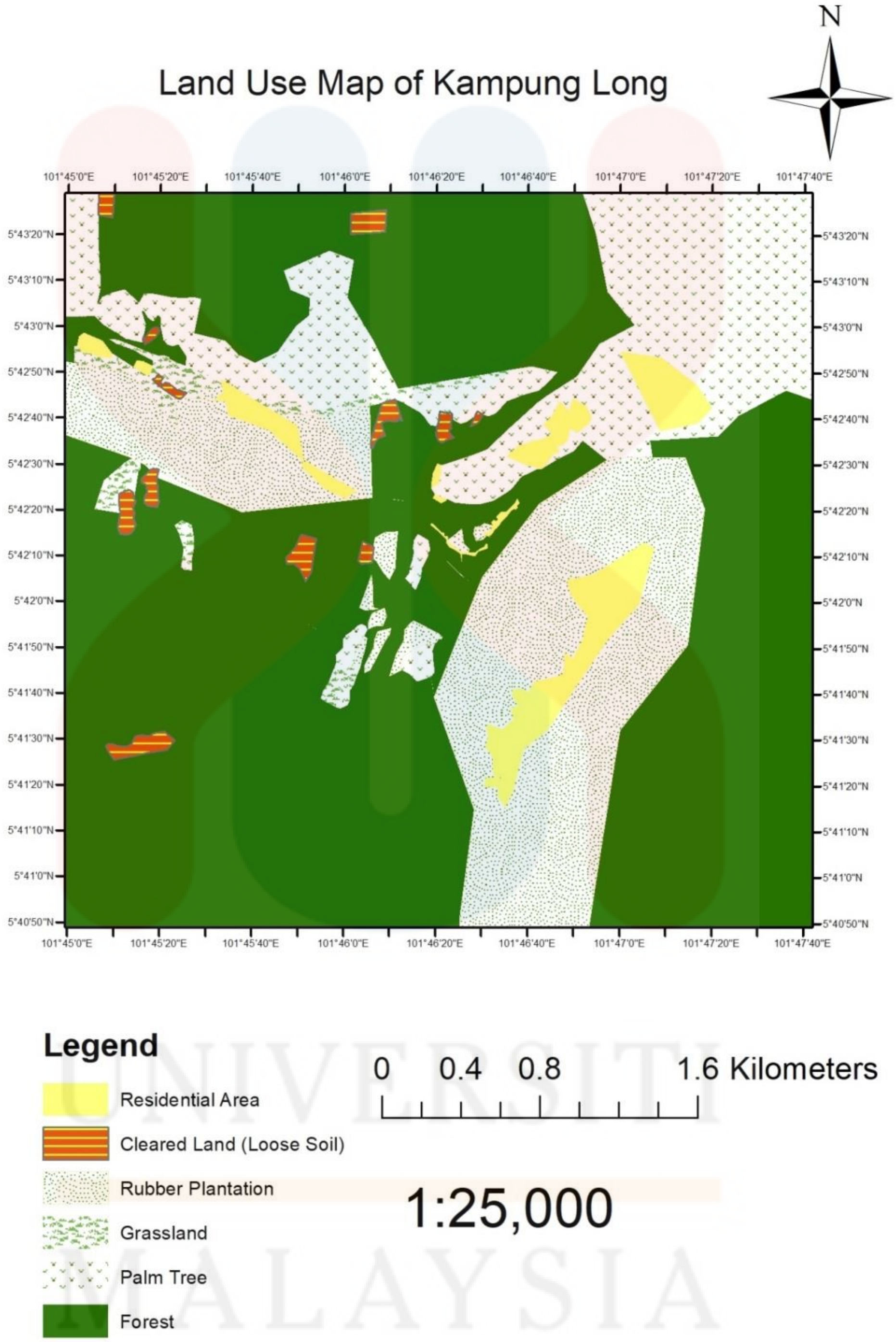


Figure 4.1: Landuse map of Kampung Long

(Source: ArcGIS Shapefile Data)

4.2 Geomorphology

Geomorphology is defined as the study of the Earth's physical land surface features, such as rivers, hills, plains, beaches, sand dunes and others. In geomorphology, it is investigated the landforms and processes. The interrelation between the understanding of origin and development of landforms which consists of three facets, the constitution, configuration and mass flow and the dynamic variable of geomorphic processes.

4.2.1 Denudation Process

Denudation processes had occurred in the study area, which include mechanical weathering, biological weathering and chemical weathering. Physical weathering that occurred in the outcrop, especially in granite outcrops near the rubber plantation; can be clearly seen.

Figure 4.2: Weathered granite outcrop

4.2.2 Drainage Pattern

Drainage pattern is a topographical feature where the runoff of stream or groundwater flow that can be classified as topographic barriers called watershed. Drainage pattern is controlled by the topography, slope, structural control, nature of rock and the geological history of the region. The drainage pattern generally consist of dendritic, parallel, trellis, rectangular, angular and contorted.

However, the drainage pattern in the study area is can be classified as dendritic pattern. The pattern of drainage is shown in Figure 4.3. This may indicate the river had branched in many direction and flow in with the direction of the valley. The watershed is indicated in the map.

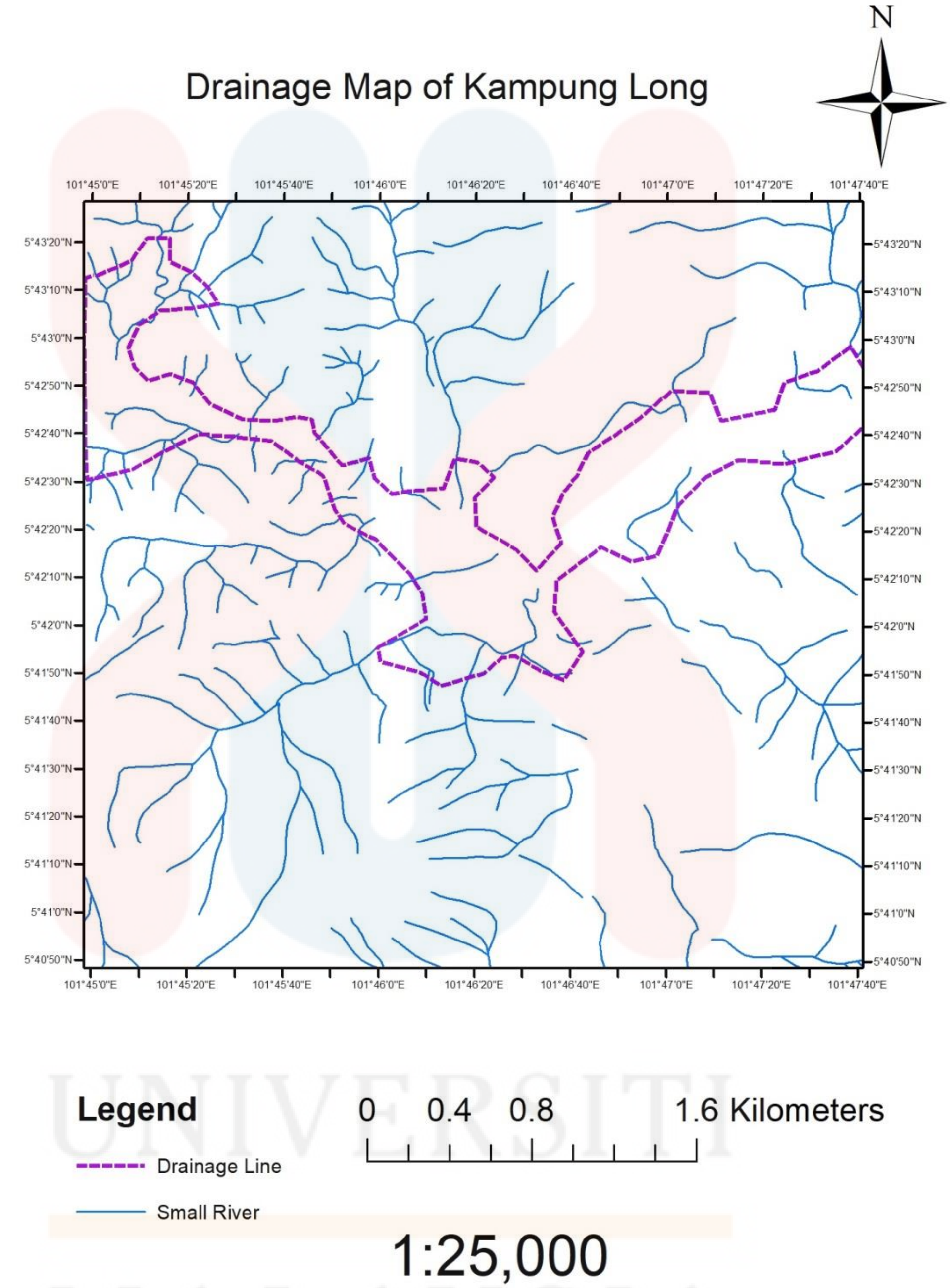


Figure 4.3: Drainage Pattern of Kampung Long

(Source: ArcGIS Shapefile Data)

4.3 Stratigraphy

Stratigraphy in the study area is mainly covered with granite and andesite. However, certain area had found little amount of hornfels.

4.3.1 Lithostratigraphy

Lithostratigraphy is describe the relationship of the strata with the stratigraphic position according to their age in stratigraphic column. Stratigraphic column is representing the geology and the stratigraphy to describe the vertical location of rock. In Kampung Long, granite and andesite type of rocks compose the area. Lithostratigraphy is describe the relationship of the strata with the stratigraphic position according to their age in stratigraphic column. Stratigraphic column is representing the geology and the stratigraphy to describe the vertical location of rock.

Table 4.1 The lithostratigraphy column of study area

Period	Lithology	Rock Type	Description
Recent		Alluvium	Mixture of deposit of clay, silt, and sand (fertile land area)
Triassic & Permo-Triassic		Andesite	Intermediate volcanic rock, dark, fine-grained
		Granite	Kemahang Granite Felsic intrusive igneous rock that is granular and phaneritic in texture

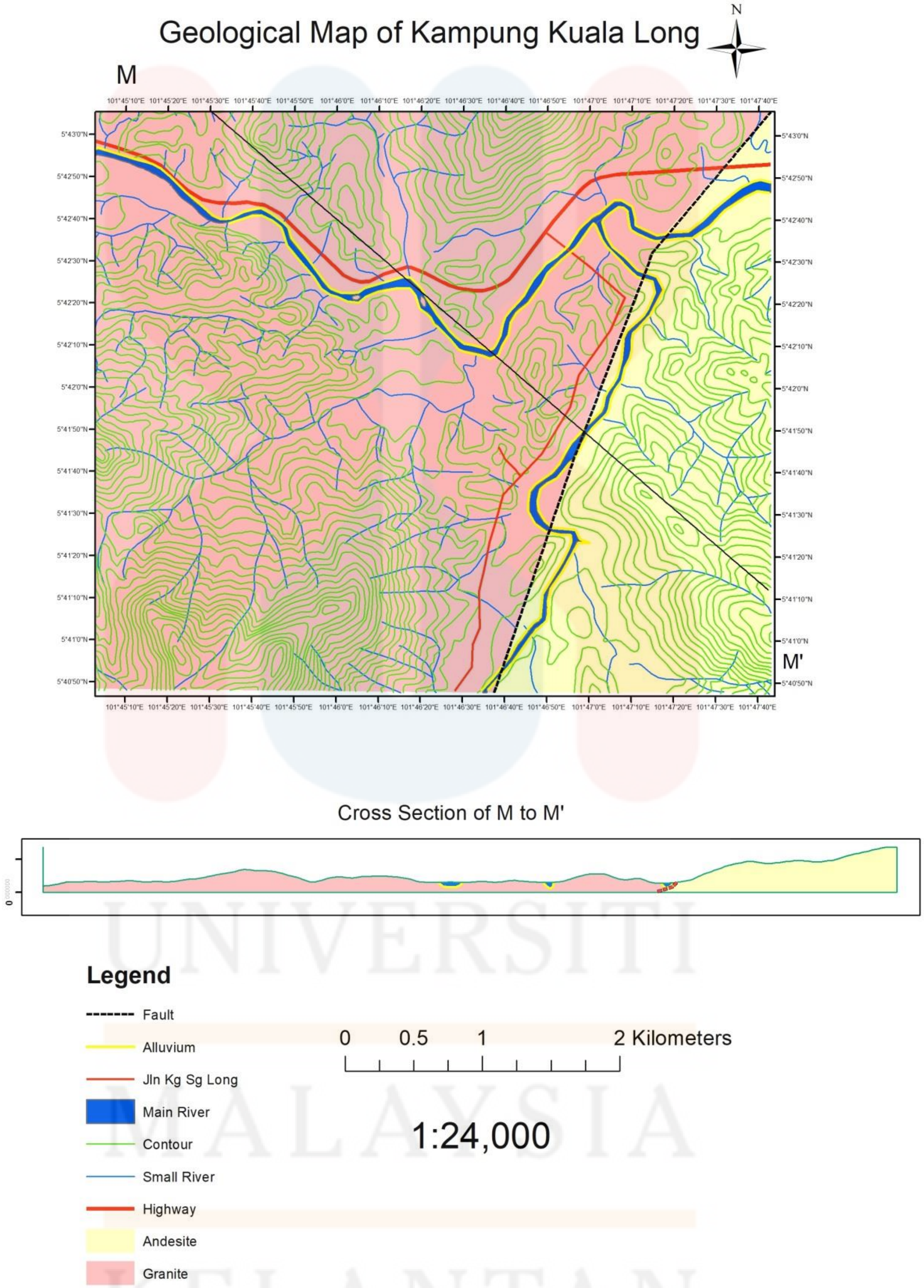


Figure 4.4: Cross section of Kampung Long

4.3.2 Petrography

a) Locality 1

The sample taken is taken at coordinate of N 05° 41’ 53.64” E 101° 46’ 47.58”, where it is located in rubber plantation area.

Based on the hand specimen, granite have a greyish colour and the textures are phaneritic and holocystaline. The minerals can be determined by the naked eyes for example quartz, alkali feldspar, plagioclase and biotite. Granite also have medium grain size.

Under the microscope, the textures of the rock is phaneritic. Minerals are quartz, feldspar and mica. The rock also have secondary mineral which is sericite. Plagioclase have a shape of subhedral and the colour under cross polorized is grey. Quartz is anhedral in shape and fill up most of the space in the rock.

Figure 4.5: Granite outcrop

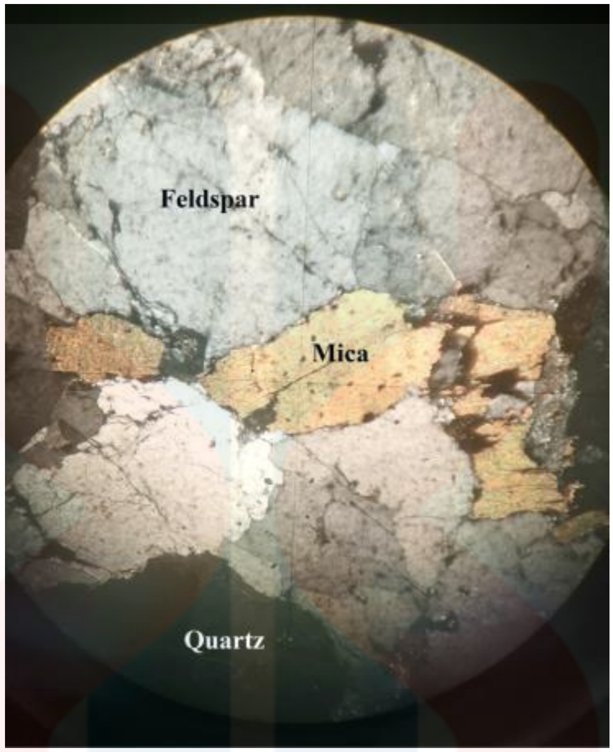


Figure 4.6: Granite thin section

b) Locality 2

The sample of andesite rock is taken in a river, which located at coordinate of N 05°41’32.47” E 101°46’40.86”. The outcrop found is spatially weathered.

Based on the hand specimen of sedimentary rock, this rock have a dark greyish in colour. This rock is a very hard and very huge. The rock had small quartz vein. These rocks are fine grained and have a aphanitic texture.

Figure 4.7: The andesite outcrop

Figure 4.8: The quartz veins found in the andesite outcrop.

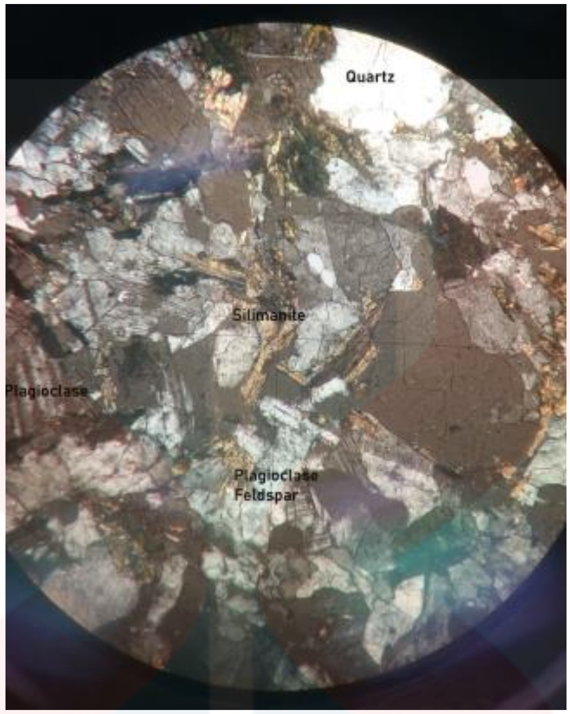


Figure 4.6: Andesite thin section

c) Locality 3

A intrusive igneous sample was taken in this locality which located at N 04 49’38.7” E 101 57’29.9 and it is surrounded with residential area. The rock was heavily weathered and it was exposed to river and heat.

Based on the hand specimen, the rock have a aphanitic texture the ground mass cannot be seen in a naked. The rock is white in dark grey. Under the microscope, the matrix of the rock cannot be determined. The colour of the rock is grey. Under the microscope, there are no foliation can be seen and minerals are allign together. Mineral are very fine and cannot be determine under microscope.

Figure 4.9: The weathered hornfel oucrops

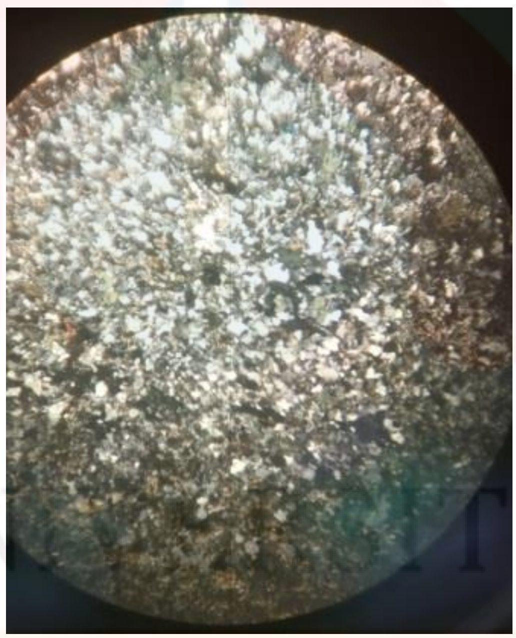


Figure 4.10: The minerals were very small and andalusite minerals were spotted

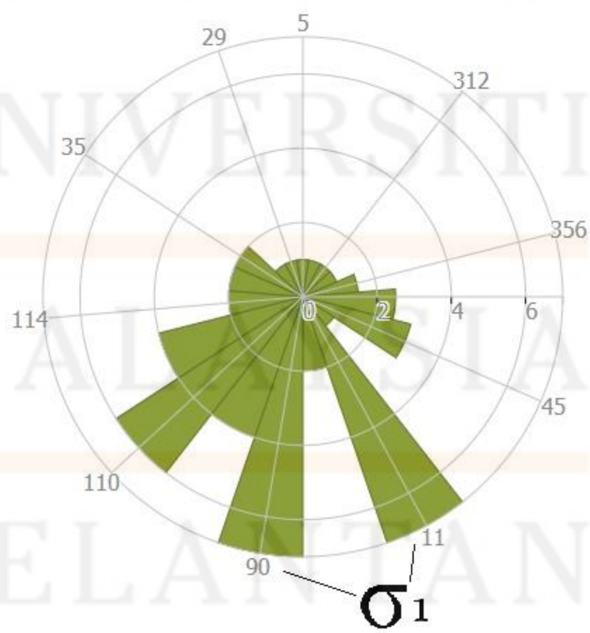
4.4 Structural Geology

In structural geology, the deformation process of rock can be studied. Deformation is the changes in shape of rock mass. The geological structure is classified into primary structure and secondary structure. Primary structure is produce during the formation of rock body such as depositional contact, unconformable contact, cross bedding or vesicle in basalt, whereas the secondary structure is produced after the rock body that affected. For example, the fault contact, folds, joints or shear fracture and tectonite fabric.

4.4.1 Joint Analysis

Joint analysis is used to identify the orientation of tectonic stress. The significance of the joint analysis is the determination of the geologic hazard, such as shear fracture.

The joint analysis in the figures had shown the forces that acted upon the structure or outcrop. The higher the value of strike and dip, then it may show the massive force is acting on the structure. The joint analysis data were taken from locality 2.



Outcrop from locality 2

CHAPTER 5

LANDSLIDE SUSCEPTIBILITY USING GEOGRAPHIC INFORMATION SYSTEM

5.1 Introduction

The landslide can happen when triggered by few factors in an area. The level of hazard prone area can be detected with few parameters. In this chapter the potential of landslide susceptibility of Kampung Long will be explained in detail. The parameters used to analyze and decide the landslide prone area is included with specific rating and the zonation of landslide susceptibility is determined.

5.2 Overlaying of Thematic Maps

In this study, the thematic maps used are including lithology map, land use map, soil map and slope morphometry. Each of the thematic maps are classified according to their own specific rating scheme of landslide hazard evaluation factor (LHEF). This rating scheme is based on the major of inherent causative factor of slope stability that include the lithology, slope and landuse. These parameters are considered to contribute the potential or failure of the landslide.

5.2.1 Lithology Map

Lithology is very important in order to control the stability of slope. The rock unit is controlled by the weathering and erosion, where the maximum weightage of lithology is 4. The causative factor of lithology is classified into three classes. Type I indicates the limestone or granite, where it is a strong and stable rock. However, the type III is indicating the weathered rocks such as weathered phyllite, shale or silt. These types of rock may be the indicator of high potential hazard to occur. Furthermore, the behavior of instable lithology such as clay, shale also may contribute to high potential of hazard.

5.2.2 Land use Map

Land use map is produce to determine the type of activities conducted on land. Majorly the study area consist of rubber plantation and palm tree plantation. The other land cover is such as forest, residential area and cleared lands. The study area is majorly consist of forest as the elevations are higher and only low lying area is used for agriculture activities and as residential area. The area with high elevation left unexplored for time being. The identification of these land use is to process of overlaying the map to produce the landslide susceptibility map.

5.2.3 Contour Map

Contour map is produce in order to identify the elevations within the study area. The highest elevation in the study area is 580 meters, whereas the lowest elevation is 70 meters above the sea level. The highest elevation of the study area consists of forest area and the lowest consist of roads and agriculture area.

5.2.4 Slope Morphometry

Value of slope has maximum potential for slope failure to occur. The factor is being classified into several classes according to its weightage. The high weightage is 5, where more than 45˚ of slope, whereas the weightage of value 1 is indicate less than 15˚.

Table 5.1: Rating of lithology

Class	Rock Type	Weightage	Rating
Type I	Quartzite/Limestone	1	0.2
	Granite/Gabbro	1	0.3
	Gneiss	1	0.4
Type II	Interbedded sandstone with thin claystone	2	1.0
	Interbedded sandstone with shale or clay	2	1.3
Type III	Slate or phyllite	3	1.2
	Schist	3	1.3
	Shale with interbedded of claystone or non-clay materials	4	1.8
	Shale, phyllite and schist (Highly weathered)		

Table 5.2: Weightage of slope morphometry

Type of Slope	Class	Weightage	Rating
Escarpment, cliff	> 45˚	5	2.0
Steep slope	36˚ - 45˚	4	1.7
Moderately Steep slope	26˚ - 35˚	3	1.2
Gentle Slope	16˚ - 25˚	2	0.8
Very Gentle Slope	< 15˚	1	0.5

Table 5.3: Rating of landuse

Type of Landuse	Weightage	Rating
Agricultural	1	0.2
Residential	2	0.5
Thick vegetated	3	0.4
Moderately vegetated	4	0.6
Sparsely vegetated	5	0.8
Barren land	6	1.0

5.3 GIS Overlay Analysis

The correlation of landslide hazard zonation is produced by the grid overlay method and GIS modelling, where the analysis is compared to access the suitability of the two approaches (Tarum Kumar Raghuvanshi, Lensa Negassa, P.M. Kala, 2015). The parameters are classified according to their own specific rating. The summation of these parameters is used to obtain the suitability value to determine the possible location to have the landslide in study area.

The landslide hazard zonation can be calculated by using the equation:

Potential hazard score (THED) = Rating of (lithology + slope morphometry + landuse)

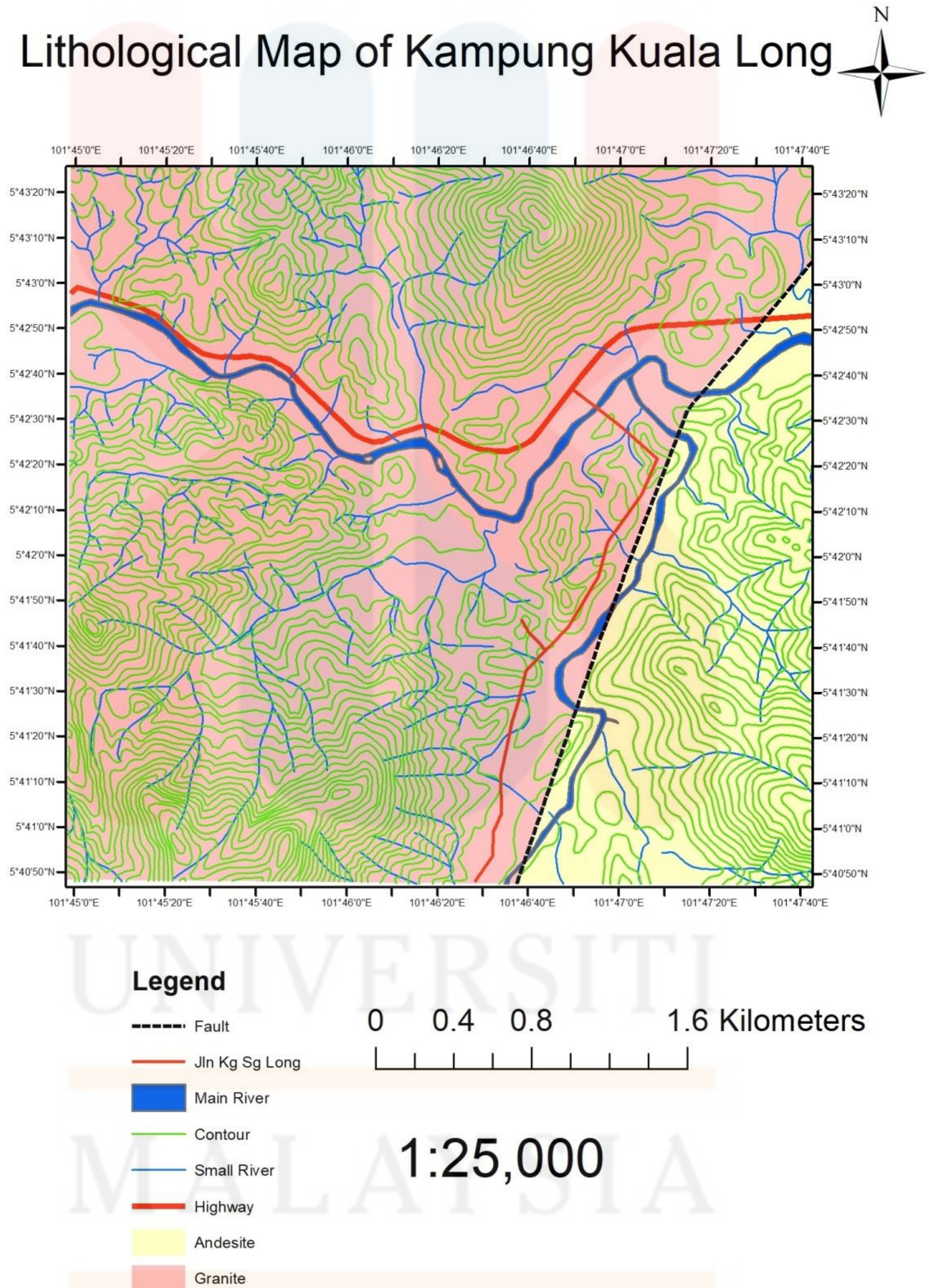


Figure 5.1: Lithological map of Kampung Long

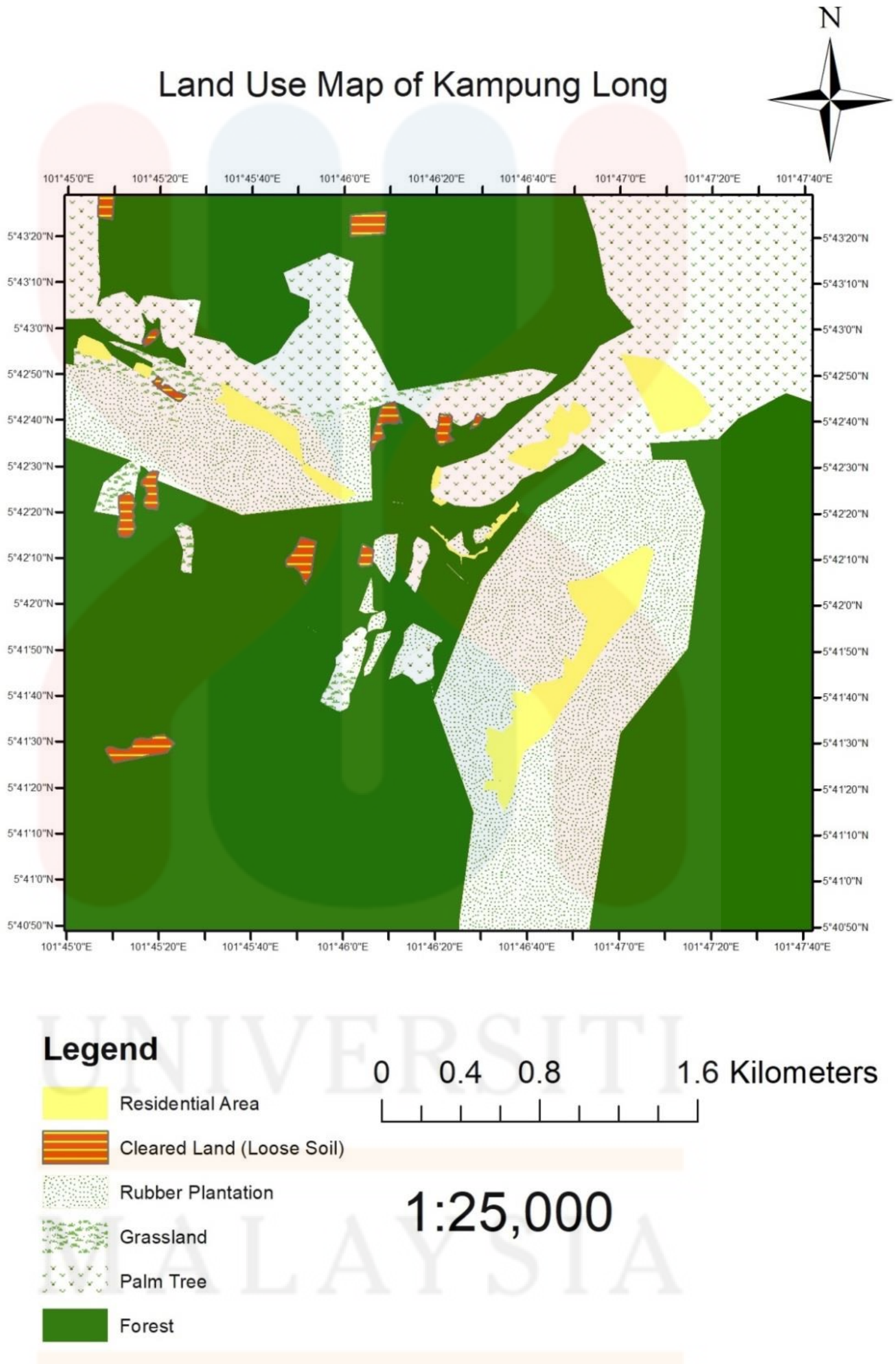


Figure 5.2: Landuse map of Kampung Long

(Source: ArcGIS Shapefile Data)

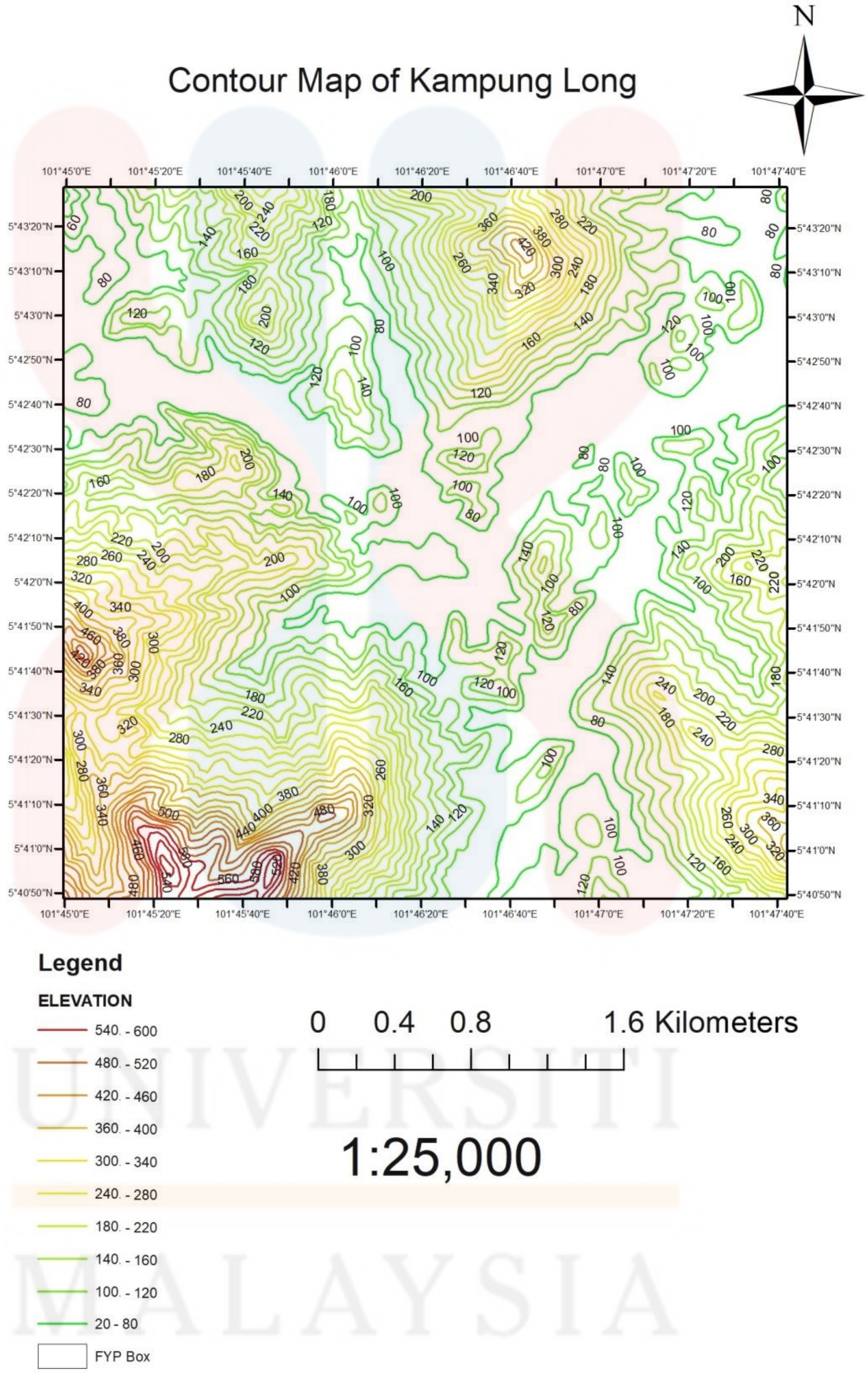


Figure 5.3: Contour map of Kampung Long

(Source: ArcGIS Shapefile Data)

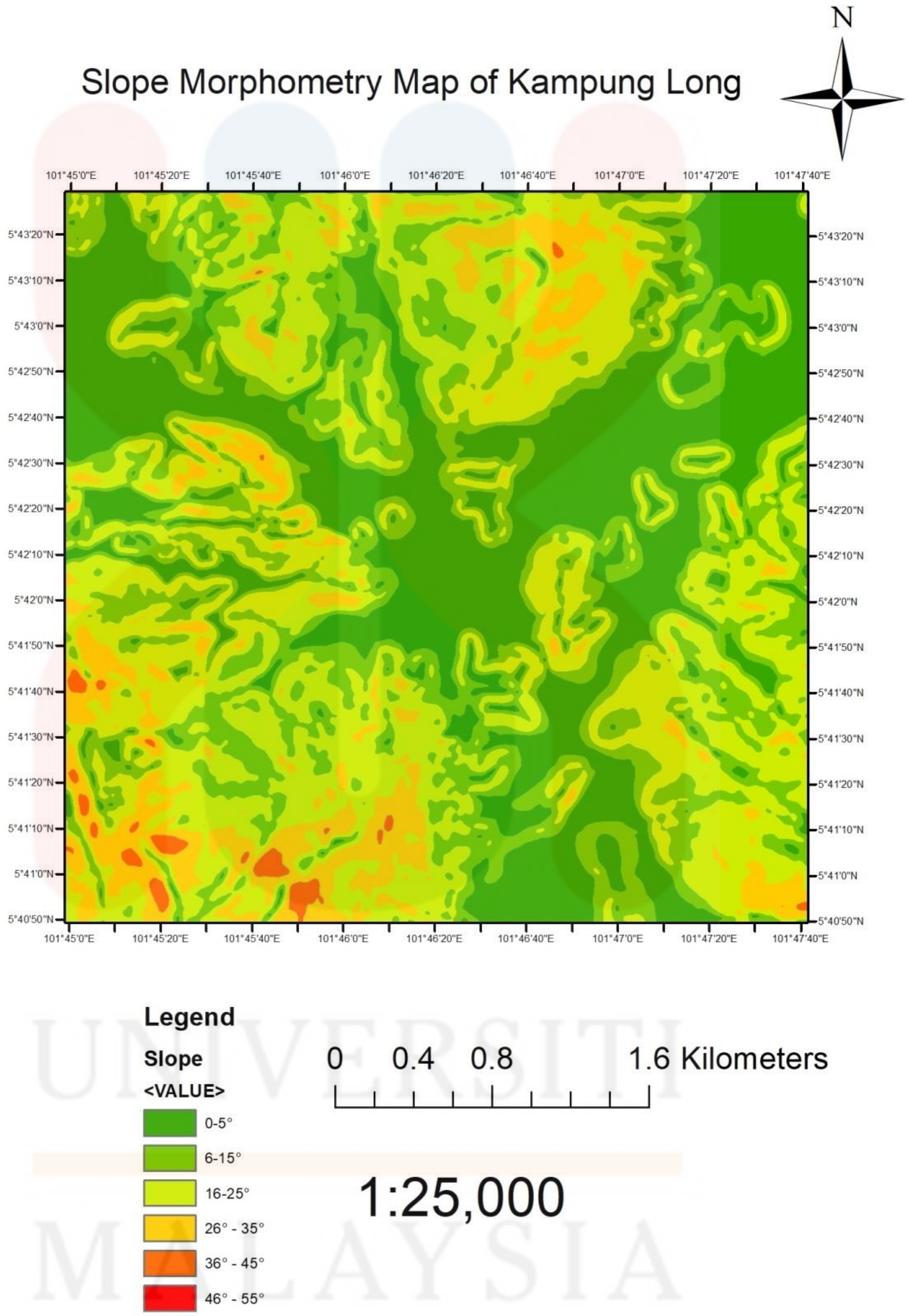


Figure 5.4: Slope morphometry of Kampung Long

(Source:ArcGIS Shapefile Data)

5.4 Map Interpretation

From the results of the maps, the variables can be described as the regression coefficient is highlighted by the factors and variables that affect the potential of landslide susceptibility.

The aspect of lithologies, landuse and slopes are considered to be related to the potential of the failure occurrences. The classes and its ratings such as lower potential at the sparsely vegetated area. The other classes such as agricultural is more high potential for the failure.

Slope angle also showed a significant coefficient trend. It emphasized the increment of slope angle which more than 36˚ may have the high potential for the slope failure to occur. The slope morphometry had shown the lower to high angle of the slope. The lower angle may not have significant change for potential of slope failure.

The combination of these factors where the coefficients with related classes and its ratings can produce the potential susceptibility map. The interpretation of susceptibility is according to the ranking of the classes which from the lowest to the highest values.

Table 5.4: Total estimated hazard value.

Zone	THED Value	Description of Zone
I	< 3.5	Very low Hazard Zone(VLHZ)
II	3.5 - 5.0	Low Hazard zone(LHZ)
III	5.1 – 6.0	Moderate Hazard zone(MHZ)
IV	6.1 – 7.5	High Hazard Zone(HHZ)
V	> 7.5	Very High Hazard Zone (VHHZ)

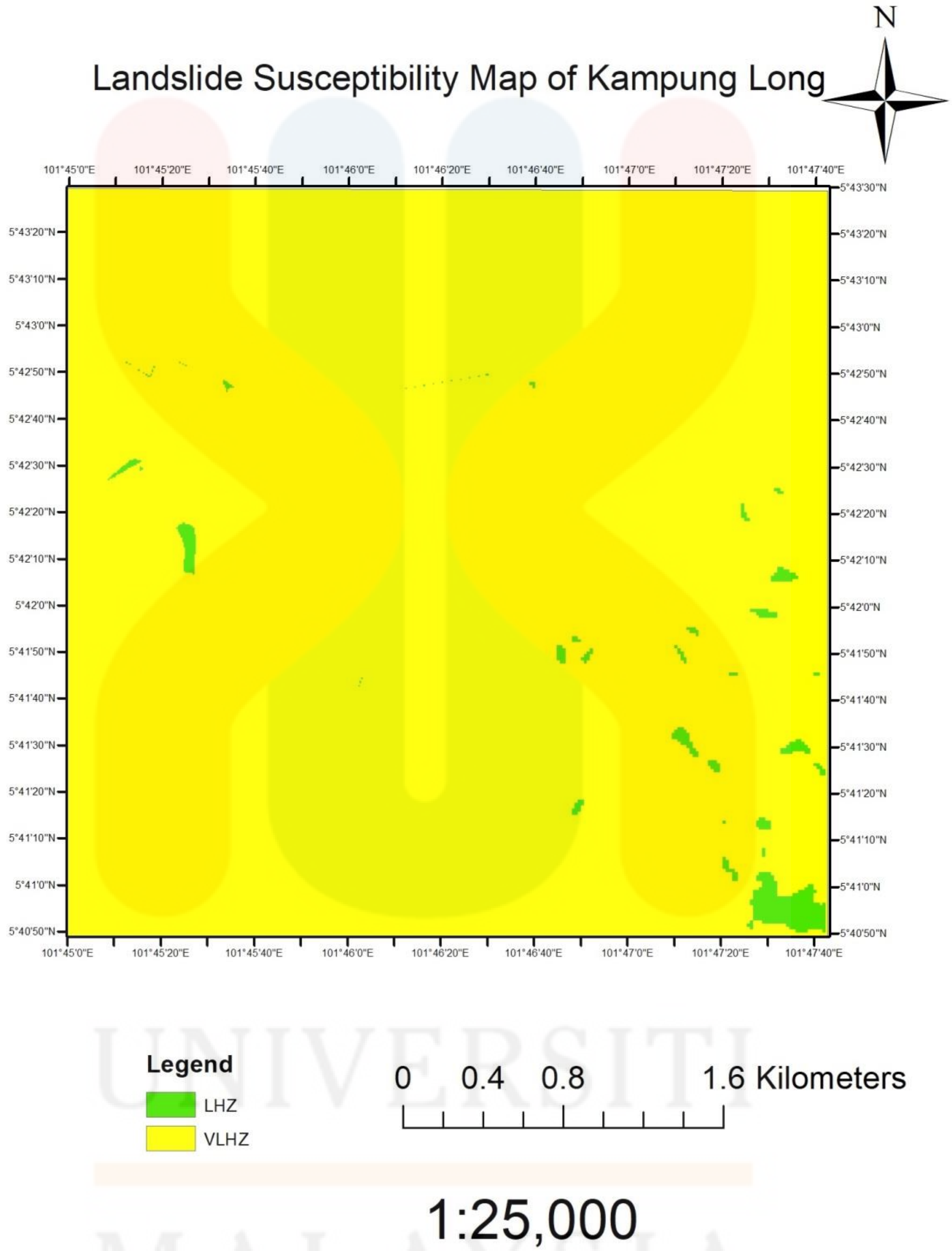


Figure 5.5: Landslide susceptibility map of Kampung Long

(Source: ArcGIS Shapefile Data)

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

In conclusion, the landslide susceptibility map produced was to provide the hazard in study area of Kampung Long, Jeli. Relationship between the factors and analyses had shown through the overlaying of thematic maps. The final outcome of the landslide susceptibility map showed the moderate to high susceptibility where the potential of landslide may be occurred. According to the result obtained the place is safe and have less prone to landslide activities.

Several limitations are determined throughout the process of analysis. The method of input and output system were affected the final result of the analysis. Data provided in the GIS package was outdated and the analysis of the map in GIS was conducted in separate ways, which consume a lot of time to get the input and output. In order to gain more information of hazard, a specific scale and more physical properties of landslide hazard is needed.

6.2 Suggestion

Overall, some uncertainties for the analysis is need to consider in order to reduce the error of final potential predictions. The accessibility of input and output need to be evaluated to improve the final result of the analysis.

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