GEOLOGY AND LANDSLIDE SUSCEPTIBILITY ASSESSMENT USING GEOGRAPHIC INFORMATION SYSTEM (GIS) IN ARING, GUA MUSANG KELANTAN

by

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DECLARATION

I declare that this thesis entitled **"GEOLOGY AND LANDSLIDE SUSCEPTIBILITY ASSESSMENT USING GEOGRAPHIC INFORMATION SYSTEM (GIS) IN ARING, GUA MUSANG 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.

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APPROVAL

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

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ABSTRACT

Aring is located in Gua Musang District, Kelantan which are very prone to have a geological hazard such as floods. It is also very vulnerable to landslide in some areas of Aring which does contributes to life losses and properties damages such as house and vehicles. The study area is located in Aring 6 with the are covered of $5km^2$ along the latitute 4° 55’ 30.00’’N to 4° 58’ 0’’N and longitude 102° 22' 30.00’’E to 102° 25' 30.00’’E. This study aims to update a geological map of Aring 6 with scale of 1:25 000 and to generate a landslide susceptibility map. The factors that influenced the landslide in Aring, Gua Musang were also identified based on the parameters. The research does involves the study of geomorphology, stratigraphy, structural geology and historical geology of the study area. The method that will be using in this research study is by overlays all the data by using the weighted overlay method in ArcGis and also by generating the probability calculation with the area under the curve (AUC). The study area was composed by Aring Formation which were divided into four lithologies unites. The parameters that caused the potential landslides such as the lithology, drainage, slope and aspect were also classified and the landslides susceptibility map was produced in ArcGIS software by using probability method. Results showed that the susceptibility map was categorized into three classes which are low, medium and high classes that is prone to have landslides in the future. Heavy rainfall intensity was identified as the factors that triggered the landslide. As a conclusion, the ability to identify landslides will provide a better knowlegde and understanding to the society on the landslide mechanisms and will also provide a better prevention of the most likely failure area that have high prone landslide for the future management.

Keywords: GIS, Landslide Susceptibility, Gua Musang, Weighted Overlays Method, Probability Method, Area Under Curve (AUC)

GEOLOGI DAN KERENTANAN TANAH RUNTUH MENGGUNAKAN APLIKASI SISTEM MAKLUMAT GEOGRAFI DI ARING, GUA MUSANG KELANTAN

ABSTRAK

Aring terletak di daerah Gua Musang, Kelantan merupakan kawasan yang berpotensi tinggi terhadap bencana seperti banjir. Walaubagaimanapun, ia juga terdedah kepada tanah runtuh di beberapa kawasan di Aring yang menyumbang kepada kematian dan kerosakan harta benda dan kenderaan. Kawasan kajian terletak di Kawasan Putat Gunungkidul dengan kawasan yang diliputi 5km^2 yang selaras pada latitud 4° 55' 30.00''N to 4° 58' 0''N and longitud 102° 22' 30.00''E to 102° 25' 30.00''E. Kajian ini bertujuan untuk mengemas kini peta geologi Aring 6 dengan skala 1:25 000 dan menghasilkan peta kerentanan tanah longsor. Faktor-faktor yang mencetuskan tanah runtuh di Aring, Gua Musang juga dianalisa berdasarkan parameter yang berkenaan. Kajian ini melibatkan kajian geomorfologi, stratigrafi, geologi struktur dan geologi sejarah kawasan kajian. Kaedah yang digunakan dalam kajian ini adalah dengan menggunakan kaedah tindanan dengan kaedah tindanan berwajar menggunakan semua data yang diperoleh dan juga dengan menghasilkan pengiraan kebarangkalian dengan luas lengkung. Kawasan kajian terdiri daripada Aring Formasi yang dibahagikan kepada empat unit litologi. Parameter yang menyebabkan berlakunya kejadian tanah runtuh seperti litologi, saliran, aspek dan sudut kecerunan juga dapat ditentukan dan peta kerentanan longsoran dihasilkan menggunakan perisian ArcGIS dengan menggunakan kaedah kebarangkalian. Keputusan menunjukkan bahawa peta kerentanan dibahagikan kepada tiga kelas iaitu zon kerentanan rendah, sederhana dan tinggi yang berpotensi untuk mengalami tanah runtuh pada masa hadapan. Kadar intensiti hujan yang banyak juga dikenal pasti sebagai faktor yang menyebabkan tanah runtuh. Sebagai kesimpulan, keupayaan untuk mengesan kerentanan tanah runtuh membawa kepada pengetahuan dan pemahaman yang lebih baik kepada masyarakat sekeliling mengenai mekanisme tanah runtuh dan membawa kepada penghindaran yang lebih baik kepada lokasi yang berkemungkinan untuk gagal di kawasan berpotensi tinggi untuk tanah longsor demi perancangan masa hadapan.

Kata Kunci: GIS, Kerentanan Tanah Runtuh, Gua Musang, Kaedah Tindanan Berwajar, Kaedah Kebarangkalian, Kawasan luas lengkung

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CHAPTER 1

INTRODUCTION

1.1 General Background

Geology is the science that examines the successive changes that have taken place in the organic and inorganic realms of nature in which the causes of the changes. The changes does contributes to the impact in the alteration of the surface and external structure of our planets are studied (Lyell, 2016)**.** It is always stated that almost all the physical changes that happened where the past is the resemblance of the future and vice versa. Geology has a very broad meaning which implements in different fields which are consists of engineering geology, astronomy, oceanography and many more. The term of geology derived from the words 'geo' which means earth and 'logy' is the study of where the definition is the study of earth. The science deals with the earth's evolutionary and physical past, the rocks that consists of physical, biological and chemical changes or experienced by the planet (Mars, 2017). For three key reasons, it is important to study geology where it exposes the deep history of the earth, correlates with other sciences and is useful for economic purposes.

The study of geology tends to contribute to the phenomenon of natural hazard since the possibilities of that particular area can be forecast for one of the natural hazards known as Earth processes such as landslides, earthquakes and floods. This might help the authorities and the government to cope with that kind of situations. Geologists work well enough to understand these processes to avoid constructing significant structures where they may be destroyed (King, 2018). If geologists are able to map areas that have flooded in the past, they can map areas that could flood in the future (Friend, 2015).

Landslide is one of the geohazard that can count as natural disasters. It occurs when within a slope that shear strengths of the material forming where slope are overcome by gravitational and other forms of shear stress. It can occur normally, but at a slow rate. Natural land distribution can be changed by changes in human activities or land use. Often, within a single landslide, there is more than one form of movement.

Because of landslides affect the settlement and structure in Malaysia such as transport, tourism and development, it also affects the economic and social lifestyle to the people surrounding. For the structures itself, when there is landslide it could damage highways, rivers, properties and livestock. Most of the landslides occurred along roads or highways in high areas where mountainous areas would have landslides on cut slopes or embankments. Landslides happened near apartments or housing areas caused death to the human being as reported by Bujang & Hua (2008).

In general, Malaysia has not experienced serious or extreme earthquakes but there are still large scale landslides which are primarily triggered by intense and prolonged rainfall. One of the example of landslides that happened on 11th December 1993 where the crumbling of the 14-storey block A of the Highland Tower in Ulu Klang, Selangor was the most devastating landslide in Malaysia with 48 deaths. The main factors causing slope collapse or landslides at hillslide developments in Malaysia are high rainfall distribution, storm water operations and poor slope management. Landslide losses and other impacts of ground changes are becoming increasingly serious as land development and human activities are rapidly increasing. As a result, the development of highlands or hilly terrain has increased particularly in areas adjacent to densely populated cities, exposing urban communities to an increased risk of landfall. The development at the hill land can have significant irreversible effects on its immediate environment as well as on the downstream environment around it. (Chong, 2012).

There have been 21,000 landslide-prone areas across the country in general, which is 16,000 or 76% are in Peninsular Malaysia, while about 3,000 are in Sabah and 2,000 in Sarawak. The most common types of landslides in Malaysia are shallow slides where the slide's surface is usually less than 4 meters deep and takes place during or immediately after heavy rainfall (Haliza Abdul Rahman, 2017). Deep-seated slides, debris flow and geologically induced failures such as wedge failure and falling rock can be other causes of landslides. The various types of landslides can be differentiated by the material form involved and the mode of motion involved. About 80% of landslides and poor slope management methods are at least partly related to human influence. (Seattle, 2001). Some environmental and socioeconomic problems such as that have been triggered by the effects of landslides such as loss of life, damage to property and facilities, psychological distress among victims, land boundary disputes and land degradation.

Landslide susceptibility is the prospect of a landfall occurring in an region under local terrain conditions (Brabb, 1984). Despite the landslide's size, length, width, depth area or volume, susceptibilty does not take its aspect into account. However, the susceptibility evaluation was able to compensate for landslides of different sizes. de

In this study, the landslides susceptibility assessment in Aring is done by using probabilistic method in Geographical Information System (GIS) where it help converting the analysis at the study area into four different zoning of area that have potential of landslides. Therefore, GIS is useful tools for mapping geologic boundaries and zoning area.

1.2 Study Area

1.2.1 Location

The study area of this situated at Aring which is known as one of the district in Gua Musang, Kelantan which is very popular with its palm oil plantation area because of the famous palm oil which is known as 'Felda' is situated and it is known as Felda Aring 6 (Figure 1.1).

This area is known as the palm oil area, stretches in an estimated area of 50.3 km2. It is also known as one of the fastest growing plantation regions in Gua Musang in economic development and population. It had been prepared as plantation area since 1980's with concept of resources oil for Malaysia exportation. It caused research area experienced physical changes between 1970 until early 1980's. Meanwhile, from the aspect of personal or group political relations, this area is far enough away from power and sources economy. Therefore, a number of the problems described above indicate that Aring as if no man's land because it consciously or not, this region uncategorized as a city

Figure 1.1 : Satellite Map of Felda Aring 6

1.2.2 Accessibility

The study area has an access to a highway named Jalan Felda Aring so it is easy to just get into there in and out. Throughout the study area, almost 80% of the coverage area had a road accessibility and could reach there by car and other transports. Figure 1.2 shows the base map of the study area in Aring Gua Musang to illustrate the accessibility.

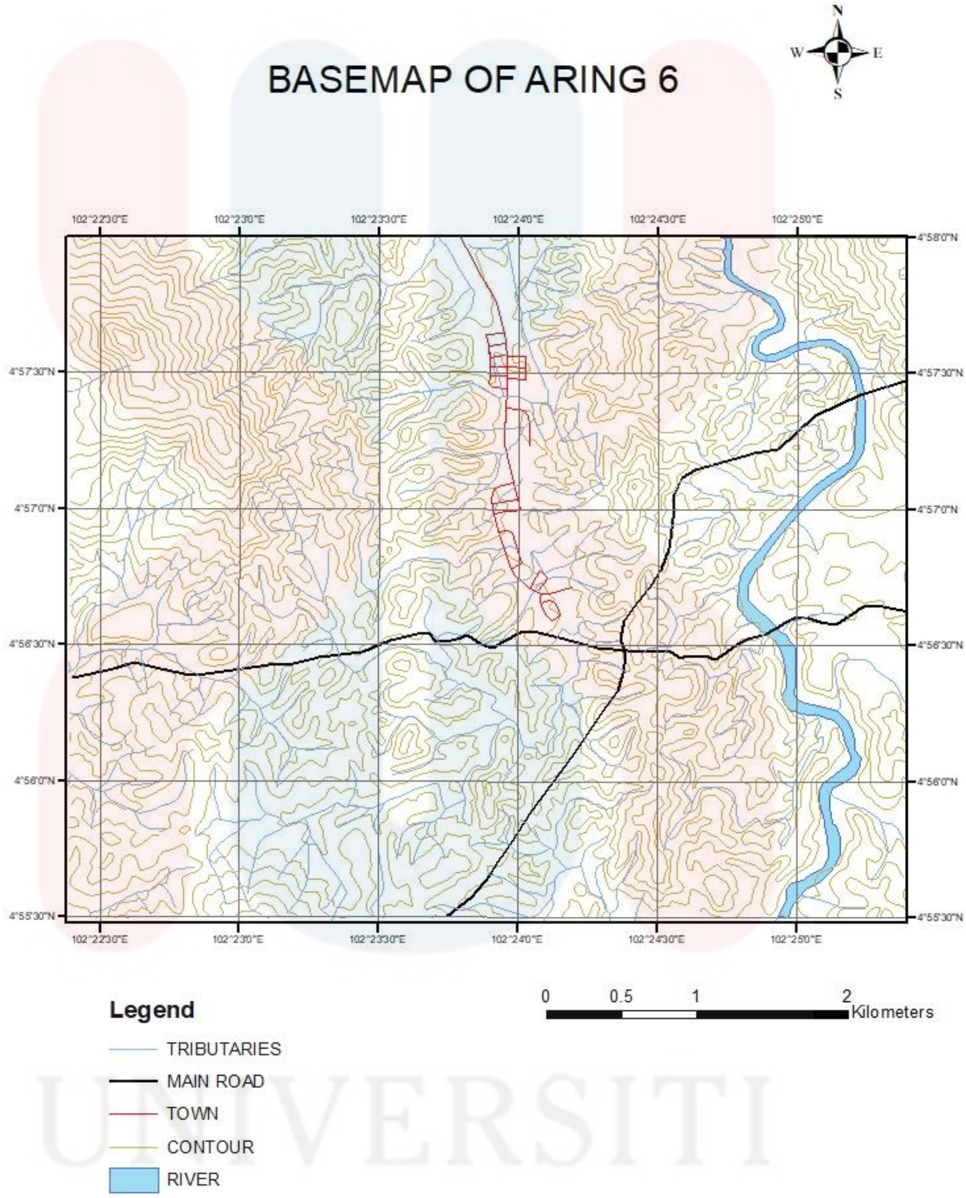

Figure 1.2: Base Map of study area

1.2.3 Demography

According to the Department of Statistical Malaysia on the population of people there, on 2019 itself it is stated that the population of people at Kelantan is at 1.89 millions so that means the number of people there kept on increasing as Kelantan is one of the target states to be as famous as Kuala Lumpur in the future. The ratio of ethnicity at Gua Musang does varies into 4 categories which are Malay (82.43%), Chinese (5.58%), Indian (0.51%) and others (11.48%). Gua Musang is divided into 3 different district which are Bertam, Galas and Chiku. In Bertam district, it is also divided into 3 area which are Ulu Nenggiri, Kuala Sungai and Limau Kasturi while in Galas district consists of Renok, Batu Papan, Ketil and Pulai. Last but not least, Chiku district have 1 area which is Relai.

1.2.4 Landuse

Land use and land cover does imported the development changes that happen in a place. Land use ranges from forest areas to different forms of land use, such as townships, industry, settlement and tourism, which could impact the climate, contributing to possible natural disasters. The production of land use in the 1984 Kelantan Basin is less diversified or not complex since only a few patterns of land use are listed as rubber, coconut, oil palm, vegetables, etc (Haliza Abdul Rahman, 2017). The pattern of land use, however, has started to evolve and become more nuanced compared to 1984. In the study area, the type of land use that are available is residential where there are a lot of housing area and settlements there. There are also industrial areas where there are the factory for processing the oil palm and other food stalls available

1.2.5 Social Economic

Social economic is where the social science that studies the economic in terms of the activity affects and how it influence the social processes. The social economy at the area are most of the people are a oil palm workers because the number of oil plam there. Due to this economic of oil palm, most of them have insufficient monthly wages because of the demand of oil palm and the current states of Malaysian currency nowadays.

1.3 Problem Statement

Due to excessive human activities such as deforestation and illegal logging that occur in that region, the number of possibilities of landslides is increased every year and it raises the concern of people surroundings, so it is very important to always update the geological map in order to keep the data on track and to avoid any unforeseen losses in the future.

Based on the previous geological map of the study area, the recent map is outdated and it cause insufficient amount of resources which invalid to be as a benchmark for other studies. So, it is very relevant to always update the recent map in order to always up to date in terms of landslide potential area. The benefits of conducting geological mapping on the landslide study is to always be prepare on the potential geo hazards that could happen specifically on the study area because Kelantan is one of the states in Malaysia would experience monsoon and it could effects on the potential landslide incidents even more higher. There are also no single agency that relates to landslides data collection does collect the landslides incidents every single year.

. Research area in Aring, Gua Musang is an urban area that undergoes rapid development and rampant land use which eventually led to some destructive impacts to the environment, such as changes in lithology and geomorphology. Therefore, all of these rapid developments within the study area tend to accelerate the process of landslides hazard.

For the past few years, landslides in Kelantan particularly in the Kuala Krai region, have caused rain and flash floods that causing the rock surface weakness along the planes of fracture, joint and cleavage. The landslides that happened in Kuala Gris station in Dabong on 2017 had gave an impact to the authorities and others towards the danger that a landslides could give. Other than that, the landslides in Kota Baru-Kuala Betis route in Gua Musang that effected some electric pole which will cause harm to the motorist especially at night had also woken up the awareness to the people in terms of management and prevention.

Most recent research that involving potential landslide hazard is from 2017, but the research used Analytical Hierarchical Process (AHP) method (Yousef, 2017). AHP is a technique that consider as heuristic method, which used expert to judging concept and expert opinion is crucial in this method. There is unconsistency in layering when including and erasing options as a part of the information set. Therefore, this become limitation for the research because it cannot detect the small location of hazard zones, only the large zones can be identify using this method. This information is very importance to local authority for planning and managing natural hazard in Aring as population there keep increasing every years. Therefore, more development will take place in the future. Thus, method that is more accurate is needed in order to identify the possibility of landslide zonation area in future. If there is no further research being done to overcome this issue, the possibilities of the landslides could happen in the future with the worst damage to the people is high.

1.4 Objectives

The research objectives in this research are:

i. To update the geological map of study area with the scale of 1: 25000.
ii. To produce landslide susceptibility map using probabilistic method
iii. To identify landslides zoning area for better planning strategies in the study area

1.5 Scope Of Study

There are different elements which are required for forming a geological map using a GIS which are divided into four elements which are hardware, software, data and methods. The first component is hardware where in GIS it is includes a computer device consists of laptop, printers and hard disk or pendrive in order for memory storage purposes while operating with the GIS components. Next, software is very useful to provides the interface and offers different results for data processing. One example of software used in this processing stage was ArcGIS. The reason of choosing ArcGis itself is because of the ability of producing map with the power for its spatial analysis and data. This software is also has a good reputation which make it an excellent and competitive computerized geographic analysis. Other than that, data is the most crucial part because without data, there is no information. Data is collected using various means and is transferred into computer based on the previous researchers data from slope intensity, landuse, drainage, lineament and soil intensity data. Besides, this study relied on secondary data of satellite imageris from Landsat TM. The land imaging from moderate resolution Earth observing satellites, Landsat varies in the production where it could observe the land use changes across those scales. It also a good informer in many disciplines such as agriculture, natural disaster and urban growth. This data is processed using various functions for generating the desired output which is the 5 x 5 km^2 of geological map and landslide susceptibility map (LSM) . Lastly the method which is probabilistic method was used in order to produce LSM and updated geological map.

1.6 Significance Of Study

Owing to earthquakes, volcanoes or rainfall, earth, soil or rock can no longer hold up and give away to gravity, a landslide can occur. Landslides can move slowly or rapidly, with disastrous consequences.

This research will give a better guidance to the authorities and even people so that they can analyse and have a new updated information on the study area for geological study. Other than that this research also provides good information for future settlement in terms of housing, transportation and so on based on the zonation classes which is high prones areas to low prones area for landslides. They can prevent the planning of housing and buildings areas at the high prone landslides in order to save their investment and could lower down the rate of incidents that can be happen at the area. Other than that, sturdy materials such as masonry, brick, stone or steel can be used to build a solid, well built retaining. Drainage materials behind the wall help to improve wall stability.

Next, this research could also enhance the awareness to the people about the landslide and how to prevent them in the future if that happens. A lot of safety measurement could be done at the areas that have high prones so that it could reduce the number of loss caused by landslides. With recent trends showing a substantial rise in the number of landslides and the loss of life and property due to landslides, being well versed with different method to avoid them can be a great help.The planting of trees and small shrubs on the slope is just another easy way to avoid landslides.

Lastly, this research could provide a head up start to the people and authorities to be prepare and could overcome the hazard from happening frequently.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will concentrate more on past studies on regional geology and tectonic environments, stratigraphy, structural geology, historical geology, and landslide research requirements.

In general, Kuala Betis, Gua Musang, Aring and Gunung Gagau are stratigraphically divided into four regions in South Kelantan (Mohamed, 2006). The research area is located within the Peninsular Malaysia Central Belt in the town of Aring. Because of their similarity in lithology and age, rock units are considered to be a significant part of the Gua Musang Group in the Aring region. Four rock units formations are indicated in the Aring area, namely Aring Formation, Telong Formation, Nilam Marble Formation, and Koh Formation, based on Figure 2.1.

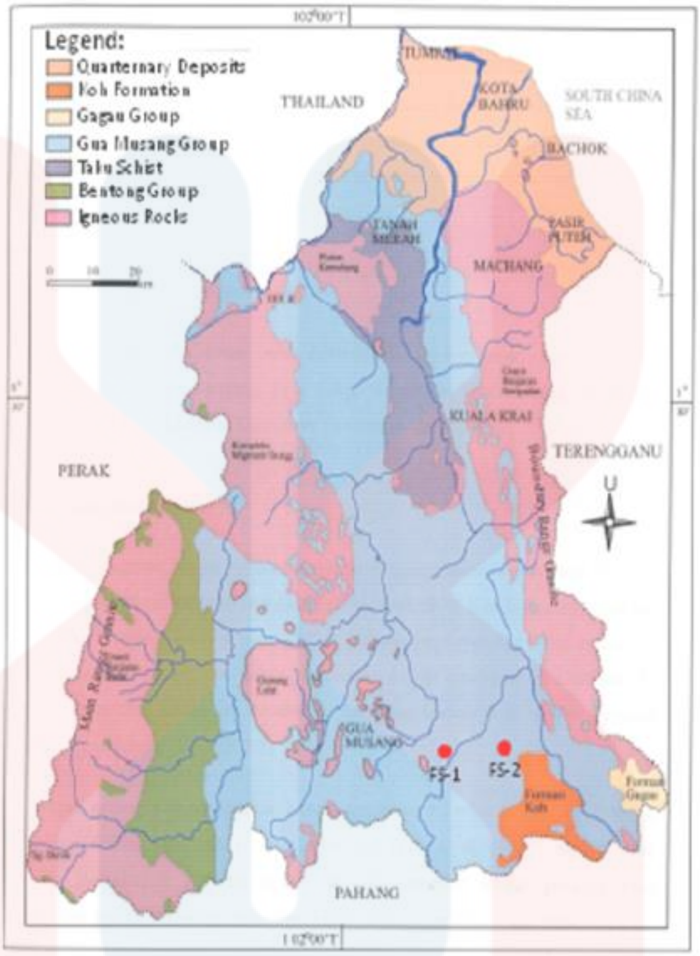

Figure 2.1 : Geological map of Kelantan

2.2 Regional Geology And Tectonic Setting

There are three divisions of Peninsular Malaysia which divided into three trending north-south areas known as Peninsular Malaysia's Southern, Northern and Central Belt. Sibumasu and Indochina land collision result in the formation of Bentong Raub Suture (Tan, 2009). Peninsular Malaysia is on the Sibumasu plate and divided into two blocks of Bentong-Raub suture, while the western part belongs to the blocks of Sibumasu while eastern part belongs to the block of Indochina (Bakhshipour et al , 2013).

The two came from Gondwanaland is called Sibumasu and Indochina. Sibumasu is characterized by glacial mudstones of Carboniferous Permian, while the eastern Malaya and Indochina blocks are characterized by calcareous limestone (Aidin et al, 2002). Predominantly, Permian sedimentary rock happens on the eastern side of Kelantan state. Gua Musang consist of massive limestone, compact and massively jointed. According to Department of Mineral and Geosciences Kelantan (2009), most of the limestone involve in the formation of Gua Musang has been recrystallized into marble.

2.3 Stratigraphy

The Aring Formation, Taku Schist, Gua Musang Formation, Telong Formation, Gunung Rabong Formation, Koh Formation and Badong Conglomerate are seven formations based on the stratigraphy of Kelantan. In the Paleozoic era, the age of Aring Formation and Taku Schist were formed, while during the Mesozoic era the other five formation ages were formed.Gua Musang formation is located in South of Kelantan state that extended to North Kelantan and North Pahang. Based on the research study, the range age of Gua Musang age from Middle Permain to Upper Triassic (Leman M. S., 2004). The findings of fossils of the pelecypods and ammonoid in Gua Musang have been proven and be indicator to the ages of formation (Gobbett & Hutchison, 1973). Aring formation was introduced by AW. P. C. for the sequence mainly pyroclastic in Sungai Lebir Valley, lower reaches of Sungai Aring and Sungai Relai in south Kelantan.

2.4 Structural Geology

Structural geology is the analysis of three-dimensional rock unit compositions, which cause the pervasive distortion. There are several factors that have led to the development of structural geology, such as tectonic cycles, sediment deposition and the Earth's energy tension. The big aspects in the geologic history can indeed be related by considering the stress field dynamics. This also concerns with its physical and mechanical rock nature characteristics as it is possible to detect structural deformation such as faulting, cracking, foliation and joints.

A lineament is a linear characteristic of a landscape that is used to denote a fault-like underlying geologic structure. In geological or topographical maps where the lineament can obviously seen. It is a linear fault line or fracture line of any broad linear surface.

The term 'lineament' first used by Yusof (2014) defining lineament as a broad line of underlying rock landscape. Lineament can be represented on the ground as a linear topographical or tonal feature that represents areas of structural weakness (Friend, 2015). It is then assumed that the lineament identified in different geological characteristics such as shear zones or faults, rift valley, truncation of outcrops, folding axial features, topography, vegetation and soil alters the lineage

Gobbett & Hutchison (1973) stated that the overall pattern of Gua Musang's major tectonics resembles the minor effects consisting tight concentric folds, asymmetric, recumbent and overfolds. The minor faults occurred with a trend in the north. The structural orientation of the strata is north to northwest. It consists of a series of tight folds which do not show anticlinal and synclinal axial trends. The variation of folding, in terms of degree intensity depends on the lithology and also the thickness of the individual beds. Figure 2.2 shows the stratigraphy of the Aring, Telong and Nilam Marble formation.

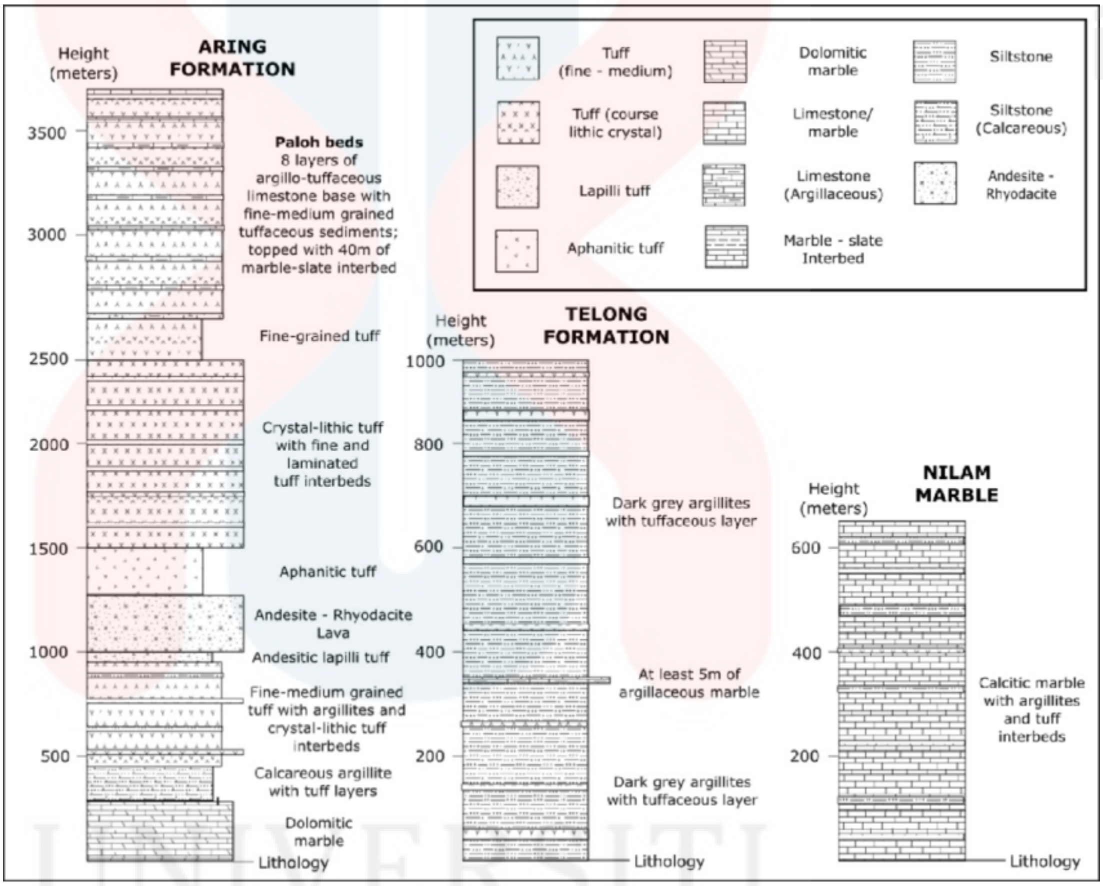

Figure 2.2: Stratigraphical column of Aring, Telong and Nilam Marble formation.

2.5 Historical Geology

A substantial portion of the newly formed landmass of the Peninsula was uplifted at the beginning of the Mesozoic Era and left subaerially exposed. Two areas, such as the northwestern depocenter Kodiang-Semanggol and the central depocenter Gua Musang-Semantan, were based on naval sedimentation (Gobbett & Hutchison, 1973). The former was built on the landmass of Upper Palaeozoic Sibumasu and was the only remnant of what was once a large marine deposition area in Late Palaeozoic times. The Gua Musang-Semantan depocenter was extended and bilt on East Malaya's Upper Palaeozoic shelf. In the Gua Musang- Semantan depocenter during Triassic times, substantial occurences of tuff and associated lava, tuffaceous siliciclastic and conglomerate suggest that volcanic activity and basinal instability were involved during the life span of the basin. Thick accumulations of turbidites have cause geologists to refer to there rocks as flysch in the deeper portions of the Gua Musang-Semantan depocentre (Gobbett & Hutchison, 1973). The Mesozoic System in the Malaysia Peninsula is located in two different basins, one on each side of the Main Range (Figure 2.3)

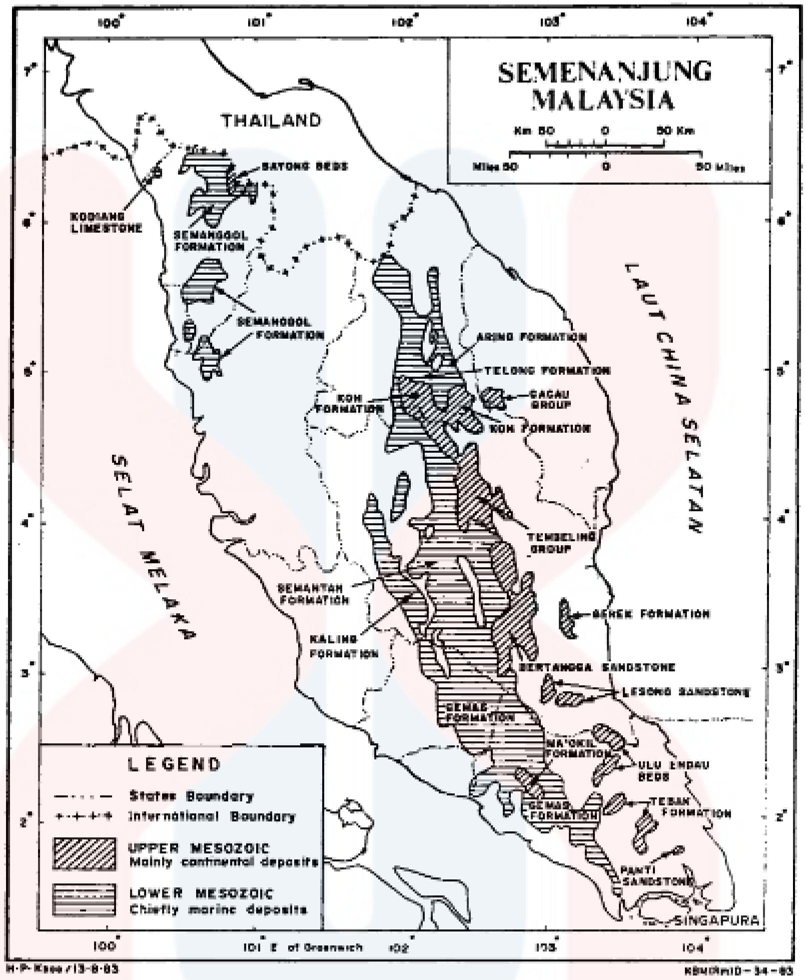

Figure 2.3 : Distribution of Mesozoic rocks

Sources: Geological Society of Malaysia (GSM)

2.6 Research Specification

2.6.1 Landslides

Landslide is natural hazard that often happens in the world's hilly region causing destruction and damage to life. Landslide, placed 5th in terms of casualties is among the top 10 most severe disasters in 2010 based on Disaster Management References in Malaysia (2016). There are many types of landslides based in Varnes Slope Movement classification as indicates in Table 2.1

Table 2.1: Varnes Slope Movement classification

Type of Material	Description
Rock	Intact and in its natural position, hard or firm mass Before any action occurred.
Soil	The sum of solid particles, normally rocks, and minerals. It can be carried or created by weathering of rock.
Earth	Materials of which less than 80% or more of the particles are 2mm, the upper limit for particles of sand size.
Mud	Materials in which 80% or more of the particles are less than 0.06mm in sized which the upper limit of silt sized particles.
Debris	Containing significant proportion of course materials, 20 to 80% of particles are larger than 2mm.

(Sources: Varnes, D.1978)

2.6.2 Landslides at Gua Musang

Landslides cases in Gua Musang was reported almost every year, which is no longer a new phenomenon anymore. Many articles and research had been published in order to investigate this geohazard. This is because landslides can be very disastrous especially when it is happen around the area of many people such as housing area or highway.

The production of landslides are mostly occcured due to the factors that triggers the geohazard such as the geomorphology parameters where structure that have higher structure such as hill and mountains could possible have potential landslides compared to the low land area. Other than that, the factors of soils erosion due to the extreme rainfall does also contribute to the unsaturated soils to start breaking apart due to the high intensity and prolonged rainfall (Gerome, 2009). Soil erosion is where there are displacement of the upper layer of the soil and that makes the soil to degrade and falling apart. The extreme prolonged rain is because of the moonson 'Timur Laut' that had strikes usually at the end quater of the year which is starting from September until December. Other than that, the total amount ot rainfall is one of the parameters that could influence the landslides as the depth of shallow landslides is normally less than 3 to 5 m. They can travel rapidly and can be highly mobile over long distances when shallow landslides are sufficiently wet. Shallow landslides and floods of debris are most frequently caused by heavy precipitation, with rainfall rates estimated at tens of millimeters per hour.

2.6.2 Landslide Susceptibility Assesment

In this research, landslide susceptibility assessment can be produced by using frequency ratio and probabilistic method. This is because it is used to produce GIS modelling. That is where spatial modeling is carried out to define the fundamental processes and characteristics for a given set of spatial characteristics. The aim of GIS modeling is to define and produce the world's spatial objects or phenomena and solve the problem. The research study used the frequency ratio, which is the ratio of the total pixel in the landslide region to the total pixel in the research area, where the potential of landslides occurring in each zoning class of three groups is measured. The probability values are then added together for each zoning class to get the landslide susceptibility index (LSI). The values of this index are then divided into three groups, which are high, medium and low, indicating the potential of landslides.

Based on the previous study on landslide susceptibility mapping along PLUS expressways in Malaysia using probabilistic based model in GIS (Yusof, 2014). It is proven that by using those method could achieve all the zoning class where specifically shown that the area in Gua Tempurung are divided into 4 classes of potential landslides that reveals the situation there consists of a lot of area with medium landslides zoning and it shows that Gua Tempurung area is a safe area for settlement and development processes. So, it is a great idea to generate the same method on identifying whether Aring are on of the area that has what kind of zoning class.

2.6.3 Application of GIS and Remote Sensing

Remote sensing and GIS is an important tool in analytical analysis in this hazard specifically in the development of landslides susceptibility map (LSM). GIS is a computer based method for mapping and interpretation of earthly objects and events. GIS technology combines common function of databases such as querying and statistical analysis with maps (Wayne, 2011). On the other hand, remote sensing is the science of collecting data regarding on object or a phenomenon without any physical contact with the object. The technology in GIS contributes a significant benefits in terms of economical, political and social issues where the upcoming development and settlement at the high potential landslides are could be prevent and in analyzing and producing LSM where there are research done in Frequency Ratio (FR) and probabilistic analysis to produce LSM.

CHAPTER 3

MATERIALS AND METHOD

3.1 Introduction

This chapter emphasized on the materials and methods that were selected in order to complete the study as well as process that was used to generate the landslide susceptibility map by using the Geographical Information System (GIS)

3.2 Materials

For this research study, the materials are divided into several parts. First is geological mapping resources based on the literature review from previous researchers. Second, secondary data evaluation in terms of geomorphology, stratigraphic column and cross section data. Lastly, data processing using software.

The materials used for geological mapping resources is needed based on the researchers previous data on that area and others scientific studies such as previous articles, journal, books and websites. Other than that, the use of hardware such as laptop, printers and hard disk or pen drive is very useful for storage purposes.

Next, secondary data for evaluation is gathered from satellite image Landat TM (Figure 3.1) from year 2011 with using spacecarft identifier LANDSAT_5 and WRS path of 127 and row 56. Besides that, Interferometric synthetic-aperture radar (IFSAR) data from United Stated Geological Survey (USGS) was also used . Other than that, landuse, slope, topography data map from year 2009 until 2019 from Department of Surveying and Mapping Malaysia (DSSM) and Department of Mineral & Geoscience (JMG) was also required in order for make an evaluation on that particular area.

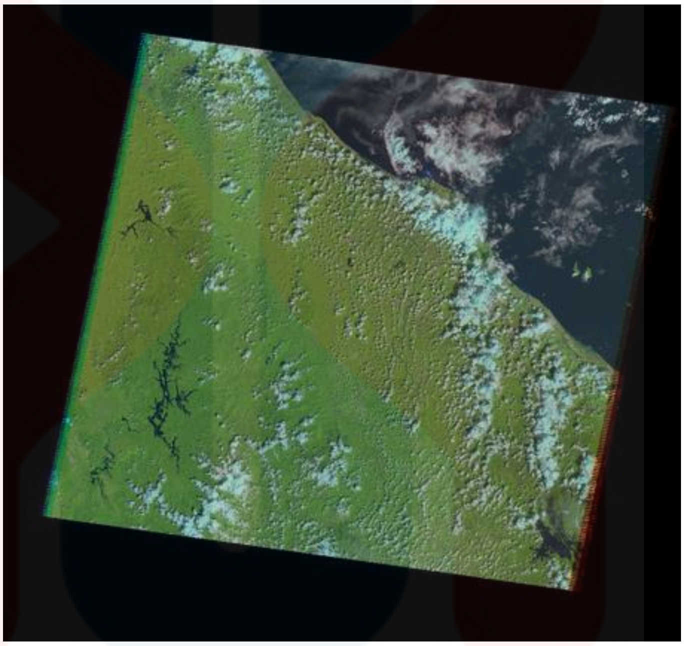

Figure 3.1 : Satellite image of Landsat_5 TM

Sources: United States Geological Survey (USGS)

3.2.1 Slope Map

Based on the secondary data evaluation which is the satellite imagery, the result that can be identified is the slope degree. This depicts a slope distribution dependent on the angle. The incline is classified using the Zuidam classification, 1985

3.2.2 Aspect Map

An aspect map is a diagram showing the direction and degree of steepness for the terrain on the slope. The map was generated by using the ArcGIS from the data USGS website.

3.2.3 Drainage Density Map

From the USGS satellite images, the drainage density can be generated due to its importances to shows the erosion rates. The hillslopes does effect the process of the runoff erosion. Lastly, the research method specifically for the software is ArcGIS to generate the landslide susceptibility map.

3.3 Methodology

In order to prepare landslide susceptibility maps, the study approach was applied in five steps which are preliminary research, literature review, data collection, data interpretation and data analysis. In order to classify the possible zoning area of landslides based on the probability process, the secondary data collected will be divided into different parameters.

The landslide susceptibility area was developed as the final product and evaluation was carried out. Using the reclassification software in ARCMAP, it was translated from the secondary data set into a raster. The raster can then be tested from low to high landslide risk into three distinct zoning groups. Figure 3.2 shows the overall research flowchart.

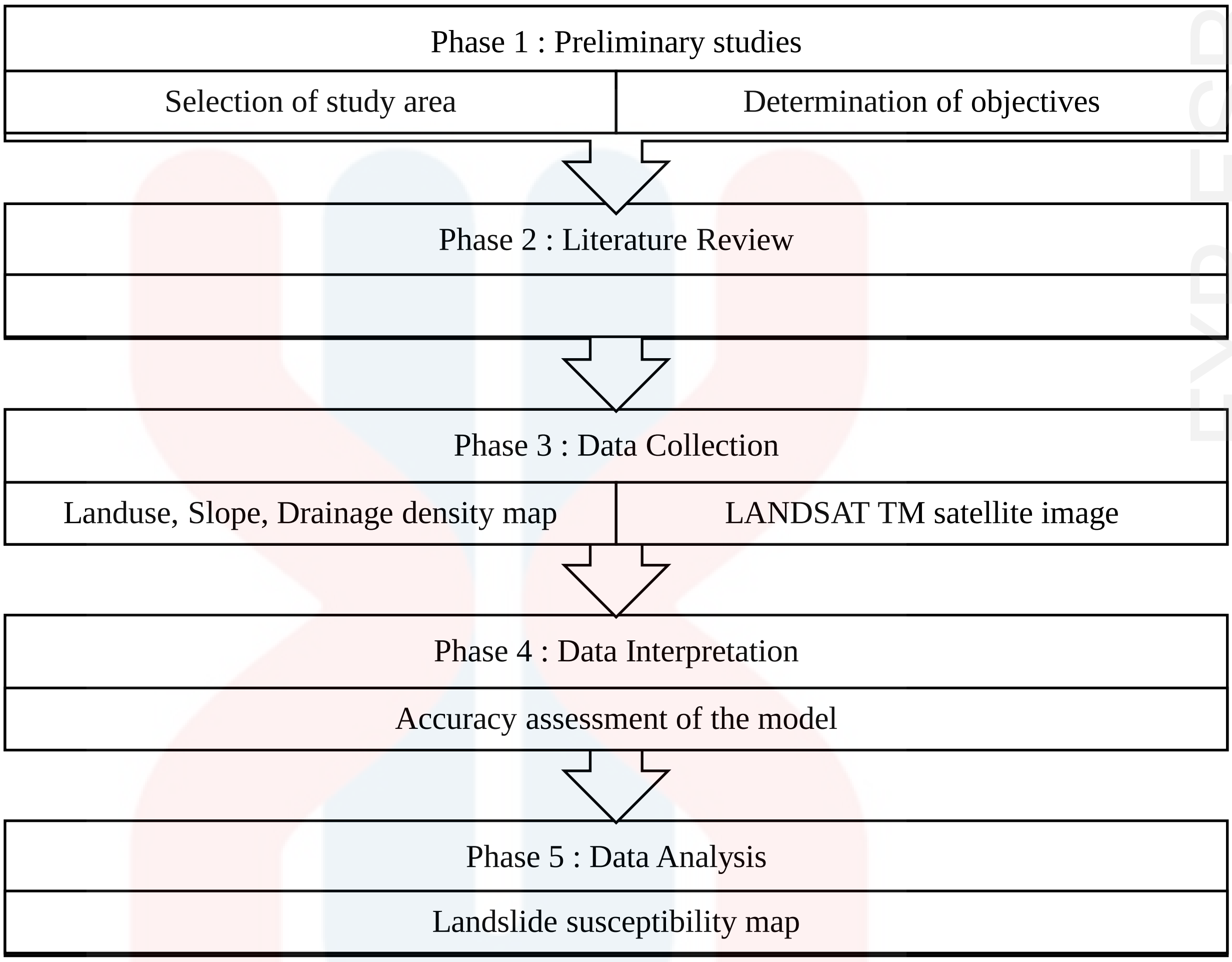

Figure 3.2 : overall research flowchart

3.3.1 Preliminary Study

The first step is to do preliminary studies. This is an action that needed to be done before interpretation, where the selection of study area must be done and determination of objectives in order to design the flow of the research. The reason why there is a need to study the previous researcher data is because in order to fill the research gap and we could see which part is have to be not focused about. Next step is identifying literature review by determining the problem statement and collecting some references of past study in order to support data collection in for later interpretation. It is very important to always have the references beforehand so that the research project analysis does not falling apart and still keep on track.

3.3.2 Data Collection

The third step is data collection stages where the geomorphology, cross section map, stratigraphy column were generated by interpreatation the satellite images, topography map, landuse and soil intensity map from previous researchers data.

In data collection, parameters of lithology, drainage, aspect and slope angle need to be extracted and identified in order to produce the landslide susceptibility outcomes.

A. Slope angle

Slope angle does correlate with the gravitational force. Hence, rather than steep slope, a steep slope is more prone to fall. The classification of slope in this study is divided into four which is class I (0-15^0), class II (16-25^0), class III (26-35^0) and class IV (>15^0)

B. Lineament

Straight characteristics such as faults, line sinkholes and volcano lines will describe the lineament. In this lineament of landslide research, the occurrence of cracks in the rocks that affect the stability of the slope is associated. The lineament classification is based on five categories depending on the distance from lineament in meters (m) unit; class 1 (100m), class 2 (200m), class 3(300m), class 4 (400m) and class 5 (>400m).

3.3.3 Data Processing

Landslide susceptibility mapping has recently been made possible due to the availability and diversity of remote sensing data and thematic layers as causative factors using GIS. Many of these landslides are referred to in the humid tropical mountain environment as significant geomorphic processes that usually form an essential feature of landscaping.

Next, the locations and even characteristics of past moving landslides should be analyzed in the landslide inventory charts, although they normally do not show the mechanism that caused them. Therefore, stock maps provide useful data on the spatial distribution of existing landfill locations and the potential for future landfill slides. These techniques were used to identify landslides in the study field. The first approach was to directly compare the DEMs and IFSAR raster images using overlying landslide vector images. This is to differentiate landslides from other types of land cover in the surrounding area. The final solution is to separate the landslides using segmentation and classification from the other types of land cover in the surrounding area.

3.3.5 Data Analysis And Interpretation

The fourth steps in research methodology is data interpretation based on the area under the Curve (AUC).In this analysis it is used to assess the model's accuracy. A cumulative landslide ratio graph is compared to the cumulative landslide pixel percentage for Aring Gua Musang for this reason. The precision of the results of the study for this area was determined by the AUC values obtained from each of the graphs plotted. Other than that, all the data from geomorphology map, topographic map, stratigraphic column and cross section is interpreted in order to proceed the last step which is data analysis where the landslides zonation area could be done for further benefits in the future.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

Geological mapping elements that include geomorphology, structural geology, stratigraphy and historical geology of the study region are included in these general geology segments. By comparing and correlating between all previous research studies and also the general knowledge based on the paper, journal and so on where all the data obtained is analyzed. Geomorphological studies involves the research on the surface of the Earth, drainage, contour pattern, weathering and processes leading to the origin and the development of the Earth. In addition, the research are also featured topography and drainage pattern.

Meanwhile, stratigraphy does included the identifying the type of lithologies as well as in generating the geological map in the study area. It is as important as knowing the historical geology where the depositional environment and its formations could be learned. In the structural geology, any geological structure that could be verified at the study area such as fault, fault and other mechanism of structure could be a head up starts to any forces exerted on that area. Other than that, the historical geology of the study area was disputed that varies from the formation, deformation of Earth at that area with the lithologies.

4.1.1 Assessibility

The study area can be reached by the Kota Bharu-Gua Musang highway to the west of the Jalan Felda Aring route. The road is the main road that leads to the citizens of that city. It took approximately 30 minutes to get there by car and approximately 1 hour from Gua Musang City to enter the study area by driving. There is also an office situated in the middle of the study area where mostly of the workers had their house nearby the office at FGVPM Aring 6. Aring is mostly covered with a palm oil estate so the main economy resources for the people there would be as a estate worker. Forests with the highest elevation of 400 meters cover the north of the study region.

4.1.2 Settlement

Settlement is a place where community in which people live. For Aring settlement, the community mostly works as a estate workers or FELDA workers. Thus, the settlement is being built for them. There also a river located in the middle of the study area named as Sungai Aring and the width of it is about 40 to 80 kilometers which widens toward south with approximately 9 kilometers long in length. The river flows from the higher elevation area of Taman Negara Kuala Koh which is situated nearby the area.

4.1. 3 Forestry

Gua Musang Forestry in Aring is well known as a land area for the development of vegetation such as palm oil plantation and rubber tree plantation. Two agencies, KESEDAR and FGV SDN BHD have handled this production.

4.2 Geomorphology

In geological mapping evaluation, geomorphology is a significant factor, as it could define the physical structure or characteristics of the Earth's landforms covering rivers, hills, plains and others. In the area of research, the processes of the development of such types of landforms are also being studied.

4.2.1 Landform

Topography map plays an important role in analyzing the natural and man-made geological features at that area. The topographic map uses the contour lines acts as a shape of Earth’s surfaces and also includes the distinct features such as roads, lakes, buildings and many more. Contours could also display the elevation.The topographic map of the study area was created in digital geographic model using the Triangular Irregular Network (TIN) in the ARCGIS software and is based on the elevation of the contour. Broad

Topographic units can be identified based on the differences in elevation in the study area based on Figure 4.1. Table 4.1 describes the landform classification by the elevation in meters above sea level.

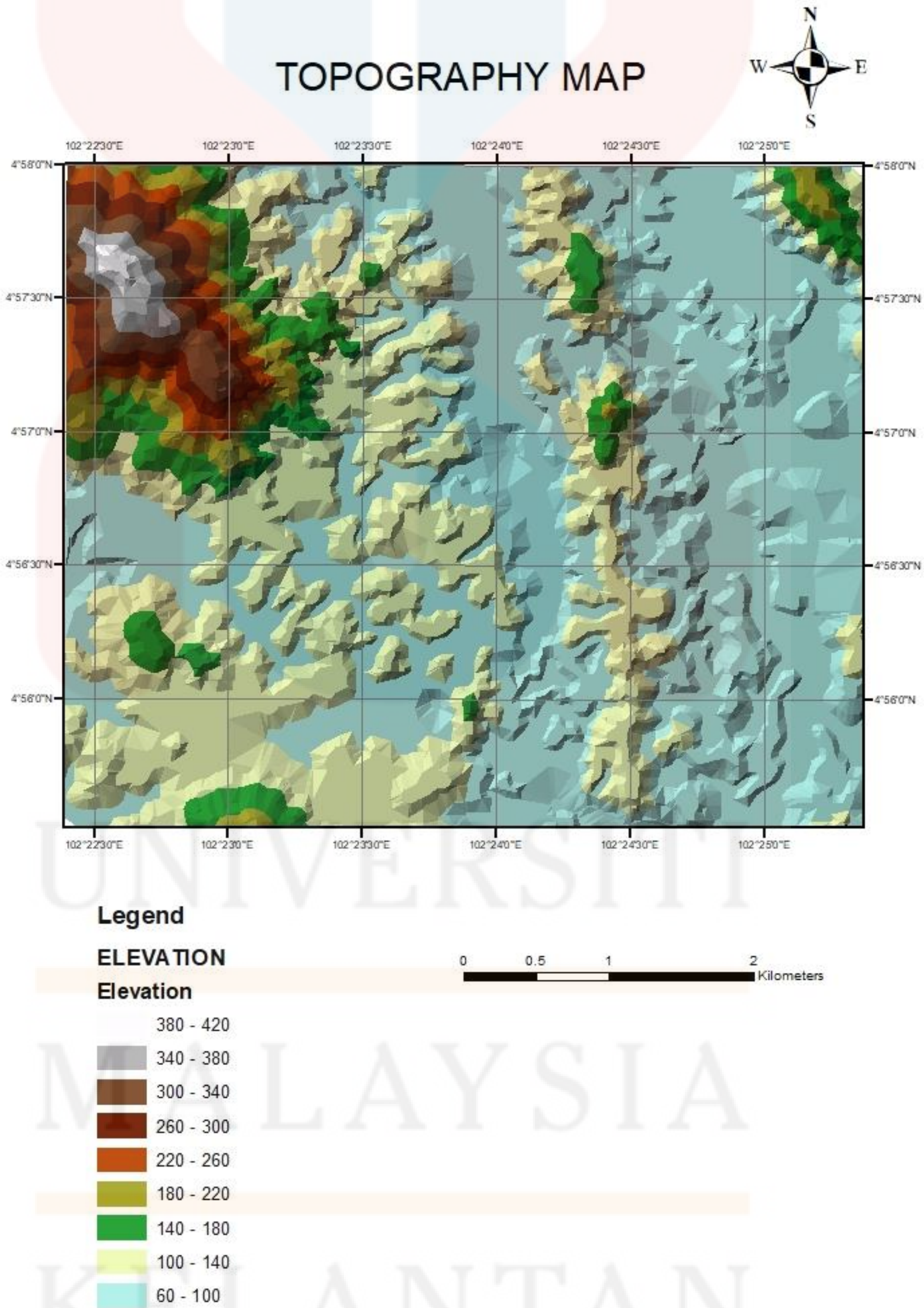

Figure 4.1: Topography map

Table 4.1: The landform classification

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

(Sources: Van Zuidam, 1985)

4.2.2 Drainage Pattern

The drainage pattern is the configuration of a stream on the Earth's surface by a drainage system. It was created by streams, rivers and lakes particularly for the drainage basin. The rock underneath the Earth established the pattern of drainage such as dendritic, parallel, trellis, rectangular, radial, centripal and deranged pattern.

There are two types of drainage pattern that can be observed at the study area which are dendritic and rectangular pattern. Dendritic pattern is the most typical pattern of drainage that is joined together as a branch of trees. It was developed when the river canal follows the slope of the terrain. The lithology underpinning this pattern is a homogeneous substance. The lithology found in the dendritic pattern research region is sandstone (Figure 4.2)

A pattern of rivers formed by steep slopes with some type of relief is the parallel drainage scheme. The streams are swift and straight because of the steep slopes, with a few tributaries all flowing in the same direction. Simultaneous patterns of drainage form where the soil has a prominent slope. A similar pattern, such as outcropping resistant rock bands, also occurs in parallel, elongated landform areas. A similar pattern, such as outcropping resistant rock bands, also occurs in parallel, elongated landform areas. The watershed can be described as the region or ridge of land dividing the water from which it flows into different basins, rivers or seas. It also includes rivers, lakes, reservoirs and wetlands and all the groundwater around them.

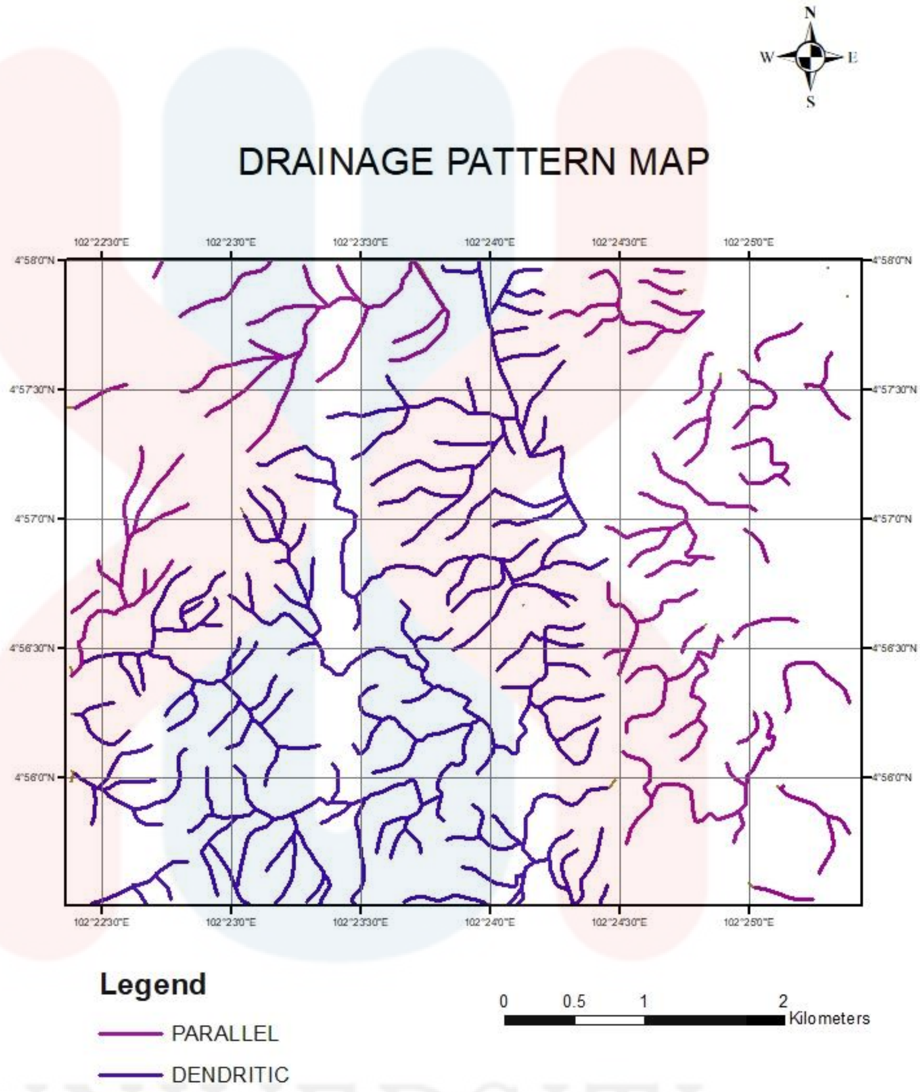

Figure 4.2: Drainage pattern map

4.3 Stratigraphy

Stratigraphy is an observation of the strata of rock and its layering. The features of the layered rocks and the relationship between the layered rocks and the age of formation have been analysed and established. Lithostratigraphy is one of the sub-disciplines of stratigraphy. It involves the analysis of the rock layer and explains the interaction between the formation of igneous and sedimentary rocks.

4.3.1 Lithology

Lithology is where it is the study of the description of physical characteristics of rocks based on the characteristics such as colour, grain size, type of rock and mineral contain. There are three main lithologies in the study area which are limestone unit, tuff unit and sandstone unit. The lithologies does divided into two period time which are varies from early to late Carboniferous to Quaternary. Figure 4.3 shows the distribution of lithologies based on the previous researches.

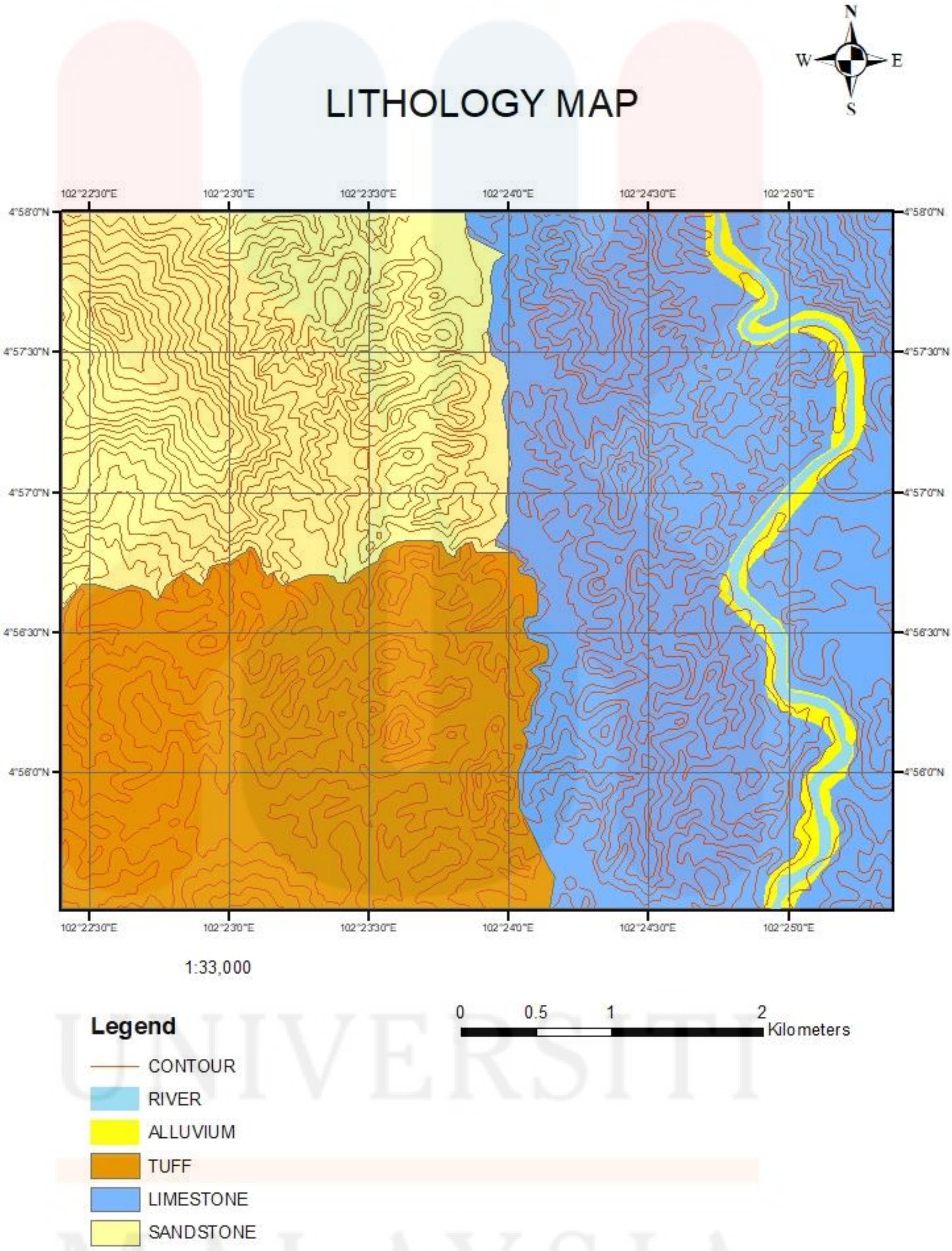

Figure 4.3: Lithology map

Table 4.2: Stratigraphic column

Formation	Era	Period	Rock unit	Description
	Cenozoic	Quaternary		Alluvium
Aring formation	Paleozoic	Early to Late Carboniferous		Sandstone
				Pyritifeceous tuff interbedded with rhyolitic to andesite lava and limestone dominated by pyroclastic rock.
				Limestone

a. Limestone

Limestone rock is one of the sedimentary rocks which composed of calcium carbonate ($CaCO_3$). Limestone can only be represented in a restricted way in the field that can be defined by the analysis of thin parts and peels. The three elements are carbonate grains, micro-crystalline calcite and cement. The primary grains are bioclasts, ooids, peloids and intraclasts.

Some limestones consisting of sand-sized carbonate grains that have traveled through the sea floor closely related to sandstones while others can be compared to mudrocks. The growth of carbonate skeletons in reef limestones or the trapping and binding of sediments by microbial mats such as algal mats in stromatolites and microbial laminites where make all limestones in situ.

The carbonate grains in current sediments consist of aragonite, heavy magnesium calcite and low magnesium calcite. Limestone is typically composed of low-magnesium calcite with original aragonite elements substituted by calcite and magnesium missing from the original high-magnesium calcite. Aragonite grains are rarely preserved, and only as fossils of impermeable mudrock instead of limestone.

b. Sandstone

Sandstone is a sedimentary rock consisting of mineral material, rock material and organic sand material. One of the most common examples of sedimentary rock found worldwide is sandstone. It was bound by cementing material that keeps the sand grains together and may contain a particle matrix of silt or clay that occupies spaces between the sand grains.

The sandstone distribution is primarily a result of the study area's geology and climate. Mechanically and chemically, some grains and minerals are more stable than others. Minerals, in decreasing order of durability, are quartz, muscovite, microcline, orthoclase, plagioclase, hornblende, biotite, pyroxene and olivine. Compositional maturity, where immature sandstones contain several fragile grains such as rock fragments, feldspars, and mafic minerals, is a useful term. Quartz, some feldspar and some rock fragments consist of mature sandstones, while supermature sandstones consist almost solely of quartz.

The accepted classification of sandstone is based on the percentage of the rock's quartz, feldspar, rock fragments and matrix. Sandstones containing an extra non-detrital portion such as ooids, bioclats and many more carbonate grains are referred to as hybrid sandstones and are defined in subsequent sections. Sandstone compositions are based on a modal analysis calculated by a petrological microscope and a point counter from a thin section of the rock.

c. Tuff

Tuff is a volcanic substance formed during the explosive eruption of a volcano. The eruption typically produced rock, lava, magma and other materials from its vent. Tuff has been carried by air and falls down to the earth. The thickest layer of tuff typically means that it is close to the volcanic vent, since the tuff is thin and easy to move in the air. The decrease in thickness reflects the distance from the volcano itself. Tuff welded the sticky or loose surface together.

4.3.2 Stratigraphic Position

Stratigraphy or lithostratigraphy is where the rock layer has been identified by its lithology which is closely related to the age of the strata. Lithostratigraphy was required to determine the history of the region and its age. The lithology of rocks has been categorised according to the stratigraphy of the region.

4.4 Structural Geology

Structural geology questions about the geological features created by tectonic changes that cause deformation. It is important to study the geometry and examine the Earth's tectonic activities as well as the stress and strain of the rock. The past of the Earth can be discovered by understanding the structural geology. Deformation allows fault, bend, joint, bedding, and veins to occur. Deformation of the Earth can be observed by geological mapping and linear analysis using a land chart. The structural geology at the study area does varies from the assessment of the lineament.

4.4.1 Lineament Analysis

Lineaments provide information about the geological structure of a longitudinal or straight line on Earth. Using a satellite image or aerial photograph, the surface of the ground expresses faults and other features on a wide scale. Lineament has been split into two categories, which are positive and negative. The positive lineament was presented by ridge and range, while the negative lineament showed streams, faults and valleys. Lineament research was conducted prior to geological mapping to identify geological features such as slip loss, fault, bending, and joint (Figure 4.4)

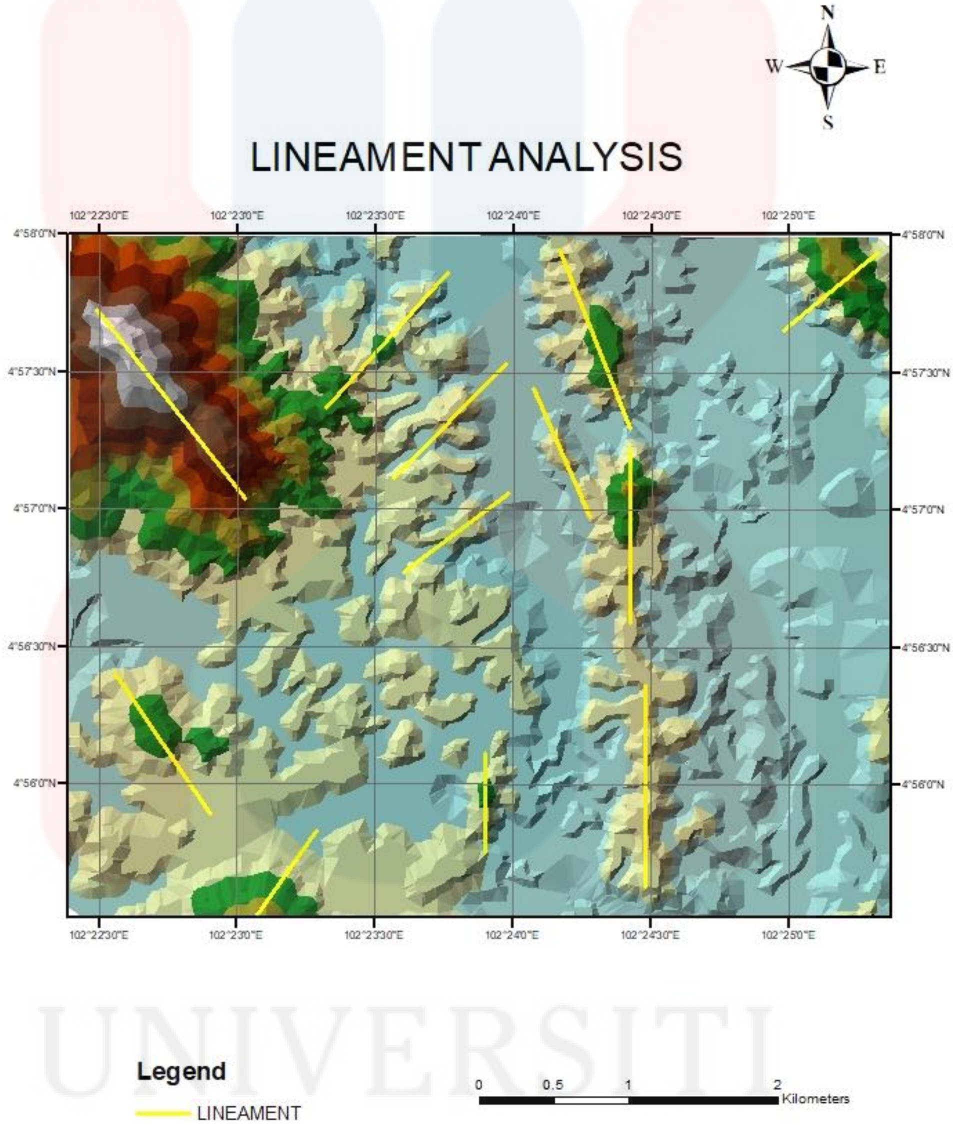

Figure 4.4: Lineament Map

4.5 Historical Geology

The formation of Aring was implemented for the mainly pyroclastic series in the Sg. Valley of Lebir, the lower reaches of the Sg. Aring and Sg. Relai in the south of Kelantan. Fossil data suggests the period from late Carboniferous to early Triassic. The overall thickness of the entire moulding is 3,000 metres and the top portion of approximately 1,000 metres, interspersed with slate or tuffaceous limestone is designated as the Paloh member. It is uncompromisingly overlain by the Telong Formation and where it is absent, by the Koh Formation. The position of the sort is along the Sg. Relai and Sg. Nuar, a tributary of Sg. Lebir. The unit is named after the Sg Aring, the next tributary of Sg. Lebir

CHAPTER 5

LANDSLIDE SUSCEPTIBILITY ASSESSMENT

5.1 Introduction

In this chapter, the landslide susceptibility assessment was analysed and classified into three classes which are low, medium and high. Thematic map of each parameters such as lithology, slope, aspect, landuse and drainage density were generated by using the digital elevation model (DEM) data from previous researchers. The cumulative weightage score of each parameters were selected and calculated into the Table 5.1 to determine the landslide susceptibility area.

5.2 Parameter Of Landslide Causative Factor

Table 5.1 indicates all parameters and weightage that was used to produce landslide susceptibility map.

Table 5.1 : The parameters of the research study

No	Parameters	Weightage (Wi)
1.	Lithology	7
2.	Aspect	9
3.	Slope	10
4.	Drainage	8

5.2.1 Lithology

Lithology among the parameter that was used to calculate the vulnerability of landslide occurrence in the field of study. Differences in lithology have played an important role where the region is prone or vulnerable to landslides. The lithological environment and formation distinguish the features of rock and soil. At the study area, there are four types of lithologies which are limestone, sandstone, tuff and alluvium which had been explained earlier in chapter 4 (Figure 4.3). Each of the lithologies does represent the structure and the formation on that area. In this case, all the lithologies does overlays in the same formation which is Aring Formation while alluvium is in the quaternary period (Table 5.2)

Table 5.2: Weightage and score for lithology

No	Lithology Class	Weightage (Wi)	Score (Sij)	Weightage x Score (Wi x Sij)
1	Limestone	7	1	7
2	Sandstone	7	2	14
3	Tuff	7	3	21
4	Alluvium	7	4	28

5.2.2 Aspect

In this map, it is generated from DEM data where it is divided into 8 classification of slope direction that due to the North (Table 5.3). The parameter does implement in order to observe the direction of slope where it show the gravitational force based on the orientation of slope. It is measured counter clockwise from the 0 degrees in North to 360 degree. Figure 5.1 shows aspect map of the study area.

Table 5.3: Weightage and score for aspect

No	Slope direction	Weightage (Wi)	Score (Sij)	Weightage x Score (Wi x Sij)
1	North-Facing (0 – 22.5) (337.5 – 360)	8	1	8
2	North-East (22.5 – 67.5)	8	3	24
3	East-facing (67.5 – 112.5)	8	5	40
4	South-East (112.5 – 157.5)	8	6	48
5	South-facing (157.5 – 202.5)	8	9	72
6	Southwest-facing (202.5 – 247.5)	8	6	48
7	West-facing (247.5 – 292.5)	8	5	40
8	North-West (292.5 – 337.5)	8	2	16

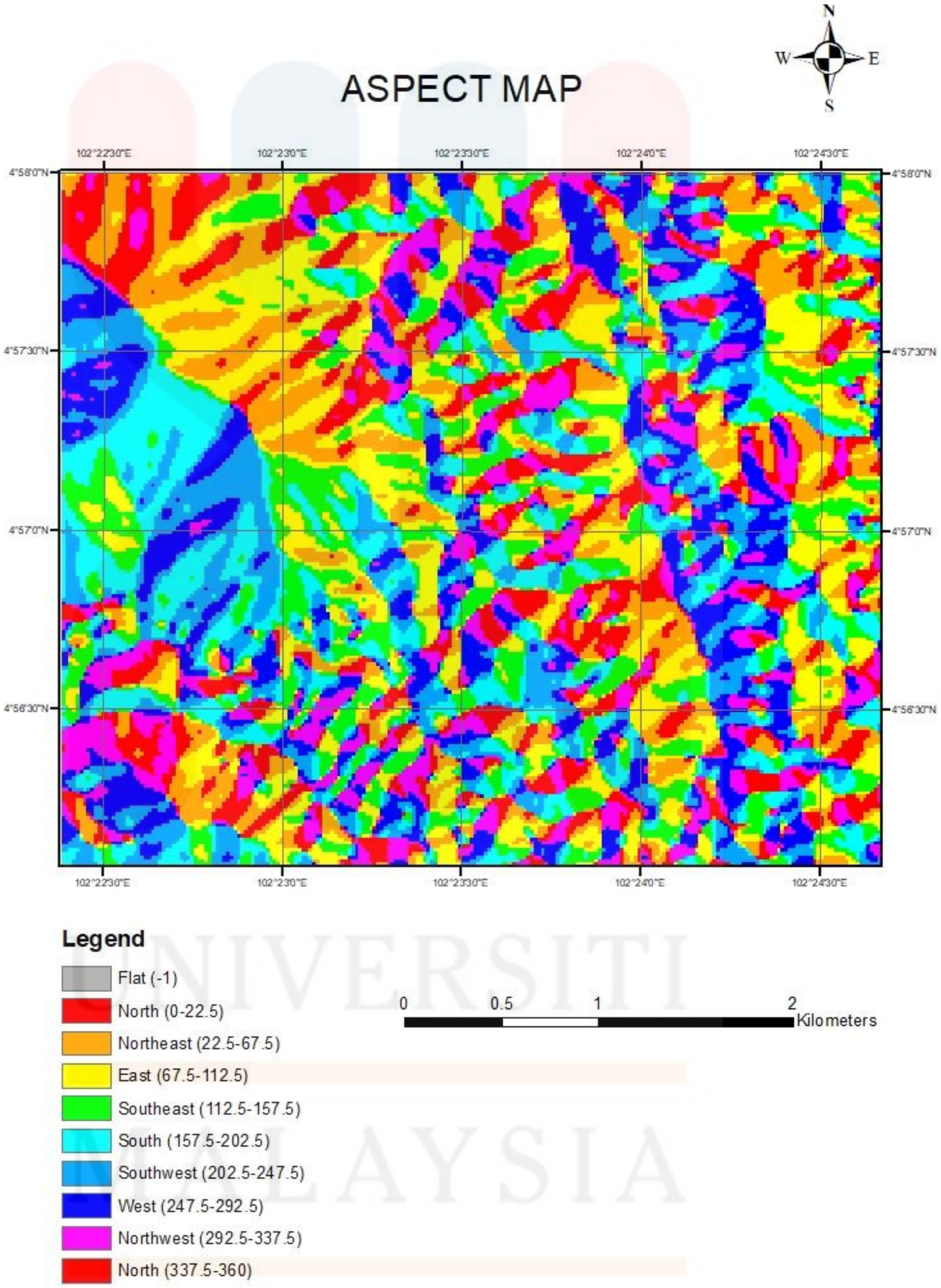

Figure 5.1 : Aspect Map

5.2.3 Slope

Landslide is the rock, debris or earth's mass movement down a slope. Gravity affected the down-slope movement of the soil and rock. The effect of down-slope forces leads to low or decreased power. Slope is an important parameter in the study area for evaluating the susceptibility to landslides (Table 5.4)

Table 5.4: Slope Classification

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

(Sources: Geology Society Malaysia, 2004)

The slope weighting and ranking is broken down into six using the Geology Society Malaysia (GSM) slope classification with 10 weighting ratings. This is because the slope aspect gives the frequency of landslides a strong impact. With the rise in the degree of slope, the scores increase. Table 5.5 refers to the weightage of the slope that have being classified into 6 different classes varies from different angle from 0º to more than 35º. The previous landslide reveals that during the geological mapping that not only did the landslide occur on a very steep slope but also on a mild slope. This was possibly linked to another parameter picked. Figure 5.2 represents slope map of the study area.

Table 5.5: Weightage and score for slope

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

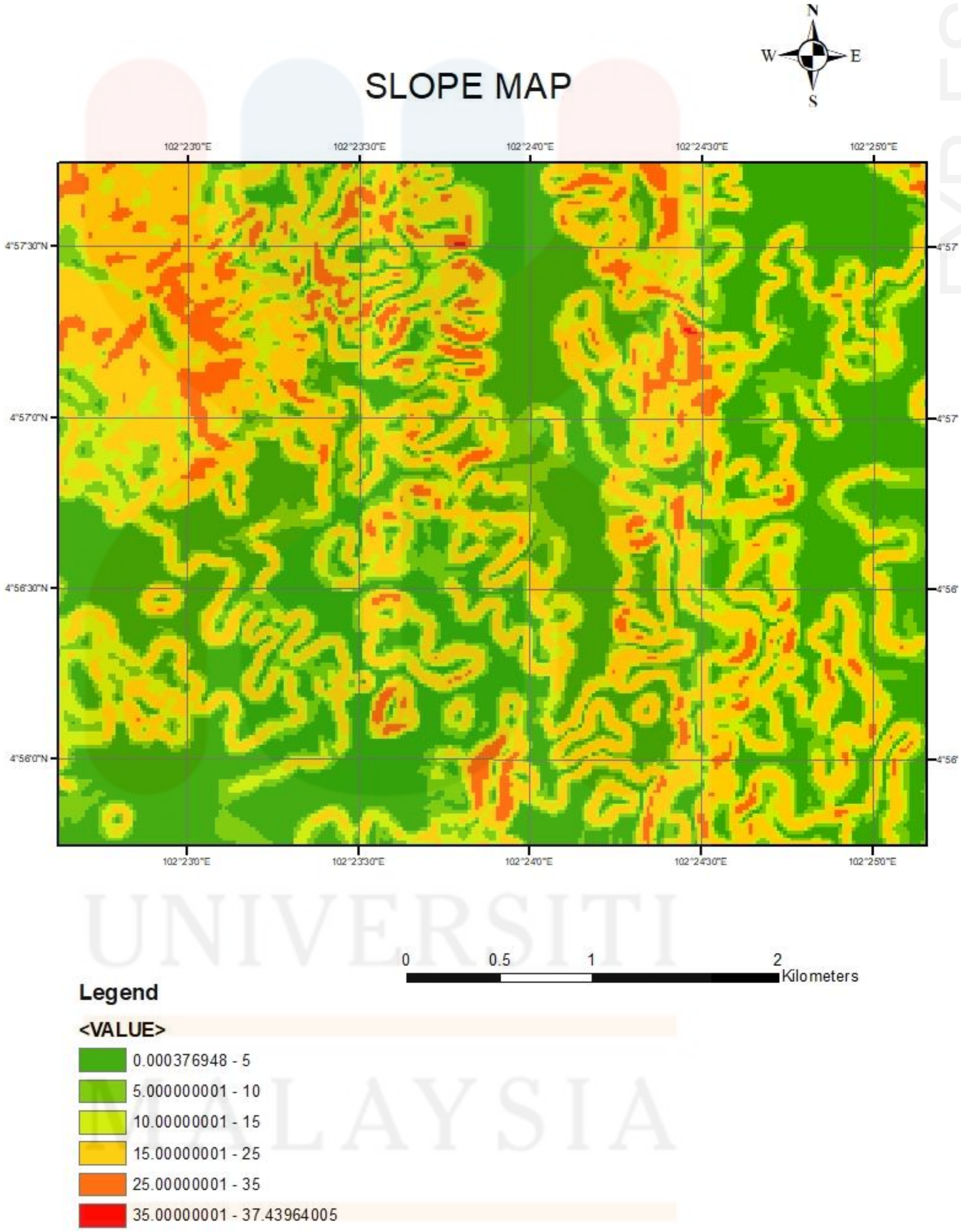

Figure 5.2 : Slope Map

5.2.4 Drainage Density

The drainage density refers to the total stream and river length of the drainage basin, which is divided by the total drainage basin area. Climate, topography, soil infiltration, vegetation, and flux density have affected drainage variation. The determination of the fluvial network in the study region is crucial. Due to rainfall penetration, the prone region of landslide to occur can be determined in the scope of debris flow and seepage.

The drainage density map was extracted from ArcGIS DEM results. The stream length divided by area is drainage density. The drainage density has been graded into three groups which is low, moderate and high (Table 5.6). The high drainage density suggests the great potential for the occurrence of landslides. This is because there is a high degree of surface runoff. Figure 5. 3 shows drainage pattern of the study area.

Table 5.6: Weightage and score for drainage density

No	**Drainage Density**		**Weightage (Wi)**	**Score (Sij)**	**Weightage x Score (Wi x Sij)**
1	Low	0–84	9	4	36
2	Moderate	455 – 145	9	6	54
3	High	911 – 207	9	8	72

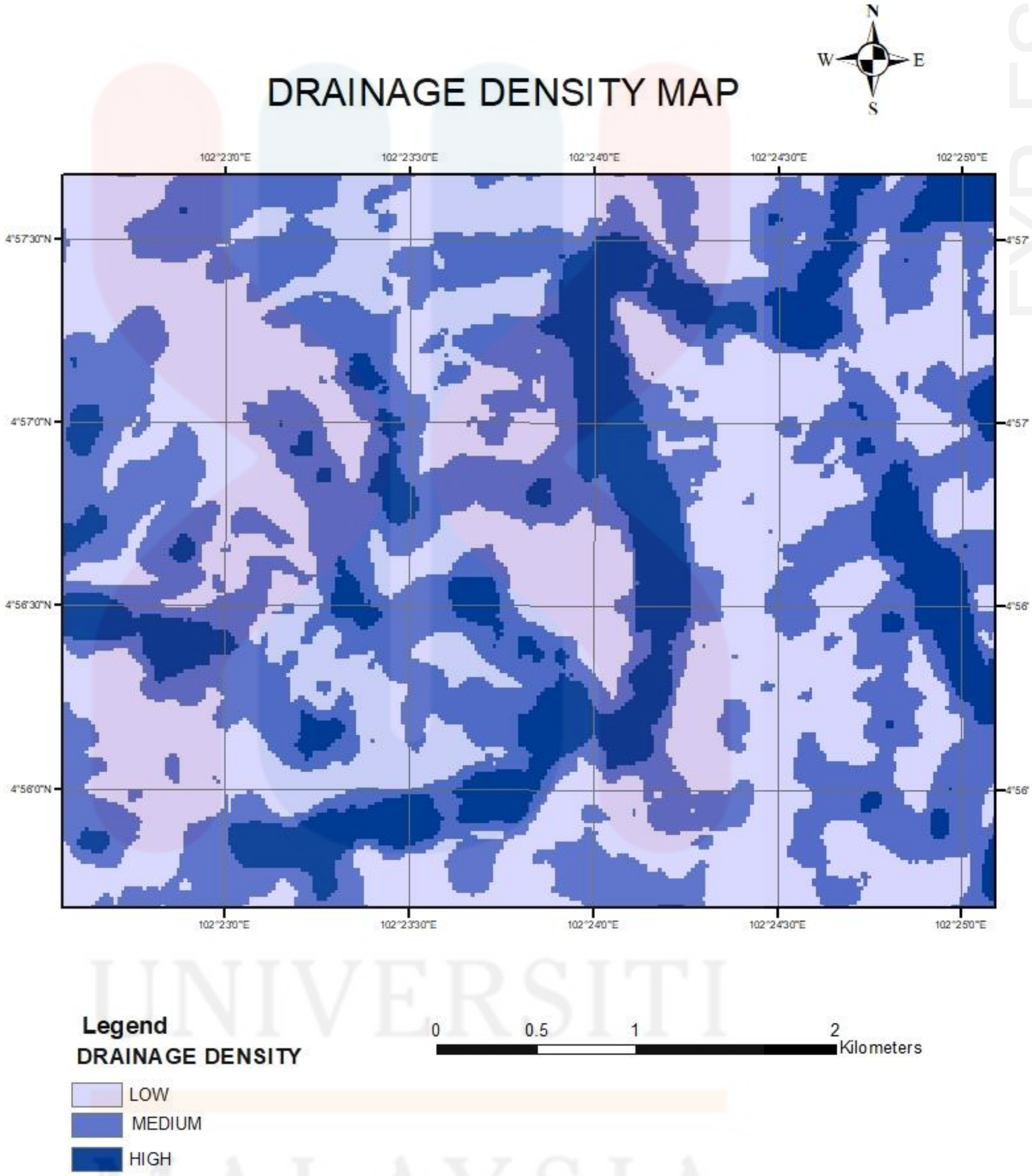

Figure 5.3: Drainage Density Map

5.3 Factors That Affecting Landslide

A variety of factors may be a factor that caused the landslide. The strength of rainfall is recognized as the primary factor in the study area that caused landslides to occur every year. Excessive rainfall, especially in an area with thick and weathered soil, may cause landslides. The excessive amount of water that slides through the bedrocks, causing landslide, leaves when rainfall poured intensely and filled the porosity and void in the soil. Figure 5.4 shows the annually average rainfall distribution based on the Cameron Highlands tower that is situated abour 80 kilometers from Gua Musang.

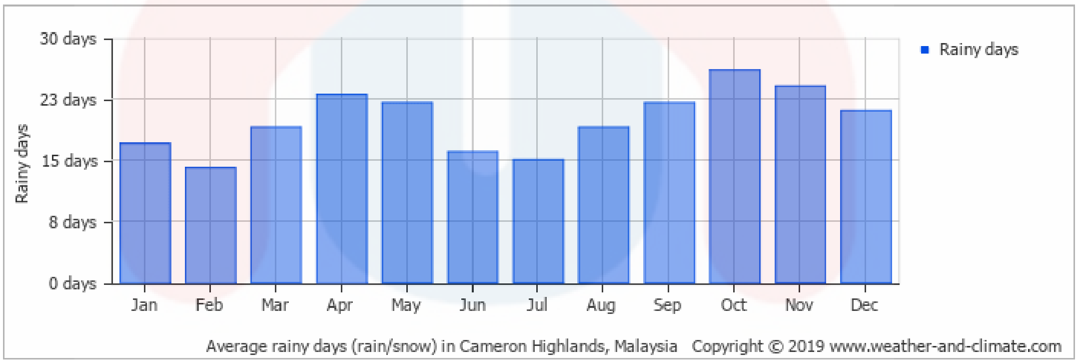

Figure 5.4 : Annual Average Rainfall Distribution

5.4 Landslide Susceptibility Analysis

Before produce the landslide susceptibility map, all selected parameters have been transform into the raster data set. The weighting of such raster data was then reclassified. Using the GIS application, the landslide susceptibility map was prepared using the weightage overlay process. Lithology, slope, aspect and drainage density are the parameters of the landslide causative factor chosen. In the study of landslide susceptibility, slope, lithology and drainage density play an important role and become parameters that have a strong effect. The steeper rate of slope has a greater tendency for landslides to occur. As the rock and soil that formed in the region have distinct porosity and void, the lithology also affects the landslide. Table 5.7 shows the value of area of percentage from three different classes which are low, moderate and high. Figure 5.5 shows the landslide susceptibility map of the study area based on the data collection on the four parameters raster class.

Table 5.7: Susceptibility of landslide hazard in the study area.

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

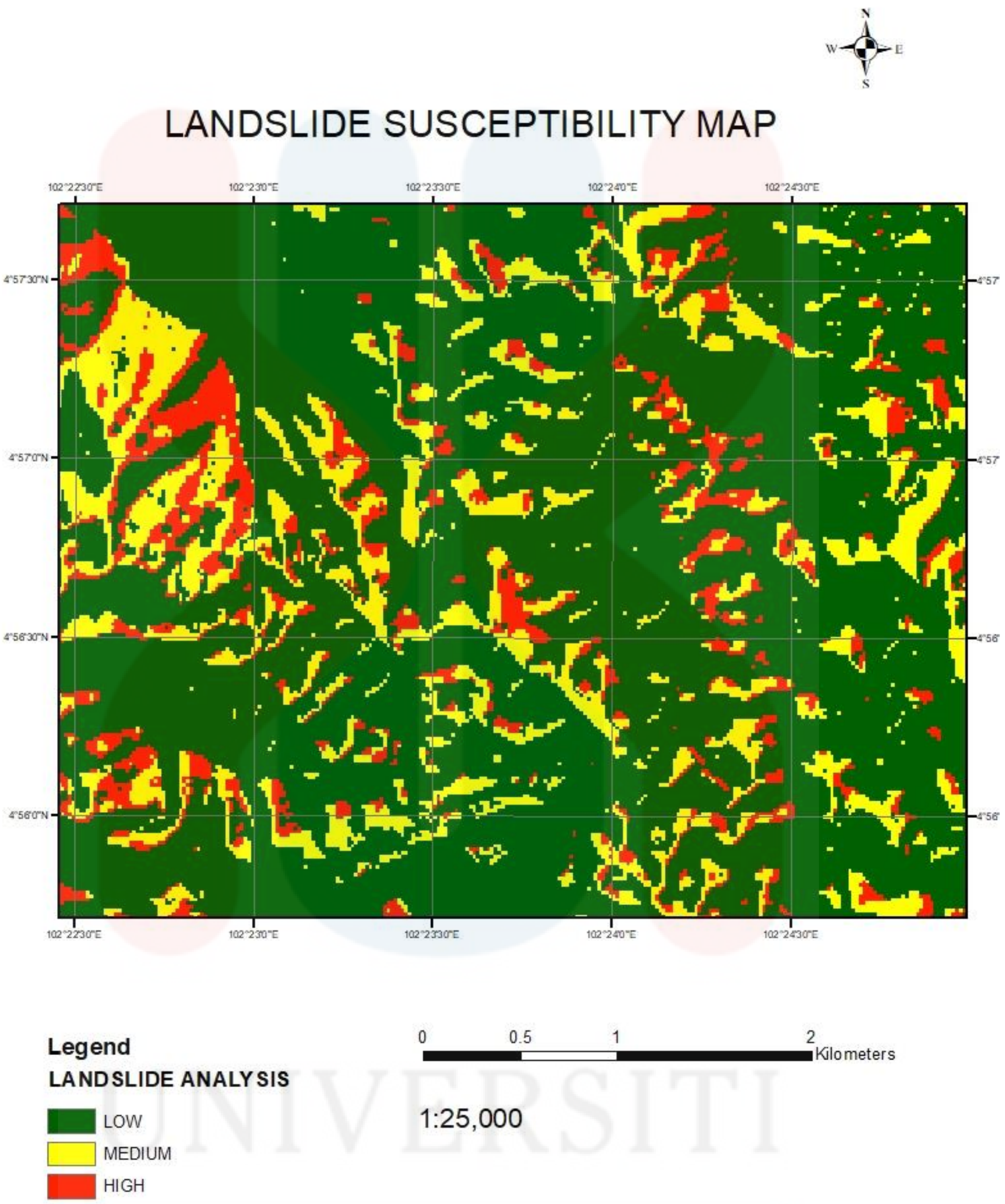

Figure 5.5 : Landslide Susceptibility Map

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In conclusion, the research does influence the potential susceptibility of landslide of Aring 6, Gua Musang Kelantan. A geological map of the study area with detailed informations based on the lithology which are sandstone, limestone and tuff unit which in the Aring formation has been updated. The stratigraphy position of the study area were discussed. The objectives of this research study has successfully being accomplished as the map of the study area with the scale of 1:25 000 are being updated with all the information gained. The landslide susceptibility map of the study area is also have being produced with the identification of the landslide zoning area based on the three zoning classes which are low, medium and high.

The parameters has been classified which are lithology, slope, aspect and drainage density in order to produce the landslide susceptibility map of the study area. By doing this research, the awareness towards the area that prone to have high possibilities of landslides could be spread among the society so that any prevention and new landmark estimation could be done

With the accurancy of the map that had successfully produced, it is hope that the authorities such as contractors and the person in charge in mitigation and disaster planning can make a right decision for a better planning in the future.

6.2 Recommendation

Based on the limitation in the execution of this study, a number of recommendations for future studies are listed. Prior to geological mapping, a literature review of the historical history of the research area should be done and well understood. In order to obtain adequate field data within the time allocated, general knowledge of structural geology and lithology needs to be established. By doing so, more quality geological maps of the study area at a scale of 1:25000 can be provided.

In order to obtain a better outcome of the landslide susceptibility map, it is recommended that the appropriate parameters for the study area is rightly chosen as the parameter can contribute to the vulnerability of the test area to the landslide. Different parameters lead to different results where the impact can be associated with the most.

Other than that, for the purposes of the weighted overlay process, it is recommended to use different methods. The use of a predictive and heuristic technique or a landslide susceptibility model that is statistically based may be used. This is because different analytical methods can lead to greater precision in the sample field's sensitivity. From the landslide susceptibility map, a proper mitigation and construction scheme can be considered prior to any development decision, especially in Aring.

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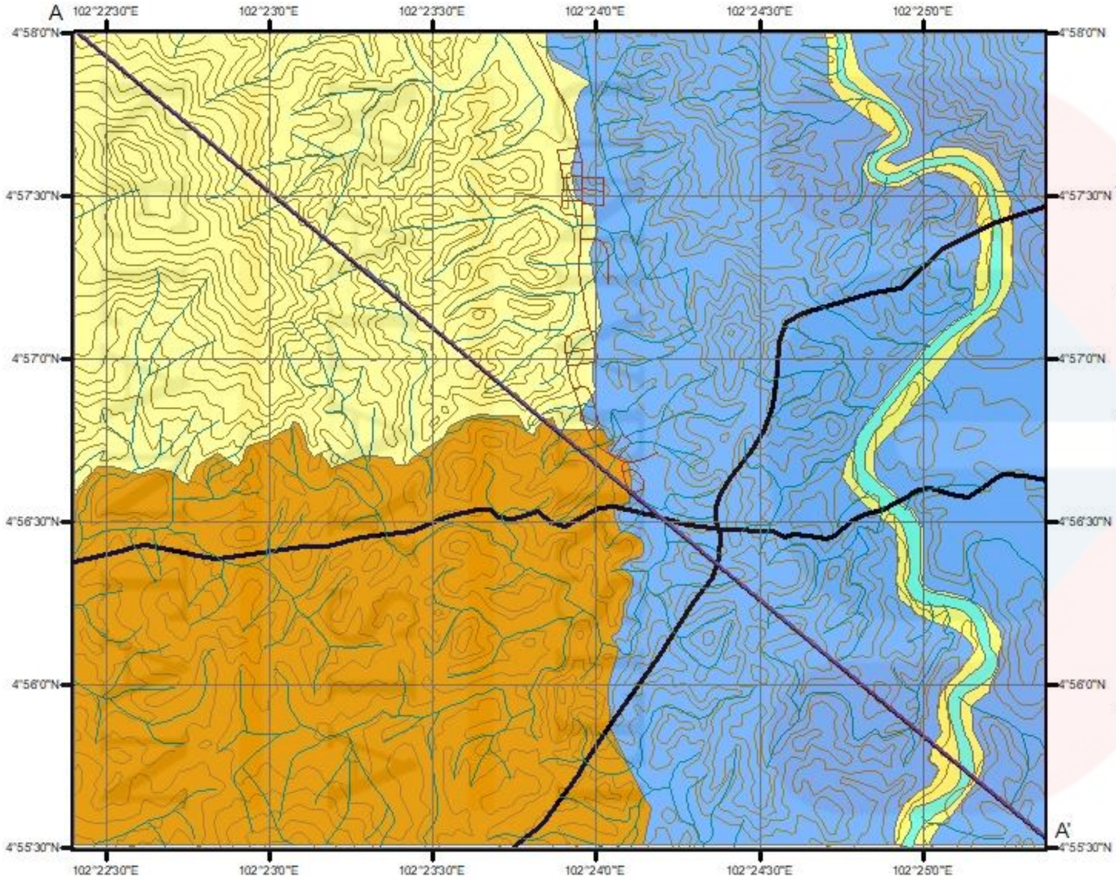
GEOLOGICAL MAP OF ARING 6



Formation	Era	Period	Rock unit	Description
	Cenozoic	Quaternary		Alluvium
Aring formation	Paleozoic	Early to Late Carboniferous		Sandstone
				Pyritifeceous tuff interbedded with rhyolitic to andesite lava and limestone dominated by pyroclastic rock.
				Limestone

Legend

- CONTOUR
- MAIN RIVER
- ALLUVIUM
- SANDSTONE
- TUFF
- LIMESTONE
- SECTION AB
- TOWN
- MAIN ROAD
- TRIBUTARIES