GEOLOGY AND LANDSLIDE HAZARD ZONATION BY USING GIS AT KAMPUNG KUNDUR, GUA MUSANG, KELANTAN.

By

MOHAMMAD AMEER FARHAN BIN ROSLI

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

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DECLARATION

I declare that this thesis of Geology And Landslide Hazard Zonation By Using Gis At Kampung Kundur, Gua Musang, Kelantan is a result of my own research except of cited as references. This 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"

Signature : ………………………………………….

Name of Supervisor I : DR HAMZAH BIN HUSSIN

Date : ………………………………………….

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GENERAL GEOLOGY AND LANDSLIDE HAZARD ZONATION BY USING GIS AT KAMPUNG KUNDUR, GUA MUSANG, KELANTAN.

ABSTRACT

The research area is located at Kampung Kundur, Gua Musang, Kelantan. This study area are covered about $25km^2$.It is bounded by longitude line 101°54°00” E to 101°56°35” E and latitude line 4°55°90 N to 4°52°45” N. These research study was conducted to update the geological map of Gua Musang with the scale of 1:25000, to analyze the factor in the research area that is causing the landslide incidence and to generate landslide hazard zonation map of study area, Gua Musang with the scale 1:25000. These research study was carried out only using secondary data from online resource such as U.S Geological Survey Earth Explorer (USGS), ArcGIS and Jabatan Pengairan dan Saliran (JPS). The geological aspect that involve in this research study are study of geomorphology, stratigraphy, structural geology, and historical geology. From the landform analysis of the study area, consists of low hills area and hills area from 90 m - 290 m. The method used in generating the landslide hazard zonation map is using Geological Information System (GIS) which is using Weighted Overlay Method (WOM). In this research, five difference parameters generated and overlay based on the its importance in order to determine the tendency of landslides occurring in the study area. These factors are land use, slope, aspect slope, geomorphology and geology. The results showed that the landslide hazard zonation was divided to five classes of zonation. Class 5 is the highest hazard and most potential hazard, class 4 is a high hazard, class 3 is medium hazard, class 2 is low hazard and class 1 is no hazard. The resulting landslide susceptibility map identified five zones of susceptibility of landslide hazards, from very high hazard zone (4.7 %), high hazard zone (33.8%), moderate hazard zone (40.5 %), low hazard zone (18.4 %), and very low hazard zone (2.6 %). The outcome was confirmed by relating with the landslide occurrences in different classes.

Keywords:GIS, geological mapping, kampong kundur, landslide hazard zonation, weighted overlay method, landslide hazard mapping

GEOLOGI DAN ZONASI BAHAYA TANAH RUNTUH DENGAN MENGGUNAKAN GIS DI KAMPUNG KUNDUR, GUA MUSANG, KELANTAN.

ABSTRAK

Kawasan penyelidikan terletak di Kampung Kundur, Gua Musang, Kelantan. Kawasan kajian ini berkeluasan sekitar 25km2.Ia dibatasi oleh garis bujur 101^{o}54^{o}00 "E hingga 101^{o}56^{o}35" E dan garis lintang 4^{o}55^{o}90 N hingga 4^{o}52^{o}45 "N. Kajian penyelidikan ini dilakukan untuk mengemas kini peta geologi Gua Musang dengan skala 1: 25000, untuk menganalisis faktor tanah runtuh di kawasan penyelidikan yang menyebabkan kejadian tanah runtuh dan menghasilkan zonasi bahaya tanah runtuh peta kawasan kajian, Gua Musang dengan skala 1: 25000. Kajian penyelidikan ini dilakukan menggunakan data sekunder dari sumber dalam talian seperti U.S Geological Survey Earth Explorer (USGS), ArcGIS dan Jabatan Pengairan dan Saliran (JPS). Aspek geologi yang terlibat dalam kajian penyelidikan ini adalah kajian geomorfologi, stratigrafi, geologi struktur, dan geologi sejarah. Dari analisis bentuk muka bumi kawasan kajian, terdiri dari kawasan bukit rendah dan kawasan bukit dari 90 m - 290 m. Kaedah dalam menghasilkan peta zonasi bahaya tanah runtuh adalah dengan menggunakan Sistem Maklumat Geologi (GIS) yang menggunakan Kaedah Timbang Berat (WOM). Dalam penyelidikan ini, lima parameter berbeza dihasilkan dan dilapisi berdasarkan kepentingannya untuk menentukan kecenderungan tanah runtuh yang berlaku di kawasan kajian. Faktor-faktor ini adalah penggunaan tanah, cerun, cerun aspek, geomorfologi dan geologi. Hasil kajian menunjukkan bahawa zonasi bahaya tanah runtuh dibahagikan kepada lima kelas zonasi. Kelas 5 adalah bahaya tertinggi dan bahaya paling berpotensi, kelas 4 adalah bahaya tinggi, kelas 3 adalah bahaya sederhana, kelas 2 adalah bahaya rendah dan kelas 1 tidak bahaya. Peta kerentanan tanah runtuh yang dihasilkan mengenal pasti lima zon kerentanan bahaya tanah runtuh, dari zon bahaya yang sangat tinggi (4.7%), zon bahaya tinggi (33.8%), zon bahaya sederhana (40.5%), zon bahaya rendah (18.4%), dan sangat zon bahaya rendah (2.6%). Hasilnya disahkan dengan berkaitan dengan kejadian tanah runtuh di kelas yang berbeza.

Kata kunci: GIS,Pemetaan Geologi, Kaedah Perlapisan Berwajaran, Kerentanan Tanah Runtuh, Pemetaan Tanah Runtuh

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LIST OF SYMBOLS

°	Degree
’	Minutes
’’	Seconds
%	Percent
<	Less than
>	More than
$\sum$	Sum

LIST OF ABBREVIATIONS

km^2	Kilometer square
WOM	Weight Overlay Method
GIS	Geographical Information System
NE - SW	Northeast - Southwest
E - W	East - West
N - S	North - South
E	East
S	South

CHAPTER 1

INTRODUCTION

1.1 Background of study

Landslide is the most frequent issue of natural disaster in many places in Malaysia. In tropical countries such as Malaysia, heavy rainfall causes most of the landslides. Therefore, many cases from the local landslide where the weather will degrade the initial upper surface of the layers of slopes, which have been excavated more weakly (Miščevič and Vlastelica, 2014). The landslide caused by the presence of joint and fractures along the rock, which makes the interaction of deformation and its weathering rate, which water can easily flow through the rock fracture and increase the degradation within the rock mass gradually (Dochez et al. 2013).

In geological priorities, the geological mapping was conducted through secondary data which covered such as lithology, topography, structural geology and stratigrapghy. Generally, each rock has a different type of feature which naturally consists of the rock formation. The natural degradation of rock is frequently occurring particularly on the highly sloping area. The occurrence of landslides has risen in recent years, and this can be due to a rapid rise in land development. The final research activities of the general geology are producing the geological map at scale 1:25 000 of the study area.

Through a scientific study of landslide inducing parameters, landslide risk areas can be assessed and predicted, and landslide damage can minimize using successful landslide hazard zoning for emergency preparedness plans. Satellite observation technique and specialized data processing method, such as remote sensing and GIS technology, are developed for analysis the landslide hazard zonation which can integrate. These new techniques are provided with accurate and timely updated information in these inaccessible areas around the study area by interpretation data. Also, the present study conduct using the weighted overlay method (WOM) to delineate possible landslide hazard zonation in the future.

Due to the climate, which rains throughout the year, the study area obtained high rainfall intensity, especially during the North-East monsoon. This will increase the landslide efficiency, and it affects the slope and aspect factor. In addition, the land use factor also has the effect of weakening the soil and losing the ability to accommodate rainwater, resulting in landslides.

The study area locates at Kampung Kundur, Gua Musang. Gua Musang one of the districts is mainly in Gua Musang formation, this formation is most extensive facies with calcareous rock, and it is the most widespread development in Middle Triassic time (Yin, 1965). Also, this area of Gua Musang estimates that limestone constitutes around 80% of overall rocks exposed in the study area of Gua Musang Merapoh but declined gradually to the north and south (Burton 1973).

It can help disaster planners, local authorities, contractors and decision-makers to take account of the accuracy of the map before deciding on development, particularly in the Kampung Kundur, Gua Musang area.

1.2 Study Area

1.2.1 Location

The study area of the research in the Gua Musang district, which are in the Gua Musang Formation. This area of study is known as the Kampung Kundur area, where the study area is located geographically consists of sedimentary rock lithology from Gua Musang formation.

The study area is 5km^2 per area, features a mixture of forest and sparsely vegetated land with major plantation is palm oil and minor of a rubber plantation that merely owns by office land Gua Musang. It is bounded by longitude line 101^{o}54^{o}00” E to 101^{o}56^{o}35” E and latitude line 4^{o}55^{o}90 N to 4^{o}52^{o}45” N (Figure 1.1). The study area covers an area of about 25 square km, covering Kampung Kundur area that is the main village of this research study area. The research study area also has geomorphologically an undulating topography. The mean elevation of the study area, with medium to the steep slope, is 200 m above mean sea level.

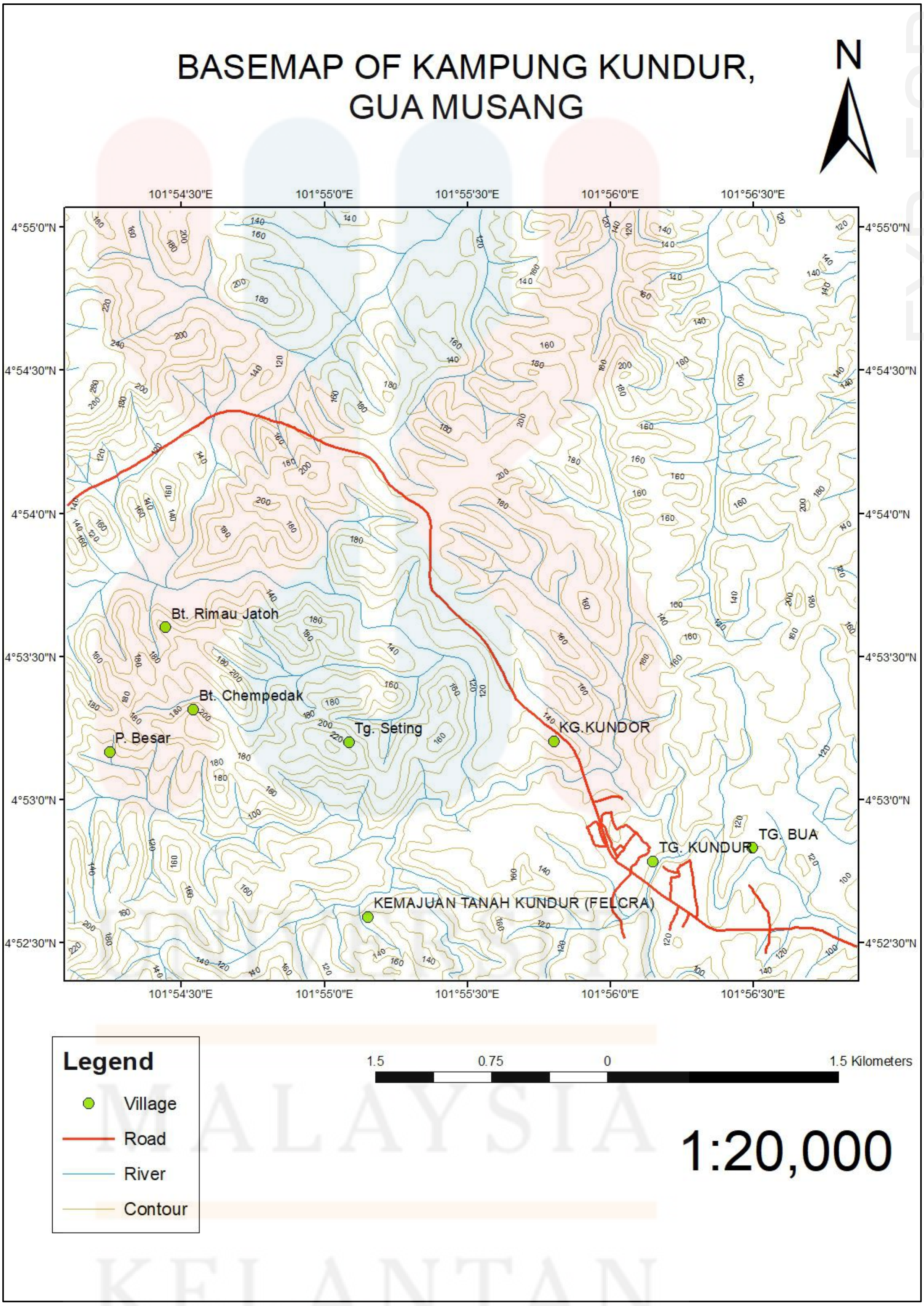


Figure 1.1 : The base map of Kampung Kundur, Gua Musang.

1.2.2 Road

The study area locates at Gua Musang, Kelantan. Gua Musang is the southeast part of Kelantan district which are approximately 200 km from the capital city of Kelantan. Gua Musang - Kota Bharu highway is length about 210 kilometre connecting Gua Musang and Kota Bharu. The connectivity to the area of research study is possible through one main road. The path would be through the study area of research from the west district to the southeast of the study area. There also may some alternative ways used by villagers to their necessity as plantation estate.

1.2.3 Demography

According to Jabatan Perangkaan Negara (2018), Gua Musang populated by a total of 113 900 people, which are the men is 62 300, the women are 51 600 living at Gua Musang. Then, this distributes by the birth rate in the Gua Musang in 2018 is 19 300 babies with the death rate is 4800 people. Gua Musang is the southeast part of Kelantan, so the percentage of people to live and work in Gua Musang is less than people that live at the Kota Bahru that have more job opportunities and accommodation facilities.

1.2.4 Landuse

Gua Musang has developed many rural and urban areas with successful and rapid access. Among them, these areas have developed many facilities that help the people in terms of health, learning centre facilities and employment opportunities. Besides, in rural areas, infrastructures such as roads have been developing. Also, there are areas of plantation such as oil palm and rubber plantations by the people from the Kampung Kundur. Then, the land use in Kampung Kundur is consists of road infrastructure, plantation development and also low settlement area. The landform also influences the social-economic for people from the Kampung Kundur to work in the plantation area. The development of the study area is rapidly changing every year to help villagers enjoy more of their lives at Kampung Kundur.

1.2.5 Social economic

The most influence social-economic that generate by the people from Kampung Kundur, Gua Musang is coming from the agricultural activity. Besides, some of the villagers are not works in the study area. The study area is mainly distributed by mostly with palm oil plantation. This research study area social-economic is coming from the Malay resident with traditional economic activity such as cultivation, carpenter and collecting herb from the near forest. Then, there also minority of immigrant that work with local people especially in the plantation area. Thus, the cooperation between local and immigrant people are helping out the villager to have an income.

1.3 Problem Statement

The problem statement in this research is the geological information does not update which it is limit for updating a geological map of Kampung Kundur, Gua Musang.

A new geological map needs to update in the study area. Especially nearly hill terrain roads are in the study area that more precaution is required to avoid landslides. Landslide is one of the natural threats in the mountains and tropics due to heavy rainfall and urbanization over fractured hills. (Tajudin et al. 2018). The landslide phenomenon is a dangerous threat to settlement and the structure that supports transportation. Thus, indirectly prove the previous research that differences predominant formation at different locations, rock types and weathering grades of rock samples will affect the deformation rate of the rock before landslide happen.

Developing such a road and building new infrastructure in the study area was reduced the strength to prevent the rock from dropping, which can be dangerous to people that using the road and particularly villagers living near the hills and study area. The previous data for a landslide is limited to a minor study area in Gua musang which was not specifically at this study area.

Then, the information of landslide occurrence factor at Kampung Kundur is not have mostly been researched by another researcher, so the details of landslide factor that need to conduct the research are lacking. Thus, the current data of landslide hazard zonation map are must be updated to ensure the precaution step can be taken by local authorities to prevent injury to people that using the infrastructure at the area. Lastly, this data was decreased the percentage of a landslide by involving the dangerous mapping area.

1.4 Objective

- To update the geological map of Gua Musang with the scale of 1:25000
- To analyze the landslide factor in the research area that is causing the landslide incidence.
- To generate landslide hazard zonation map of study area, Gua Musang with the scale 1:25000

1.5 Scope of Study

This research scope of the study focuses on the study of landslide hazard analysis, which includes cliff along the road and another high potential area that used as a development area in Kampung Kundur, Gua Musang. Further study of the geological prospect of the study area is to understand the rock content so that information can give about the rock structure and the rock mass strength that may affect the landslide.

The research also includes the secondary data collection method from online resources such as the United State Geological Survey (USGS) and Jabatan Pengairan Saliran (JPS). The different secondary data are collected and analysed later with Geological Information System (GIS) to conduct the Weight Overlay Method analysis. The Weight Overlay Method conduct to support the determination of the factor of landslide occurrence through the weightage of each factor such as slope, precipitation, distance to road, distance to drainage and land use. This factors also provided landslide hazard zonation map of Kampung Kundur, Gua Musang.

1.6 Significance of Study

The importance of this research study is to update the latest mapping area of the geological map in the study area in Gua Musang, Kelantan while conducting the research. This geological map also provides geological information for Malaysia Geological Department to store the data and information from the study area, so it can be useful as a reference to another researcher to conduct the geological study at the study area in the future. Also, a land developer can use data from The National Slope Master Plan (2009-2023) which is a program that includes specific elements of a systematic and efficient regional policy, strategy and action plan for the 2009-2023 slopes nationally to mitigate risk from landslides.

Then, the research is conduct to determine the factors of a landslide that happen at the area. So the land enforcement people will take precautionary measures to ensure that landslide does not hurt people that live or using the area by placing a signboard that shows the study area is a high risk of landslide occurrence.

Next, the research also provides a landslide hazard zonation map to update the area that is a high possibility for a landslide to happen. Thus, from this study, it can use as valuable information, especially to local authorities that responsible for the development and improvement of the area infrastructure.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

These research studies are a distribution of compilation of several articles, journals, a published and unpublished thesis that had been used as a reference. This literature review, are more highlights the regional geology and tectonics, stratigraphy and also structural geology. The review of the literature relates to the area of the study that is generally in the Gua Musang.

Then, this literature review also includes the specification part of the research interest of Geological Information System (GIS) and Weight Overlay Method for landslide hazard zonation analysis. The more details discussion of the research specification such as factor contributes to landslide such as slope, land use, distance to road, distance to drainage and also precipitation as weightage for landslide analysis.

2.2 Regional Geology and Tectonic

Based on sedimentological and paleontological evidence. This result suggests the formations of Gua Musang were formed in a warm, shallow marine setting within the Paleo-Tethys Seaway of the Central Belt during the Permo-Triassic period. The Palaeo-Tethys, therefore opened in the Lower Devonian, triggered by the separation of Sibumasu from Gondwanaland, and closing in Triassic, caused by an earlier Indosinian orogenic collision with Indochina Block sutured into Eurasia. According to (Mohamed et al. , 2016) Gua Musang is divided into four zones according to their stratigraphy in the southern area of Kelantan which is; Aring, Kuala Betis, Gua Musang and also Gunung Gaga. Gua Musang Formation shows that there are three different rock types, such as limestone, and other rocks, such as metamorphic and igneous.

These are widely dispersed argillite and carbonate interlocking each other. It was depositional alternate during times of high-low detrital depositional environment. (Leman, L. 1995) suggest, the regional volcanism in the region was triggered volcanic and pyroclastic deposition in Gua Musang. Thus, creating a land type of the Seaway through the formation of topographical heights, and created a shallow environment ideal for the development of calcareous stones.

2.3 General Geology

Formation of Gua Musang is known as Middle Permian-Middle Triassic sediment primarily of crystalline limestone with argillaceous faces as a thin layer of shale, tuff, chert and sandstone that occurs as interlocked in the formation. The average temperature that exposed to the Gua Musang Formation ranging from 1300C-1400C that the catagenesis phase had occurred. Geologically Kelantan consists of western Kelantan Olistostrom area, Taku Schist area and also Gua Musang Formation.

In Kelantan, example of Igneus rock is granite, porphyry diorite, andesite, ignimbrite and dolerite. Kelantan is structurally bounded in the west by olistostrom and in the east by Lebir Fault Zone (Setiawan, 2010). In the stratigraphic Lexicon of Malaysia, (Peng et al. 2004) has stated that based on the fossils record on bivalve, algae, and brachiopod, the Gua Musang formation initiated Middle Permian to Upper Triassic. Gunung Rabong Formation that unconformably overlay Gua Musang formation.

2.4 Structural Geology

The Central Belt sequence is often referred to as is clinically folded and flawed based primarily on the presence of widely separated stratigraphy horizons repeated throughout the strike (Gobbett, 1973).

The belt is geologically composed of fragmented sediments and calcareous stones, as well as igneous rocks derived from volcanoes and volcano which this clastic activity of the Permian to Triassic period (Shah et al. 2012). The shearing is consistent with vertical flattening of an already steeply inclined foliation, detected by the formation of low-angle, NW-SE descending axial planes compliant with collapse folds (Hafid et al. 2006). (Yin, 1965) has reported that the overall trend of substantial tectonics in Gua Musang followed minor effects consisting of strongly clustered folds, asymmetric, recumbent, and folding. The difference rock lithology of Kelantan state is consists of igneous, metamorphic, and sedimentary rock that influence the character of the rock strength form at each zone.

2.5 Historical Geology

Malaysia is a part of South East Asia that has derived from the Gondwana Southern Hemisphere (Metcalfe 1988). The Gondwana divided into three different parts of Peninsular Malaysia, which are Central Belt, Eastern Belt, and Western Belt. The Central Belt situated in the east of the suture zone Bentong-Raub. It includes Permo- Triassic metamorphic rocks and marine sedimentary rocks deep to shallow (Kobayashi and Tamura, 1968; Makoundi, 2004).

The Central Belt is between the eastern foothills of Main Range, ranging from Kelantan to Johor. This belt also includes Triassic calcareous stones with volcanic and volcaniclastic rocks intermediate to felsic, which founded in the forearc region of the palaeo-arc basin (Richardson, 1939; Gobb. The upper Palaeozoic rock of Gua Musang is composed of argillaceous strata and volcanic rocks. These were subordinate by arenaceous and calcareous sediments that accumulated in the shallow marine environment. The beginning is from Upper Carboniferous and peaking from Permian to Triassic, the cycle of sporadic submarine volcanism.

Granites of the main range belong to the middle Triassic age which comprises intermediate intrusive igneous rock. The state 's central belt consists of both Triassic and Permian-age sedimentary and metasedimentary rocks. The Triassic sediment is an interbedded sandstone, siltstone and shale conglomerate, while the Permian counterpart contains phyllite, slate and shale (Nazaruddin et al. 2014). Also, the central belt is intersected by intermediate to basic volcano, mainly pyroclastic sediment. Specifically, the study area, Gua Musang, falls south of the state within the central geological formation mostly of the Triassic and Permian sedimentary rocks (Yao et al. 2017).

2.6 Geographic Information System (GIS)

GIS is very had an important in determining the map, hazard analysis and risk management of landslide hazard susceptibility. Besides, the geospatial tools are important in analyzing advanced digital database and updating information about the landslide. GIS is allowing the classification to be made by each landslide factor that leads to landslide analysis in the study area. The weight factor is measure and class to determine the zonation of the landslide hazard.

The thematic layer construction method comprises many qualitative and quantitative approaches (Soeters and van Westen, 1996). Researchers have recently made considerable efforts to produce maps of susceptibility to landslides using the Geographical Information System (GIS) (Youssef et al. 2015). This strategy is successful as it is capable of recognizing suitable and unsuitable area for construction activities. Finally, this analysis sets the parameter of the landslide hazard for future research.

The advancement of geospatial technologies, geographic information systems (GIS) and remote sensing (RS) has allowed researchers to produce more effectively map, analyze and synthesize various input data and generate maps of susceptibility to landfill that can help decision-makers in planning and mitigating possible landslide impact (Vojteková et al. 2020).

2.7 Landslide Hazard Zonation

The conditioning factors used in this study were chosen based on the factors most commonly reported by the researchers. In other words, the factors selected in this analysis are those used by other researchers and those which have a major impact on the terrain's inconsistency potential (Jebur et al. 2014). The densities extracted for each factor class were later used to derive the ratings for each factor class that were combined statistically to assess the landslide risk in the region (Hamza et al. 2017). These factors were triggered by external and intrinsic. An intrinsic factor is defined as a geological factor for the landslide such as (lithology or soil form, structural discontinuity characteristics, material shear strength, groundwater condition and effect), slope geometry (slope inclination, shape, elevation, curvature) and land use (Raghuvanshi et al. 2014).

The external factor that commonly triggers tropical landslide is the occurrence of rainfall, construction activities, and unpredictable cultivation practices in the slope area, increasing the landslide factor. Previous studies show that Southeast Asia experienced seasonal dry periods, excessive rainfall intensities, steep slopes on the hills and unstable soils that can cause landslides (Mohd et al. 2019).

Landslide can also be classified into two which are material type landslide and movement type landslide (Varnes, D. J., 1978). Table 2.1 show material type landslide that consists of rock, earth, soil mud and debris form that was form in past landslide analysis.

Table 2.1: Varnes Classification of Slope Movement

Material type landslide	**Description**
Debris	Containing significant proportion of course materials, 20 to 80% of particles are larger than 2mm.
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.
Earth	Materials in which 80% or more of the particles are less than 2mm, the upper limit of sand sized particles.
Soil	Aggregate of solid particles, which generally of minerals and rocks. It can be transported or formed by weathering of rock.
Rock	Hard or firm mass that was intact and in its natural position before any movement occur.

(Sources: Varnes, D. J 1978)

2.7.1 Factor contribute to Landslide

The review from the past research is consist of several factor to landslide occurrence. These factors are slope, aspect, drainage, elevation and land use, which need to be studied to understand the overall application of each reason to form the landslide hazard zonation.

A. Slope

From the previous study, researchers have determined that the slope factor is one of the key reasons why landslides occur (Alkhasawneh et al. 2013). Slope Associated parameters such as exposure to sunlight, drying winds, rainfall (degree of saturation), and discontinuities can affect the incidence of landslides. Slope angle is often widely used in landslide susceptibility studies as landslides are strongly associated with slope angle (Çevik et al. 2003). Higher sloping conditions and wide angles increase the shear stress of the rock slope material (Zulfahmi et al. 2007). The height of the slope is one of the most significant factors influencing slope instability and also influences the earth's surface, which changes the topography such as curvature profile, gradient slope and also the slope dimension. (Saadatkhah et al. 2014).

The six-class gradient map will rank higher when the gradient of the slope increases (Tajudin et al. 2018). Requirements for slope gradient effect by exposure of rock to sunlight, drying winds, rainfall (degree of saturation), and discontinuities may also be has correlated with the slope component.

Based on the Department of Mineral and Geoscience Malaysia slope area with above 25 degrees which is has stated as a risky slope area for development. Table 2.2 shows the slope angle from low to high slope angle that contribute to landslide occurrence, the value (0-5) are the lower slope angle while the slope angle (25-30) is the highest which the most weight for the factor of the landslide.

Table 2.2 : Slope angle division (Department of Mineral and Geoscience Malaysia, year 2017)

Slope angle (^{0})
0-5
5-10
10-15
15-20
20-25
25-30

B. Land Use

Land use is another anthropogenic factor used in this analysis, which has identified as a significant factor that indirectly influences landslide occurrence. (Chen et al. 2019). Some land use (e.g. deforestation, road construction slope ruptures, steep slopes) increases the number of unstable slopes. (Meneses et al. 2019). Some landslides that occurred in the forest region are then triggered by the reactivation of older landslides and also by roads constructed across the hilly topographical landscape. (Sharir et al. 2016). Also, Road construction has inducing friction in the rock mass and mountain slope that surrounding area the rock formation (Chang and Wan 2014). The observation that mountainous areas with forest cover are less vulnerable than unforested mountain slopes to shallow ground slides (Galve et al. 2015). For this analysis, the land use map has categorized into five groups using GIS software, such as arable land, settlement, forest, the body of water and scrub and grass. (Wadhawan et al. 2019).

C. Aspect slope

In any landslide hazard zoning, aspects are an important parameter. According to Clerici et., al (2006) Aspect (slope orientation) influences exposure to sunlight, wind and precipitation. Therefore, other factors such as soil moisture, vegetation cover and soil thickness that contribute to landslides indirectly affect other slope.

Aspect map are divided into nine categories Flat(-1°), North-Facing (337.5 – 22.5°), North-East (22.5 – 67.5°), East-facing (67.5 – 112.5°), South-East (112.5 – 157.5°), South-facing (157.5 – 202.5°), Southwest-facing (202.5 – 247.5°), West-facing (247.5 – 292.5°) and North-West (292.5 – 337.5°). In general, the south-east and some pockets of south-western slopes are influential in creating landslides due to the availability of moisture during the rainy season. According to Shit et., al (2016) , the frequency of landslides was lowest on the east-facing, west-facing and north-west-facing slopes, except in flat areas.

D. Geomorphology

Geomorphological indexes can be used, according to some studies, to evaluate the formation and evolution of landslide hazard. (D., & Mah, C. W. (2012) The geomorphological classification consists of characterising the various elevations that display different forms of land. This allowed the best weighting parameters for landslide hazard zoning to be evaluated. Van Zuidam (1985) had devised a topographic classification method based on the elevation of geomorphological feature in the field. Table 2.3 shows Van Zuidam topographic classification method that used in this study, it class into low lying plain, low hills and hills.

Table 2.3: Van Zuidam, 1985 landform classification

Landform	
5-100m	Low lying plain
100-200m	Low hills
200-500m	Hills
Source: Van Zuidam,1985	

Altitude is helpful in classifying the local relief and locating maximum and minimum height points within the terrain. The altitude is the height of the study area and varies from 0 to 400 m.

E. Geology

According to Gobbett, D. J. (1973) , The geology of the Kelantan Central Zone consists of sediment and metasedimentary rocks bordered to the west by granites of the Main Range and to the east by granites of the Boundary Range. The intrusive granite within the central region is composed of Senting batholiths, Stong Igneous Complex, and Kemahang pluton.

Geology is commonly recognised that geology has a significant influence on the occurrence of landslides. This lithological and structural variations often lead to a distinction in the strength and permeability of rock and soil .Along the adjacent slope, where the substrate has optimum permeability, water penetration into the soil content is increased. In streamflow depth, the permeable rock can flow water more, which will reduce the percentage of water penetration into the soil, and the faster the movement of surface flow. (Cevik and Topal, 2003).

2.8 Weight Overlay Method

The weighted overlay technique is specified to create a mapping overlay of many raster layers by giving each raster layer weight according to its importance. (Saaty 1990). For this study, weighted overlay method was used to produce maps of landslide hazard zonation, as it is a suitable technique for this purpose study. This approach to weight recognition depends on the causative variables associated with the landslide frequency of the landfill in the study area. (Shit et al. 2016). To combine for it appropriate to reclassify each cell from each map layer into a different preferred scale, such as 1–9, which number 9 being the most favorable (Shit et al. 2016). The all thematic maps are integrate using Weighted Overlay Model (WOM).

$$S = \frac{\sum W_i S_{ij}}{\sum W_i}$$

Thus, which (Wi) is the weight ith for factor each map, (Sij) is the jth factor map 's spatial class weight. Then, (S) is the output map's spatial unit value. Then, the Weighted Overlay Method for planning a Landslide Hazard Zonation map has implemented into the GIS program.

CHAPTER 3

MATERIALS AND METHOD

3.1 Introduction

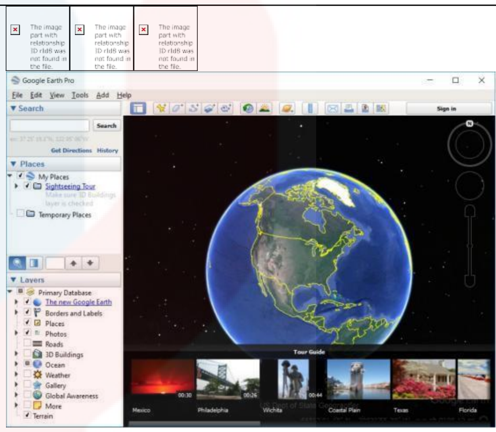
In the research study, there are several tools which were used. Besides, before starting interpretation research, it is essential to prepare and complete some main tools and methods as described. The materials used in this research have cleverly listed that shown in Table 3.1 as their role in geological data collection and analysis is significant to perform a final result. For the method uses, these must carefully be studied on the previous research to get the precise result, and perfectly organized every step and followed until the correct result obtain.

In the methodology section, there are two types of techniques that are a quantitative and qualitative approach. Qualitative research results in a lot of data and provides an in-depth picture and is particularly useful for investigating how and why events have occurred. Numerical data generated and analysed using mathematical and statistical methods are always quantitative research data, which, on the other hand, qualitative research is one that does not include data from numbers. The style of approach to be used in this study is the combination of qualitative analysis and quantitative analysis.

A preliminary study, data collection for secondary data, data processing, and data analysis are the methodologies to be used in carrying out the study. First of all, after the preliminary study is completed, data collection is carried out to collect the information, Digital Elevation Data (DEM), precipitation data and land use data are several types of data collection for this study. Using the Geological Information System (GIS) software to perform the Weight Overlay Method (WOM) for landslide hazard zoning determination, which includes several factors, the data process (slope, precipitation, land use, distance to road, and distance to drainage). The overall purpose of the analysis study is to provide the study area with a landslide hazard zonation map.

3.2 Material

Table 3.1: Material uses for the research study

Google Earth Pro (software) Function; Google Earth Pro Software, is a geospatial software application that displays a virtual globe, which offers the ability to analyze and capture geographical data. This software is use in this study to interpret data through aerial image at Gua Musang District. The software are built to support ArcGIS software to import and export the KML/KMZ format data.	

United States Geological Survey Function; The USGS Earth Explorer (EE) app allows users to query, scan, and order multi-source satellite photos, aerial photographs, and cartographic items for process the data.	USGS science for a changing world
ArcGIS (software) Function; ● GIS software. The function of the Geological Information System for this research is to create a geological map based on the geography data. The capability to data processing, data storage, and analysis with adds the spatial data will provide a complete map.	ArcGIS

CoralDRAW Function To create the cross section map for Kampung Kundur, Gua Musang in 2 Dimension visual image. Then CorelDraw also can draw an line and other shape for use as processing the geological feature in mapping section.	

3.2.1 Material for Landslide Hazard Zonation map

In order to generate a zonation map of landslide hazard, secondary data collection is needed for topographical data, digital elevation model (DEM) and satellite image, which includes the elevation map, slope map, aspect map, land use map, and drainage density map.

A) Slope

From the topographical map derived from the digital elevation model, the slope of the study area was determined. The elevation incline was then categorised by its degree of slope.

B) Aspect

A topographical map derived from the Digital Elevation Model (DEM) in ArcGIS was used to produce the aspect map. The aspect represents the direction of the slope in the study area.

C) Geomorphology

Study area geomorphology was determined from the topographical map derived from the Digital Elevation Model. The elevation of the study area was recognised, observed, and recorded in the data collection.

D) Land use

The land-use data was derived from satellite image data for this research study. The data was obtained from the USGS website, which extracted and converted to raster data from Landsat-8 in the Arc GIS software.

E) Geology

The geological map of the study area is derived from the Arc GIS software topographical map analysis and from previous research. The data was generated and classified such granite and metasedimentary rock into each lithology.

3.3 Research Metadology

3.3.1 Preliminary study

This study is to investigate the landslide hazard zonation in the study area by identifying the potential factor of landslide hazard zonation. Firstly, review data and research of the previous study that related to landslide hazard zonation. There are many information and data that can be referred through journal, article, books and newspaper to gain updated information, especially at the study area. Then, to investigate through imaginary data, the Google map and Google Earth are used to view the surface of the study area by aerial photo. This satellite image helps the researcher to interpret the study area by the visual of land use, contour, and terrain map.

3.3.2 Data Collection

The data interpretation method achieves by visual interpretation of the satellite image data. This analysis is complete by the aid of software which is processing the secondary data from previous study data to form a geological map. It used to create interpretation keys such as tone, texture, form, scale, pattern, site and association and provide guidance on how to identify difference geological objects in satellite imagery.

The interpretations from the map are focus to describe and analysis morphology feature in the study area, which based in secondary data collection. The data are providing with geological element such drainage pattern, vegetation, slope of difference elevation and dimension of a certain morphology. The satellite data that contain a high resolution image can determine the difference lithology type of rock unit. The collection data will give an idea about extent of landslide hazard zonation and mitigation of hazard process by develop landslide hazard map area.

Secondary data

A) Digital elevation Model (DEM data)

DEM data use in the research collect from the United State Geological Survey (USGS) for the free version. DEMs data Is composed of digital raster graphics (DRGs), digital line graphs (DLGs) to improve visual knowledge for data retrieval and revision applications and to create a digital image of hybrid landslide hazard zonation. Table 3.2 shows the collection of Digital Elevation Data from two different years which from 2015 and 2019 to compare and get the updated data for a 30-metre resolution to interpret the slope data

Table 3.2: 2015-2019 Digital Elevation Data in Gua Musang Kelantan (Source: United States Geological Survey)

Properties	Type of data use (Digital Elevation Data)	
	Year 2015	Year 2019
Source	Jabatan Pengairan Saliran	Jabatan Pengairan Saliran
Area	Gua Musang	Gua Musang
Resolution	30 metre	30 metre

B) Precipitation

Precipitation data is a component of the hydrological effect. This component uses to strengthen the evidence that rainfall distribution affects the landslides in the study area. Table 3.3 shows the precipitation data collect from Jabatan Pengairan dan Saliran (JPS) that are specifically from 2015 and 2019 to determine the average precipitation data as a factor for a landslide at the study area.

Table 3.3: 2015 and 2019 Data Precipitation Gua Musang, Kelantan **(**Source: Jabatan Pengairan dan Saliran (JPS)

Properties	Type of data use (Precipitation)	
	Year 2015	Year 2019
Source	Jabatan Pengairan Saliran	Jabatan Pengairan Saliran
Area	Gua Musang	Gua Musang

C) Landuse

Land use data in this study offer a useful way to assess the degree of different land uses and cover it types include such urbanization, forested, building and, farming. Data is commonly present in a raster or grid data structure, with each cell having a value corresponding to a different classification. This system allows the development of summary tables and the conduct of landslide suitability analyzes in the study field. Table 3.4 show data collection used for land use data by USGS data in the study area.

Table 3.4: 2015 and 2019 Landsat data for land use in Gua Musang, (Source: United States Geological Survey 2015 & 2019)

Properties	Type of data (Landsat 8 satellite data)	
	Year 2015	Year 2019
Source	USGS	USGS
Spatial resolution	30 meter	30 meter
Datum	WGS84	WGS84
Type of Projection	Based on UTM	Based on UTM

D) Geological data

The collection of data for geological data such lithology and geomorphology has been provide from the digitizing method in GIS software. The thematic layers of the main subject (lithology and landform) are digitized and calculated to collect the geological data area of landslide hazard zonation. The result was recorded and analyzed to compare the geological data to another factor of a landslide at the study area.

3.3.3 Data processing

A) Methods for landslide susceptibility area

The data obtained from secondary data are used to generate a landslide hazard zonation. Weighted Overlay Analysis in one type of semi-quantitative technique that can measure the theory with this technique has also played a role in decision management in landslide hazard analysis by using GIS Software. For the weighted overlay analysis, each density map was prepared to shape a landslide hazard zonation for all layers. The selection of criteria is one of the most critical steps depends on the availability of data and the complexity for this area of study from the perspective of politics, geology and climate.

The steps involved in the method of the weighted overlay, which need to identify the study area problem. Therefore, each factor that uses is to be calculated, which is the slope, land use, precipitation, geomorphology and geological type of rock.

B) Evaluation of causative factor that triggered landslide to occurence

The landslide factor maps from the lithology and geological map, river topography maps, land use of google earth images and digital elevation model (DEM) were obtained in this research study. Five parameters were used to determine the zoning of landslide hazards such as slope, aspect, elevation, land use and geology.

C) Landslide hazard zonation map

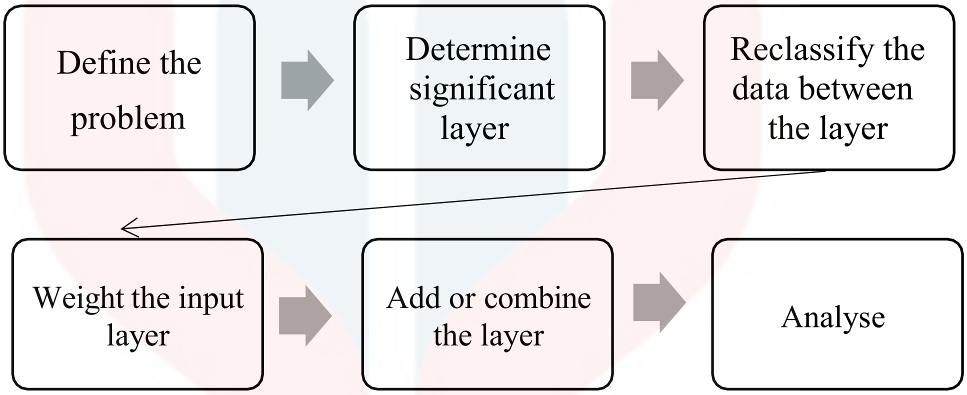
For landslide hazard zonation production, the weight calculates according to the relative value of the raster layer, either primary data or secondary data set, which is decided by expert opinion. Table 3.6 show all weightage or weight values indicate total weights of all layers equal to 100. After each layer reclassifies, each layer weight by factor value, and after assigning weights to the standard, all raster layers was added to the weighted overlay method for susceptibility analysis. Eventually, using ArcGIS software, the map of the landslide hazard zone was finally obtained using weighted overlay process. With the scale of 1 to 5, the landslide was evaluated. As shown in Table 3.5, the assignment of ranking and weightage values of different thematic layers are based on (Shit et., al 2016)

Table 3.5: Assignment of ranking and weightage values of different thematic layers (based on Shit el., al 2016)

Parameter	Ranks	Category	Weight
Slope	9.5	<10	1
		10-20	3
		20-30	6
		30-40	8
		40	9
Slope Aspect	5	North-Facing (337.5 – 22.5)	1
		North-East (22.5 – 67.5)	2
		East-facing (67.5 – 112.5)	5
		South-East (112.5 – 157.5)	6
		South-facing (157.5 – 202.5)	9
		Southwest-facing (202.5 – 247.5)	6
		West-facing (247.5 – 292.5)	5
		North-West (292.5 – 337.5)	2

Land use	7	Orchard	2
		Rubber	3
		Forest	2
		River	2
		road	4
		Palm tree	6
		Mixed plantations	4
Geology	9.3	Igneous	2
		Metasediment	4
		Alluvium	6
Geomorphology	8.5	River	3
		Low lying plain	1
		Low hills	4
		hills	7

Table 3.6 : The steps that involved in weighted overlay method



3.3.4 Data analysis

The preparation of landslide hazard zonation map for Kampung Kundur, Gua Musang was analysed with the concept of non-direct landslide hazard zonation mapping using Weight Overlay Method applied in ArcGIS software. Non-direct landslide hazard zonation mapping shown by determining the degree or weight of landslide hazard based on the event of landslide factor (Mohd et al. 2019). These factors are land use, slope presence, elevation, geomorphology and geology of rock was determined as weighting to create a landslide hazard zonation. Frequency of each weight determined from the combination of each landslide condition factor with a landslide inventory map.

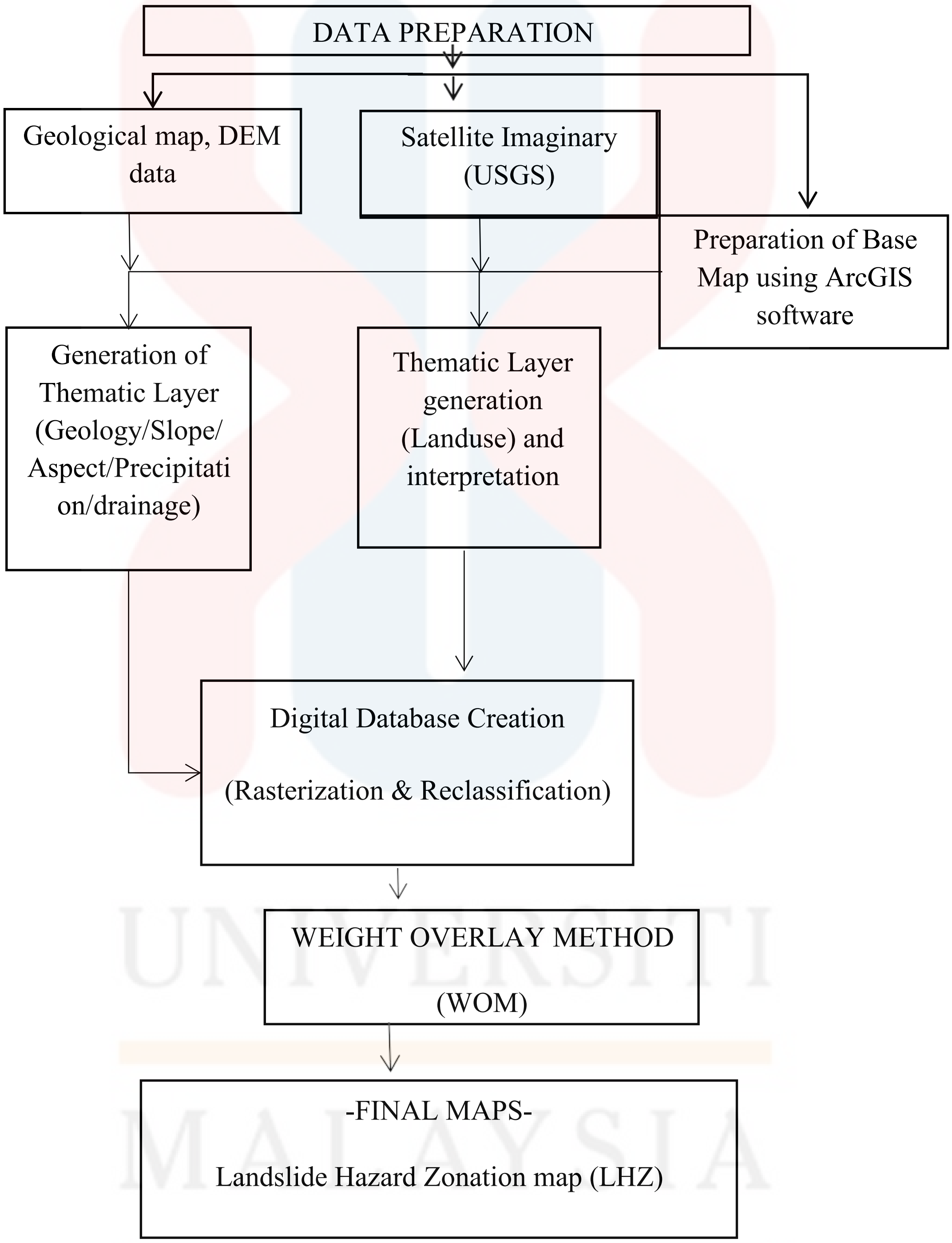
The Weight Overlay Method uses to assign all layers that are important to landslides. Besides, it is incorporation into the GIS platform to delineate landslide hazard zoning based on weighted overlay system (Ahmed et al. 2014). In this analysis, five natural landslide factors were established for mapping the vulnerability of landslides. Then, table 3.7 shows the scale of relative importance to differentiate each weightage, which is from low to highest number for each factor.

Table 3.7: The scale of relative importance (Saaty, 1990)

Intensity of importance	Definition	Explanation
1	Equal weight	There are two operations that contribute equally to the objective
3	Moderate weight	Experience and judgement favors one operation slightly above another activity.
5	Strong weight	Experience and judgement strongly favors one activity over another.
7	Very strong weight	Activity is strongly preferred over others, and its influence has been shown in practice
9	Extreme weight	Evidence that favors one conduct over another is of the highest possible order of affirmation.
2,4,6,7 (Reciprocals)	Intermediate values between adjacent scale values	Whether compromises are necessary

Then, all layer of vectors changes to a raster format, was compiled into spatial datasets and processed using ArcGIS. Each factor weight measured by combines all factor maps for landslide hazard zonation maps. Lastly, figure 3.1 show the research flow chart from the beginning of process until the landslide hazard zonation in the study area area done.

Figure 3.1: Research flow chart for landslide hazard zonaton



CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

The data collection and analysis are measured in general geology by aerial photography observation. In this chapter, information relating to general geology, such as geomorphology, structural geology and historical geology, is explained in the specific study area. Geomorphology has made a significant contribution to the identification and measurement of different natural hazards. It is also because geomorphology is considered to include anything related to the Earth's surface and its alteration.

In general, the geology of the Kampung Kundur region consists mostly of sedimentary and metasedimentary Triassic and Permian-age, with minor igneous and metamorphic rocks. Therefore, the characteristics of each rock in the study area have different criteria that can be differentiated from the study analysis. In stratigraphic studies, each assessment covers each study such as lithology, lithostratigraphy and petrographic studies of rocks and mineral content that occupy the characteristics of rocks in the study area. In the identification of lithological types and also in the construction of geological maps in the study area, topographic and surface features can also be used.

Geological structure in study area that was found from the study area are lineament analysis, and fault will be discussed in this chapter. The major force inhibiting the study area can be determined from the value and direction of the structural analysis. Moreover, historical geology was also discussed in order to add information based on the geology of the study area.

4.1.1 Accessibility

The accessibility of the study area of Kampung Kundur is important to facilitate the relationship between the external areas to the place of study. The connectivity to the area of research study is possible through one main road which important network to several locations outside the study area. In addition, there are several small roads that used for plantation are suitable for off road vehicle such motorcycle and four wheels drive car. In figure 4.1, the accessibility map was shown to depict the accessibility of the study area connect to Gua Musang. Figure 4.2 show the accessibility for Kampung Kundur from Cameron Highland road.

Figure 4.1 : Accessibility road that connect study area to Gua Musang

Figure 4.2: Accessibility road that connect study area to Cameron Highland road

4.1.2 Settlement

The settlement of the study area was focused on one village, Kampung Kundur. Moreover, most areas were covered by crops that were planted and monitored by the Subong Land Office or by estate workers who work in the field and inhabits the proximities of study area. According to Jabatan Perangkaan Negara (2018), Gua Musang populated by a total of 113 900 people, which are the men is 62 300, the women are 51 600 living at Gua Musang. Then, this distributes by the birth rate in the Gua Musang in 2018 is 19 300 babies with the death rate is 4800 people

4.1.3 Forestry (for vegetation)

Forestry in Kampung Kundur area was mainly composed of area of plantation such as oil palm and rubber plantation area that was developed by people from Kampung Kundur. The growth of plants in the study area covers almost the entire region. It is also because the surrounding community still has many areas that are not developed. Thus, the highly vegetation can help reduce soil erosion and landslide risk from happen. Then, the land use in Kampung Kundur is consists of road infrastructure, plantation development and also low settlement area.

4.2 Geomorphology

Geomorphology studies are important as it consist of geomorphology, topography and also drainage system that shown in the study area. The geomorphology had difference elevation based on topography which becomes an indicator to know the flowing of water trough high elevation to low elevation. The difference landform in certain area was initially form by various of tectonic activities in past event of earth formation

The process of landform classification had many variables correlated with current geomorphology analysis that happen in the earth system. Example as weathering process that can be seen at the surface of rock which degrading from initial strength. This geomorphological study provides a rough idea of the topography of the study area and its surroundings.

4.2.1 Geomorphology classification

Geomorphology is a scientific study of the origins of landforms and their forming processes. Geomorphology has contributed significantly to the classification and estimation of various natural hazards associated with the surface of the Earth and its alteration. It includes the nature of the earth's surface land, such as the formation of a series of mountains and hills, river basins, river profile, and a series of patterns built to form the landscapes. This process takes a long times and various moments of tectonic under different environment conditions.

Van Zuidam (1985) had devised a topographic classification method based on the elevation of geomorphological feature in the field. Table 4.1 shows Van Zuidam landform classification method that used in this study.

Table 4.1: Landform classification based on Van Zuidam, 1985

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

(Source: Van Zuidam,1985)

Based on the topography of the study area, most of the study area is a low valley area with slightly geomorphological flat land area, where the highest peak is 323meter and lower area is 90meter. Figure 4.3 shows 3-Dimensional map of landform for study area, which class to low lying plain, low hills and hills.

According to Huggett (2011). The magma bodies that exist under the surface of the Earth that undergo cooling and solidification are plutonism and intrusions. This leads to different volcanic landforms, such as stocks, batholiths, laccoliths, and sills.

According to Heng et al. (2006), the granite intrusion located in Kampung Panggong Lalat, which are nearly to Kampung Kundur is referred as a batholith, which is the largest intrusion landform as figure 4.4. It is known that the features of the batholith are large, usually over 100 km^2. In addition, batholith is known to represent large bodies of molten pluton and are metamorphosed, resulting in the formation of resistant igneous rocks. The dense batholith body will be exposed when the older layer is eroded. Figure 4.5 show geomorphological map of Kampung Kundur which class as low lying plain, low hills and hills based on elevation of topography.

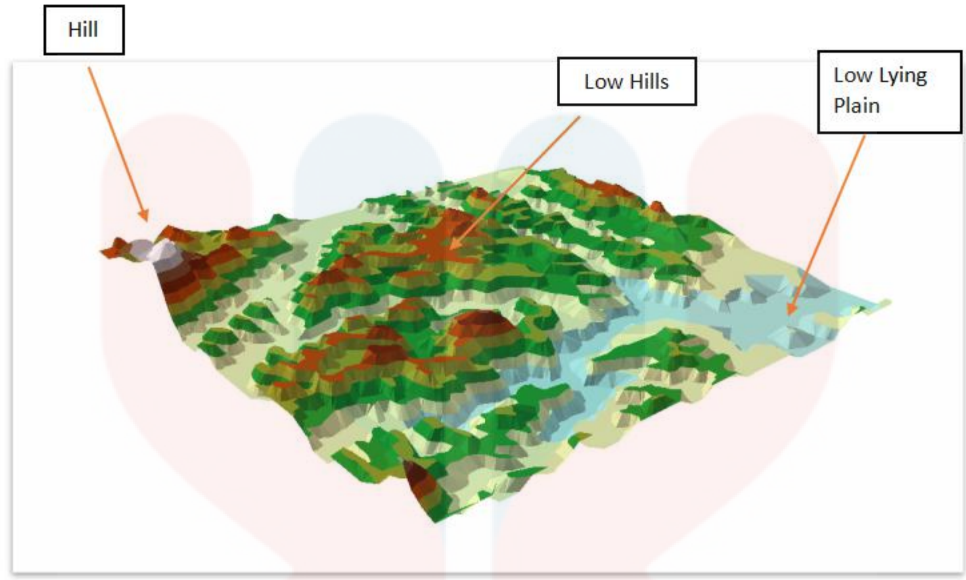


Figure 4.3: 3-Dimensional map of landform for study area

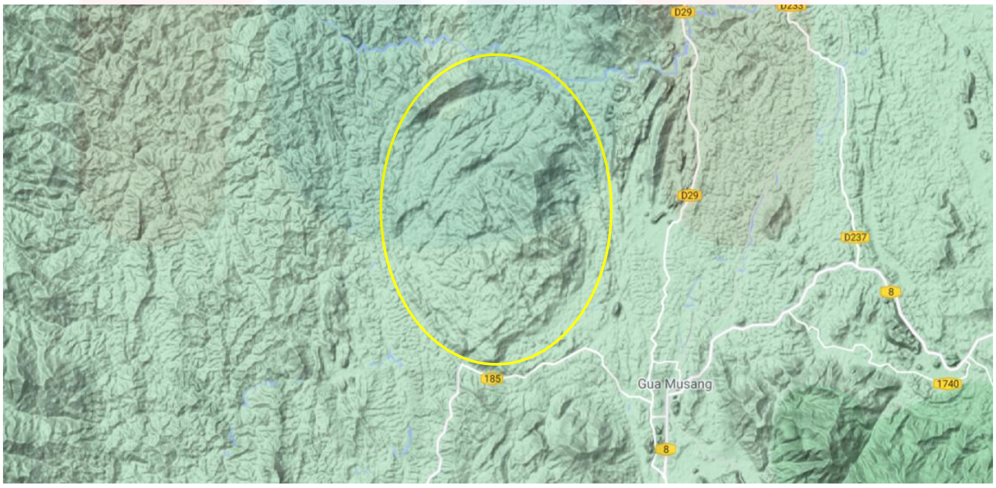


Figure 4.4: Batholith formation at area of Kampung Kundur and Stong area.

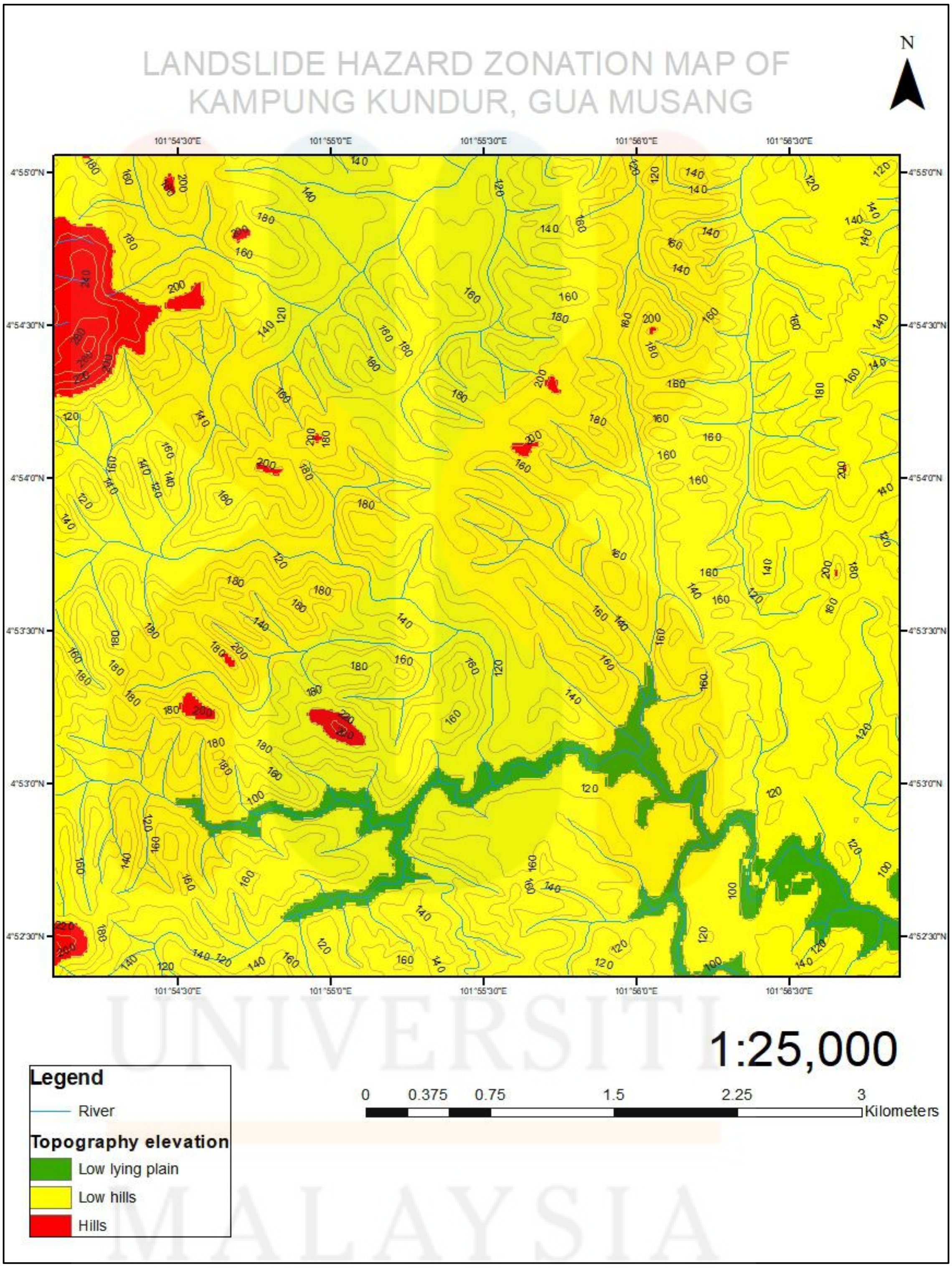


Figure 4.5: Geomorphological map of Kampung Kundur

4.2.2 Drainage pattern

The drainage pattern of the river was observed through the features of the networks that completely connect the streams and rivers. The geographical morphology of the river system can also represent a drainage pattern. Charlton (2008) states that there are many variables that can affect the input, output and transport of sediment and water in a drainage basin, such as soil type, topography, bedrock type, climate and vegetation cover.

One of the most commonly defined models that was defined by geomorphological map analysis is the dendritic pattern. This pattern system contains many streams from the direction of difference that then flow together as tributaries of one main river, resembling tree roots' branching shape. This pattern was usually found in the area of study with the existence of homogeneous lithology of materials such as sandstone, claystone and volcanic breccia with low resistance to water flow.

The pattern of parallel drainage consists of several river currents which flow almost parallel to each other. When the riverbed flows over an almost uniform slope of the region, parallel patterns can be obtained. If there is a main fault or fracture whose position is parallel or in the same direction as the slope of the layer, this type of pattern will be clearly seen at the topography map.

Radial pattern shows when multiple grooves flow from the source in all directions (spinning) or flow from different directions to one location. This pattern was discovered when the dome structure is found on sedimentary rocks or the sedimentary rock boundary between igneous rock fragments. The main groove usually forms a radius pattern, while the branch groove forms the fibrous pattern, the smaller branch groove forms a parallel or almost parallel drainage pattern. Figure 4.6 show drainage pattern in study area that consist of dentric, radial and parallel pattern.

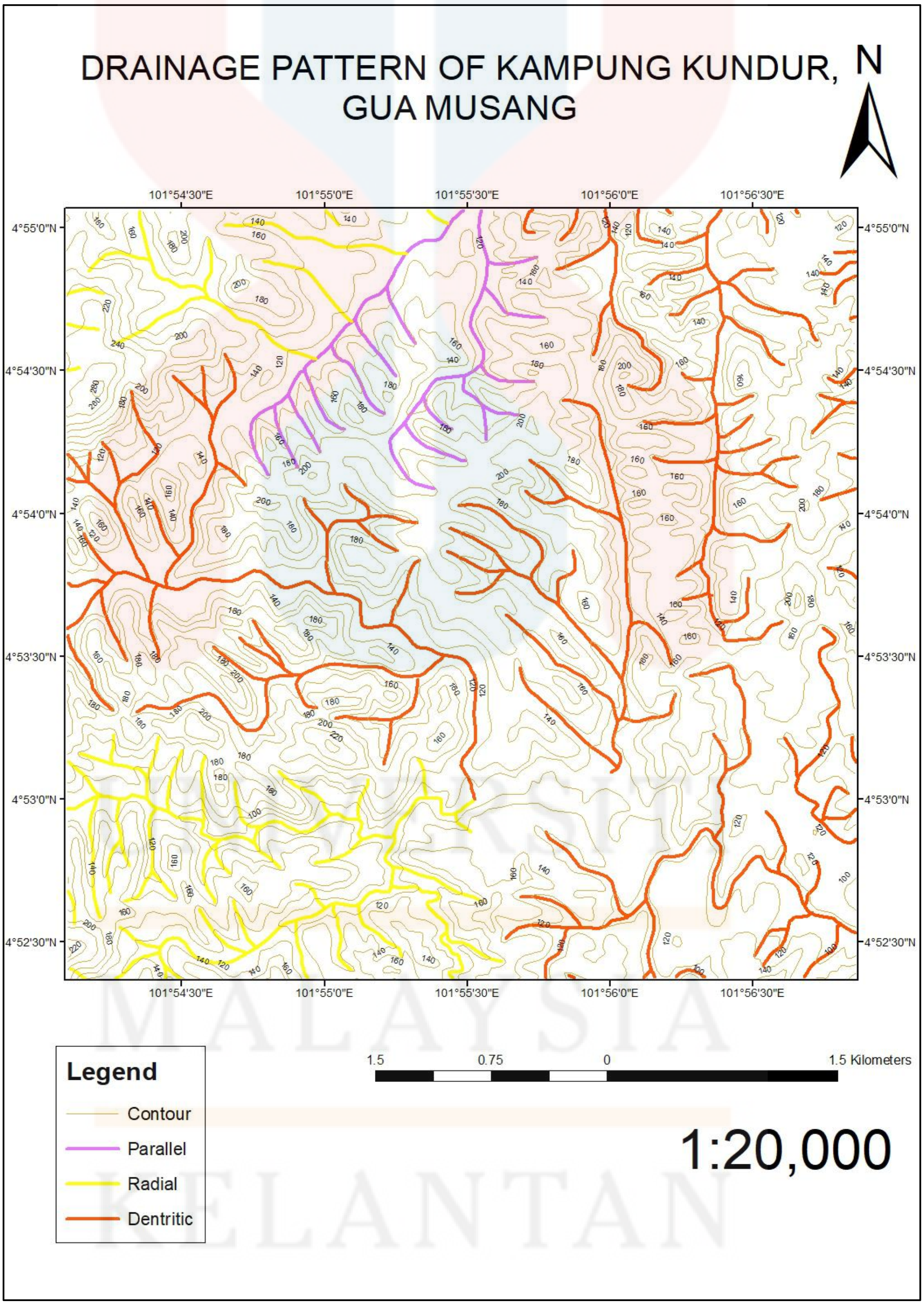


Figure 4.6: Drainage pattern map of Kampung Kundur

4.3 Lithostratigraphy

Lithostratigraphy is defined as a sub-disicpline of stratigraphy, geological studies of rock layer and position in the strata. Lithostratigraphy focus on geochronology, and comparative geology of study area. In lithostratigraphy aspect, the lithology of each rock formation component that include in the strata and also stratigraphic position that become part of classification rock bodies. From previous research in the study area, main components that consists of igneous and metasediment that are based of Gua Musang group that have different type of rock.

The properties of each lithology were composed of various past geological process and range of deposited environment. These studies important to establish chronological sequences that happen in the study area geographical activities.

4.3.1 Stratigraphic position

There are two types of rocks which were found and determined in the study area. The lithology that are found in the study area are granite and metasediment. It is consisting of two different major group of rock, which are igneous rock and metamorphic rock. From the lithology map, granite is colour red and metasediment are colour grey which both are mainly composed in Kampung Kundur area. From the previous study of Gua Musang Formation, the age of the lithology was determined. The metasediment rock is younger than igneous rock due to Pre-Mesozoic metasediment formation, and the metasediment was intruded by igneous rock during the Createaceous era. Figure 4.7 show geological map of Kampung Kundur which consist of granite, metasediment, alluvium and faulting at study area.

Almost 50 % of the land in the study area is covered with granite rocks. Granite is an intrusive igneous rock that intrude the older rock. From the interpretation of a topography map, the intrusion of granite can have observed and mapped. Each part of the body forms its own hills, separated by the main grooves, as a result of this vigorous erosion process which the height of this hill is approximately identical. The sedimentary rocks that have been metamorphic can be interpreted based on the position and shape of the ridge. The curved-shaped ridges around the igneous body of the intrusion can be interpreted to have undergone tactile metamorphism.

4.3.2 Unit explanation

The study area is located at Kampung Kundur, Gua Musang. Gua Musang is one of the districts primarily in the formation of Gua Musang, it is mainly in the formation of Gua Musang, this formation is the most extensive facies with calcareous rock, and it is the most widespread development in the Middle Triassic period (Yin, 1965). As a complement to previous studies, findings from geological studies in this area show nearly identical information. However, naming and grouping of rocks in the Kampung Kundur adjusted based on field observations, which covers the rock types, geological structure and lithology study.

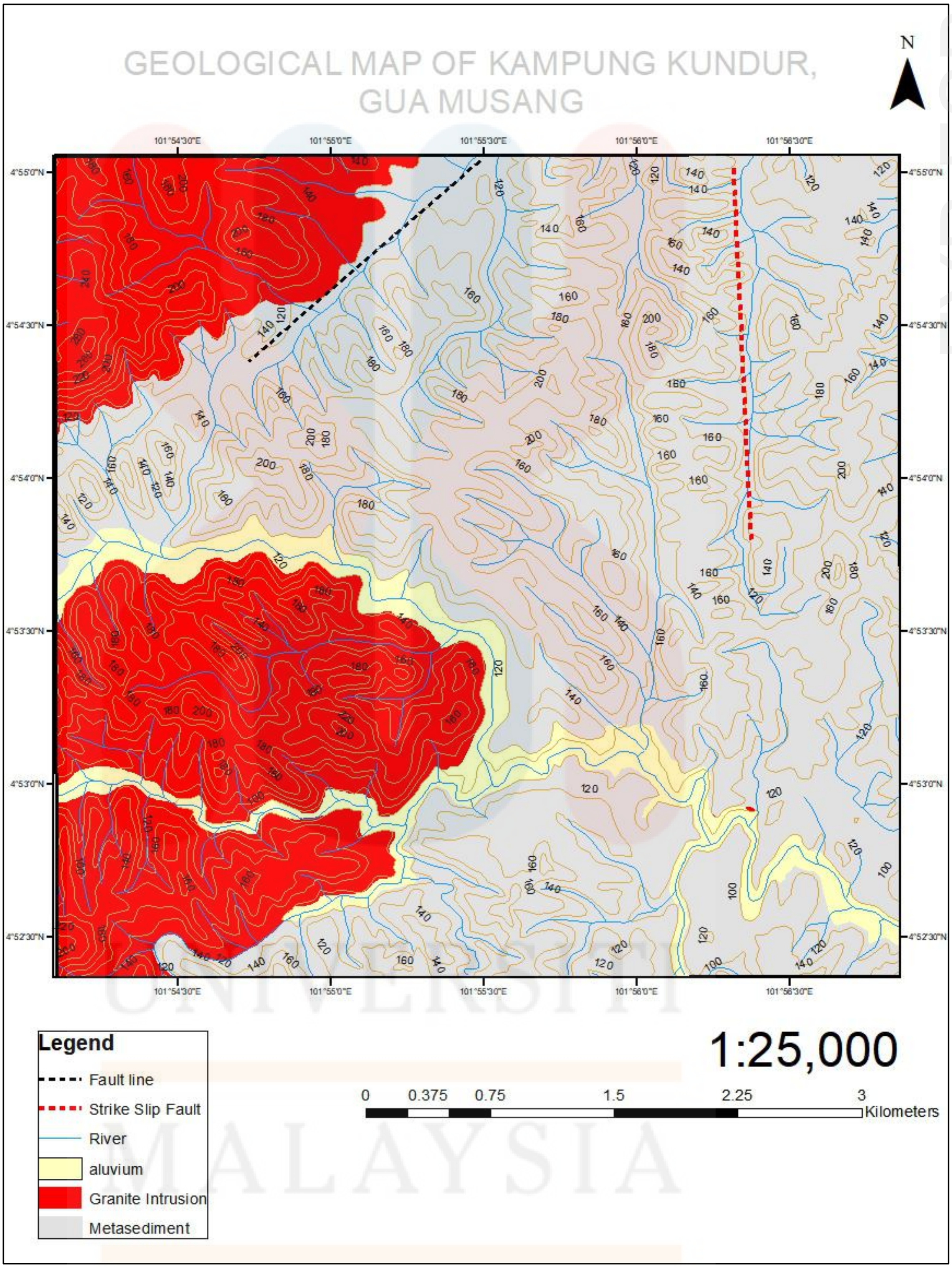


Figure 4.7: Geomorphological map of Kampung Kundur

Table 4.2: stratigraphy column of Kampung Kundur

Era	Period	Formation/ Rock Unit	Lithology	Explanation
Cenozoic	Quartenary	Alluvium	Alluvium Unconformity	It is fine partial presentin river area that is not permenant in one area for long time
Mesozoic	Triassic	Gua Musang Formation	Meta sediment	The argillaceous facies which consists of shale, silststone, mudstone, slate, with very fine grain to fine grain size
		Acid Intrusive	Granite	Granite is one of the intrusive igneous found in light grayish colour with coarse grain. Made up of mostly quartz ,feldspar and plagioclase.
Palezoic	Permian			

As table 4.2, it show stratigraphy coloum which two types of rocks are primarily distributed in the study area, which is igneous rocks as units of granitoid rock and metasedimentary rocks units. In the north west part of the study region, the distribution of granitoid units is largely dominated, with granitoids belonging to a large batholith with an area of about 200 km^2. Besides, the rest of study area is majorly composed by metasedimentary rock because the area are intruded by igneous and became a baked zone, which rock are in process of metamorphic from sediment to metamorphic.

b. Unit explanation

In the study area of Kampung Kundur, the lithology and rock units was distinguished from each other. It is shown by their respective forms, either owned by igneous rocks of metasediment. As follows, the division of rock units was defined from the youngest to the oldest.

i. Granite unit

The granite unit of study area was naming based on the lithological characteristics that dominate the lateral lithology on the study area. The granitoid units cover much of the study area's north west area. Moreover, this rock unit in the area of study is granitoid are intrude the metasedimentary rock. The granite is defined during the geological mapping process based on some of the higher landform features and drainage patterns that flow from the top to the bottom of the river.

ii. Metasedimentary unit

Based on the lithological characteristics dominating the lateral lithology in the study area, the metasedimentary rock unit of the study area was named. There are also several units, including tuffaceous shale, slate and phyllite shale, for metasedimentary lithology. Almost all of the study area lithology rock is covered by this metasedimetary rock. Due to the intrusion of granite that affects the young rock in the study area, the age of metasedimentary rock. The metasedimentary rock was forming a less steepness elevation which lower than granite unit elevation. The central belt of the state consists of both sedimentary and metasedimentary rocks from the Triassic and Permian-age. The Triassic sediment is an interbedded conglomerate of sandstone, siltstone and shale, while phyllite, slate and shale are part of the Permian counterpart. (Nazaruddin et al. 2014).

4.4 Structural Geology

The structural geology analysis in the study area is indicated by the early formation of many tectonic plate movements down at the earth core. The resulting of the tectonic activities is forming structure which divide to two type structure, primary and secondary structure. Different secondary structures, such as folds, faults, joints, rock cleavage, differ from primary structures such as bedding and vesicular structure that develop in rocks at the time of their formation. These structure then were analyses to reveal the past event history of earth especially in study area.

4.4.1 Lineament Analysis

Lineament is any straight-shaped patterns like ridges, steep cliffs, and ravines found on the surface of the earth. The direction of the layer is usually represented by the ridge found in sedimentary rock areas, while the steep cliff ravine represents the main fault or crack. Lineament can be analyse from aerial photograph, geological map contour, terrain map that traced from google map image.

According to Mohd Hashim and Akhir (2010), The positive line is shown by the ridge and range, while streams, faults and valleys are reflected in the negative line. Generally, it is important to alter a line representing drainage ditches or any indentation (negative lining) longer than 5 km to represent planes or fault lines, while shorter ones represent significant cracks. The figure 4.8 below shows the negative lineament map of Kundur area, Gua Musang, Kelantan, it show the straight line of river and valley that indicated fault or structural geology at that line area while figure

4.9 shows positive lineament.

1.Negative lineament

.

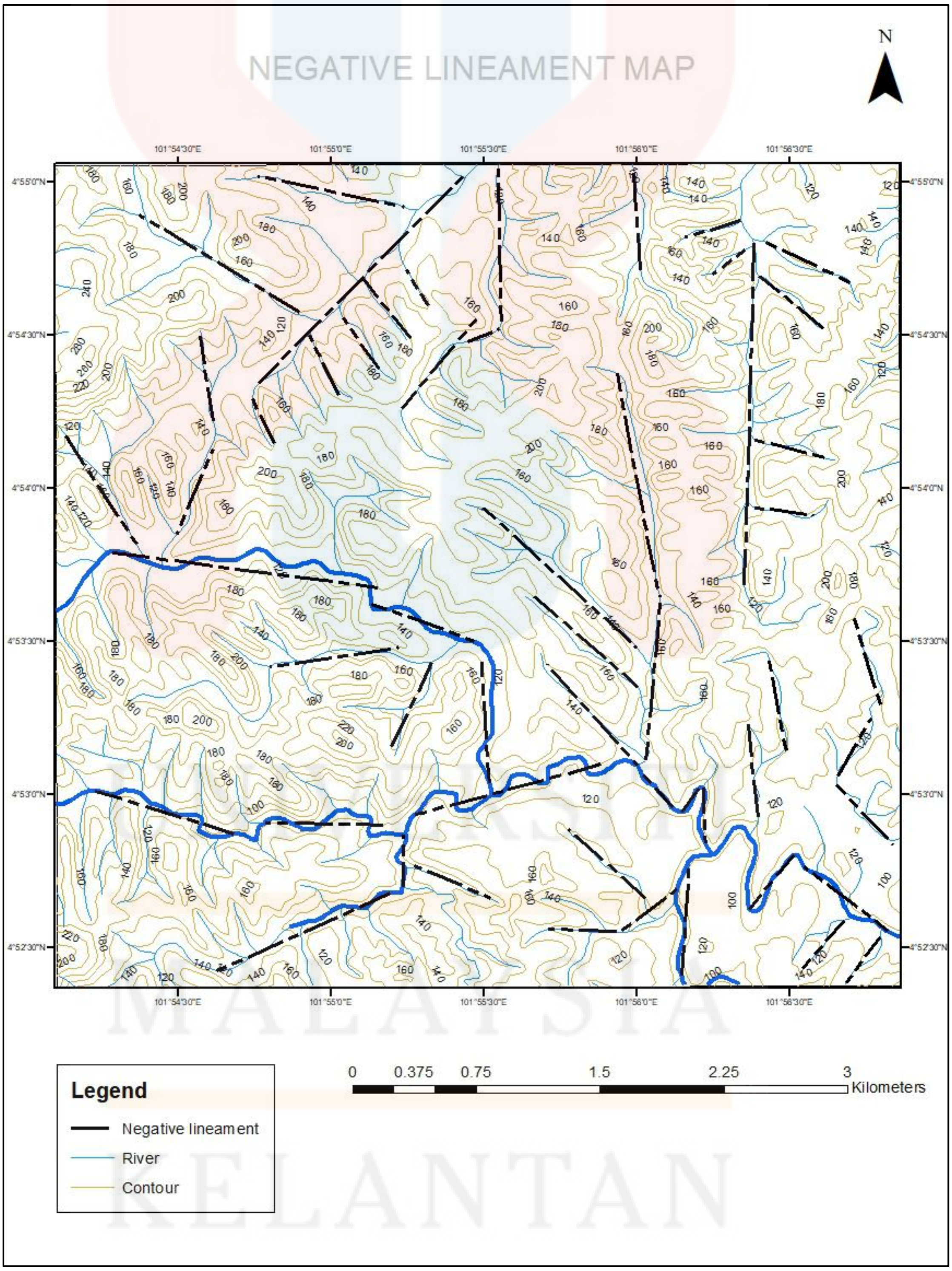


Figure 4.8: negative lineament map of Kundur area, Gua Musang, Kelantan

2. Positive lineament

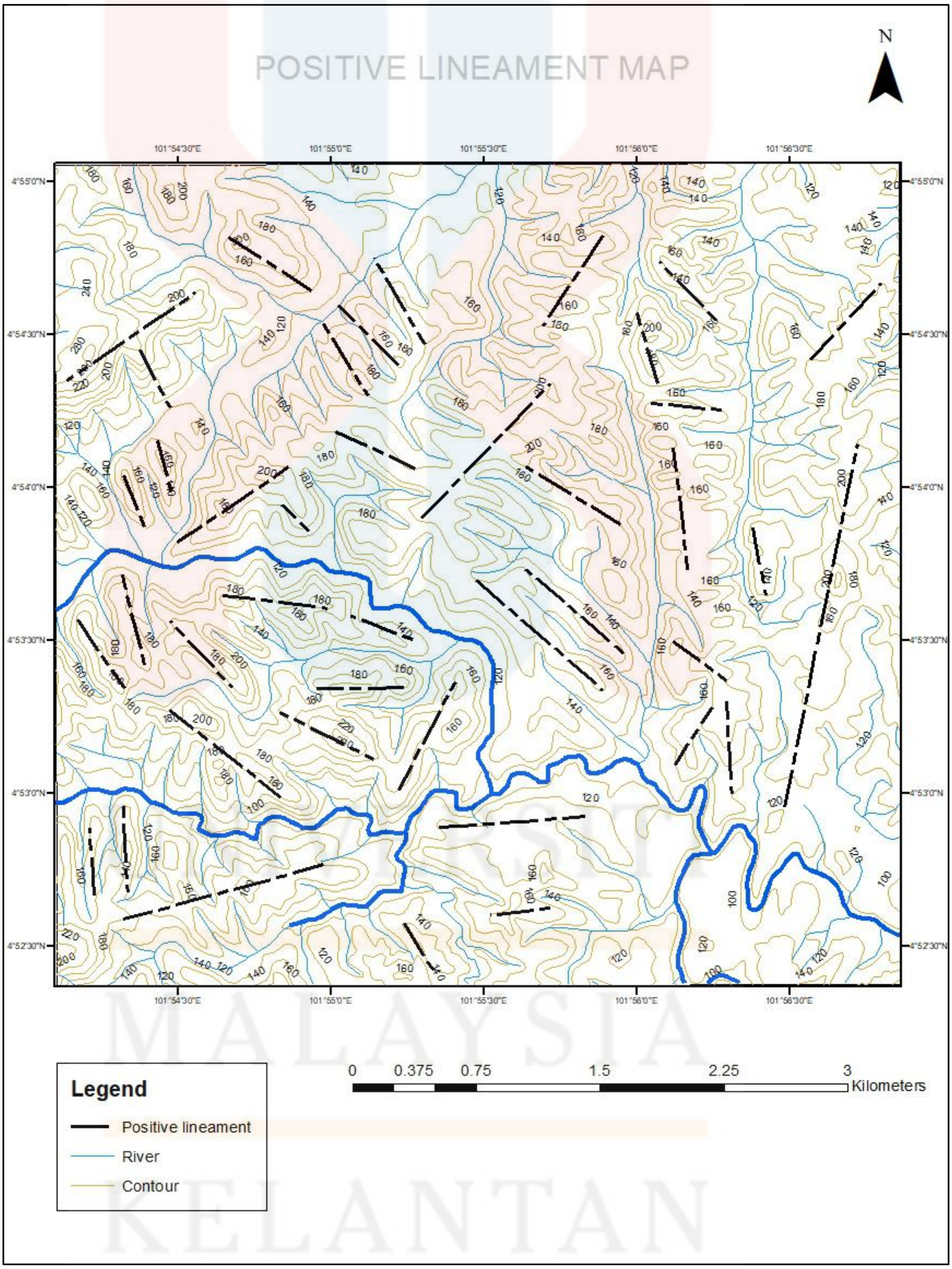


Figure 4.9: Positive lineament map of Kundur area, Gua Musang, Kelantan

4.4.2 Fault

a fault is a plane formed as a result of the movement or displacement of rock layers by tectonic activity. Main faults are easier to interpret based on aerial photographs or guided by topography maps with addition of lineament that show linear feature of faulting.

Normal fault and strike slip failure is the type of fault that was determined from the geological map in the study area. The aerial photography and topography map should take the strike and dip direction of the fault. The fault is called left-lateral if the block turns left on the other side of the fault it calls strike slip fault. The fault that the block on the far side turns to the right, is considered right-lateral.

Therefore, strike-slip movement explained the position of the differential stratigraphic unit within the suture zone. Therefore, the main force direction indicates a sinistral strike slip (left lateral) motion consisting of a shear fracture indicating the study area.

4.4.3 Mechanism structure

Lineament analysis was used to determine the main movement mechanism caused by the main stress applied in the study area, based on the data and calculations recorded during the geological mapping analysis process. From the lineament analysis in Figure 4.10 and Figure 4.11 , the major principle stress, σ1 is determined at:

I. Normal fault analysis - Major principle stress from N 30 ° E

II. Strike - slip fault analysis - Acute angle from N 315 ° W

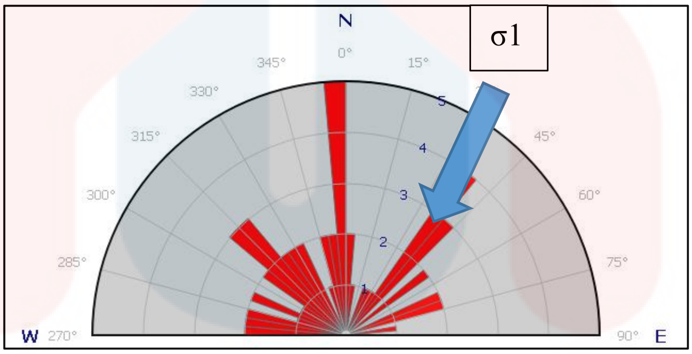


Figure 4.10: Lineament analysis from Strike - Slip fault in Kampung Kundur.

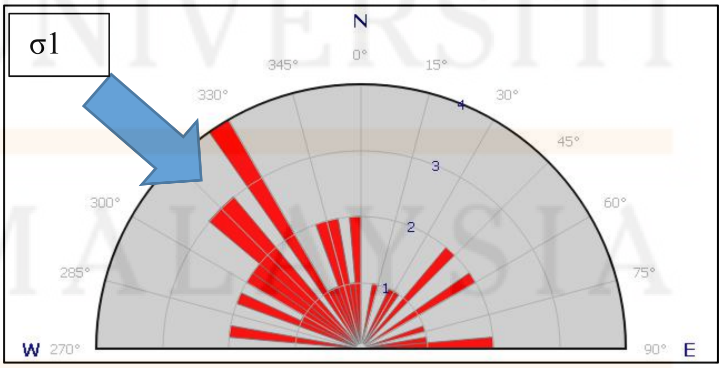


Figure 4.11: Lineament analysis from Normal fault in Kampung Kundur.

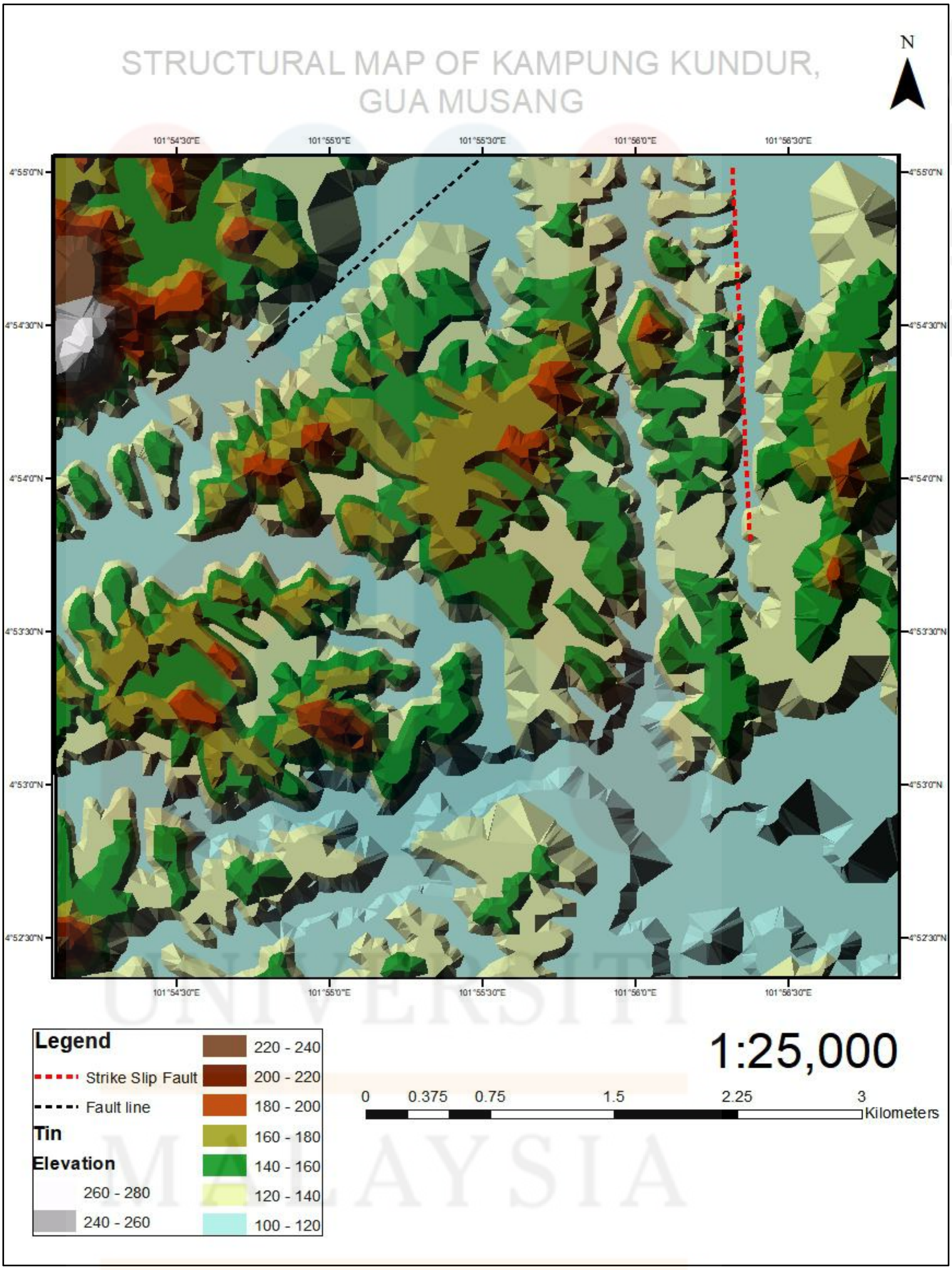


Figure 4.12: Structural map of Kundur area, Gua Musang, Kelantan

From the known direction of force from kinematic analysis and the lineament analysis, there were two interpreted formation of fault that consists in the study area. The formation of the faults and the it position are shown in the figure 4.12.

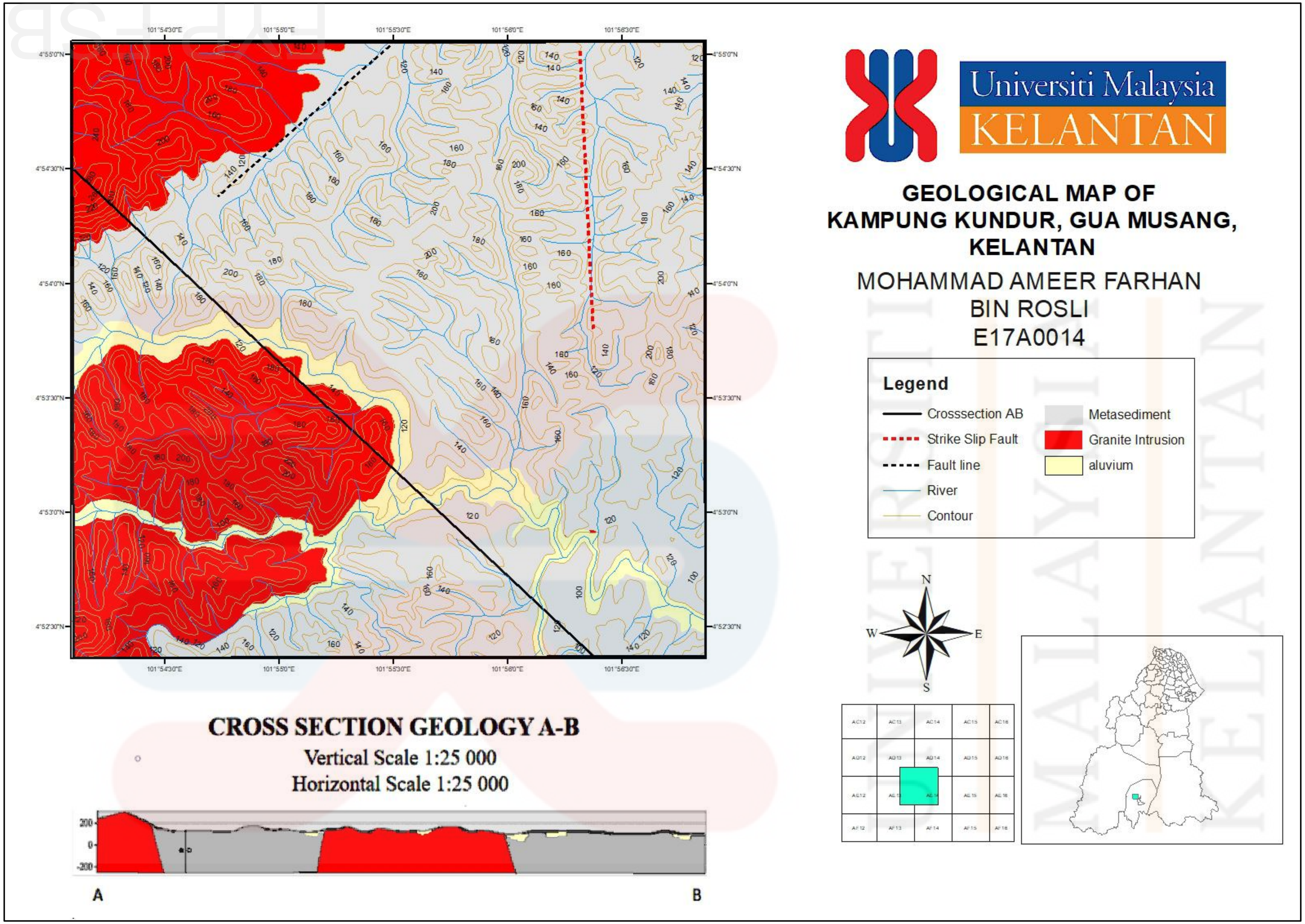
i. Fault A (normal fault) - this fault is elongated form North to several km to South West direction. This normal fault caused by the intrusion of granite that forced the surrounding area that consist of other rock along the intrusion granite to move downward.

ii. Fault B (Strike-slip fault) - this fault formation continued from Subong area, which possibly are a part of Subonng Fault from North toward South direction. This fault is indicating a sinistral strike slip (left lateral) motion which area consists of shear fracture.

4.5 Historical Geology

The rocks found are similar to the characteristics of the formation in the Gua Musang formation, from the findings in the study area. Gua Musang's formation is known primarily as the Middle Permian-Middle Triassic sediment of crystalline limestone with argillaceous faces as a thin layer of shale, tuff, chert and sandstone that occurs in the formation as interlocked.

According to Heng, Kelantan Central Zone geology consists of sediment and metasedimentary rocks that are bordered by granites of the Main Range to the west and granite of the boundary Range to the east. The intrusive granite is composed of Senting batholiths, Stong Igneous Complex and Kemahang pluton within the central region.



GEOLOGICAL MAP OF
KAMPUNG KUNDUR, GUA MUSANG,
KELANTAN
MOHAMMAD AMEER FARHAN
BIN ROSLI
E17A0014
Legend
Crosssection AB
Strike Slip Fault
Fault line
River
Contour
Metasediment
Granite Intrusion
aluvium
CROSS SECTION GEOLOGY A-B
Vertical Scale 1:25 000
Horizontal Scale 1:25 000
A
B
Universiti Malaysia
KELANTAN

CHAPTER 5

LANDSLIDE SUSCEPTIBILITY ANALYSIS

5.1 Introduction

In order to determining landslide zones, there are several factors or parameters used to determine the tendency of landslides occurring. These factors are land use, slope presence, elevation, geomorphology and geology will be identified and evaluated later. As a result, the Weight Overlay Method, the landslide hazard zonation of Kampung Kundur area was determined.

5.2 Result and discussion

5.2.1 Slope presence

The greater the slope's steepness, the more probable it is that rain will run off instead of infiltrating. In addition, the steeper the slope is the faster the water travels. The other reason why this class is given the maximum weightage is the condition that water movement is the most frequent slope instability mechanism.

For the landslide hazard zonation study analysis, the slope map prepared with the help of DEM extracted data, and then use the GIS to classify each criterion in the slope of the five categories of the study area. From the slope map in figure 5.1, most of the map are covered by slope angle from 0^0 - 5^0 that known as gentle slope. Then, the steep slope of the area had angle above >35^0 are distributed only at certain area in the study area. Figure 5.1 shows the classification of slope into 6 class which are very gentle, gentle, moderate, moderately steep, steep and very steep slope degree.

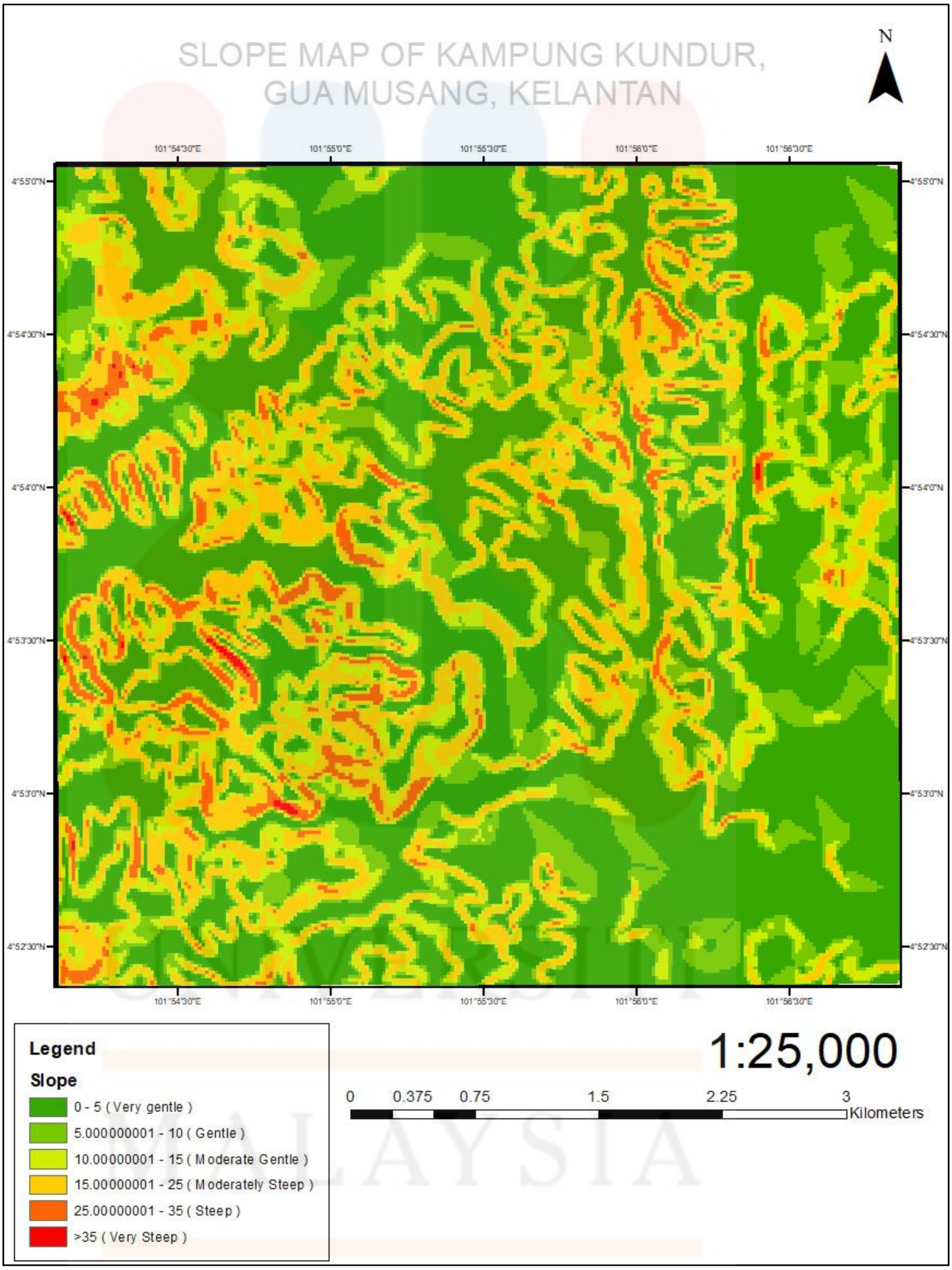


Figure 5.1: Slope map of Kampung Kundur, Gua Musang

The slope weighting and score is subdivided into six using the Geology Society Malaysia (GSM) slope classification with 10 weighting scores. This is because the slope factor gives the occurrence of landslides a significant influence. The score increasing number with increasing of slope degree. Table 5.2 shows, the weightage and the score for slope in the study area.

5.2.2 Aspect map

Aspect map was generated by Digital elevation model (DEM). The feature of the aspect was derived from the DEM in the present study area and was categorised into 8 classes except for flat, North (0-22.5^{o}), Northeast (22.5-67.5^{o}), East (67.5-112.5^{o}), Southeast (112.5-157.5^{o}), South (157.5-202.5^{o}), Southwest (202.5-247.5 ^{o}, West (247.5-292.5^{o}) and Northwest (292.5-337.5^{o}) as (figure 5.2). The aspect map is also relevant as a parameter in the landslide hazard zonation map as the different direction of the slope map results in different gravitational force effects.

According to lee, Landslides were the most abundant relationship between the incidence and aspect of landslides on slopes facing south and northeast. The frequency of landslides was lowest on east-facing, west-facing, and north-west-facing slopes, except in flat areas. Table show the slope direction of aspect and figure shows the aspect map of study area.

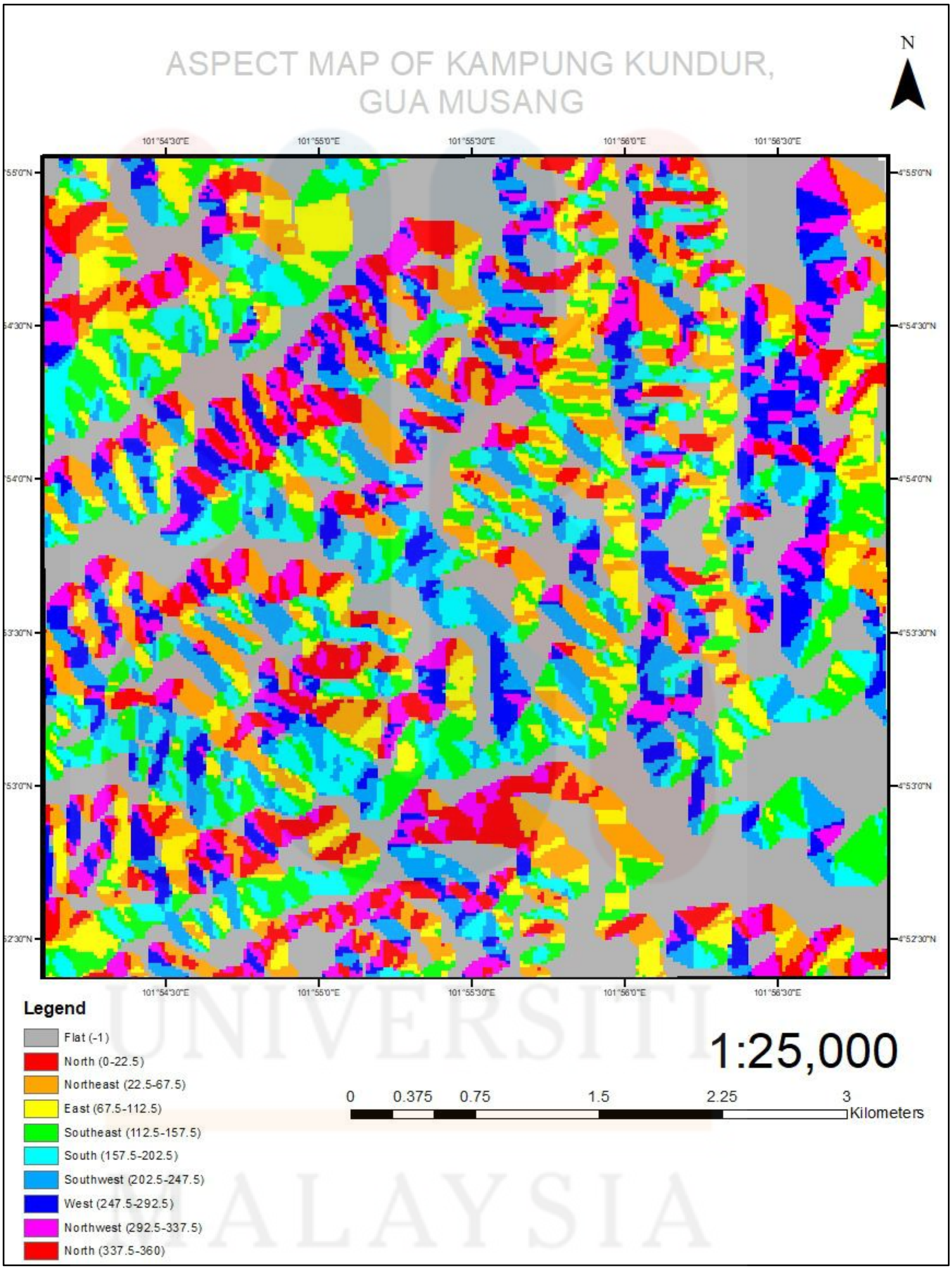


Figure 5.2: Aspect map of Kampung Kundur, Gua Musang

5.2.3 Land use

The lack of vegetation in the region of the slope and along the road would increase the impact of the absorption of rainwater from entering the gap between the rocks, increasing the risk for eroded rocks and landslides and increase the strength of soil by root reinforcement.

In order to record and interpret the land feature from the ground surface, the data can be obtained directly from high-resolution satellite images for the research study. The change in land use becomes one of the parameters as the parameter is different based on the weight of vegetation to that show land use indicates the risk of a landslide. Land use map (figure5.3) show the vegetation distribution of study area. These vegetation was composed mainly by Rubber plantation at Northern part till the South part of the study area. There also several type of plantation in the study area such as forestry, palm oil plantation, and mix type of plantation.

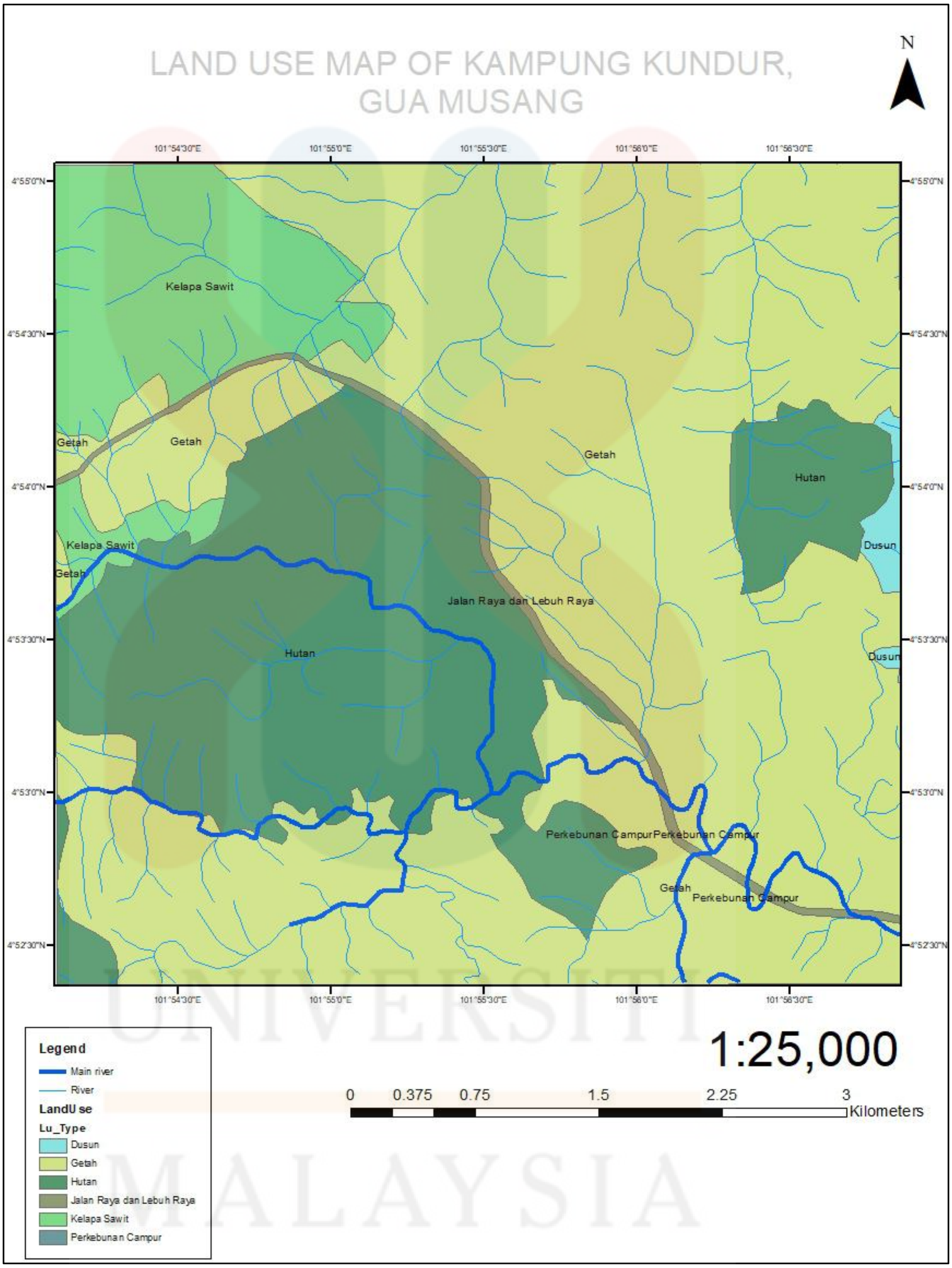


Figure 5.3: Land use map of Kampung Kundur, Gua Musang

5.2.4 Geology

Geology of the study area used in generate the landslide hazard zonation occurrence. From the map of geology of the study area, red colour show igneous intrusion rock, grey colour show a metasedimentary rock and yellow colour show an alluvium. Granite is the igneous rock that crystalline under the surface of earth. In order to create such large mineral grains, granite must solidify very slowly in deeply buried locations which form a harder rock.

For metasedimentary rock, the rock was partially sedimentary rock that was nearly metamorphism into a metamorphic rock. Sedimentary rock primarily a sediment that was deposit in the surface of earth by sedimentation process. This process forms a sedimentary rock that have a bedding of layer to shown the sedimentation rating. Due to igneous intrusion at the study area, the sedimentary rock is transform and changing several physical properties as result of overheat and pressure that change the mineral composition. This process resulting a foliated or banded texture at the rock surface which distinguish from sedimentary rock structure. Figure 5.4 show geological map of Kampung Kundur, Gua Musang which consist of granite rock, metasediment rock and alluvium.

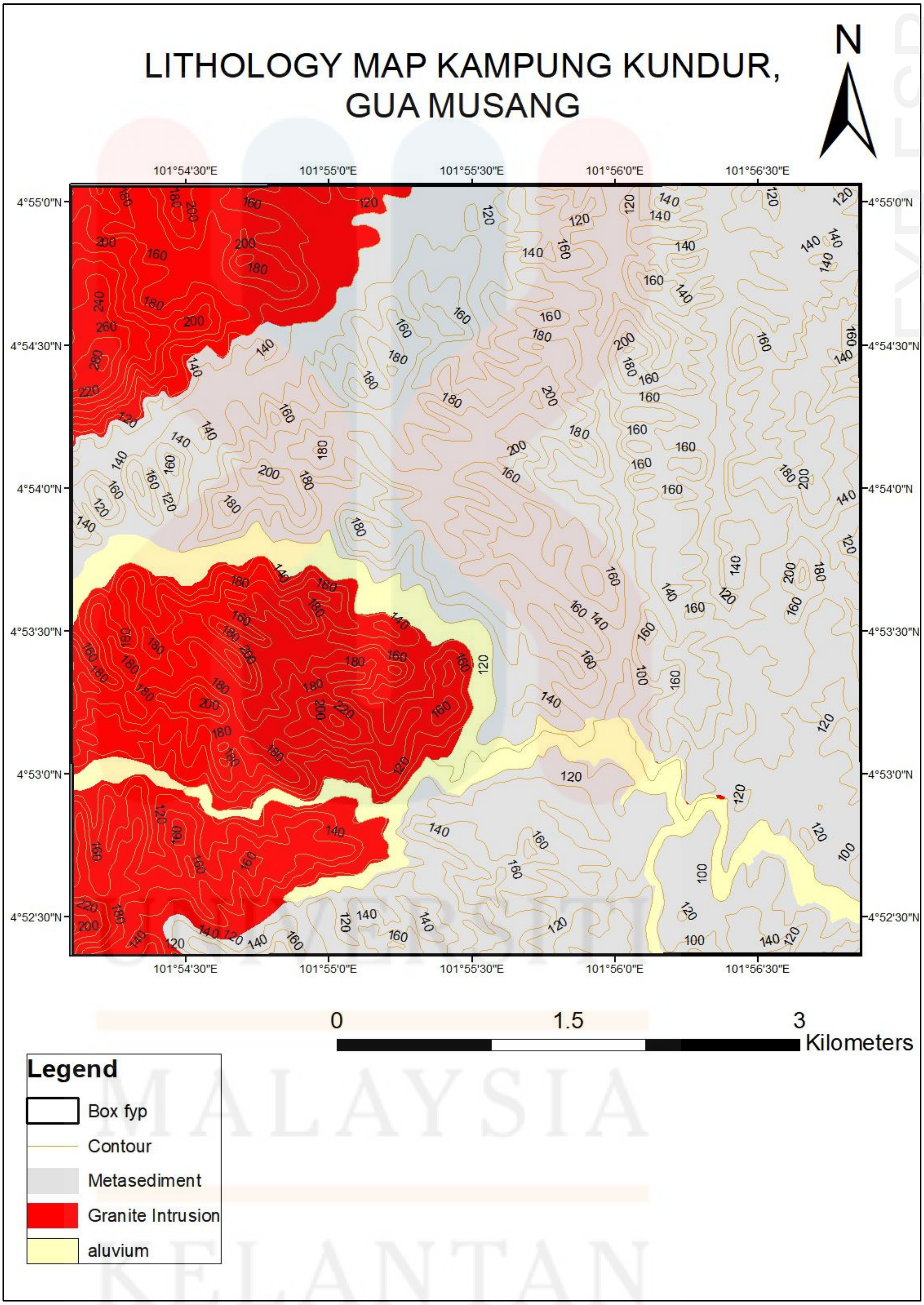


Figure 5.4: Geology map of Kampung Kundur, Gua Musang

5.2.5 Geomorphology

For the present study the elevation was sub divided into five classes which are 90.6 -100m, 100-200m and 200-500m respectively (Fig.5.5). The low potential of landslides in the 90.6 to 129.0 m elevation class can be primarily due to the occurrence of low elevation, on these slopes present. There are three different colour that indicate the different in elevation for each landform in the area. For the red colour, it show the elevation from 205.8 - 244.2 m. For the elevation > 200m, the red colour shows the hills type of landform. The lithology is mainly composed by igneous of granite intrusion. Then, for the elevation 100-200 m, the yellow colour shows the low hills landform type in the area. This lithology is composed by metasedimentary rock such shale and slate.

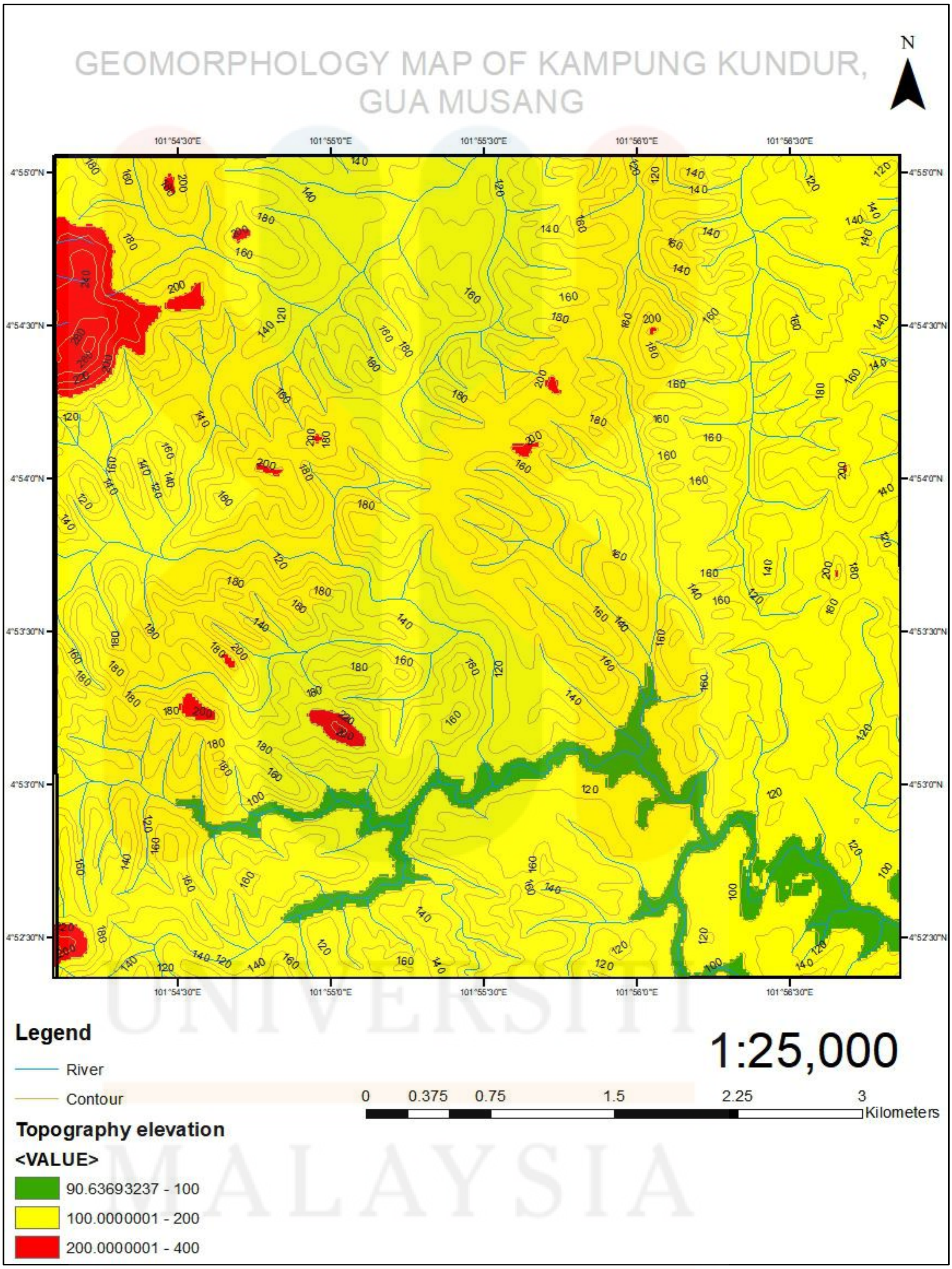


Figure 5.5: Geomorphological map of Kampung Kundur, Gua Musang

5.3 External factor Triggered Landslide

There are few things that can be a landslide-triggering factor. The rainfall analysis was done in the study area to determine the correlation between the rain and the occurrence of landslides. The irregular movement of groundwater along the rock discontinuity formation will reduce the shear strength of the material of the rock on the slope. Thus, the risk of slope failure, particularly in tropical countries such as Malaysia, is increasing and the risk of failure in the slope has increased. (Lee et al. 2007).

5.3.1 Rainfall

The degree of precipitation is one of the considerations for slope stability.The presence of streams affects the stability of toe erosion or toe material saturation, or both. (Sujatha et al. 2012). By penetrating beneath the bedrock, rain adds weight to the slope and removes the void or fracture of the pore. Mechanical disintegration, also known as physical weathering, is a process that takes place near the earth's surface due to Malaysia's heavy rainy seasons. Without modifying the chemical composition of the rock, this motion was caused the rocks to fracture and break apart. Based on this data, the study area rainfall data collected considering the amount of rainfall in Malaysia especially in Gua Musang area.

Table 5.1: Rainfall distribution in Gua Musang from 2015 - 2019

Months	Rainfall Distribution (mm)				
	2015	**2016**	**2017**	**2018**	**2019**
January	102	112	376	279.5	71
February	13.5	148	80	29.5	39.5
March	59	2	79	135.5	231
April	88.5	149.5	64.5	66	53
May	299	65	431	7	217.5
June	112	276	214.5	79	165.5
July	121.5	207.5	152.5	150	172.5
August	314.5	156	340	94	216
September	246.5	181.5	227.5	402.5	272
October	220	188.5	403	305.5	285
November	258	214.5	344	274	306.5
December	219	139	293	317.5	-
Average	**171.1**	**153.3**	**250.2**	**178.3**	**184.5**

(Sources: Jabatan Pengairan dan Saliran, Malaysia)

Table 5.1 show the rainfall data distribution that collected from Jabatan Pengairan dan Saliran (JPS) from 2015 - 2019. The rainfall distribution in five years was collected from January 2015 till end of December 2019. The rainfall distribution is higher in November till January annually, which are indicated by Moonsoon effect that bring high humidity in the East Coast area, especially study area in Gua Musang, Kelantan. In March - May, the rainfall distribution become low and become drought seasons which all water from surface become dry. Therefore, many cases from the local landslide where the weather was degraded the initial upper surface of the layers of slopes, which have been excavated more weakly (Miščevič and Vlastelica, 2014).

5.4 Reclassify of raster

All parameters were converted to raster data sets after all parameters were generated from DEM data. Based on its relevance to landslide hazard zonation analysis, Scale 1 to 5 was created. Scale 1 is the minimum landslide factor, and scale 5 is the maximum landslide factor. The sum of all variables must be equal to 100% in order to have the map completed. This reclassification is therefore essential for the Weighted Overlay Method to generate the landslide hazard zonation analysis. Table 5.2 shows the reclassify of parameter data and the influence use in the Weight Overlay Method which the highest influence used is slope (30), land use (15), geology and geomorphology (25) and aspect (10).

Table 5.2: The reclassify data and influence

No	Raster Datasets	Influence
1	**Slope :** 0 - 5 º 5 - 10 º 10 - 15 º 15 - 25 º 25 - 35 º	**30**
2	**Land use :** Orchard Rubber River	**15**

	Forest road Palm tree Mixed plantations	
3	**Geomorphology** River Low lying plain Low hills hill	**25**
4	**Geology** Igneous Metasediment Alluvium	**25**
5	**Aspect slope** North-Facing (337.5 – 22.5) North-East (22.5 – 67.5) East-facing (67.5 – 112.5) South-East (112.5 – 157.5) South-facing (157.5 – 202.5) Southwest-facing (202.5 – 247.5) West-facing (247.5 – 292.5) North-West (292.5 – 337.5)	**10**

5.5 Landslide Hazard Zonation Analysis

In this study, analyses of the susceptibility to landslides was carried out using the Weighted Overlay Method. Prior to the analyses, the factors affecting landslides in Kampung Kundur area were identified. Landslide regions were defined using the landslide inventory map and satellite images. The parameters were then overlaid using the weighted overlay tools in ArcGIS after all parameters had undergone reclassification. The method of weightage overlay was applied to calculate landslide hazard zonation for the current study area. The modelling, estimation, and analysis procedures are similar for each parameter. The weighting value indicates the relative effect of variables in the initiation of landslides influencing events.

For the preparation of hazard zonation mapping, each preparatory parameter layer was prepared in the GIS domain. Slope, aspect and elevation play an important role in landslide analysis of trends and are very influential parameters. There is a greater tendency for higher steep slopes to produce landslides. The aspect also affects the landslide as the higher topography elevation in the study area was increased the rate of sloping and water flow density from elevation to bottom area. The closer to drainage indicates that the hydrological factors that flow the water can trigger landslide as much of the high landslide potential occurs along the river and streams.

The moderate factor of landslide hazard zoning in the area was affected the land use and geology. In addition, the rainfall factor is triggered to increase the landslide intensity to occur simultaneously. Landslide hazard zonation maps were divided into five landslide hazard susceptibility zones, which are Very High Hazard Zones

(VHHZ), High Hazard Zones (HHZ), Moderate Hazard Zones (MHZ), Low Hazard Zones (LHZ) and Very Low Hazard Zones.

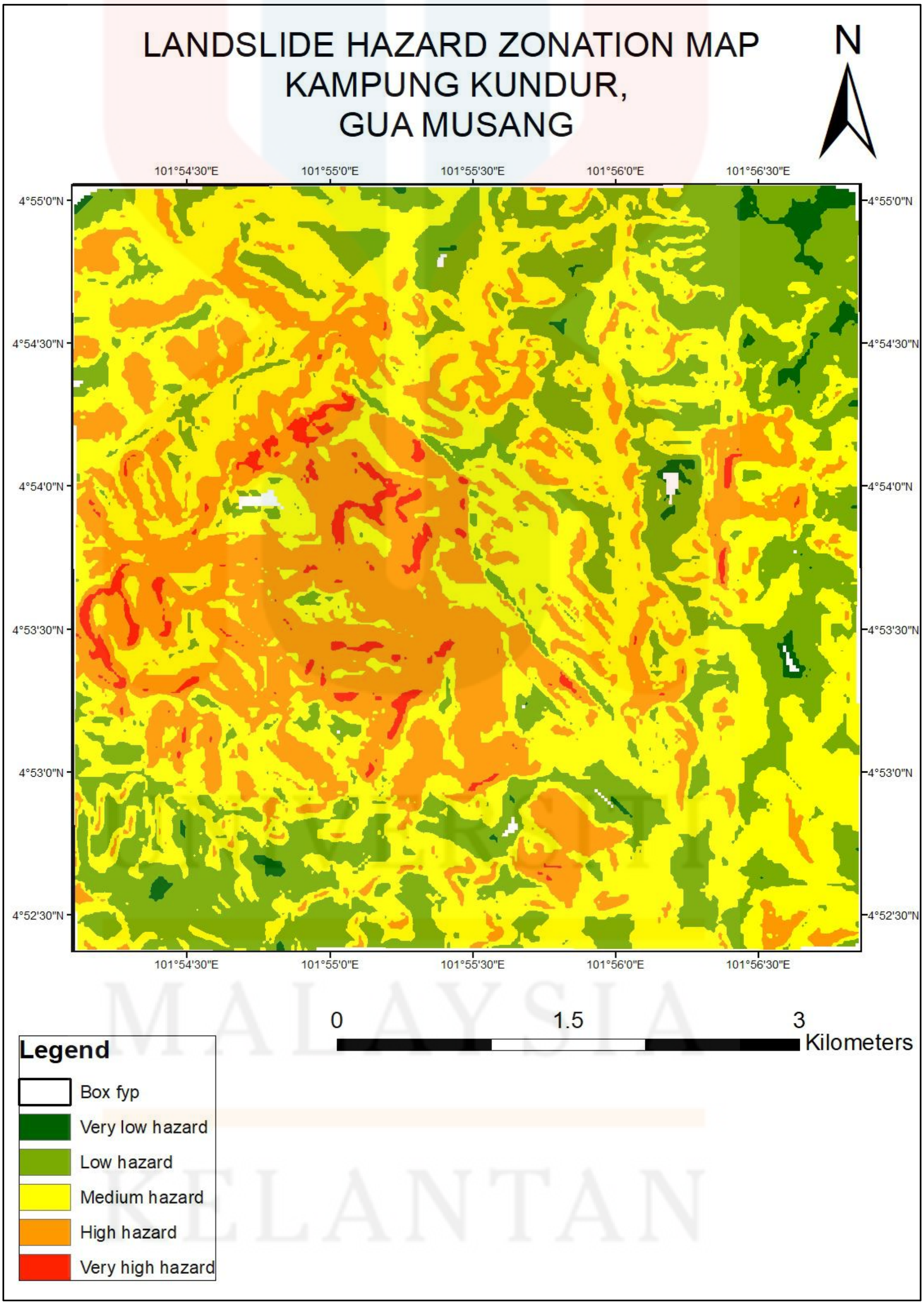


Figure 5.6: Landslide hazard zonation of Kampung Kundur, Gua Musang

Table 5.3 : Percentage area of risk zones

Susceptibility Class	Area (km2)	Area Percentage (%)	Cumulative area percentage (%)
Very low hazard zone	0.65	2.6	2.6
Low hazard zone	4.6	18.4	21.0
Medium hazard zone	10.1	40.5	61.5
High hazard zone	8.5	33.8	95.3
Very high hazard zone	1.2	4.7	100

From the table 5.3 and figure 5.6 shows, the landslide hazard zonation map with the percentage area of risk zone. The very high hazard zone in the study area is consists of 4.7 % of study area, for the highest percentage area is 40.5% (medium hazard zone), 18.4 % of the study area is low hazard zone, the second highest percentage area is 33.8 % (high hazard zone) and 2.6 % of study area is very low hazard zonation. Total accuracy of the landslide hazard zonation is 68% accurate based on the parameter used. The landslide zone in the study area is mostly vulnerable along the stream and river by referencing the landslide hazard zonation. This factor is reinforced by steep conditions and distance to drainage patterns in the study area, causing easy collapse of the area around the stream or river. (Shit., et al 2016). Slope and aspect of zonation mapping is very important in landslide hazards, as its stability forms the basis for hazard frequency and intensity (C., D., & Mah, C. W. (2012).

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In conclusion, all the research objectives specified in section 1.3 have been achieved. The first objective is to update the 1:25000 scale of the geological map of Gua Musang. This objective was achieved by produced geological map of Kampung Kundur, Gua Musang through geological mapping by the secondary data. The detail of geological aspect for the study area such geomorphological aspect, stratigraphy aspects and structural aspect was discussed in chapter 4. In general, the study area in Kampung Kundur was composed by Granite and Metasedimentary rock.

The second objective was analyzed the landslide factor in the research area that is causing the landslide incidence. The study area obtained high rainfall intensity, particularly during the North-East monsoon, because of the climate that rains throughout the year. It effects the slope and aspect factor to increase the landslide effectiveness. Other than that, the land use factor also has the effect of weakening the soil and losing the ability to accommodate rainwater, causing landslides.

The third objective is achieved by generate landslide hazard zonation map of study area, Gua Musang with the scale 1:25000. The landslide hazard zonation map of the study area was produced by using five difference parameter such as slope, aspect, geomorphology, geology and land use. A hazard zonation maps were generated and reclassified into three classifications using the weighted overlay method in ArcGIS software. Landslide hazard zonation maps were divided into five landslide hazard susceptibility zones, which are Very High Hazard Zones (VHHZ), High Hazard Zones (HHZ), Moderate Hazard Zones (MHZ), Low Hazard Zones (LHZ) and Very Low Hazard Zones. Thus, the study area consist of 40.5% of medium landslide hazard as highest area possibility to become landslide and lowest percentage 2.6% as very low hazard zone.

This research is significant to increase the awareness to to ensure the precaution step can be taken by local authorities to prevent injury to people that live as the prediction for landslide hazard zonation was done. In addition, with help of accuracy of the map produced, the the precaution step can be taken by local authorities to prevent injury to people by mitigation step and disaster planning especially in high risk area zonation

6.2 Recommendation

It is suggested to specify sufficient parameters for the study area to achieve a better outcome of the landslide zonation map due to the determination of the parameters that may differ. It is suggested to specify sufficient parameters for the study area to achieve a better outcome of the landslide zonation map due to the determination of the parameters that may differ. Other than that, it recommend to used a higher quality of DEM data as secondary data because the higher quality data will provide a sharp result of image after processing. The USGS website only provide a free data to download which are low quality. Thus, the image resolution is low quality compared to the higher quality data. Also, to get more accurate data, field mapping

In order to generate a better result for landslide hazard zonation, more parameter and suitable parameter must be weighted for landslide in the area because the determination of parameter can be varies result. Different parameters lead to different outcome which the outcome can with the most influential parameter that lead to hazard zonation of landslide in the study area.

In addition, it is proposed to use different mechanisms for the purpose of the weighted overlay process to know if the calculation of differences ways affects other parameters. The use of mathematical and heuristic methods or statistical-based landslide inclination models can be used. This is because different analytical methods will contribute to a higher precision of the inclination of the research area. From landslide maps of vulnerability, proper mitigation system and construction can be considered before any development decision especially in the study area

Lastly, to obtain more accurate data, field studies need to be done to obtain rock samples and then analysis mineral characteristics in the rocks using thin section method. This information from mineral studies help research to identify the rock properties such rock grain size, rock strength and other physical properties that related to landslide. Field studies also help the researcher to study the structural geology direct from the surface of rock formation. Moreover, it will have revealed the evidence of past event formation through the structure in the study area.

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