GEOLOGY AND ASSESSMENT OF GROUNDWATER POTENTIAL ZONES USING GIS METHOD IN LOJING, GUA MUSANG, KELANTAN

by

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DECLARATION

I declare that this thesis entitled "**GEOLOGY AND ASSESSMENT OF GROUNDWATER POTENTIAL ZONES USING GIS METHOD IN LOJING, 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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Date : ___________________________

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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Name of Supervisor I :

Date : ………………………………..

Signature : …………………………........

Name of Co-Supervisor :

Date : ………………………………..

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Geology and Assessment of Groundwater Potential Zones using GIS Method in Lojing, Gua Musang, Kelantan

ABSTRACT

The groundwater resources are to support the water resources. Currently no continuous and active research is carried out to delineate this precious resource in the study area. In this case, an assessment was carried out to increase up the groundwater resources. So, as for this limited availability due to the improper strategic planning and mitigation of groundwater resources, Geographical information system (GIS) has become one of the main tools in the field of groundwater research which helps in assessing groundwater resources. A research entitled Geology and Assessment of Groundwater Potential Zones using GIS Method in Lojing, Gua Musang was conducted to find out the groundwater potential zone which covers area of 25km^2. The aim of the research is to produce the geological map of the study area with scale 1: 25000, to identify parameters for potential zone of groundwater and to produce the groundwater potential zone map with scale 1:25000. The geological aspects involve the study of geomorphology, stratigraphy, structural geology, and historical geology of the study area. The geological characteristics were analysed through geological mapping method. The landforms of the study area are hilly and mountainous area with elevation 180m to 420m. There are four main lithologies in the study area which are granite, mudstone, quartzite and slate. The method used in generating the groundwater potential zone map is by using the Weighted Overlay Method (WOM). The parameters that trigger the groundwater potential zone were analysed and overlaid in order to generate the groundwater potential zone map. Digital Elevation Model (DEM) data were used to extract the parameters. The results were classified into 5 classes: very low, low, moderate, good and very good. Based on the zonation map, the study area is covered with a low groundwater potential zone probability to occur.

Geologi dan Aplikasi GIS Zonasi dan Penilaian Potensi Kawasan Keberadaan Air Bawah Tanah di Lojing, Gua Musang, Kelantan

ABSTRAK

Sumber air bawah tanah adalah untuk menampung sumber air yang sedia ada. Pada masa ini tiada kajian berterusan dan aktif dijalankan untuk menggambarkan sumber berharga ini di kawasan kajian. Dalam kes ini, penilaian dilakukan untuk meningkatkan sumber air bawah tanah. Oleh itu, untuk ketersediaan terhad disebabkan oleh perancangan strategik yang tidak wajar dan pengurangan sumber air bawah tanah, sistem maklumat geografi (GIS) telah menjadi salah satu alat utama dalam bidang penyelidikan air bawah tanah yang membantu dalam menilai sumber air bawah tanah. Kajian ini diberi tajuk Geologi dan Aplikasi GIS Zonasi dan Penilaian Potensi Kawasan Keberadaan Air Bawah Tanah di Lojing, Gua Musang, Kelantan. Kawasan kajian terletak di Lojing,Gua Musang, Kelantan dengan kawasan kajian berukuran 5km$^{2.}$ Kajian ini bertujuan untuk menghasilkan peta geologi di kawasan kajian dengan skala 1: 25000, untuk menilai potensi kawasan air bawah tanah dan untuk menghasilkan peta zonasi potensi kawasan air bawah tanah dengan skala 1: 25000. Aspek geologi melibatkan kajian tentang tentang geomorforlogi, stratigrafi, struktur geologi, dan sejarah geologi di kawasan kajian. Ciri-ciri geologi tersebut dibuat melalui kaedah pemetaan geologi. Bentuk muka bumi kawasan kajian adalah kawasan berbukit dan gunung dengan ketinggian sekitar 180m hingga 420m. Terdapat lempat litologi utama di kawasan kajian iaitu granit, sedimen, kuarzait dan slate. Kaedah yang digunakan untuk menghasilkan peta zonasi potensi kawasan air bawah tanah adalah dengan penggunaan Kaedah Perlapisan Berwajaran (WOM). Parameter kebarangkalian untuk adanya potensi kawasan air bawah tanah dikaji dan akan dilapiskan untuk menghasilkan peta zonasi kawasan air bawah tanah. Model Ketiggian Digital (DEM) digunakan untuk mengekstrak parameter tersebut. Parameter-parameter tersebut yang diekstrak dari data DEM adalah seperti data cerun, ketumpatan saliran, ketinggian, litologi, geomorfologi dan aspek. Parameter tersebut dilapiskan menggunakan Kaedah Perlapisan Berwajaran (WOM) dengan skala untuk menghasilkan peta zonasi potensi kawasan air bawah tanah dan pengkelasan kawasan air bawah tanah tersebut. Keputusan menunjukkan peta zonasi potensi kawasan air bawah tanah dibahagikan kepada lima kelas. Yang pertama ialah sangat rendah, rendah, pertengahan, bagus dan sangat bagus. Daripada peta zonasi tersebut jugadikenal pasti bahawa kawasan kajian dikelilingi oleh kawasan potensi air bawah tanah yang rendah untuk keberadaanya di kawasan kajian tersebut.

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LIST OF ABBREVIATION

DEM	Digital Elevation Model
GIS	Geographic Information System
GPS	Global Positioning System
OLI	Operational Land Image
USGS	US Geological Survey Earth Resources and Science Center
WOM	Weighted Overlay Method

CHAPTER 1

INTRODUCTION

1.1 General Background

This research entitled “Geology and Assessment of Groundwater Potential Zones using GIS technique at Lojing, Gua Musang, Kelantan. This research covers two different aspects which is geology and assessment of groundwater potential zones. Geology include lithology, geomorphology, structural geology, topography and many more. Furthermore, to get the geologic information, field observation and geological mapping was carried out in the study area. Groundwater potential zone map is produced by using Geographical Information System (GIS) based on several parameters such as satellite image data, slope, aspects, land use and drainage. The technique of GIS was applied in order to identify the zones of potential groundwater by producing the database.

In geology perspective, fieldwork and geological mapping was carried out. Preliminary studies and field mapping was the first stage of research in order to know the accessibility of the study area, to identify regarding conditions of the study area either it is a housing area, plantation or forest as well as to get the facilities around the study area.

Besides that, fieldwork like traversing and sampling task was conducted. For traversing and sampling, all the details of the geologic features were taken and recorded. For an example, the sites of the outcrop, the strike and dip, the lithology, any geological and sedimentary structures and all the geologic information were recorded. When the sample was taken, the fresh sample should be taken and not weathered sample. The sample must be big enough and not too small to represent the locality. The samples were taken to the lab for further petrographic studies and thin section. The final research activities of the general geology is producing the geological map at 1: 25 000 of the study area.

GIS tool for the assessment of lineament data taken for groundwater potential mapping from SPOT imagery was used by (Sreedhar Ganapuram, 2009). In addition, the first step of preparation of many kind thematic layers, such as lithology, geomorphology, drainage density and slope in GIS environment that emphasizes in a spatial domain of weightage gave big help to the identification process of potential groundwater zones. So, in other perspectives, it can save energy, cost, time, and manpower in this research.

Most people have been overused of groundwater resources which has been studied in past and recent years that lead to the environmental problems such as groundwater become more reducing, water limitation, and make the water flow leading to pollution of groundwater. The sources of ground water must be assessing thoroughly to know the demand needs. The mapping of ground water is essential for the beneficial ground water potential zones with goods limitations. The ground water occurrence, its quality and the way to explore it, depending on aquifer features. The movement of ground water, origin were focused on the geologic framework such as thickness, lithology, permeability of aquifers and structures. In fact, to determine the groundwater potential zones, survey and study need to be detail and were carried out to get enough data and information about the study area. For this research, GIS and remote sensing is a very useful technique that can be used in mapping especially in mapping zonation of groundwater assessment.

1.2 Study area

1.2.1 Location

In Kelantan State, Gua Musang is the largest district. Gua Musang which is located in the middle between the Terengganu State at the east, Perak State at the west and Pahang State at the south part. Gua Musang has an area 817,595 hectar. It is separated into several three which is Bertam District, Galas District, and Chiku District. Nenggiri River, Galas River and Lebir River is the main tributaries of Kelantan River network. Nenggiri River is the main drainage network system of Gua Musang. Lojing or Lojing Highlands is a hilly village in the Gua Musang area of Kelantan, Malaysia. Lojing is a hinterland and a small colony located in the state of Kelantan. Lojing upper point which is the peak is at 2000 meters that is above sea level. Lojing Highlands can be reached from Gua Musang, Kelantan and from Pahang at Cameron Highlands.

The biggest ethics of the indigenous people in Lojing is mainly Temiar tribe of the Senoi nations. It is at the coordinates E 101°49’0’’, N 4°49’30’’ until E 101°49’0’’, N 4°47’0’’. That place is located near the Cameron highland in Pahang, along the second East-west Highways. The only way to go to the study or research area is through the improper road that basically always use by lorry. There are no any facilities such as railway as it in the rural area. In the study area, there are many of small river tributaries there is no main river. It is at the coordinates E 101˚48’50.75’’, N 4°49’31.21’’ until E 101°48’50.75’’, N 4°46’51.78’’. Figure 1.1 shows the base map of the study area. Then, Figure 1.2 shows the location map of the study area.

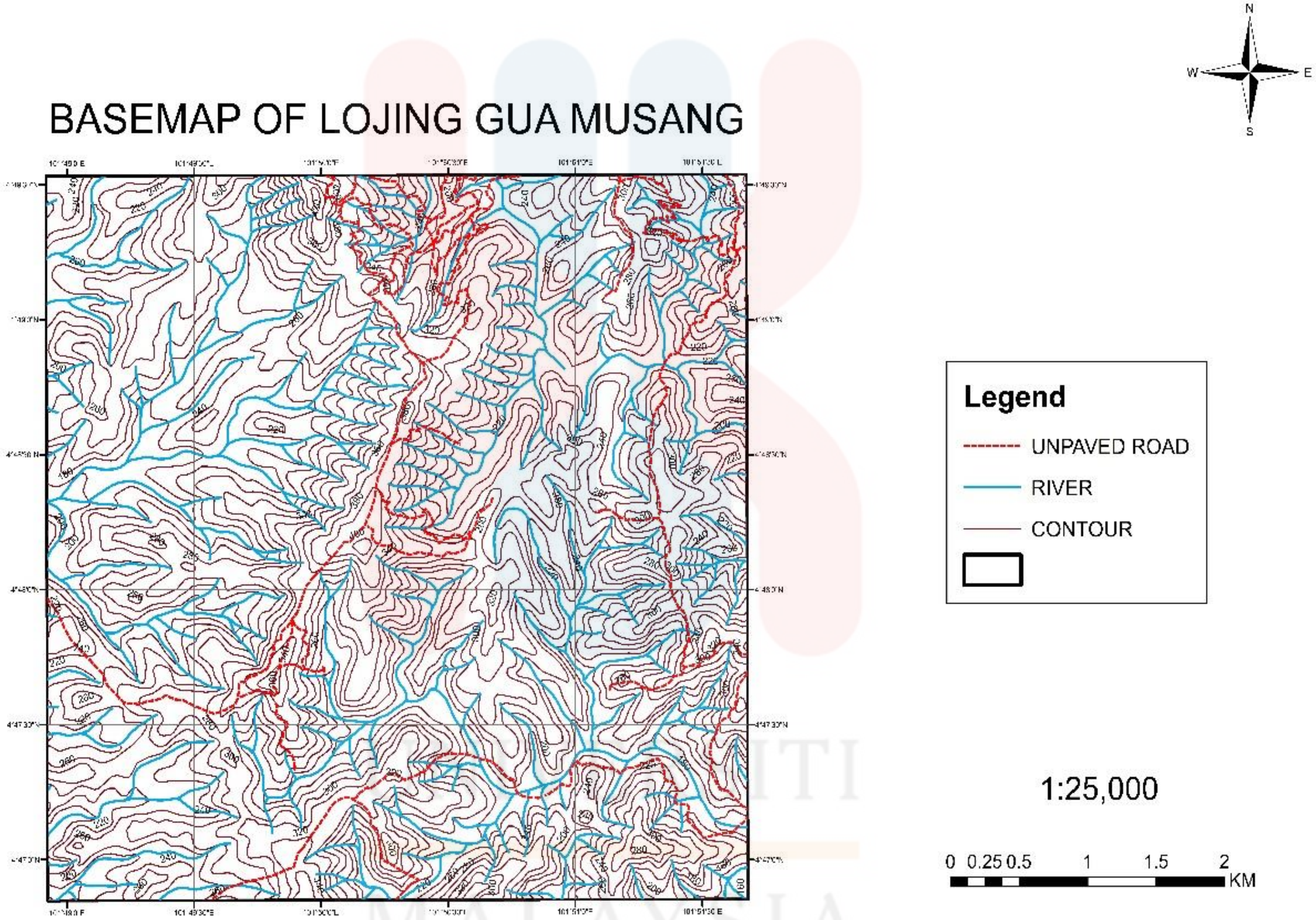


Figure 1.1: Base map of the study area

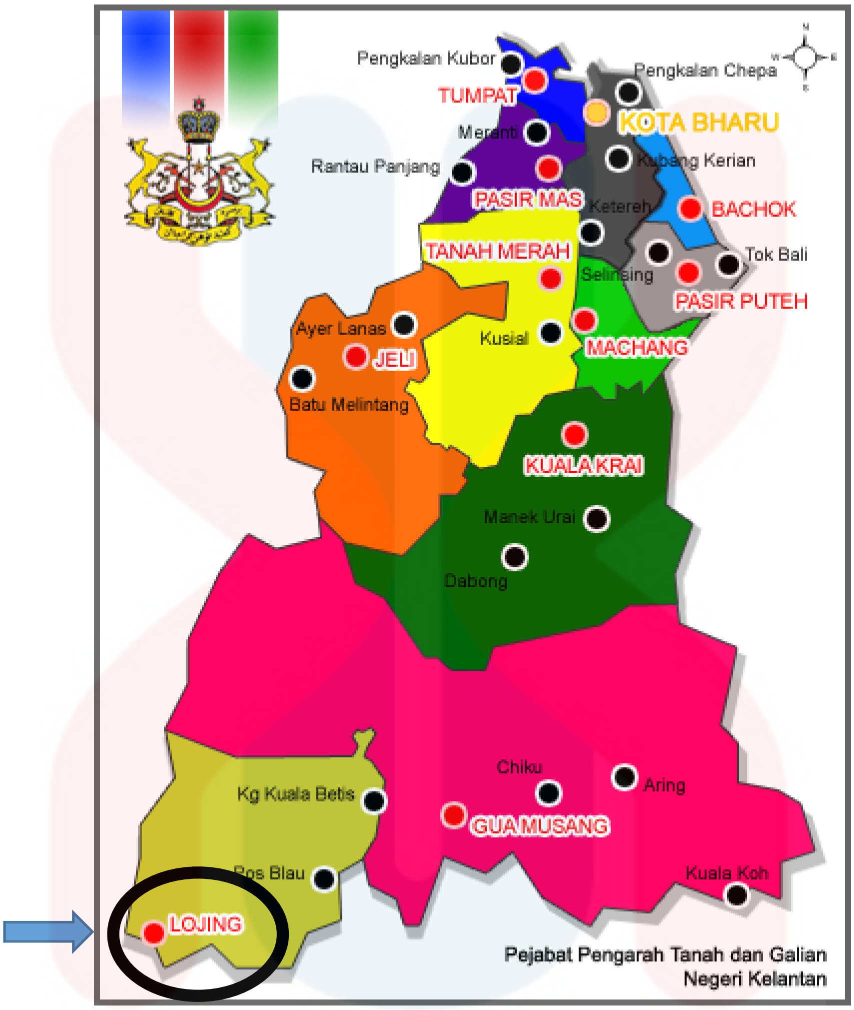


Figure 1.2: Location map of study area

1.2.2 Accessibility

There are a few ways in order to reach Gua Musang including planes, trains, bus or travel by cars. People can come and go to Kelantan by using transport plane and landing at the Sultan Ismail Petra Airport in Pengkalan Chepa, Kota Bharu. In addition, it is around 195 km and it took about 2 hours and 58 minutes to travel from the airport to the Gua Musang.

From Kuala Lumpur to Gua Musang it took about 260km and around 3 hours and 53 minutes through Kuala Lumpur to Gua Musang Highway and it took about 4 hours and 36 minutes around 354 km via the East-West Highway that connect Kuala Lumpur to Perak and through Gerik to reach Gua Musang . From Jeli, in order to get to the Gua Musang, people get to choose between two possible routes which is one travel via Dabong. It only took around 1 hour and 45 minutes and about 114 km compared to via Tanah Merah which is took longer time. Figure 1.3 shows the route way travel starting from Jeli to Gua Musang via Dabong while Figure 1.4 indicates Route map from Gua Musang to Lojing.

Figure 1.2: Route map from Jeli to Gua Musang via Dabong

Other than that, the other way for people also can access from Kuala Lumpur to Gua Musang by using train. Train Keretapi Tanah Melayu Berhad (KTMB) operated daily to Gua Musang from west Peninsular Malaysia. It took 11 and half hours to arrive with 501 km distance and at the same time Figure 1.4 shows the route map from Gua Musang to Lojing in order to see more clearly regarding the way to the study area.

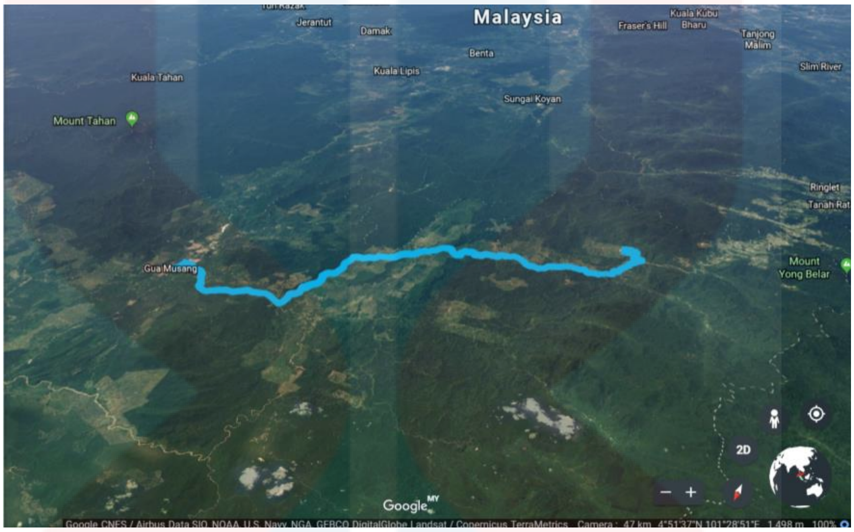


Figure 1.3: Route map from Gua Musang to Lojing

1.2.3 Demography

There were about the total population is 90,057 people in Gua Musang in 2010 (Malaysia, 2010). Furthermore, Gua Musang is major dominated by Malay which is more than 94% ethnic followed by the Chinese with 6% while for Indian not more than 1% and others ethnic with 0% because of very small number of people in that location area. However, there were no specific numbers of populations in Lojing area stated or come out with current data or statistics by any responsible parties.

1.2.4 Land Use

Lojing, Gua Musang which is focused in the study area is mainly dominated by forest which is 97% from the study area and got all the data from the topographic data and satellite image and then, the balance remaining 3% is slightly including of bush forest. There are a few small places of area consist of rubber plantation and oil palm plantation. Almost 97% is the reserve forest where the area was covered by trees, bushes and shrubs. The forest reserve area was mainly on the east part in the study area. Figure 1.5 indicate the percentage of land use in Lojing, Gua Musang.

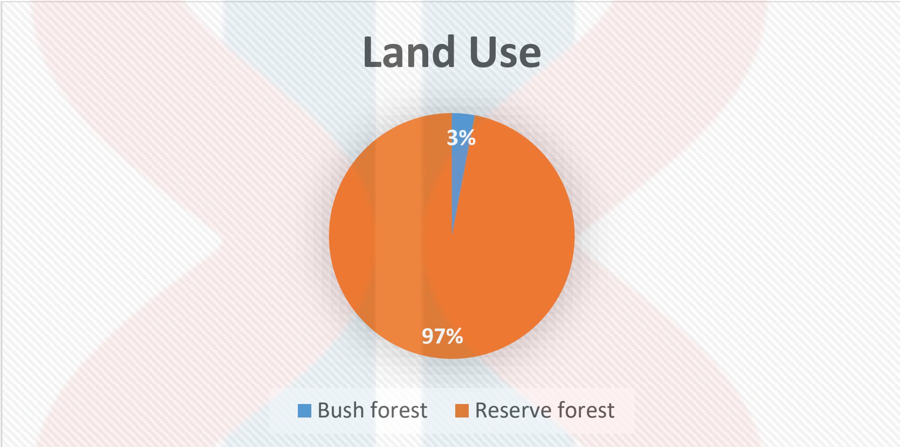


Figure 1.4: The percentage of land use in Lojing, Gua Musang

1.2.5 Social Economic

The main works or an activity for people in Kuala Betis to generate income is through plantations activities and some logging activities. Most of the people work in the plantations area and logging in the forest. This is due to the vegetation of the area which is mainly dominated by the plantations and forest. Most of the residences in Lojing, Gua Musang only did this kind of jobs because of lacks of development in the area. Lojing was also a bit far from the town and it is also can be categorized as rural areas that isolated from the town and development. Thus, people here are not very up to date o any recent development. However, although Lojing is in the rural area, it also has many social facilities which is Klinik Kesihatan Lojing, Masjid Keputeraan Lojing and school at Lojing, Gua Musang as it is shown in Figure 1.6 below. There are no any facilities such as railway as it is in the rural area.

Figure 1.5: Klinik Kesihatan Lojing, (Source, *Google image)*

1.3 Problem Statement

There were some problem statements which needed to be emphasize in this study. Firstly, geological data which is in the study area is incomplete and less information regarding the geomorphological sides. Through the observation and geological mapping, the geological map can be updated.

Next, currently no continuous and active research is carried out to delineate this precious resource in the study area. In this case, an assessment was carried out to increase up the groundwater resources. So, as for this limited availability due to the improper strategic planning and mitigation of groundwater resources, it is worth it to look for more hidden sources of groundwater throughout Kelantan especially Gua Musang area. Extensive hydrological observations and investigations are often needed to fully understand ground water conditions by implementing assessment of groundwater zonation to come out with a proper planning and assessment.

1.4 Objectives

The objectives of this research are:

1. To update a geological map of Lojing, Gua Musang at 1: 25 000 scale.
2. To identify the parameter for the potentiality of groundwater resources by using integrated GIS tool.
3. To produce a groundwater potential zone map of Lojing, Gua Musang at 1: 25 000 scale

1.5 Scope of Study

In this research study, it focused on producing geological map which is 25 km square of Lojing, Gua Musang. Besides that, in order basically to produce the geological map, assessment, the geological mapping and observations had been done to get all the geological information regarding study area. A few of mapping equipment were used for conducting the geological mapping. At the same time, the hardware used for the study are personal computer, scanner or colour and printer while the software used are ArcGIS 10.2 (ArcMap, ArcCatalog, Arc Toolbox), Microsoft office and data from satellite image. Furthermore, to achieve the objectives, data has been gathered for the starting steps of thematic maps of the study area.

Furthermore, this research or study was also emphasized on the groundwater potential map within the study area. The map of groundwater potential zone is done by using an integrated geospatial technology and ground based observation. In addition, primary data that were used from the field observations and the secondary data from the satellite image data were using together in order to get enough information.

1.6 Significance of study

For this research study it were very significance because it can give and prepare the information and details regarding the hydrological information of the study area by doing assessment from different aspect such as lithology, geomorphology, drainage density and geological structures that occur in the area. Furthermore, a detail mapping is one of the effective ways of aspects to observe the geological features, provide more details geological information of Lojing, Gua Musang.and more detailed geological map can be produced.

The updated geological map in Lojing area was beneficial to the people around and also locals. The lithology of the study area were identified systematically and given name by combining both petrographic analysis and field. Furthermore, identification of types of lithology together with other highlighted features such as geomorphology and structure were assisted in the systematic future development of groundwater at Lojing, Gua Musang, Kelantan.

This study is trusted to provide very important information to the decision makers and found the groundwater demands in the entire area to a good sides and this research can also be used as good aims and references in future. For delineating the potential rate of groundwater of the study area, the groundwater zonation map can be used as base data to support land use planning and agriculture activities in the context of widespread and planning and assessment tenacities. Through that way, it brings less risk towards the community that lives there.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discussed about the literature review regarding the past study which had been carried out in the study area and also that related to the research topic. The literature review highlight and determine the procedure and methodological that was carried out or conducted for this research. This chapter covers the structural geology, stratigraphy, regional geology and tectonic setting, historical geology of Kelantan and also the groundwater potentiality zones assessment.

2.2 Regional Geology and Tectonic Setting

Sundaland is including of two block which is Sibumasu Block and West Sumatra Block. At the beginning of Mesozoic Era, a big section of the forming of new Peninsular Malaysia of landmass then uplifted and maintained exposed aerial. Peninsular Malaysia started to form in the period of Triassic where the time of collision of Indochina plate with Sibumasu plate was. In this case also it basically wholly or fully stress during the Cenozoic and is throughly tectonically relatively stable where the process of the activity is being limited to uplift of epiroigenic and local gentle downwarps and tilting some fault movement, (Gobbett D.J & Tija, 1973). The Malay Peninsular is separated down into several three parts which are Central Belt, Western Belt and Eastern Belt. Then, it is divided into a sector of northwest and a sector of Kinta-Malacca of The Western Belt. It is overlain by limestones, clastics and minor volcanics. In addition, the period of the Langkawi folding timing of (Tan, 1983) is got starting Devonian to mid-Permian and in this section is not just limited to southeast of Langkawi but overall it covered up of Terutao and Langkawi place and and make it until southeast to the mainland of Kedah creating a direction of northwest expending of belt that is known as the Patani Metamorphics (Khoo, 1983). In the Central Belt part, lies The Bentong-Raub Suture Zone and overlained by Permian-Triassic clastics, volcanics and limestones. Paleo-Tethys in Peninsular Malaysia is showed by The Bentong-Raub Suture Zone. Between the Lower Paleozoic sediments of the Bentong Group and Lebir Fault Zone lies The Central Belt (Hutchison, 2014). At the part Eastern Belt, a matter of metamorphism, folding and uplifting occured in the late Paleozoic overlain by the Permian-Triassic clastics and volcanics also The Eastern Belt.

Kelantan is located at eastern part of the Peninsular Malaysia that having of sedimentary and metasedimentary rocks of a central zone bordered on the east and west by Boundary Range and the Main of Range Granite. Granitic intrusive can be investigated at the central part, where more well-known of these from the Ulu Lalat (Senting) of batholith, the Kemahang Pluton and Strong Igneous Complex. It also shows a north-south of these country rocks and belts of granite.

Peninsular Malaysia is known as the east section of the Eurasian Plate and the place at the north where Sunda Arc of subduction arc zones that still actives. It also been separated into two terranes of tectono-stratigraphic where the Sunda Shelf (where the Eurasian plate-Indochina) and terranes of Sibumasu . Permo-Triassic where the island arc system which is also known from The Eurasian plate (Ariffin, 2012).

East of Bentong Suture line where located the Formation of Central belt as quite hard and complicated also complex. The occurring of collisions between these two plates later combined along the Raub-Bentong Suture Zone. Then, from the collision of structure happened has trigerred main N-S or NW-SW well known dilational Riedal and left slip fault and a small shears also a lot of splays together with the fault (Ariffin,2012).

2.3 Stratigraphy

For the Bentong –Raub Suture Zone, the lithostratigraphy is consists of schist series, chert-argillite sequence, melange and olistostrome, amphibole schist, serpentinite and Bilut redbeds. The western margin consist of Main Range Granite and the eastern margin is include of bedded chert, (Hutchinson, 2009). The central belt lies between the Lower Paleozoic sediments of the Bentong Group. The Upper Paleozoic sediements consists of argillaceous, volcanic, calcerous and arcenaceous rock of the Raub Group, Formation of Gua Musang, Aring Formation and also Keping Beds.

For Raub Group consist Calcerous Series and Volcanic series of the Carbo-Permian strata according to (Hutchinson, 2009). Also in this group, consist of two formations which is Formation of Gua Musang and Formation of Aring. The Formation of Gua Musang is created from crystalline limestone,chert nodules, tuff, interbedded of shale ,sandstone and volcanics. As for the Aring Formation, the name is given based on the Sungai Aring in Kelantan. This formation is made up of pyroclastics, dolomitic marble, and argillite. Those are the stratigraphic same of the

Gua Musang Formation calcareous-argillaceous and also consist of the same rocks to south in the western Pahang and northwestern (Hutchinson, 2009).

2.4 Structural Geology

The information regarding structural geology is about geological characteristics that formed during the process formation of rock. Furthermore, also have quite several factors which created to the forming of the structural geology such as deposition of sediment, tectonic process, the force of energy and many other aspects. The structure of geology also can be occurred between before the rock formation, time of the period the formation of rock. Through geological mapping, it is enable to indirectly determine the ground features and conditions through the surface and features of subsurface such as land use, topography, drainage, geomorphology and geology.

Structural geology of Peninsular Malaysia shows a very wide hard of tectonic evolution maybe from Cambrian to Cenozoic. It is suggested the western Gondwana part of the Sibumasu collided with the Indochina block during the Upper Triassic Indonisian Orogeny (Metcalfe, 2017). For the Central Belt, the margin area is thoroughly observed with the long line is mainly north-south trending of faulting.

Hydrological methods such as resources assessment of groundwater, planning, and urban drainage system also soil erosion the data of the remotely sensed derived has derived attention with (Kumar, 2016). A few geologists have used the GIS applications and the derived data remotely sensed for groundwater assessment, water resources management, and modeling. The technique of using GIS and remote sensing has been showed and determined to be an effective and efficient tool or equipment in groundwater research studies (Rammohan.V, 2015).

2.5 Historical Geology

In the historical geology one of the main important technologies developments in Peninsular Malaysia geological in this recent years has been the wide and general acceptance of the separated division of the peninsular into 3 belts each with its processes of evolution and geologic history. This 3 fold division is not a recent observation. As these three belts have the relationship in terms of geology, the specific marginal areas between the belts have naturally received much interest and attention. However, the demarcation of the boundaries still be a problem and have been made a few proposals (Tan, 1983).

The boundaries of the Central-Western Belts were shown combined together in the occurrences in the rock formations of serpentine bodies creating the foothills of the eastern of the Main Range of Granite. This line is basically called Bentong-Raub line (Hutchison C,1977).

2.6 Groundwater

Groundwater is consistent and cost-effective natural source for supply of drinking and agricultural purpose. Therefore, conducted of an assessment of this resource is very important for the sustainable and systematic management. Moreover, satellite of remote sensing gives good view, which is very helpful in determination identification and assessment of many types of landforms, structural elements, terrain characteristics, linear features and be important indicators of potentiality of groundwater zones in the scope study area. Preparation of many or various thematic layers, such as lithology, geomorphology, drainage density and slopes in GIS environment with accurate weightage which is in a spatial domain supported the assessment of potential groundwater zones.

Hsu, (2008) states that the assessment of the potentiality zone of groundwater source of recharge is very significance in order for the prevention steps quality of water and the groundwater management to become more systematic. In addition, upcoming or further groundwater potential research was already conducted in Taiwan with the advance help of the geographical information system (GIS) and remote sensing by using the five factors that contribute: land, lithology, lineaments, drainage, cover/land use and slope. The factors of weights contributed to the recharge of groundwater are made using geology maps, aerial photos, field verification, and a land use database.

2.6.1 Past assessment of groundwater in Malaysia

There are several assessment regarding groundwater that happened in Malaysia which is about groundwater is in high request in areas where there is not enough of surface water supply and does not occured in Malaysia. Groundwater is in demand in areas where surface water supply is inadequate and nonexist in Malaysia (Mohamad abd manap, 2010). According to (Saim, 2009) groundwater is become important especially for general water supply in the area of Perlis and Kelantan (Mohamad Abd Manap, 2010). At the same time, for example other states likes Pahang, Terengganu, Sabah and Sarawak have been used groundwater as a supply in their water supply systems. In the state of Kelantan the total water supply which is derived from groundwater is about 70% especially in the Kota Bharu areas.

2.6.2 GIS in Assessment of Groundwater Potential Zone

GIS is a system of computer which have been use to manage information data in systematic and practical way which is digital form. Geographical showing the locations of the data information. Next, it is in the form of coordinates system. GIS is a good and effective approach to do assessment of spatial and non-spatial data on drainage, landforms and geological parameters to know the correlation between them. The concept of integrated GIS already showed to be a good equipment or tool in creating urban planning and groundwater further studies. GIS is a collection of computer hardware, software and geographic data for capturing, storing, analyzing, and manipulating data for geographical information (Shukla, 2015). Works by Rao, (1996) have shown that parameters or features controlling groundwater potential at West Godavari district, Andhra Pradesh state, India such as geomorphology, lithology, recharge condition and structure of the study area. These parameters were analysed using Arc Info GIS software. An assessment of potential of groundwater and creating of a map investigated three main hydrogeological features or conditions with difference groundwater sides that be as a basic method or tool in the exploitation or extraction of groundwater resources of the area was presented.

The GIS technology allows advance and systematic of quantification, organization, and interpretation of large quantities of hydrogeological information or data with high point of accuracy and minimum effort or risk of basic error (Pinder, 2002). Remote sensing is main of the source with surface characteristics information of groundwater for example land forms, land use, and drainage density. All the data can be further input in GIS for the identification of groundwater zones (Reddy, 2018). The exploitation and exploration of groundwater resources needs to understanding geology, geomorphology of that area. The data and thematic maps such as satellite images, soil data, geology data, drainage data and rainfall data, are helpful for mapping of groundwater potential zones (Devendra Nath Giri, 2012) ,

Geographical Information System (GIS) data combined with Remote sensing technique are very systematic to identify the potential zone of groundwater of any place or area. The current results where the integration of thematic maps used or prepared from remote sensing and conventional techniques by using GIS gives more systematic, accurate and good results (Subin K. Jose, 2012).

2.6.3 Groundwater zonation

(Deepesh Machiwal, 2011) proposed a normal methodology to know groundwater of potential zones using method of RS, GIS and multi-criteria making of decision (MCDM) method. The steps are showed by a case study in district of Udaipur of Rajasthan, western India. At first, many thematic layers have been considered back. Thematic layers where is the weight and their characteristics after that standardized by using AHP (analytic hierarchy process) eigenvector method and MCDM technique. Finally, thematic maps that were selected were assessed by combination of weighted linear method in a GIS condition to create or generate a groundwater potential map. From the satellite data we can identify the water holding capacity for different geomorphological and structural units. From the land use, slope and rainfall data we can identify the groundwater quality of the study area (Rajvir Singh, 2015). Remote Sensing and GIS technique has proved that it is time saving process and low cost for obtaining slope, drainage density, geology, geomorphology maps (Sharma, 2016).

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

This section discussed several types of methodologies and materials that were used to conduct in this study. Work flow of the study which was covered preliminary research, field study, materials, sampling, laboratory investigation and analysis of data and interpretations were explained with detail in this study.

3.2 Materials

Materials are divided into two parts which is geological mapping and groundwater specifications. Several materials were needed in order to conduct the research activities. From geological aspects, a few mapping tools is needed such as Brunton, hammer, compasses ,roll up tape, hand lens, acid bottles and GPS. For the groundwater sides, several secondary data from the satellite image were needed to generate the groundwater potential zone map.

3.2.1 Materials for Geological Mapping

a) Hammer- to take the sample of the rock and break the exposed outcrop and used for splitting and breaking rocks. In field geology, it were used to get a fresh quality surface of a rock.

b) Acid bottle- The bottle of acid that contains the hydrochloric acid was used to add on or test on the limestone rock. If one drop of the hydrochloric acid was dropped on carbonate rocks, it will show reaction. The acid reacts with the rocks and gas bubble or frizzy effect can be seen.

c) Global Positioning System (GPS) - Global Positioning System (GPS) basically a navigational way or method. GPS was used to detect or locate the latitude longitude and to create or plot tracks along the study area.

d) Brunton compass- to get the measurements of directional degree (azimuth) by using of the the Brunton Compass Earth's magnetic field.

e) Roll up tape – The tape that were roll up was used for the dimensions of the outcrop to be measure.

f) Hand lens- The hand lens was used to identify or observe the properties or characteristics of the mineral that is contain in the rock. The mineral can be seen easily in the rock by using the hand lens.

g) Information and data

    a. Data about the distribution of rainfall in Lojing, Gua Musang, Kelantan from Department of Irrigation and Drainage Malaysia.

    b. Data and information about the total population by age group from Local Authority area and state Malaysia.

c. Topographic maps of 1: 25 000 scale from Department of Surveying and Mapping Malaysia (DSSM) to prepare the base map of the study area.

3.2.2 Materials for Groundwater Potential Zone Map

Furthermore, in order for producing the assessment of groundwater potential zone map, the collection of secondary data which is regarding the data of topographical, satellite image and digital elevation model (DEM) is needed where the map regarding the parameters consist of the lithology map, drainage map, soil map, aspect map, land use map and slope map. Figure 3.1 shows the example of satellite image of other study area as first interpretation regarding the satellite image.

Figure 3.1: Satellite image of other study area

Generation of Thematic Maps& Image: First and foremost, from the contour map DEM was prepared and all the contours that was done manually and systematically from the Toposheet.

(a) **Contour map**: As for the preparation of contour map, all the maps were arranged according the specific terms and separately for different characteristics or features in Arc-GIS software to generate various maps. The toposheet then scanned and after that it was done of the scanned Raster (TIFF) files of Georeferencing, then it was done manually the trace of contours line, after that selecting the tool of sketch for constant or keeping the contour interval as shown in Figure 3.2.

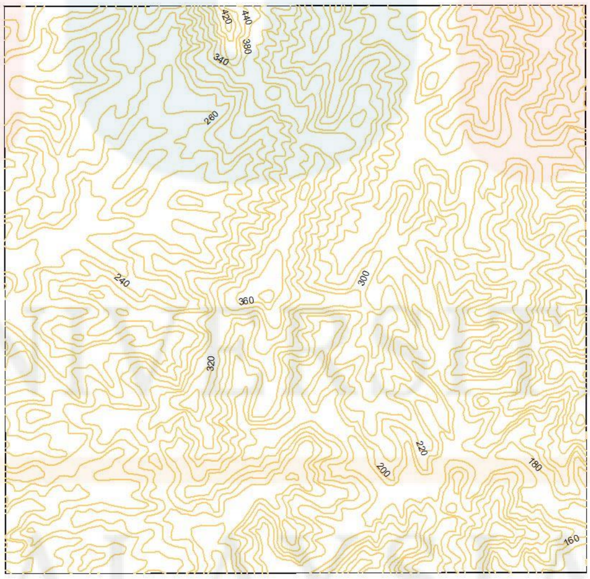


Figure 3.2: Contour map of the study area

Preparation of Thematic Maps

For the delineation of ground water potential zones, thematic layers namely lithology, slope, geomorphology and land use/ cover, lineament density and drainage density maps were prepared. For the data loading, the data was imported into the computer system, where it was processed and classified in GIS software.

Lithology

Lithology of the study area data were collected during the geological mapping. The lithologies in the study area were recognized, observe and recorded in the data collection so that the lithology can be mapped out.

Land use

For this research study, the land use data was also derived from the satellite image. The data from Landsat-8 operational land imager (OLI) and the TIRS thermal infrared sensor were used. The information data also was got through the USGS website. Area of Interest (AOI) was prepared of different themes namely forest, river / water body, habitation and waste land by Visual Interpretation of the image, followed by unsupervised classification. Unsupervised classification is a method which examines a large number of unknown pixels.

Slope

The slope in this research was generated or extracted from satellite image data. After that, the next step the slope then differentiated or categorized based on the slope degree. The slope play an important role in groundwater availability.

Soil map

A good understanding of the soil with reference to their nature and distribution is essential to locate any ground water potential zone. Availability of water varies from soil to soil because of their different texture and water holding capacity. The soil data were collected during the period of geological mapping. Furthermore, the heavy rainfall in the study area affected the soil.

Drainage

The drainage density is important because the relationship between drainage and density. The drainage density map was generated from the USGS satellite image from the USGS website. The pattern of the drainage in the study area was also determined.

Geomorphological

Geomorphological feature of any region determine the land form and the processes that shape the land form. Information on land form is an important input for land management, soil mapping and identification of potential zones of ground water occurrence.

Lineament

The lineament map is first produced by following the ridge along the hill and mountain of the map area. Moreover, lineament is directly proportional to groundwater potential. Areas having a positive lineament were categorized as excellent groundwater potential zone for the availability in the area.

(I) Integration of thematic layers using GIS

Integration of various thematic maps was performed by overlaying one theme map over the other in GIS software. The thematic layers include lithology, geomorphology, Land use/ cover, slope, drainage and lineament. Each of the class in the thematic layers will be qualitatively described and reclassified by assigning numbers (scoring). After assigning weights, the integration of all the thematic layers will be carried out applying raster overlay analysis in a GIS environment. The classification can be done by several methods available in overlay method.

3.3 Methodology

In the geological aspect, in order to generate the geological map field observation and image processing is needed to be done. The ArcGIS 10.2 software is needed produce the geological map. Besides, the ground and field observation also were done to validate the groundwater potential zonation map and in Figure 3.3 shows the overall research flowchart.

3.3.1 Preliminary Studies

The first step before starting or conducting the research the preliminary research must be done. At the same time, all the information about how to conduct the research must be observed and understand. The information and data getting from the previous research that were be done before in the study area or about the condition and specification such as assessment of groundwater potential zone. This step is very significant to ensure all the methods involve in the making of the research is collected.

3.3.2 Field Studies

a. Sampling

Sampling is known as a method of collecting sample. Furthermore, the samples that were collected for further studies. Steps of random sampling were used because of certain condition in part of the study area is unreachable by using normal traverse.

Rock sampling was taken by breaking the exposed outcrop that found in the study area which is almost at the new or fresh area. The size of the sample need to be taken is not too big or too small. Hammer is needed to remove the sample from the outcrop. In order to prevent the rock chips from entering the eye, goggles were used during the period.

b. Traversing

Traverse was determined by observing the topographical map and set by passing the point of interest in the study area. Traversing is usually a method of taking care and controlling the process across country, to avoid relocate place from scratch every time an observation was made at an area of outcrop. It is also a way or methods of investigate and covering the study area required. Traversing also need detail of mapping area where rocks are well exposed.

3.3.3 Laboratory works

a) Petrological studies and thin section

This step consisted of identification of mineral, clast and matrix, texture, as well as classification of rock. The samples that were collected at the field was then examined using investigation in the laboratory. The collected sample of rock needed to be cut into smaller pieces. After that, process such as polishing and grinding was be done. Then, the samples were showed under the thin section. Then, the polarized microscope examined the rock thoroughly.

Thin section is a way where slice thinly and nicely in order to observe the rocks under the microscope. To get a better observation of the minerals under the microscope, the fresh sample should be use rather than the weathered outcrop. Then, the petrological studies consist of identification of mineral, clast, texture, and matrix as well as classification of rock.

3.3.4 Data Processing

a) Methods for Groundwater Potential Zone Zonation

The base map, contour and drainage network were digitized in GIS environment for the study area of toposheets of 1:50,000 scale. The map of slope was prepared from contour data in ArcGIS Spatial Analyst module. The drainage density map were created using the analysis tool of line density in ArcGIS. Then, the thematic layers was changed or converted into a raster format (30 m resolution) before they brought into weighted overlay GIS environment. The groundwater potential zones were gotgenerated by superimposing all these thematic maps in ways of methods weighted overlay using the spatial analysis tool in ArcGIS 10.2. Then, weighted overlay analysis, the level or ranking were given for each of the individual parameter of each thematic map, and weights were weighted to each class of that particular feature.

At the end of the research, an expected map of groundwater potential of the study or research area was produced based on six thematic layers. Each layer were processed in terms of a set of physical properties that showing groundwater flow and storage. The layers include lithology, lineament density, drainage density, geomorphology, land use and slope. This map basically was classified into five or several classes including very low, low, moderate , good, and very good. Each layer was processed in terms of a set of physical properties that showing groundwater storage, flow and figures.

In this research, the database consists of:

1. Contour data from topographical map
2. Drainage data from topographical map
3. Geological map of the study area
4. USGS data to identify hydro geomorphological units and mapping of lineaments
5. Lineament data from the satellite imagery
6. GIS overlay to find suitable zone for groundwater potential

b) Evaluation of parameters factors of groundwater assessment

During this research, biophysical and environmental factors six major like geomorphology, slope, lithology, lineament density, land use land cover (LULC), and drainage density were analyse and considered. Satellite image were the sources of these data, digital elevation model (DEM), occurences thematic maps and data of metrological station. Finally, all the factors were combined together and computed also saved the model using the overlay of weighted so that the mapped potential groundwater areas.

c) Groundwater potential zone map

Furthermore, groundwater potential zonation, the method Weighted Overlay Method were used in this research. In addition, it got from the satellite image and data collection that was got, it were mapped after that converted into raster. After state the study area, for each variable base map preparation was undertaken using maps of topographic with a scale of 1:25,000. To assess and evaluate groundwater prospect of the area, classification and identification of the basic baseline maps of slope, geomorphology, drainage density, land use land cover (LULC), lithology, and lineament density, were done of the study area.

Then, the different thematic baseline maps were prepared, in which they were used in the combination of the groundwater map suitability. To start with preparation slope of the area, with 30 m spatial resolution was used as in the ArcMap of ArcGIS of a digital elevation model (DEM), spatial analysis equipment and tool. Then, it was classified the study area’s slope into several six classes with lowest and highest value respectively. The steep and flat gradient of the area has important effect or impact on groundwater movement and occurrences. The other determinant factor handling groundwater occurrence is drainage density. It was mapped and calculated directly in the Arc map of ArcGIS, using DEM of 30 m spatial resolution of spatial analysis extension tool. In addition, three drainage density differentiations were identified and classified which significance in controlling groundwater occurrence and movement is important.

3.3.5 Data Analysis and Interpretation

For the general geology aspect, traversing and sampling is the hardest and crucial part where from the traversing and sampling, all the geological aspects were observed and were recorded. From the field observation, the data from the satellite image were then compared. The outdated data is updated from all the observations that already been done. For the updated geological data information of the study area were presented in the geological map.

Before data get from the field it were converted to the base map and the data processing were be done. Data processing consists of gathered out in the data get and at the same time it becomes more accurate about the data from the field. Field work data analysis is one of the methods showing the data in the field. Figure 3.3 shows overall research flowchart of the study.

FLOWCHART OF RESEARCH METHODOLOGY

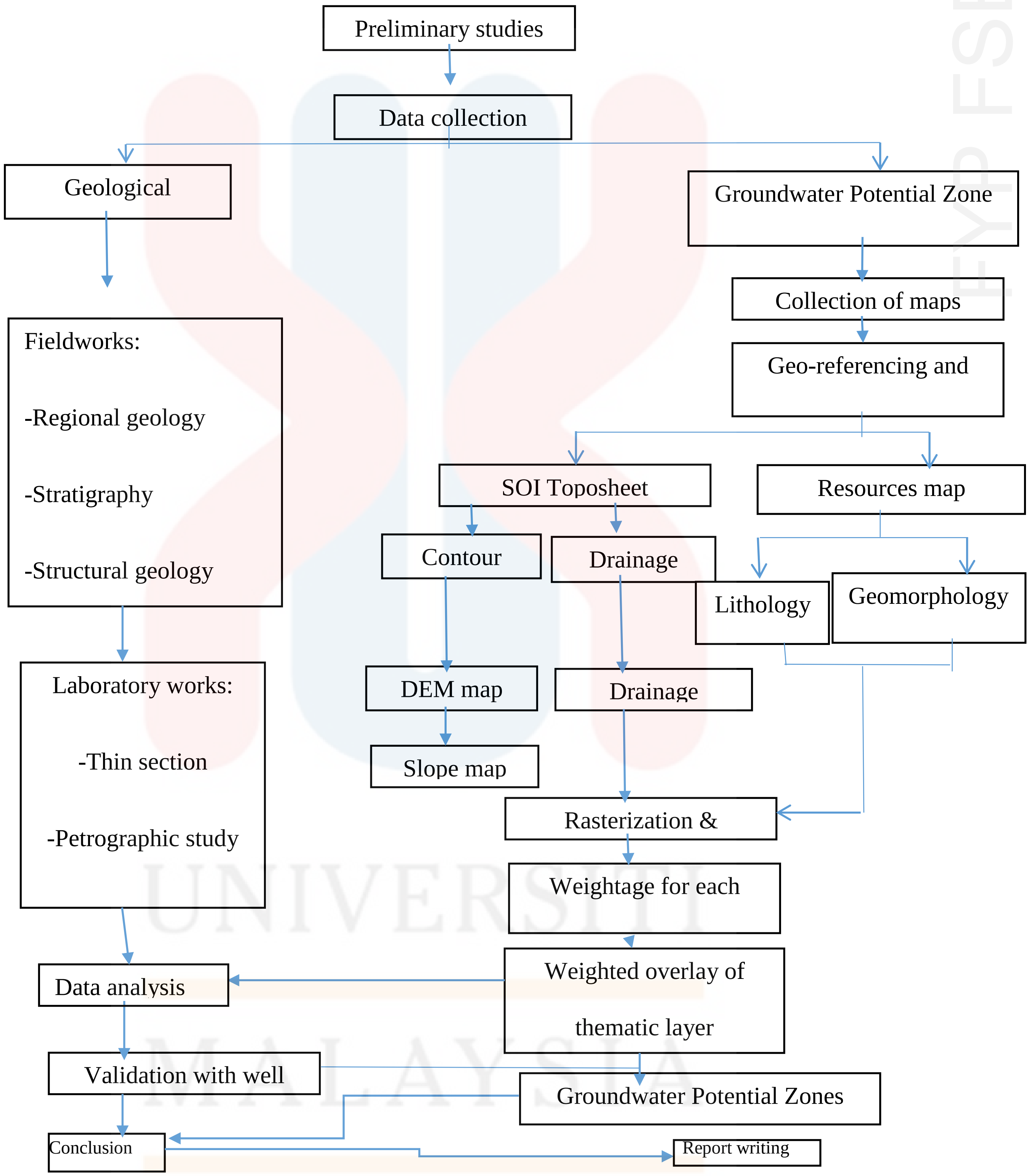


Figure 3.3. : Research flowchart

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

In this chapter, geological mapping that highlighted including, geomorphology, stratigraphy, petrography, structural geology and historical geology were discussed with details regarding the study area given. Furthermore, geomorphological study includes the assessment about landform, drainage, contour pattern and weathering of the study area. Besides that, for the stratigraphy the assessment included lithology, lithostatigraphy and petrographic study is the study of rock and the minerals details and contents. Next, for the structural geology, the geological structure that have been found in the study area were discussed and analysis have been made while for the historical geology, the history of that specific area were also discussed. This chapter is important for the further study about the general geology of the study area.

Petrography analysis also was conduct to determine the rock type of the area using structural analysis to determine the lineament and cracks of the area. The part of the stratigraphy and historical geology was also cover in this chapter.

4.1.1 Accessibility

In this area of study, the most or overall accessibility that were used was unpaved road specifically dirt roads and no highway as shown in Figure 4.1 below. In can be passed by lorry, motorcycle and other big vehicles. Along the way of accessibility, there is palm oil plantation and deforestation area. Mostly all the connection of road lead to hilly areas in the study area. Next, basically the roads can be passable by car on terrain for example packed gravel to loose dirt and vegetation.

Figure 4.1: Road accessibility in the study area

4.1.2 Settlement

A settlement, populated place or locality in which people live in a community. The complexity of a settlement can be from a small number of dwellings grouped together to the largest of cities with surrounding urbanized areas.

Figure 4.2: The settlement area

4.1.3 Forestry

For forestry in the area of study, are enclosed by natural forest area as shown in Figure 4.3 below. In addition, mostly part of the study area was a reserved forest in Lojing, Gua Musang. Furthermore, forest there is generally known as a plant that growth which consist mainly of trees and other various types of woody vegetation as shown in Figure 4.3 below that showing the forestry area.

Figure 4.3: Forestry area

4.1.4 Traverses and observation

Traverse at the same time doing observation in the study area were involved in placing and putting the survey or observation points along a path or line of traverse, and after that using the previously site observation points as a step for observing the next place or point. Figure 4.4 below shown the traverse and observation map of the study area. For example, if saw an outcrop along the way, the observation was been done there.

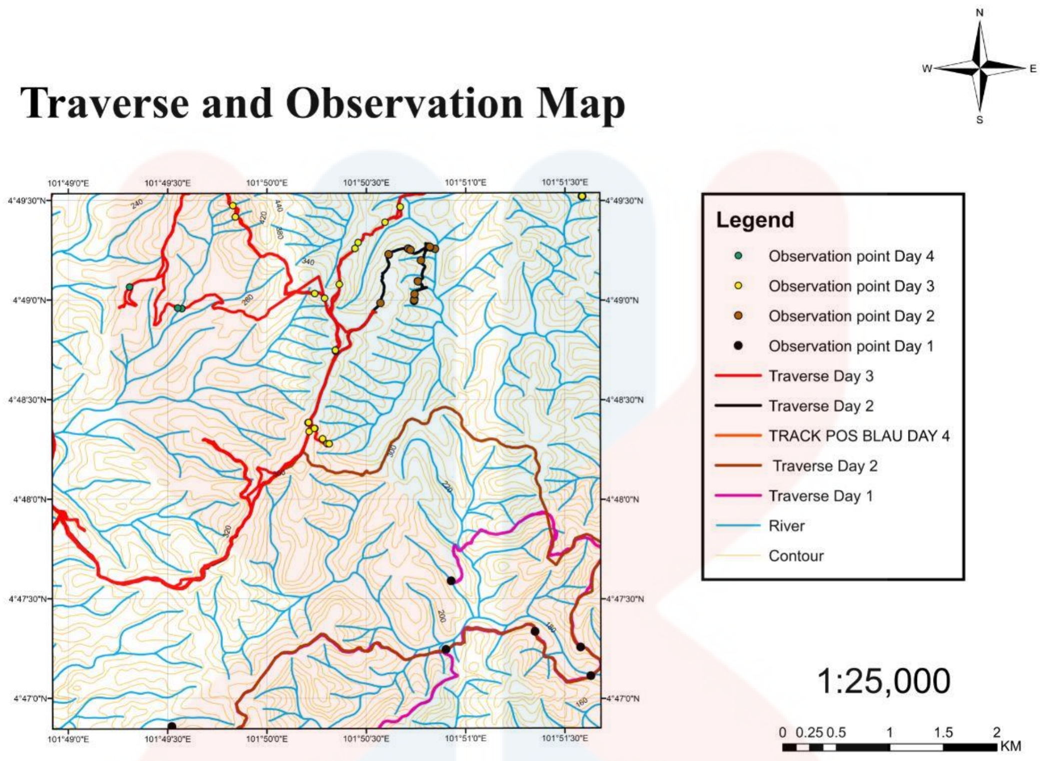


Figure 4.4: Traverse and observation Map

4.2 Geomorphology

Geomorphology is a field that focuses on studying and describing the Earth morphology in terms of its geometry and related to the process of formation and development of landform in each of the area. It is also the scientific study of scenery which concerned with the study of the landform and nature of the land surface as a whole and of it as various part such as mountains and valleys, rifts and scarps, river channels profile and pattern that make up the landscape. The geomorphologic was influenced by the topography, faults, drainage system and also the weathering process.

Methods which where the study area of the topographic map and the ground observation from peak of hills in the study area. By using these two methods, data regarding the landform, drainage, contour pattern and weathering were identified.

Through this geomorphological study, it gives the rough idea about the study area topography and its surrounding.

4.2.1 Landform

Landforms are categorized by characteristic physical attributes such as elevation, slope, orientation, stratification, rock exposure, and soil type. Mountains, hills, plateaus, and plains are the four major types of landforms. Generally, in the study area the landform is divided into two types of landform which are hilly and mountainous area. Different types of landform have different types of lithologies. The hilly areas usually consist of sedimentary rock or metasedimentary rocks. For the mountainous area, it usually has igneous rocks. Different type of landform gives out different type of lithologies and elevation as shown in Table 4.1.

Table 4.1: Landform unit and the range elevation for each unit.

Description	Mean Elevation (m)
Low lying	<15 meter ASL
Rolling	16-30
Undulating	31-75
Hilly	76-300
Mountainous	>301

Figure 4.6 shows the 3D map of the study area. It can observe that there nine different colour shows the difference in elevation of each landform area. For the dark red colour, it shows the elevation between 420m to 452m. For the elevation >300m, the landform type is the mountainous area based on the Table 4.1. The lithology is

mainly is igneous which is granite. For the elevation from 76m to 300m, it represents the hilly type landform. From the Figure 4.5, the yellow color, light green color, the green color and the dark green color represent the same landform type which is hilly landform.

A hill is a piece of land that rises higher than everything surrounding it. Hills are formed all the time, by different types of geologic activity. One of these activities is faulting, which happens because the rocks underneath the Earth's surface are constantly moving and changing the landscape. Hills formed by faulting can eventually become mountains. Hilly area can also be created by erosion, as material from other areas is deposited near the hill, causing it to grow.

Meanwhile, mountainous area are formed through tectonic forces or volcanism. These forces can locally raise the surface of the earth. Mountains erode slowly through the action of rivers, weather conditions. Elevation, volume, relief, steepness, spacing and continuity have been used as criteria for defining a mountain. Mountains are generally less preferable for human habitation than lowlands, because of harsh weather and little level ground suitable for agriculture.

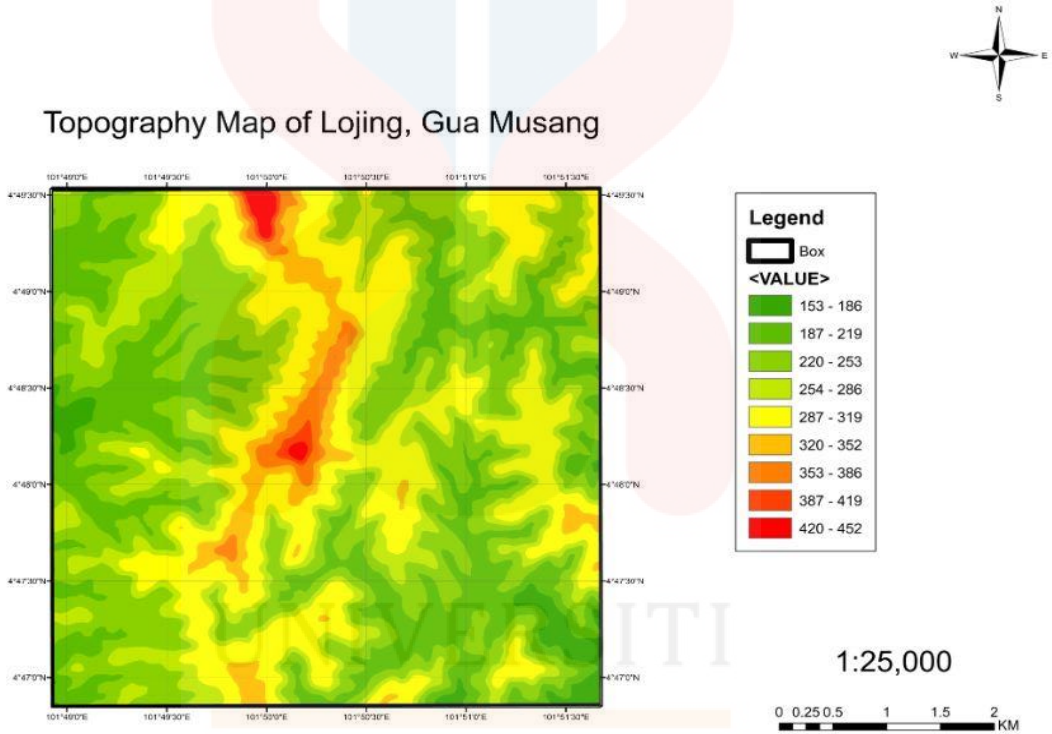


Figure 4.5: Topography Map of Lojing, Gua Musang

The landform map of the study area is shown in Figure 4.6. From the Figure 4.6, the landform can be divided into two which is the first one is hilly and the other one is mountainous area. The mountainous area is mainly covered with forest and plantation which is oil palm plantation and rubber plantation. For the hilly area, it is mainly covered by the oil palm plantation. The igneous rocks usually have a higher elevation compared to sedimentary rocks. This is because igneous rocks have a better resistance of weathering process and not easily eroded by the weathering process compare to sedimentary rocks that have low resistance towards weathering process. Due to the weathering process, the sedimentary rocks easily eroded.

The geomorphology of the area also can be divided based on the structural and tectonism. The sedimentary rocks area is represent the structural activity where there is a major fault occurs in the area. The igneous rocks represent the tectonism which is volcanic activity. This is because it is an igneous intrusion that triggered by the tectonism activities.

The mountainous area is the dark blue color while the hilly area is the light blue and light yellow color. Figure 4.7 shows the triangular facets. It is geomorphological features that formed due to structural activities. The triangular facets has become the indicators to the major faulting that occurred. Figure 4.8 shows the mountainous area. It is located in the study area.

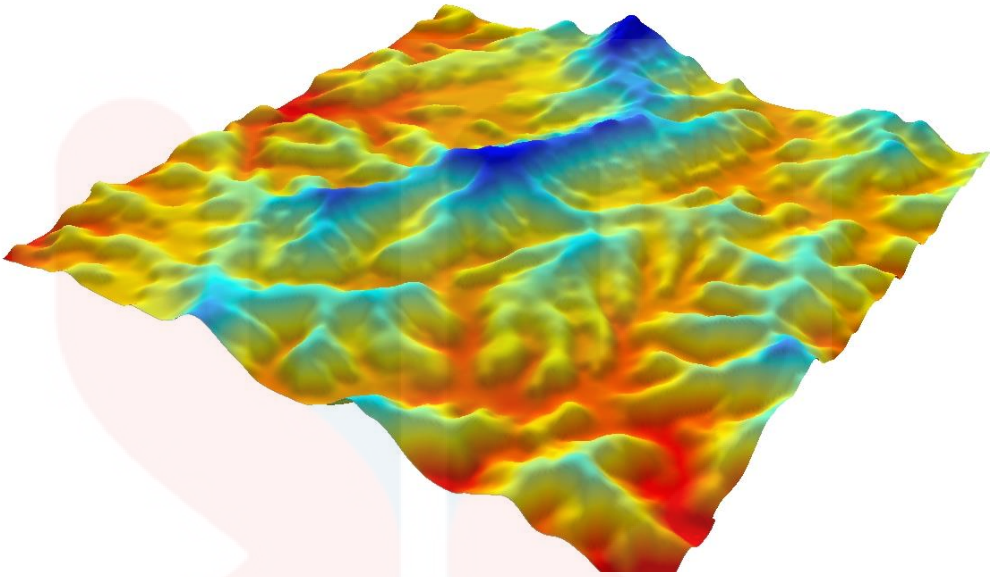


Figure 4.6: 3D Map of Landform Map

Figure 4.7: The triangular facets

Figure 4.8: The mountainous area

4.2.2 Drainage Pattern

In geomorphology, a drainage system is the pattern formed by the streams, rivers, and lakes in a particular drainage basin. They are governed by the topography of the land, whether a particular region is dominated by hard or soft rocks, and the gradient of the land. A drainage basin is the topographic region from which a stream receives runoff, through flow, and groundwater flow. Drainage basins are divided from each other by topographic barriers called a watershed. A watershed represents all of the stream tributaries that flow to some location along the stream channel. The number, size, and shape of the drainage basins found in an area varies and the larger the topographic map, the more information on the drainage basin is available.

The study area is surrounded by several rivers and tributaries and in the study area also does not have main river. Generally, the drainage pattern of the study area is divided into three patterns which is the first one is parallel pattern, then the second one is rectangular pattern and the next one is dendritic pattern of the stream. Figure 4.10 shows the three pattern of the drainage in the study area. The pink colour represents the parallel pattern of drainage, the green colour represents rectangular drainage while the blue colour represents dendritic pattern of the drainage system.

Rectangular pattern is a pattern that formed at the location where little topography as shown in Figure 4.9 below. It is formed due to system of bedding planes, faults, folds, fractures and other geological structures. This can be proven as at the area where the stream is rectangular pattern, many features such as folds, fractures and bedding planes can be found. It is also located on the faulting area. Parallel pattern formed when the tributaries all flow in the same direction and move swiftly in the same direction. Due to the slopes, the stream is straight and swift. It is also formed at the region of parallel and elongated landforms.

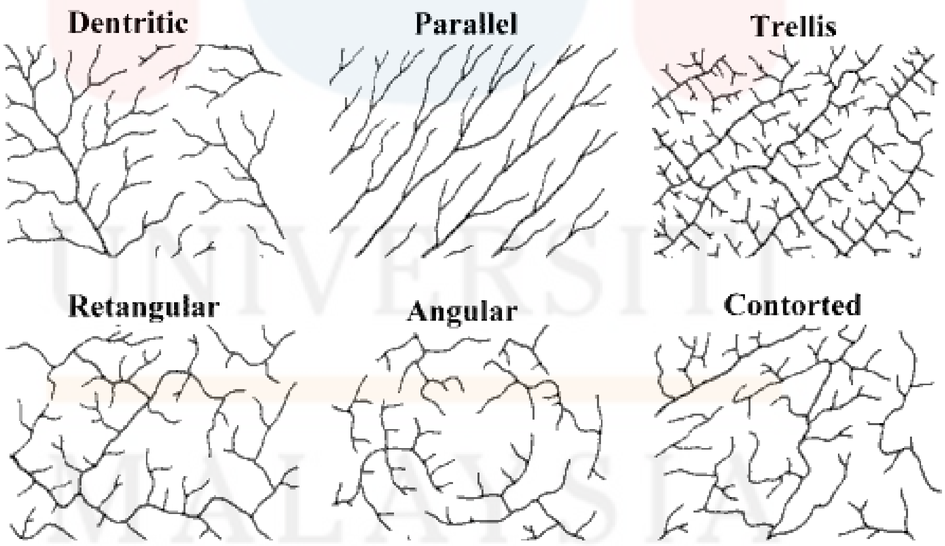


Figure 4.9: The types of drainage system

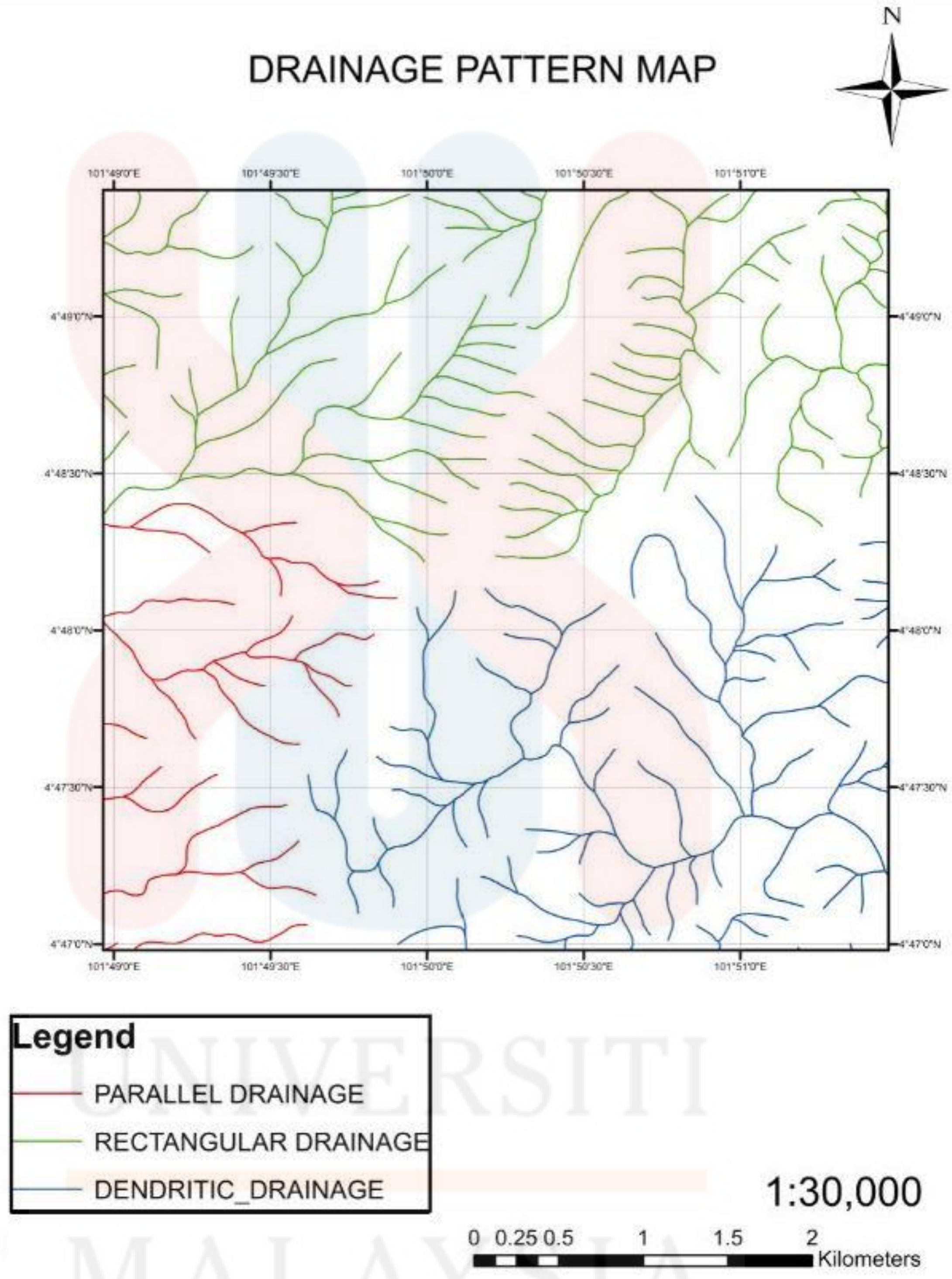


Figure 4.10 : Drainage pattern map of the study area

4.2.3 Contour Pattern and Weathering

Resistance pattern was measured by analysis on how well rock in the study area resist on the erosion. Figure 4.11 shows the resistance pattern map of the study area. Based on the map, it can see that region that located at eastern part has a high elevation whereas region on the western part has a much lower elevation. From this result, it concludes that the eastern area has a lower weathering rate and more resistance toward the weathering. In this area, mineral with higher resistance ability towards weathering process are present. Mineral such as quartz, muscovite and feldspar has high resistance towards weathering. While, in the western area has a high weathering rate and less resistance toward the weathering.

The weathering exist in the study area is physical or mechanical weathering. Physical weathering, also called mechanical weathering or disaggregation, is the class of processes that causes the disintegration of rocks without chemical change. The primary process in physical weathering is abrasion (the process by which clasts and other particles are reduced in size).

In the field, most of the outcrop is weathered. Weathering is a process where the rocks undergone changes whether physically, chemically, and biologically. On the eastern part, the area is covered by granitic rocks which contain minerals such as mica and quartz and is shown in Bowen Reaction Series in Figure 4.12. These two minerals are highly resistance based on the Bowen Reaction Series. Weathering is the study area is mostly physical and biological weathering. Malaysia favors a high weathering rate because it located at the equator and has a tropical climate in which hot and humid throughout the years.

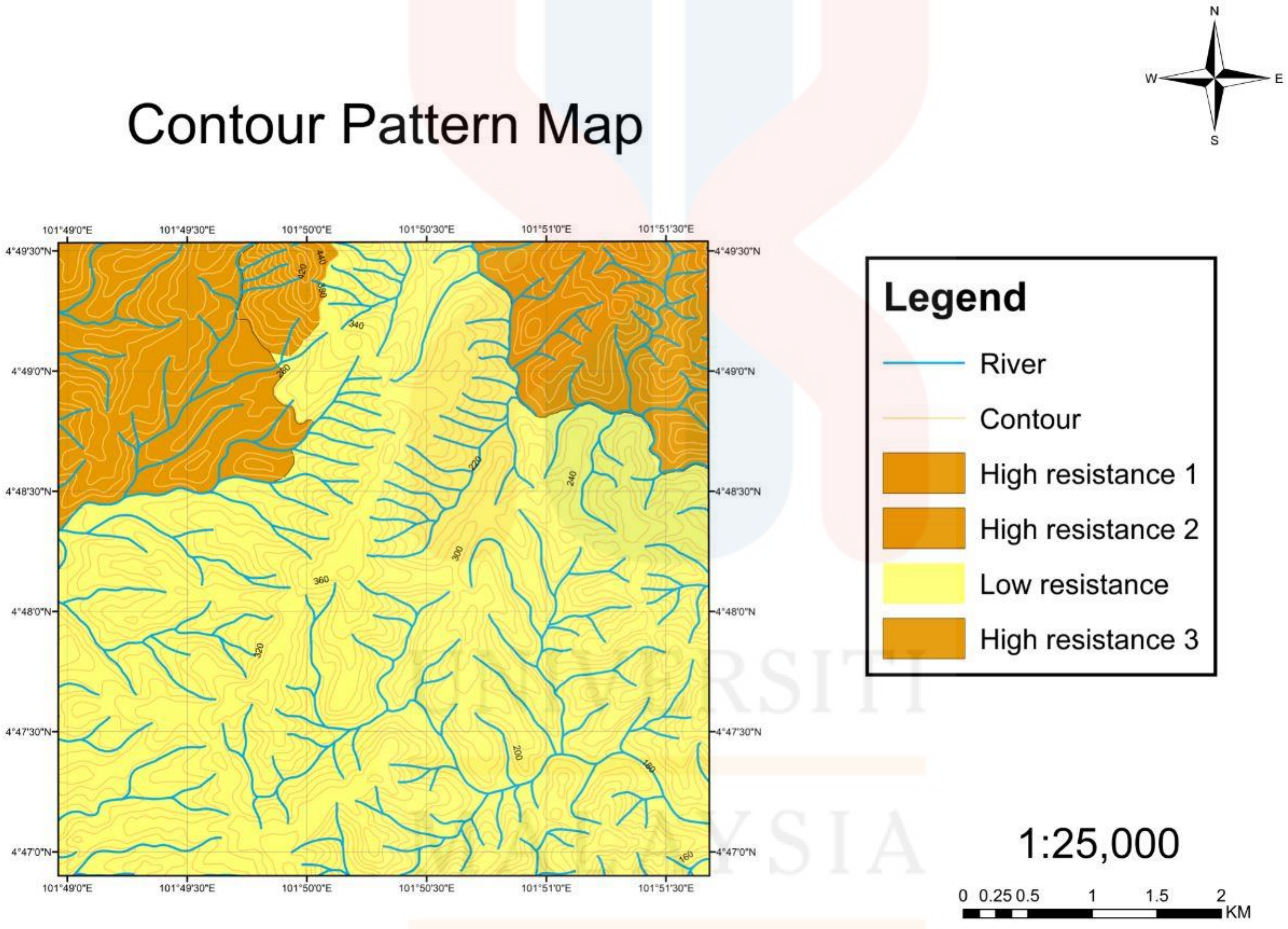


Figure 4.11 : The contour pattern map

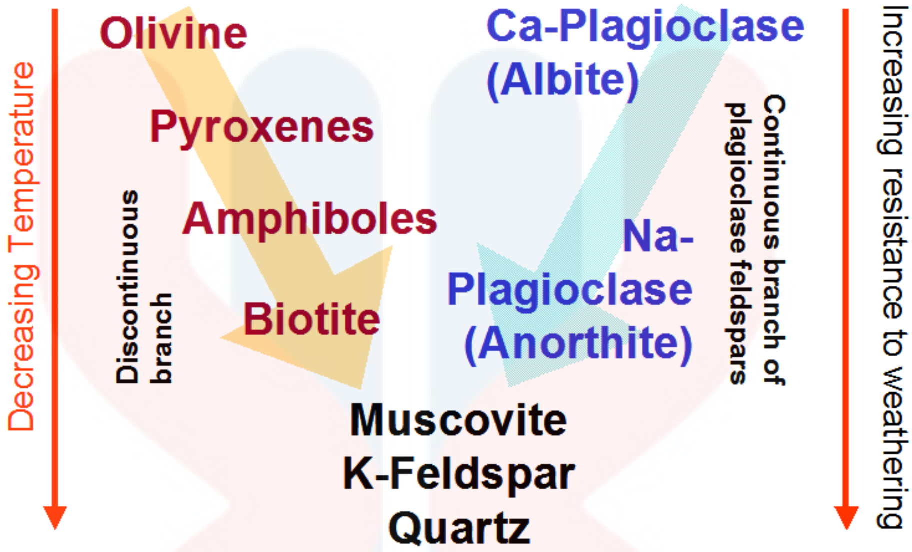


Figure 4.12: The Bowen Reaction Series

Physical weathering is a term used in science that refers to the geological process of rocks breaking apart without changing their chemical composition. Over time, movements of the Earth and environment can break apart rock formations, causing physical weathering. Physical weathering can also refer to other things in the environment breaking down, like soil and minerals. Pressure, warm temperatures, water and ice can cause physical weathering. Figure 4.13 shows an outcrop that is physically weathered. Physical weathering occur due to continuously hot and raining weather. Biological weathering is the weakening and subsequent disintegration of rock by plants, animals and microbes. Growing plant roots can exert stress or pressure on rock. Next, Figure 4.14 shows the biological weathering. This is because the outcrop is in the river. The microorganisms such as algae live on the rock as it is dampy area.

Figure 4.13 : The physical weathering of an outcrop

Figure 4.14: The biological weathering of an outcrop

4.3 Stratigraphy

4.3.1 Lithology

From the mapping, lithology refers to study and description of the physical character of rocks, particularly in hand specimens and outcrops. The lithologies characteristics are including the colour, type of rocks, mineral contents and the size of grain. The lithology is differentiated if there is a slight change in these characteristics. The boundary where two different lithologies meet is called the lithology boundary or contact. Each boundary may have different type of contact such as sharp contact, gradational contact, interfingering contact and many more.

The layer of the lithologies also can exist in two types which are conformity and unconformity. Conformity is where the layer of the lithology is not being disturbed by any geological features such as features. Unconformity is when the layer of lithology is being disturbed by geological features such as fault, crack, fracture and joint. In the study area, there are four main lithologies were found which are granite lithology, metasedimentary lithology, mudstone lithology and quartzite lithology. Figure 4.10 show the lithology map of the study area. The metasedimentary unit is slate. These lithologies is been combined as one lithology called metasedimentary lithology.

a) Granite

In the study area, the first outcrop is granite. Granite take placed in the eastern part of the study area. 10 percent of the study area is covered by granite. This outcrop is located at the eastern part of the study area. The size of the outcrop is about 200cm length and 90cm width. The outcrop is located at the rubber plantation. The outcrop of the rock may be exposed due to weathering and erosion process. The granite outcrop is in the river channel.

Figure 4.15: The granite outcrop

Figure 4.16: The granite outcrop

Figure 4.15 and Figure 4.16 shows the granite outcrop in the study area. The outcrop is weathered as it is continuously exposed to hot and humid weather. Weathering gradually weakens rocks, and eventually produces new geological materials (rock fragments, sands, silts and clays) that are more stable in the new environment. Figure 4.17 shows the hand specimen of the granite outcrop. The granite is light grey granite and has a phaneritic texture which is course grain. The degree of crystallinity is holocrystaline which is the crystals minerals are still in a good shape. Granite is nearly always massive lacking any internal structures, hard, and tough.

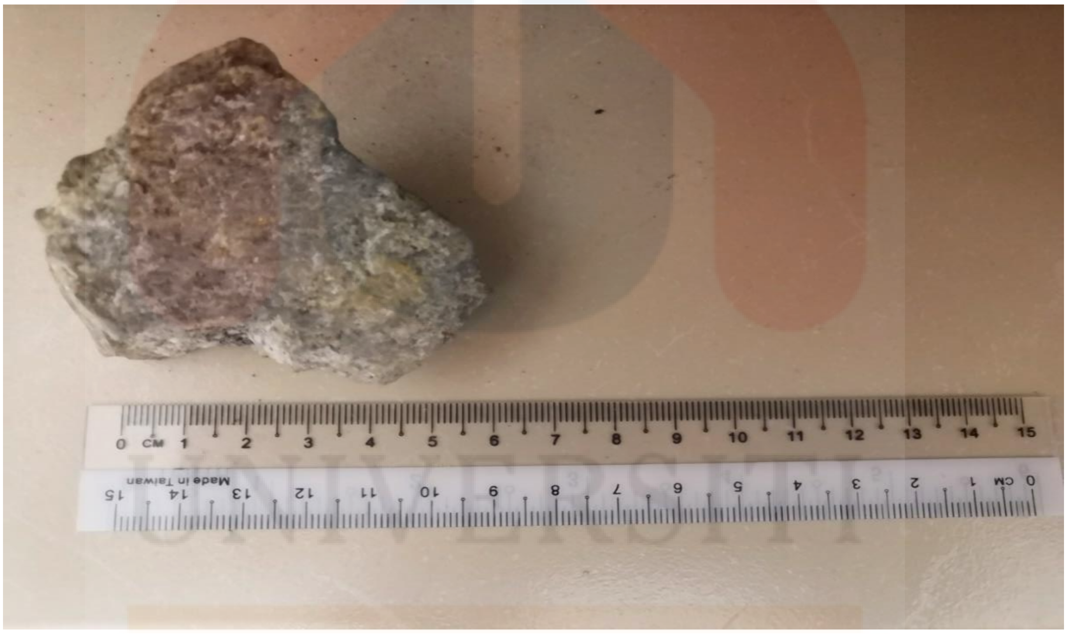


Figure 4.17: Granite hand specimen

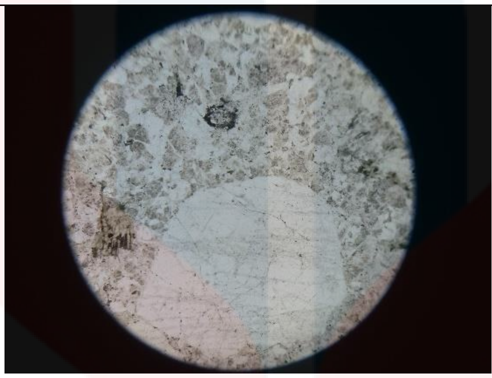
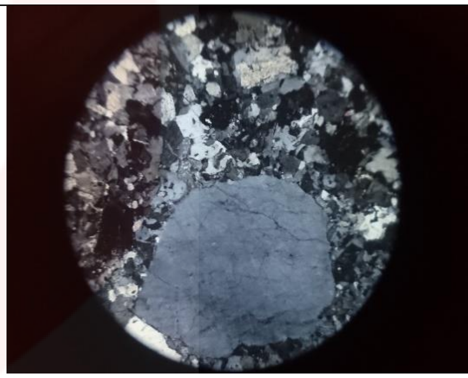
Petrography of Granite

Name: Granite

Rock type: Igneous rocks

Microscopic explanation: From the observation, the observation was done using magnification glass 10x, and was seen that the texture was phaneritic texture where the grain sixe of mineral is course-grained.

Table 4.2 : Petrography of Granite

Minerals composition	**Under Plane Polarized**	**Under Cross Polarized**
		
Plagioclase	Colour : Colourless clear Twinning : Carlsbad Albite twinning Relief: Low relief	Colour: Light pink Shape: Subhedral to euhedral Pleochroism: Medium to low Cleavage: 1 direction
Quartz	Colour: White,colourless Relief: Low relief Birefringence: Low grey first order	Colour: Milky white to black Twinning: Albite twinning Shape: Anhedral Cleavage: None Pleochroism: Low
Sericite	Colour: Brownish Relief: Low relief Pleochroism: Low Shape: Anhedral Cleavage: None	Colour: Brownish Birefringence: Low

Opaque mineral	Colour: Dark colour,black	Colour: Dark colour ,black

b) Sedimentary rock

The second outcrop type is the sedimentary rock. There is three types of sedimentary rocks found in the study area which are mudstone, carbonaceous mudstone and tuffaceous mudstone. Mudstone looks like hardened clay and, depending upon the circumstances under which it was formed, it may show cracks or fissures, like a sun-baked clay deposit. Mudstone is an extremely fine-grained sedimentary rock consisting of a mixture of clay and silt-sized particles that have been observed on the rocks. Figure 4.18 and 4.19 shows the outcrop and and specimen relatively of mudstone.

The outcrop is located at the coordinates N 04˚49’13.7” E 101˚50’36.7”. The mudstone outcrop is highly weathered as most mudstones shows various hues of grey, indicating a high content of clay combined with small amounts of non-oxidized, ferrous iron-rich minerals. Brown or red mudstones may contain oxidized ferric iron minerals such as hematite. Hematite is colored black to steel or silver-gray, brown to reddish-brown.

Mudstone, a type of mudrock, is a fine-grained sedimentary rock whose original constituents were clays or muds. Mudstone is made up of tiny clay particles (less than 0.05mm) that can't be seen with the naked eye. Mudstone lithofacies are those where mud content exceeds 70%.

Figure 4.18: The mudstone outcrop

Figure 4.19: The hand specimen of mudstone

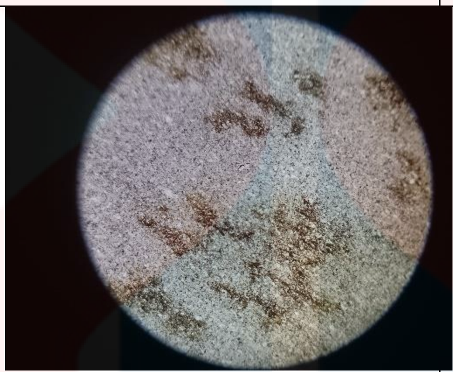
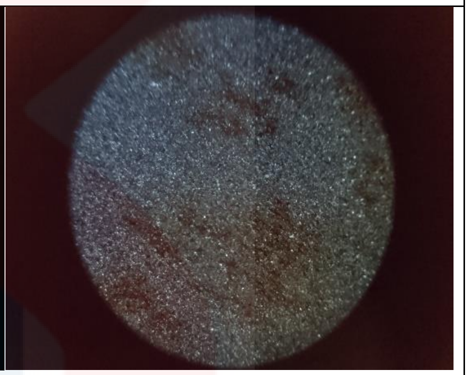
Petrography of mudstone

Name : Mudstone

Rock type: Sedimentary rock

Microscopic explanation: From the observation, the observation was done using magnification glass 10x, and was seen that the sortation was good, and also starting to see a foliation.

Table 4.3 : Petrography of mudstone

Minerals composition	**Under Plane Polarised**	**Under Cross Polarized**
		
Quartz	Colour : White Relief : Low relief Cleavage : None Pleochroism : Low Shape : Anhedral in thin section	Colour : White colour to dark colour Birefringence : Low Twinning : -
Silica	Colour : Milky white Relief: Low Pleochroism : Low Shape :- Cleavage : -	Colour: Cloudy to dark black colour Birefringece : Low Extinction angle : - Twinning: -

Clay silica	Colour : Brown Cleavage :- Shape :- Pleochroism :-	Colour ; Cloudy brown Twinning :- Extinction angle ;-
Opaque mineral	Colour : Dark colour	Colour : Dark colour

The carbon content of the carbonaceous mudstone typically ranges from 0.5% to 3%. Highly carbonaceous mudstone containing over 3% carbon is dark black and very soft, almost transitional to coal. Normal grading is rarely seen in the carbonaceous mudstone facies. Generally, in thin section, the carbonaceous mudstone is dominated by fine grains of illite or muscovite as well as small rounded quartz grains set in a matrix of clay minerals. Figure 4.20 and Figure 4.21 shows the carbonaceous outcrop and hand specimen respectively.

Figure 4.20: The carbonaceous mudstone outcrop

Figure 4.21: The carbonaceous mudstone hand specimen

Figure 4.22 and Figure 4.23 shows the outcrop and closely picture of tuffaceous mudstone respectively. The sample were not taken as the physical texture of the carbonaceous mudstone are easily to break into pieces. The tuffaceous mudstone is the mudstone lithologies that have characteristics of tuff. The compositions are as same as tuff but due to metamorphism process, the tuff is altered into tuffaceous mudstone. The dimensions of the outcrop are 3m height and 2m thick. The tuffaceous mudstone is located at the roadside along the main road in the rubber plantation.

Figure 4.22: The tuffaceous mudstone outcrop

Figure 4.23: The closely observation of tuffaceous mudstone

c) Metasedimentary

The third outcrop type is the metasediment. There is only one type of metasedimentary rock which is slate. The coordinates of the slate outcrop location is located in the river. Figure 4.24 and Figure 4.25 both show the outcrop and the hand specimen. Slate, fine-grained, clayey metamorphic rock. Slate was formed under low-grade metamorphic conditions, under relatively low temperature and pressure. The original material was a fine clay, sometimes with sand or volcanic dust, usually in the form of a sedimentary rock example is mudstone. Slate is frequently grey in color, especially when seen in the study area. Slate is composed mainly of clay minerals or micas, depending upon the degree of metamorphism to which it has been subjected.

Figure 4.24: The slate outcrop

Figure 4.25: The hand specimen of the slate

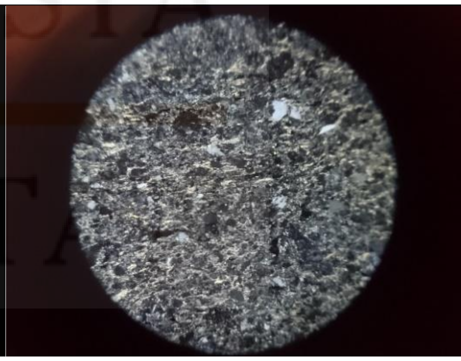
Petrography of slate

Name : Slate

Rock type : Metasedimentary rock

Microscopic explanation : From the observation, the observation was done using magnification glass 10x, the sortation is good, and starting to show foliation. But still cannot be seen clearly the right foliation.

Table 4.4: Petrography of Slate

Minerals composition	**Under Plane Polarized**	**Under Cross Polarized**
		

Quartz	Colour : White colour Relief : Low relief Cleavage : No cleavage Shape : Anhedral	Colour : Dark colour Twinning : No twinning Birefringence : Low
Calcite	Calcite : White colour Cleavage : 1 direction Relief : Medium relief Pleochroism : Medium to low	Colour : Dark colour Twinning : No twinning Foliation : Likely seem the line of foliation
Sericite	Colour : Milky white colour Relief : Low relief Cleavage : Not clearly seen Shape : Anhedral	Colour : Brownish to red colour Twinning : No twinning Extinction angle :-
Opaque minerals	Colour : Dark colour, black	Colour : Dark colour, black

d) Quartzite

The distribution of the quartzite in the study area is only about 10 percent. The quartzite outcrop is located at the coordinates high slope of hills. It forms when a quartz-rich sandstone is altered by the heat, pressure, and chemical activity of metamorphism. These conditions recrystallize the sand grains and the silica cement that binds them together. The result is a network of interlocking quartz grains of incredible strength. Quartzite is usually white to gray in color that have been observed in the study area. There, sandstone is metamorphosed into quartzite while deeply buried. Figure 4.26 show the outcrop of the quartzite outcrop.

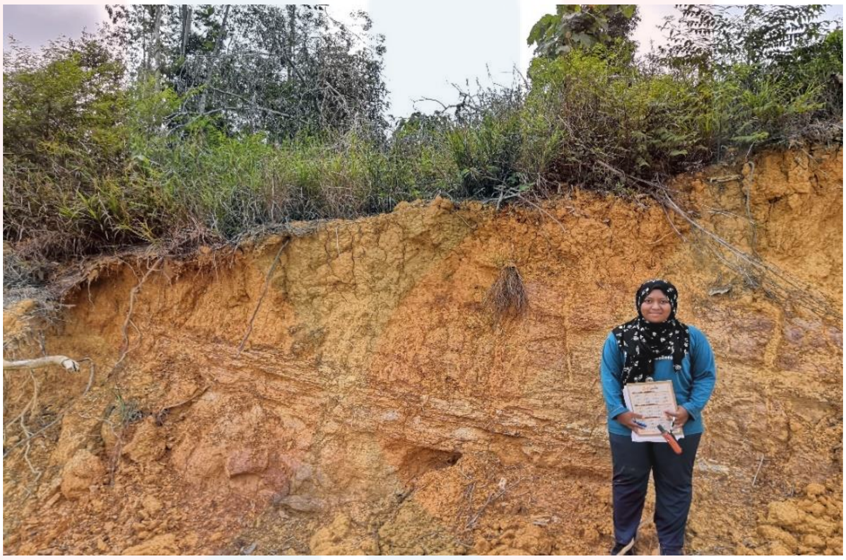


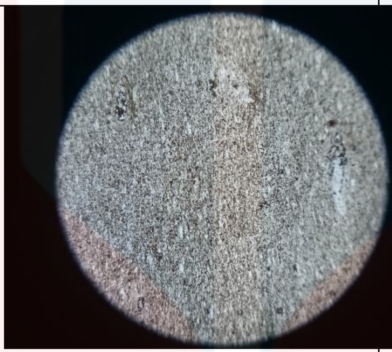
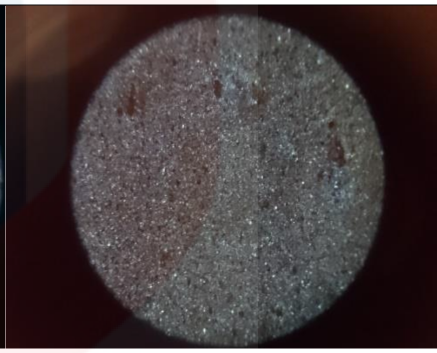
Figure 4.26: The quartzite outcrop

Petrography of Quartzite

Name : Quartzite

Microscopic explanation: From the observation, the observation was done using magnification glass 10x, the sortation is good, and starting to show foliation. Due to weathering, the mineral contained cannot be seen clearly.

Table 4.5 : Petrography of Quartzite

Minerals composition	Under Plane Polarized	Under Cross Polarized
		
Quartz	Colour : White colour Relief : Low relief Cleavage : - Shape : Anhedral Pleochroism : Low	Colour : Dark to black colour Twinning :- Extinction angle :- Birefringence : Low
Clay oxide	Colour : White Relief :- Pleochroism :- Cleavage : -	Colour : Brownish to black Twinning : None Birefringence :-
Opaque minerals	Colour: Dark colour, black	Colour: Dark colour, black

4.3.2 Stratigraphic Position

Stratigraphy or lithostratigraphy is a condition where layers of rocks is defined by its lithology and related to the age of the strata. It related with the study of the stratigraphic relationships among strata that can be identified on the basis of the lithology. Lithostratigraphy was needed in determining the history of the area based on the age of the strata. In lithostartigraphy, rocks are being classified based on their lithostratigraphic unit. Lithostatigraphic units are bodies of sedimentary, extrusive igneous, metasedimentary or volcanic rock distinguished on the basis of lithologic characteristics.

Furthermore, in the study area, it was divided into four lithostratigraphic units. The first unit is the granite unit. Next, is the metasediment unit, quartzite and slate. Then, the sediment unit is mudstone. Figure 4.27 shows the stratigraphic column of the study area. From the previous study of Gua Musang Formation, the age of the lithology in the study area was determined. The granite rocks from the Mesozoic Era followed by the mudstone in the Paleozoic Era then quartzite and slate also in the Paleozoic Era. The granite is the younger rock intrudes the older Gua Musang Formation during Cretaceous.

4.3.3 Unit Explanation

Under the 4 main lithologies, there are several units. The first one is granite. As the granite is mappable under the 1:25000 scales, it was be one of the main part of the lithology unit. As it happened the intrusion of granite. Granitic magma must make room for itself or be intruded into other rocks in order to form an intrusion.

STRATIGRAPHIC COLUMN

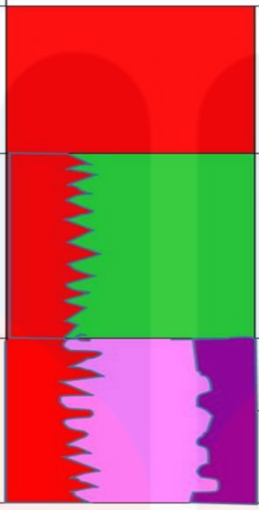
Age		Legend	Rock Unit	Explanation
Era	Period			
Mesozoic	Triassic		Granite	-Type of felsic intrusive igneous rock . -Granite is a coarse-grained, light-colored igneous rock -Composed mainly of feldspars and quartz ,minor amounts of mica and amphibole minerals.
Paleozoic	Permian		Mudstone -Carboneceous mudstone	Mudstone -Fine-grained sedimentary rock, dark purple in colour Carbonaceous mudstone -Contains less than 10% grains. -Composed of more than 90% carbonate mud and black colour.
Paleozoic	Permian		Quartzite	-A high quartz content. - Color : White -Grain size :Medium grained
			Slate	-Fine-grained -Color : Dark grey -Derived from mudstone that has experienced intense heat or pressure

Figure 4.27: The stratigraphic column of the study area.

For the metasedimentary lithologies, there are also several units including quartzite and slate. As for it, this is because the metasedimentary rocks may experience different degree in metamorphism. Slate is low grade metamorphic rock. They may vary due to slight difference in temperature and pressure exposed to them.

Most quartzite forms during mountain-building events at convergent plate boundaries. There, sandstone is metamorphosed into quartzite while deeply buried. Compressional forces at the plate boundary fold and fault the rocks and thicken the crust into a mountain range. Quartzite is an important rock type in folded mountain ranges throughout the world. As for the mudstone lithology, there are several units which is including mudstone, carbonaceous mudstone and tuffaceous mudstone.

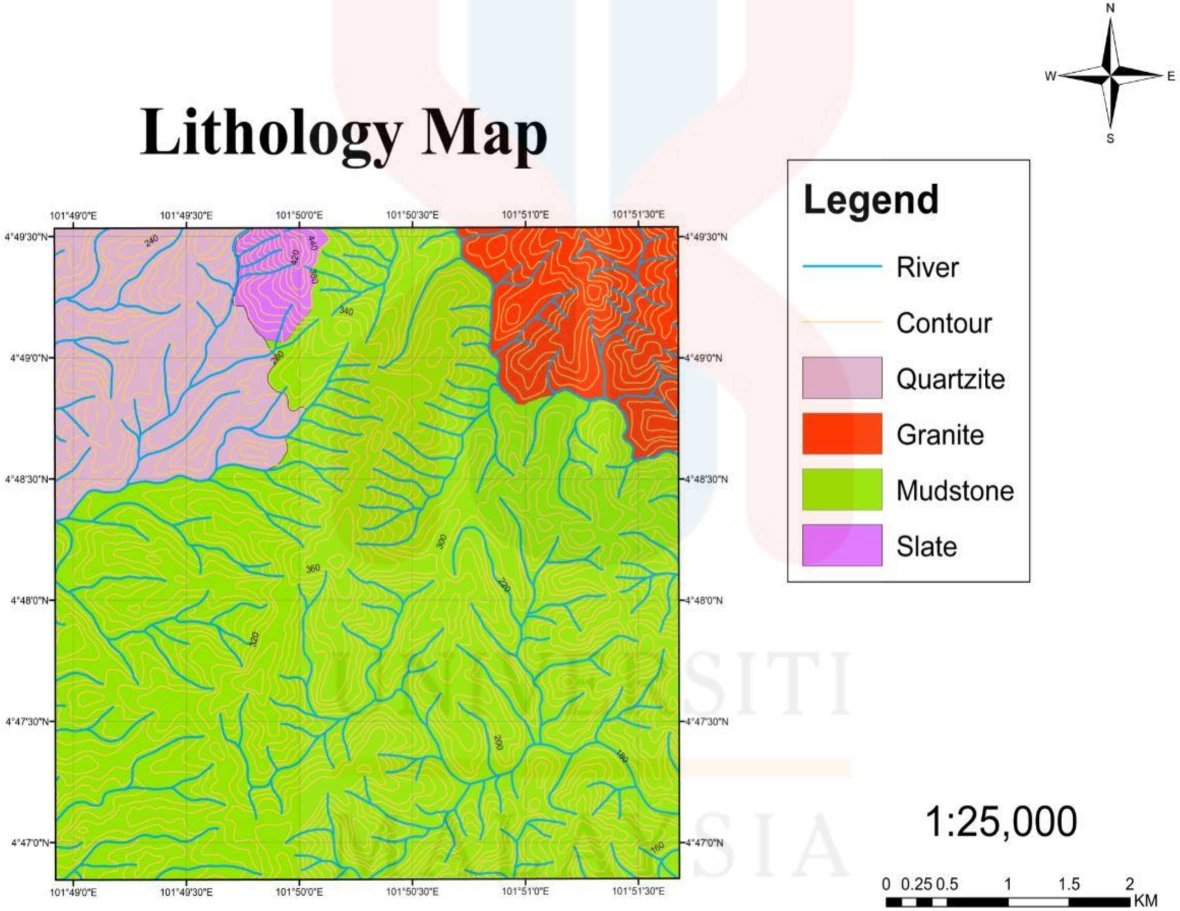


Figure 4.28: The lithology map of the study area

4.4 Structural Geology

Structural geology is any geological features that formed due to any moving of the plates. Structural geology is concerned with the deformation of rocks and rock formations. The moving of the plates, depends on the tectonism activities down at the earth core. The primary goal of structural geology is to use measurements of present-day rock geometries to uncover information about the history of deformation (strain) in the rocks, and ultimately, to understand the stress field that resulted in the observed strain and geometries. This understanding of the dynamics of the stress field can be linked to important events in the geologic past. Fault, fold, fractures, joint , bedding are the example of geological structures. These structures then were analyse for further analysis.

4.4.1 Lineament Analysis

Lineament is a linear feature that appears in the terrain map. Lineament is one of the indicators to locate geological structures in the study area. Lineament analysis is done before the ground observation. I order to locate geological structures, such as fault, fractures and joint the study of linear features or straight features in the topography map were done. Fracture zones, shear zones and igneous intrusions such as dykes can also be expressed as geomorphic lineaments. Lineament mapping is normally undertaken based on geomorphological features such as aligned ridges and valleys, displacement of ridge lines, scarp faces and river passages, straight drainage channel segments, pronounced breaks in crystalline rock masses and aligned surface depression.

Figure 4.29 shows the lineament map that were done before the mapping were done. Based on the lineament map, there were several linear features that can be observed. The lineaments not only represent the features such as faulting, it also can represent the features such as river, and road. The orientations of the lineament were taken to determine the general orientation of the force that act on the study area. The force generated is from North to South direction same as the direction of the faulting that occur in the study area.

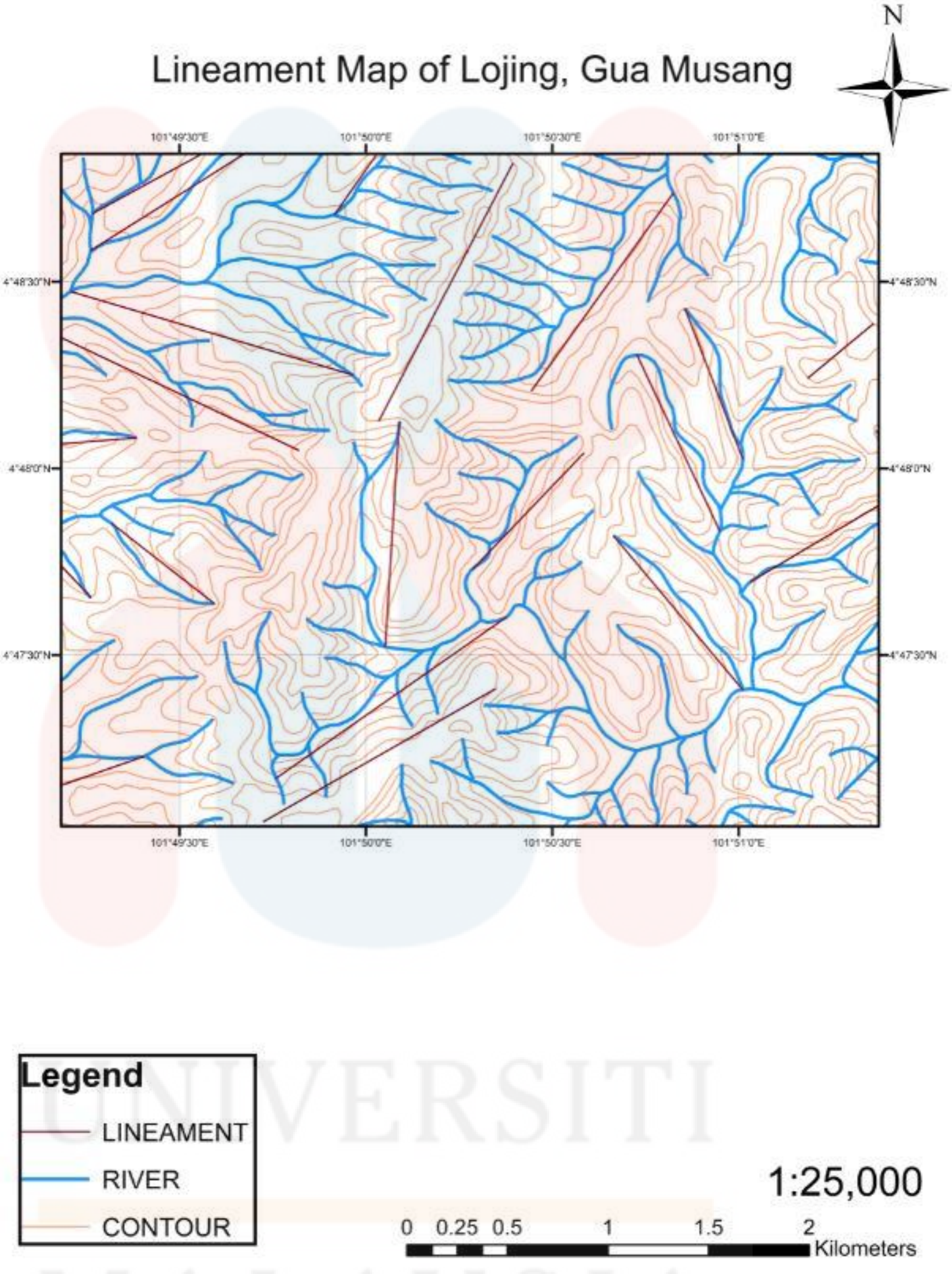


Figure 4.29: The lineament map

4.4.2 Joint Analysis

Joint analysis was done by taken the reading of the joint on the outcrop. Joint is the fracture or cracks that occured on the rock and it have a displacement that can be measured. Joint is a structure that formed due to the movement of the tectonic plate. Joint can be defined as a fracture of a surface along or across in a small movement. There are two types of joint which are shear and extensional joint. Shear joints result from sliding of the rock in two different directions. When this happened, the rock fractures in a plane are parallel to the stress that acts on it and also perpendicular to the minimum principle stress. Figure 4.30 shows the joint that were taken at the coordinates N 04˚49’05.7” E101˚50’36.7”.

Figure 4.30 : The shear joint

Shear joints are those, which are due to shearing stresses involved in folding and faulting of rocks. These joints are rather clear-cut and tightly closed. Shear joints occur in two sets and intersect at a high angle to form a "conjugate joint system".

Table 4.6 shows the reading of the joint that were taken in the study area. The reading of the joint were then analyse by using the GeoRose software to obtain the rose diagram. From the rose diagram that represents the joint reading in the study area, the maximum principles of stresses of the study area were determined.

Table 4.6: The joint reading

225	247	178	240	340	352	317	148
229	341	270	321	80	59	233	228
260	315	265	330	156	198	229	137
227	345	232	222	218	225	164	85
275	330	234	267	153	220	157	224
215	186	349	255	40	155	345	80
176	199	333	355	210	150	215	236
241	180	392	252	345	81	230	225
226	17	90	227	149	221	229	183

Figure 4.31 shows the rose diagram. Rose diagram is a diagram that represents the joint reading of the study area. It is a method to analyse the joint reading that were taken. The joint diagram was generated using the GeoRose software. The area where the force is abundance is at the angle 330˚ and 45˚.Then, this indicates that when the shear stress acts on the body of rocks, the maximum stress caused the rock to slide in 330˚ and 45˚ at point 15˚.

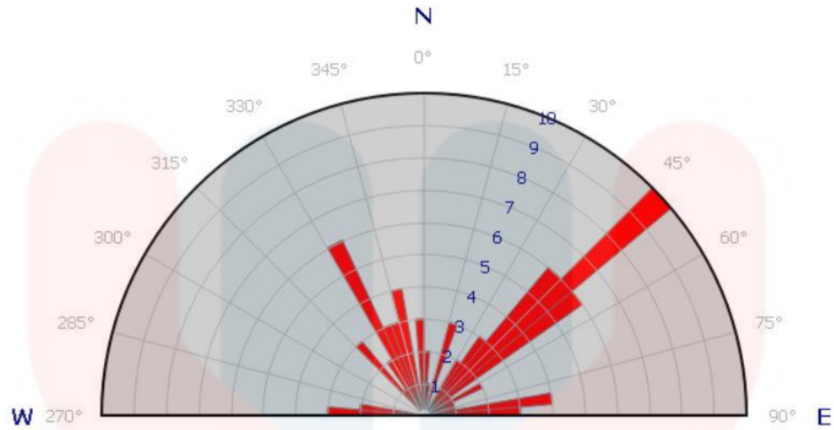


Figure 4.31(a): The rose diagram for the joint reading

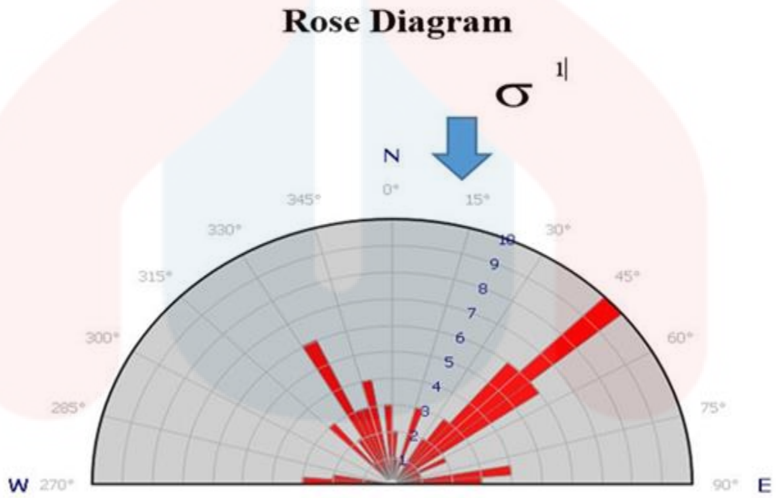


Figure 4.31(b): The greatest compressive stress

Sigma 1 is defined as the greatest compressive stress. This means that one principal stress is always vertical, and the other two are perpendicular to it and in the plane of the Earth's crust. Sigma 1 is defined as the greatest compressive stress, sigma 2 is the intermediate stress, and sigma 3 is the least principal stress.

In the principle of stresses, there were 3 forces that act when a rock experienced a stress. There were three forces that act when a rock experienced a stress. There were σ1, the greatest forces, σ2, the normal forces, and σ3 the lower force or weak zones. Furthermore, figure 4.32 below show the principle of stresses. While, the minimum stress direction is perpendicular to the direction of maximum stress. In addition, from there can be seen through in the study area, there are minor distribution of joint in different direction. This minor joint distribution formed due to minimum stress that acts on the rocks with perpendicular direction to the maximum stress.

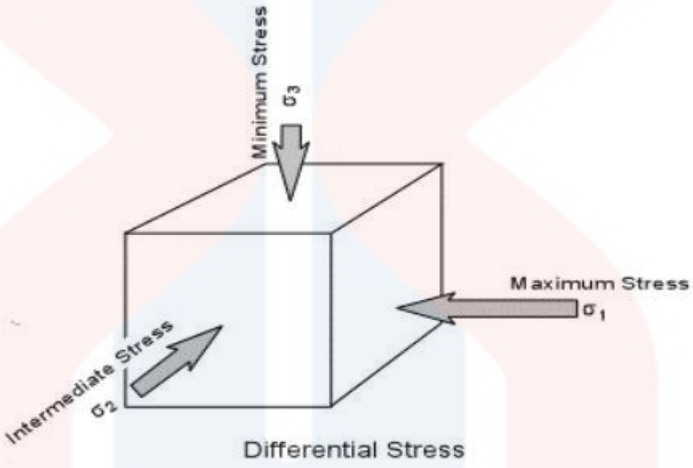


Figure 4.32: The principle of stress

The maximum stress or σ1 shows that the place or location in the study area experienced the greatest force. The weak zone is the area which is experienced the lower forces and there were many features such as fractures, cracks and joints that can be found there.

4.4.3 Bedding Analysis

Bedding plane is one of the geological features that can be measured in the study area. Each bedding plane must have attitude which is strike and dip of the bedding. Bedding is a feature that formed due to deposition process of rocks. Bedding only can be found in the sedimentary and metasedimentary rocks. Originally, bedding plane is horizontal but due to tectonism activities, the bedding may have been tilted or moved.

Figure 4.33 shows the bedding of the mudstone found located at the location that is located in the rubber trees plantation. The strike of the bedding is 176˚ and the dipping around 30˚. The bedding is clearly been seen at the outcrop there. The outcrop is highly weathered and have some biological weathering there. Meanwhile, Figure 4.34 shows another bedding at the mudstone outcrop and the next one is Figure 4.35 shows the bedding at the sandstone outcrop.

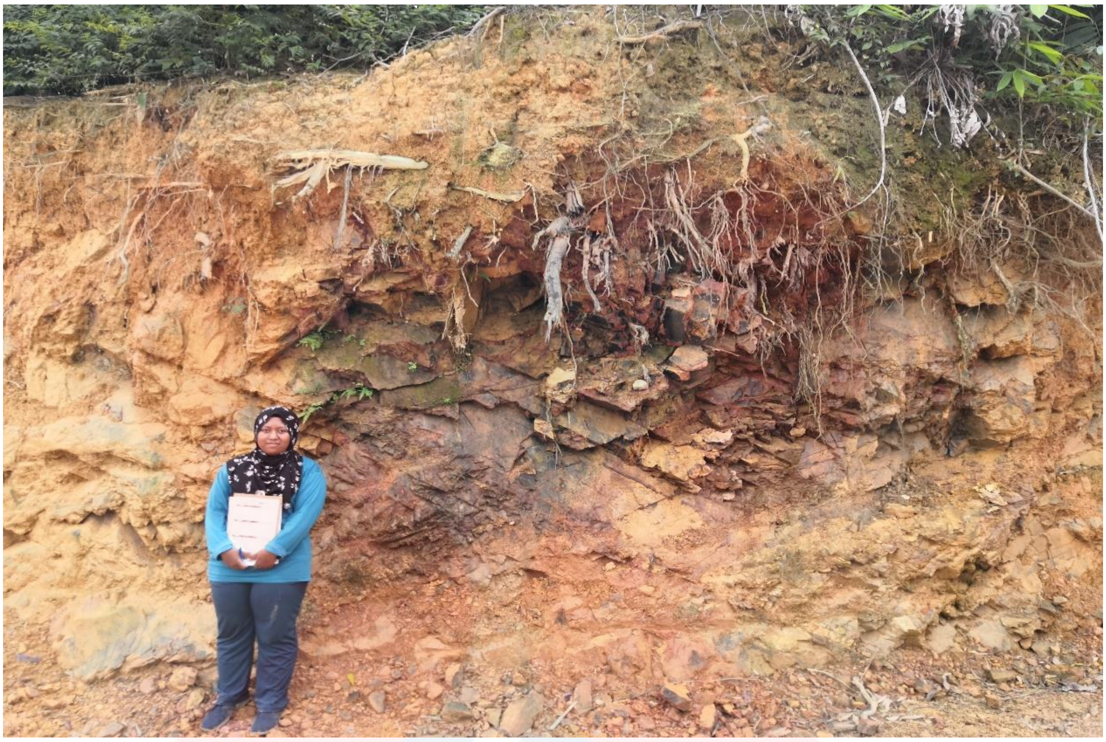


Figure 4.33: The bedding of the mudstone

Figure 4.34: Another bedding at the mudstone outcrop

Figure 4.35: Bedding at the sandstone outcrop

One of the key features to measure is the orientation, or attitude, of bedding. Bedding plane is subtly and importantly different. It refers to the discrete horizon of no thickness, a stratum-parallel boundary that separates two different beds.

4.4.4 Vein

Vein is a hydrothermal process product. Vein occur when there is a crack on a rock where the hot fluid that contains dissolved minerals from the magma sources flow upright through the cracks. As the temperature gets cooler, the dissolved minerals that contained in the hot fluid will deposited in the cracks of the rocks. Commonly, in the study area was quartz vein. Quartz veins are mostly fracture related and have clear contacts with their host rocks. Quartz veins are very common, they need a source of dissolvable Si, which is a really abundant element. The simplest type of a quartz vein is the filling of an already present crack in rocks. In the majority quartz veins, most of the quartz is precipitated as massive, milky quartz, and well-formed crystals, if found at all, are only a small portion of the vein filling.

Figure 4.36: Quartz vein in sandstone

Quartz deposits in sandstone units are often present on the crests of ridges where they help cement the sandstone fragments and make the entire unit more erosion resistant. Major faults are commonly filled by quartz veining, which may have been fractured many times during mountain building. The sandstone-hosted veins contain a lot of milky quartz, but usually have a higher percentage of rock crystal present. This is due to the nature of quartz crystallization and the geometry of the actual deposits themselves. When quartz begins crystallize, it must have a nucleation site. If one is already available, such as a fractured quartz grain on a sandstone face, then quartz crystal will start to grow.

4.4.5 Fault

Fault is one of the geological structures that formed due to any tectonism activities of the plate boundary. The type of motion along a fault depends on the type of fault. The main types of faults that were found in the study area was normal fault. Based on the study of the lineament map in Figure 4.29, there were several lineament that were identified. From the identified lineament, as assumption of faulting was made. In order to prove the assumption, the ground observation that was through the geological mapping. Several indicators to prove the faulting occurrence in the study area was observed.

The fault that occurred in the area is a normal fault. Tensional stress, meaning rocks pulling apart from each other, creates a normal fault. The first indicator of the fault is through the geomorphological observations. The indicator is the river. If the river is not been exposed to any great forces, the streams usually meander. Due to the great forces that occurred there, the river is being moved until it becomes the straight river.

Besides that, the other indicator is from the distributions of strike and dip of rocks. From the observations, the reading of the strike and dips of the rocks is quite similar to each other. Usually if the area is not been exposed to the great deformation, the distribution of the strike and dip will be quite same to each other. The analysis of the strike and dip of the rocks had been done. The analysis of the strike and dip of the rocks had been done.

Figure 4.37: River occurrence experienced faulting

Because of friction and the rigidity of the constituent rocks, the two sides of a fault cannot always glide or flow past each other easily, and so occasionally all movement stops. The regions of higher friction along a fault plane, where it becomes locked, are called asperities. When a fault is locked stress builds up, and when it reaches a level that exceeds the strength threshold, the fault ruptures and the accumulated strain energy is released in part as seismic waves, forming an earthquake.

Strain occurs accumulatively or instantaneously, depending on the liquid state of the rock; the ductile lower crust and mantle accumulate deformation gradually via shearing, whereas the brittle upper crust reacts by fracture instantaneous stress release resulting in motion along the fault. As shown in Figure 4.38 the mechanism of faulting. A fault in ductile rocks can also release instantaneously when the strain rate is too great.

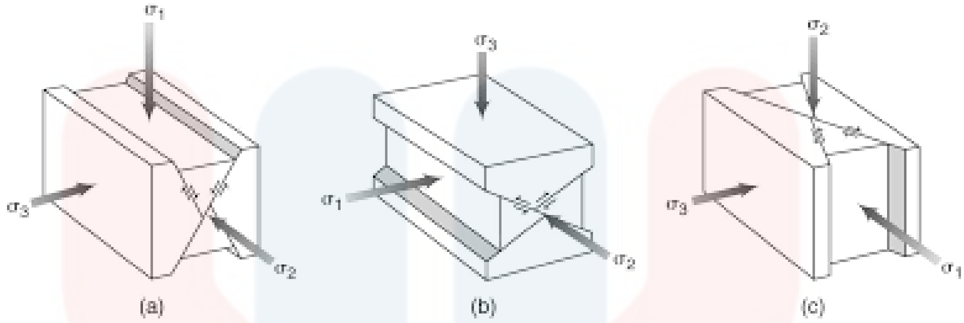


Figure 4.38: The mechanics of faulting

4.4.6 Fault plane

A fault plane is the plane that represents the fracture surface of a fault. A fault trace or fault line is a place where the fault can be seen or mapped on the surface. The dip of a fault plane is its angle of inclination measured from the horizontal. The plane, or surface formed between the two rock blocks that slip one with the other during an earthquake. Figure 4.39 show the fault plane that can been found in the study area. It is located at the coordinates N 04˚ 48' 50.5" E 101˚50' 30.1" at the elevation 287m.

Figure 4.39: Fault plane

4.5 Historical Geology

Generally, the Central part of Peninsular Malaysia is under the Raub Group which consists of Aring Formation and Gua Musang Fomation. Lojing, the study area lies under the Gua Musang Formation. This formation is formed during the Pre-Mesozoic Era. The granite intrusion on the Eastern part of the study area is formed during the Mesozoic era. The granite intrudes the metasedimentary rocks, it generated great amount of forces, heat and pressure.

In addition, the effect of intrusions developed geological features such as fault. Since there is intrusion of granite in the study area, at the same time it shows that in the past geologic time, already happened unstable condition in the earth subsurface. Thus, in order to achieve stability and buoyancy, the magma rises from the subsurface in form of intrusions then it is intrude the metasedimentary rocks in the area. Then, minerals start to crystallize when the magma cooling and after that forming a granite.

Technically , an intrusion is any formation of intrusive igneous rock; rock formed from magma that cools and solidifies within the crust of the planet. A granite intrusion into country rocks, effusive rocks overlying basement rocks or dykes and sills are younger than the enclosing country rocks. Then, also original relationship between both igneus and sedimentary rocks later metamorphosed.

Besides that, in the study area also undergoes metamorphism in the past time. It occurs primarily due to heat, pressure, and the introduction of chemically active fluids. The chemical components and crystal structures of the minerals making up the rock may change even though the rock remains a solid. The rise in temperature makes the minerals in the rocks become unstable of their position. Figure 4.40 shows the traverse map of the study area while Figure 4.41 shows the geological map that have been done in order to complete the geological mapping.

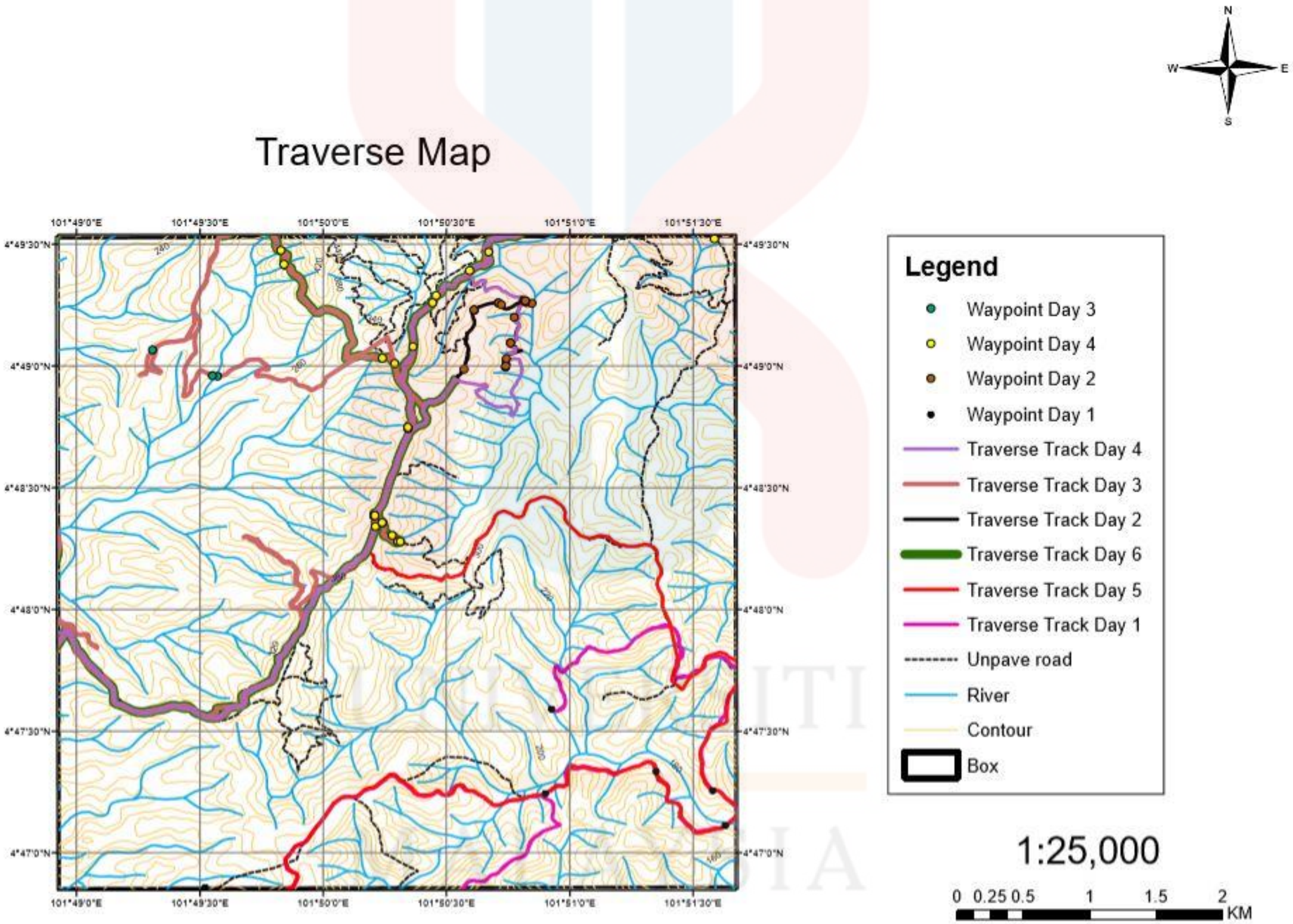


Figure 4.40: The traverse map of the study area

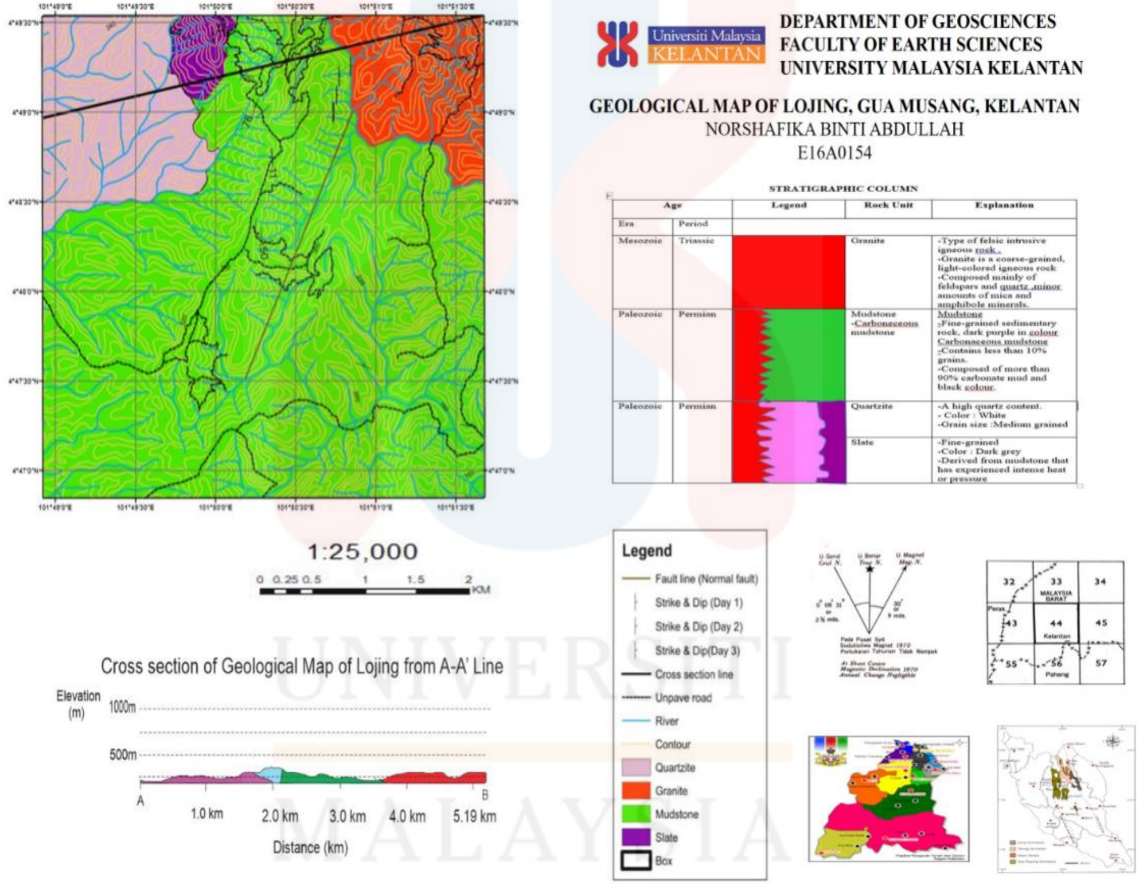


Figure 4.41: Geological map of the study area

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Introduction

In this chapter, the groundwater potential zonation was produced using ArcGIS 10.2 software and assessment was done. Besides that, certain parameters were used as guidance in order to produce maps such as lineament, lithology, drainage density, land use land cover, slope, and aspect data that were obtained from raw satellite image from year 2017 until 2019. At the same time, the results of the groundwater potential zone map were used for assessment in terms of availability of groundwater area. The results obtained from different objective were analyzed and the results are properly discussed.

5.2 GIS analysis for Groundwater Potential Zone

The data needed for GIS was downloaded from USGS where various thematic maps were generated using Arc GIS software. The different thematic maps have their description as follows:

5.2.1 Geomorphology

Geomorphology has an essential meaning “scientific study of the history and nature of landforms on the Earth surface and a few other planets, and also related processes regarding their creation.” The differences between geomorphology units were generated from information of satellite and are shown in Figure 5.1. At the same time, different classes were observed and distinguished in the study area and are shown below such as (i) mountainous area and (ii) hilly area.

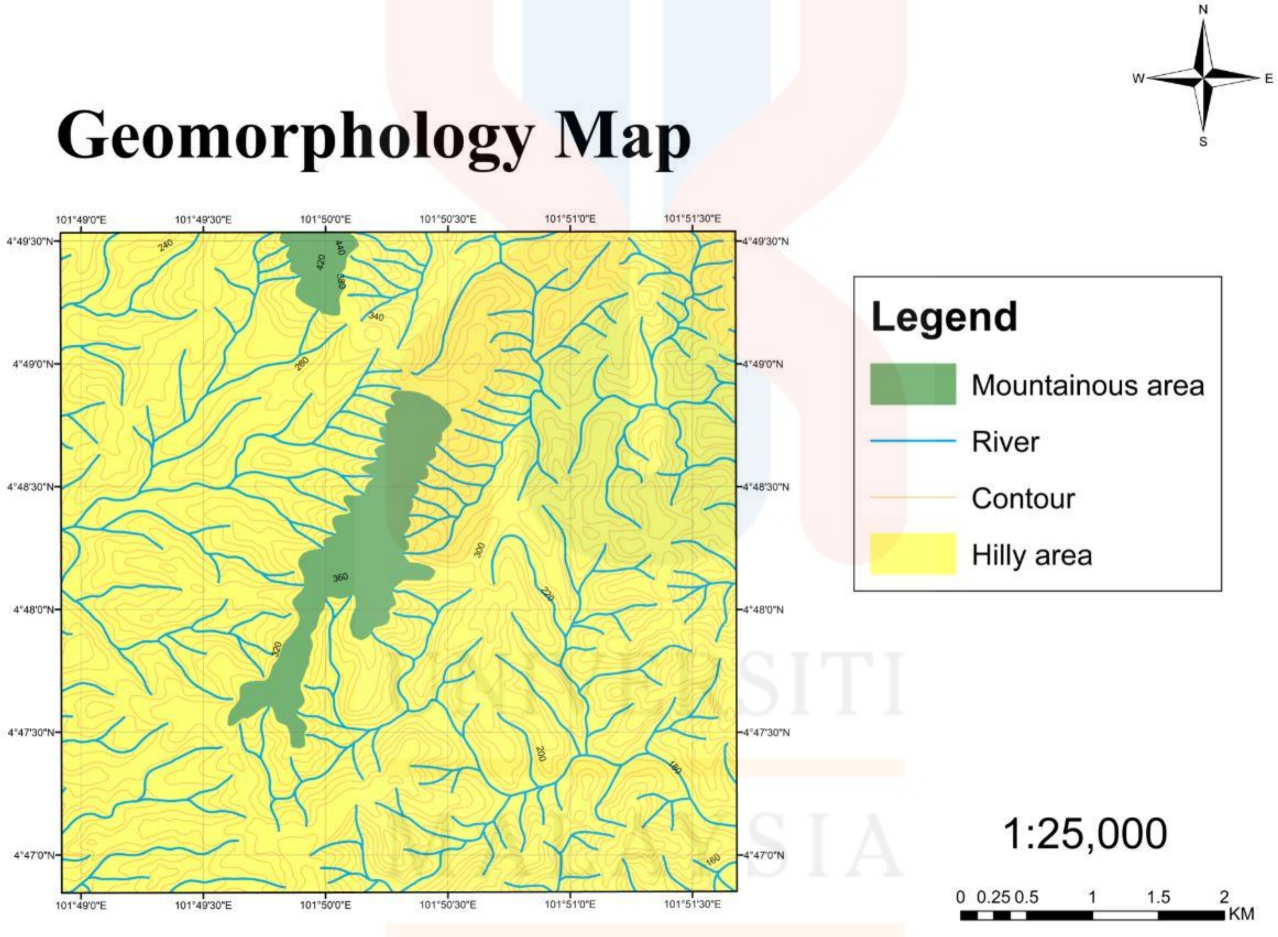


Figure 5.1: Geomorphology map

5.2.2 Landuse / landcover

Different landuse/landcover classes was weighted based on their water requirement. The lowest priority was given to barren land as it lacks a vegetation cover. Next, in order to prepare landuse map, data from ArcGIS is created or generated. The map showing the usage of the land forms of vegetation and non-vegetation area. Land use plays a significant role in the development of groundwater resources. It controls many hydrogeological processes in the water cycle, infiltration, evapotranspiration, and surface runoff. The landuse or land cover is shown in Figure 5.2 below.

5.2.3 Lineament Density Map

For lineament density map, the lineament map is first produced by following the ridge along the hill and mountain of the map area. Then, the map is delineated and reclassified into density mode using application in ArcGIS Toolbox. Lineament analysis of the study area was carried out by visual interpretation from raster to reclassify of lineament becoming lineament density map as shown in Figure 5.3 below. It was classified into extremely high, high, moderate, low to moderate and lastly to a low level. Furthermore, lineaments play a very vital role in recharging of groundwater in the hard terrains rock and also groundwater potential is much more likely higher near lineament zones.

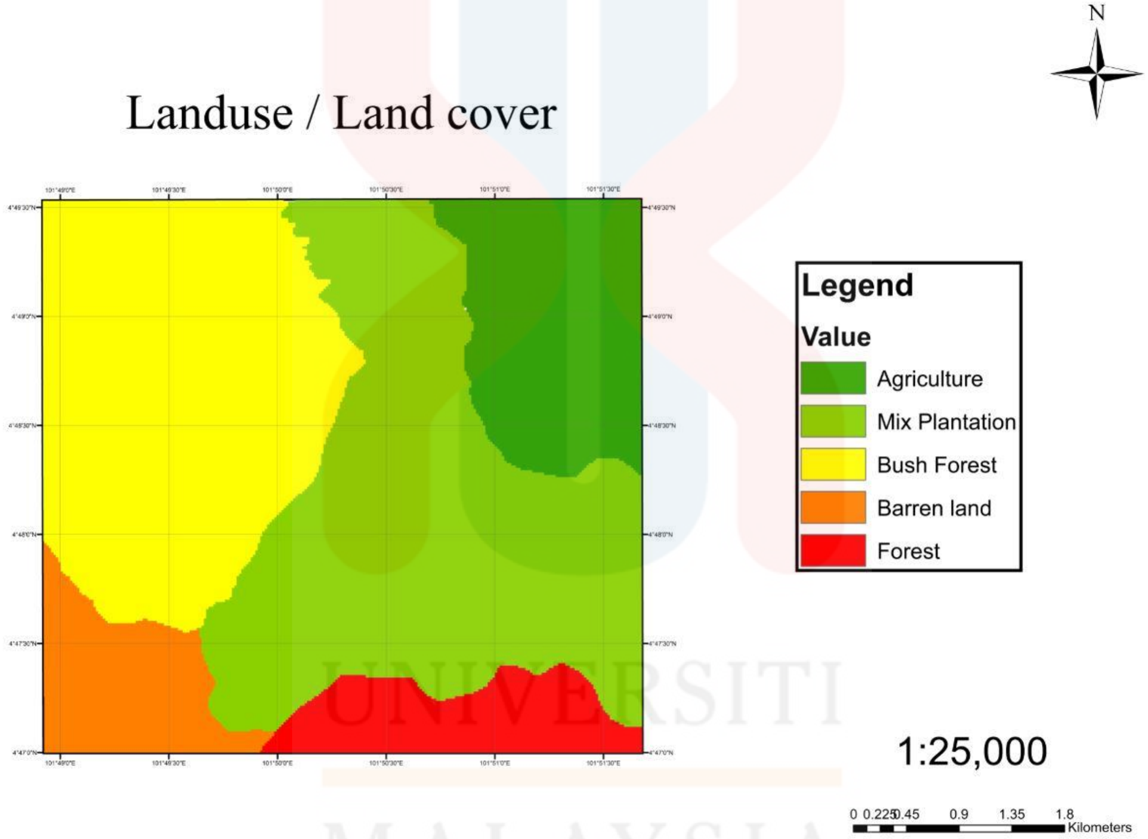


Figure 5.2: Landuse / Land cover Map

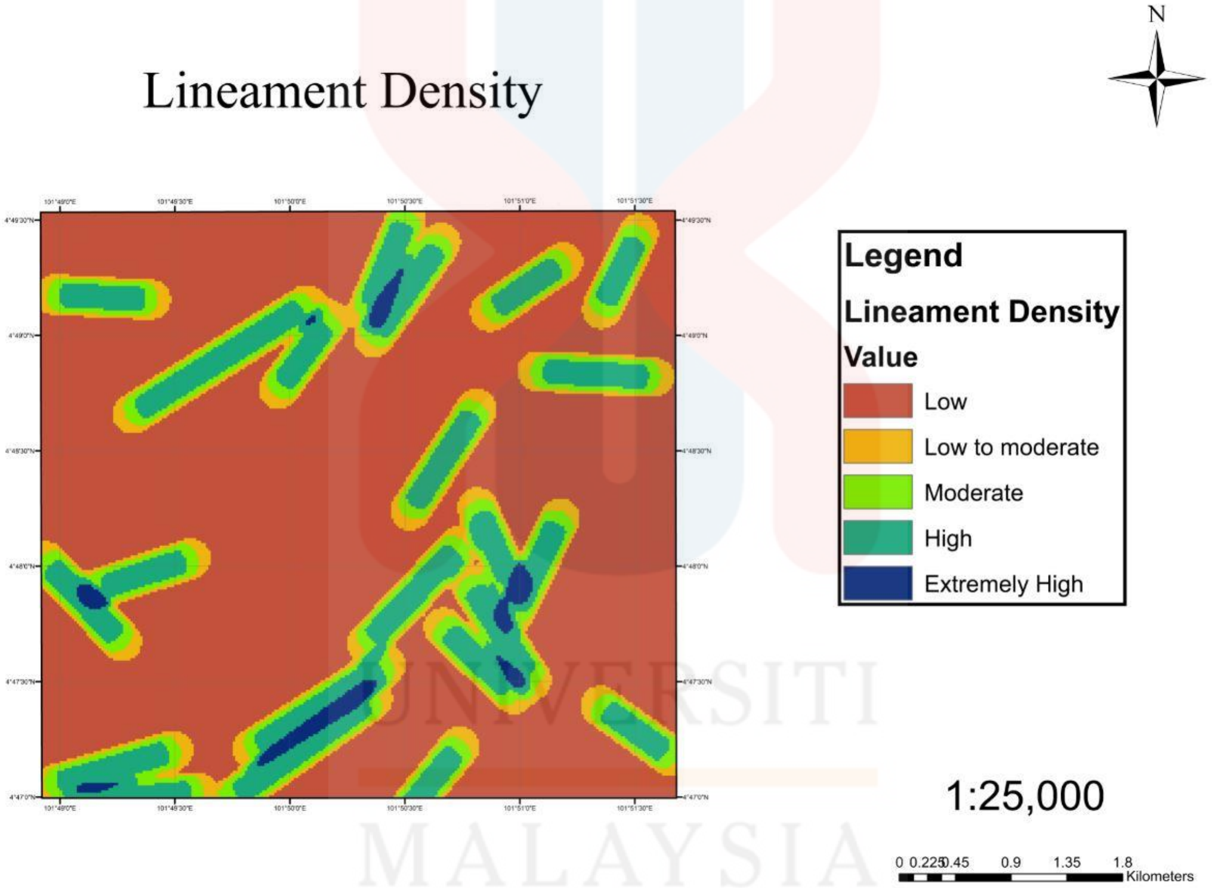


Figure 5.3 : Lineament Density Map

5.2.4 Drainage density

For drainage density map, the drainage map is first produced. Then, the map is delineated and reclassified into density mode using application in ArcGIS Toolbox. Meanwhile, drainage density of the study area was calculated as the ‘total length of streams in the sub area and expressed as km/km2 after was divided by the study area. Drainage density value was grouped into five groups which is : (i) very high, (ii) high, (iii) moderate, (iv) low and (v) very low. A low drainage density area causes high of infiltration and it helps in better potential zones of groundwater as compared to a high drainage density area. The drainage density map is shown in Figure 5.4.

5.2.5 Slope Map

For preparing slope map, the data from ArcGIS is first generated into 3D map with the basis of elevation. Then, in the 3D analyst toolbox, the slope map produced. Slope range was differentiated into six groups. Finally, six classes of slopes were produced which are <5°, 5° < 25°, 15° < 25°, 25° < 35°, 35° < 60° and lastly > 60 ° as shown in Figure 5.5 down below. Higher slope basically will make more runoff with infiltration that is more lessens, and it will have a poor assumption of groundwater availability compared with low slope region.

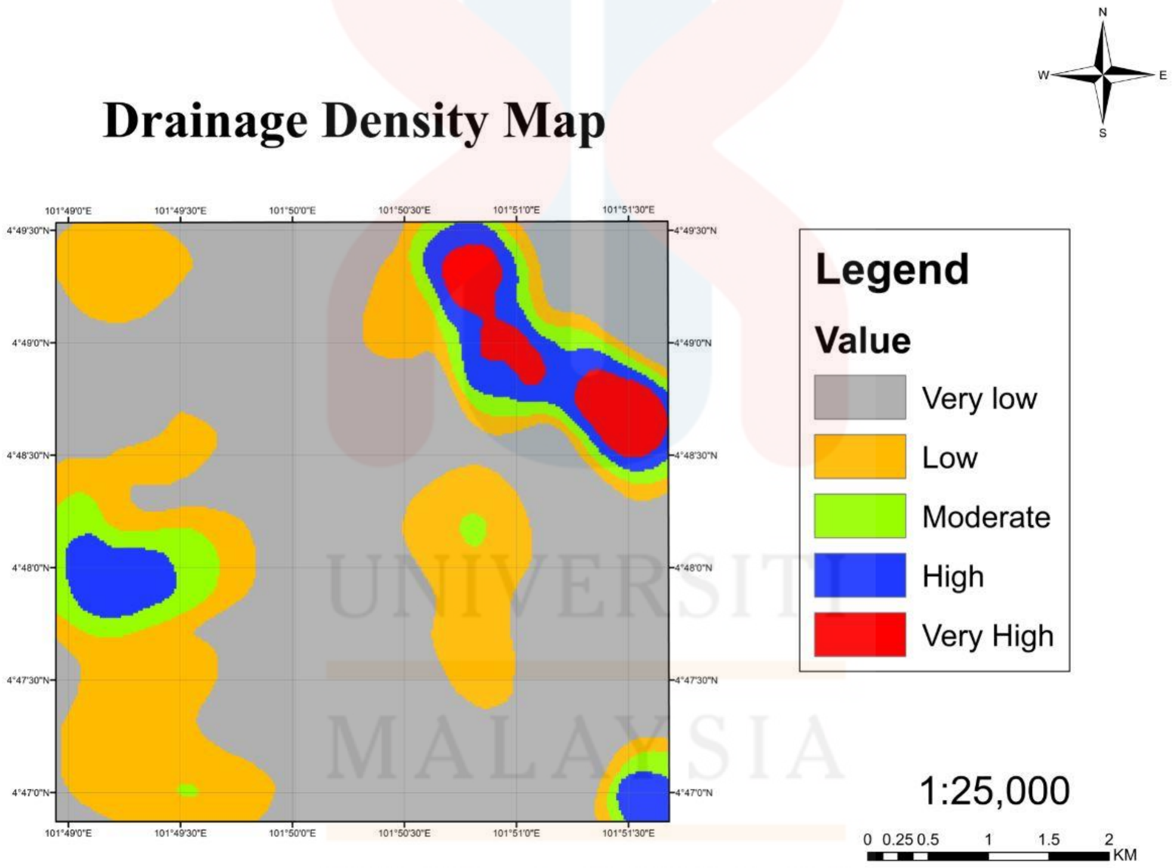


Figure 5.4: Drainage density Map

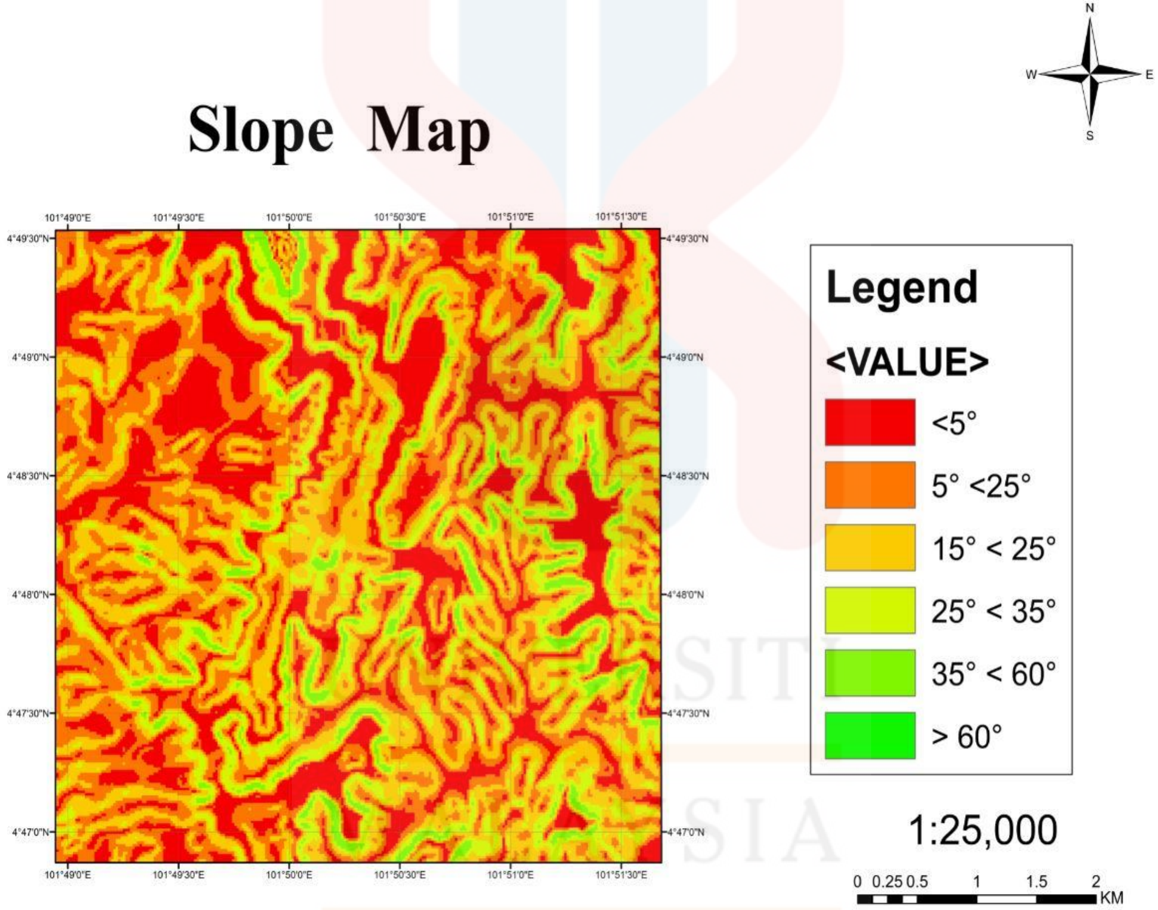


Figure 5.5: Slope Map

5.2.6 Lithology Map

For preparing this map, the geological feature in type of rock lithology was generated using ArcGIS 10.2. Most of the study area was covered by sediment and meta sediment. This type of sedimentary rock possesses higher groundwater potential than other types of rock, such as igneous and metamorphic rock. Unconsolidated materials like gravel, sand, and even silt make relatively good aquifers, as do rocks like sandstone. Other rocks can be good aquifers if they are well fractured. This type of lithology can have a good potential for groundwater exploration. Figure 5.6 shows the lithology which is consist of mudstone, granite, quartzite and slate.

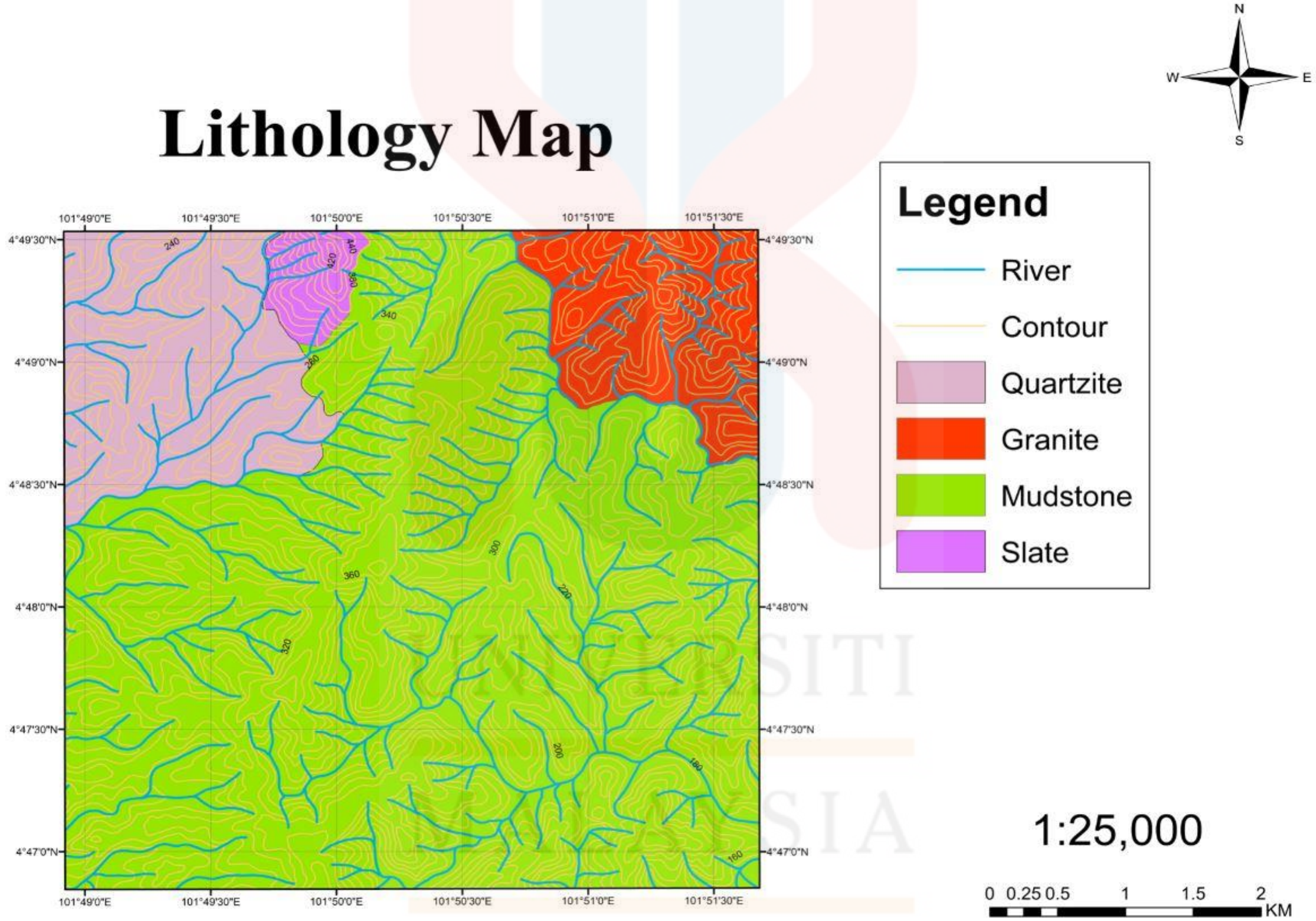


Figure 5.6: Lithology Map

5.3 Integration of Various Thematic Layers for Modeling using GIS: Weighted Overlay

Maps that are produced in order to get the area of groundwater potential is derived by the interpretation of satellite data such as lineament density, type of lithology, landuse, slope, and saved as shapefile in GIS software. Lithological map and landuse map were digitized and saved as polygon coverage, while lineament and drainage map were digitized as line coverage. Based on the groundwater potentiality, each class of the main six thematic layers (geomorphology, slope, drainage density, lineament density, soil, land use) are roughly placed into one of the following groups which are,(i) Very good, (ii) Good, (iii) Moderate, (iv) Low (v) Very low. At the same time, suitable amount of weighted value is given to each class depends on their distribution regarding availability of ground water potentiality. Besides that, all the thematic maps were produced and integrated.

The main objective of this project is to use GIS for the assessment, evaluation and analysis of spatial distribution of ground water potential zones in the Lojing, Gua Musang. By referring to the map, the west part was having a very good potential for groundwater purposes. The area is on the hilly part of the map. Then, the area with the low potential for the groundwater prospects is around the low lying area of the map. The maximum value is given to the feature with highest groundwater potentiality and the minimum given to the lowest potential feature. So, this can be an indicator for the exploration of groundwater in the study area. Any trials in extracting the groundwater in the region study area should be done in the area that marked as having a high potential in the map. Each weightage theme was put a weight regarding on its influence on the movement, occurrence and groundwater storage.

5.4 Digital Elevation Model

Digital Elevation Model (DEM) was obtained from the USGS website. From the DEM obtained, parameters such as slope, aspect, elevation and stream density were obtained. These parameters were used in order to generate groundwater potential zone map.

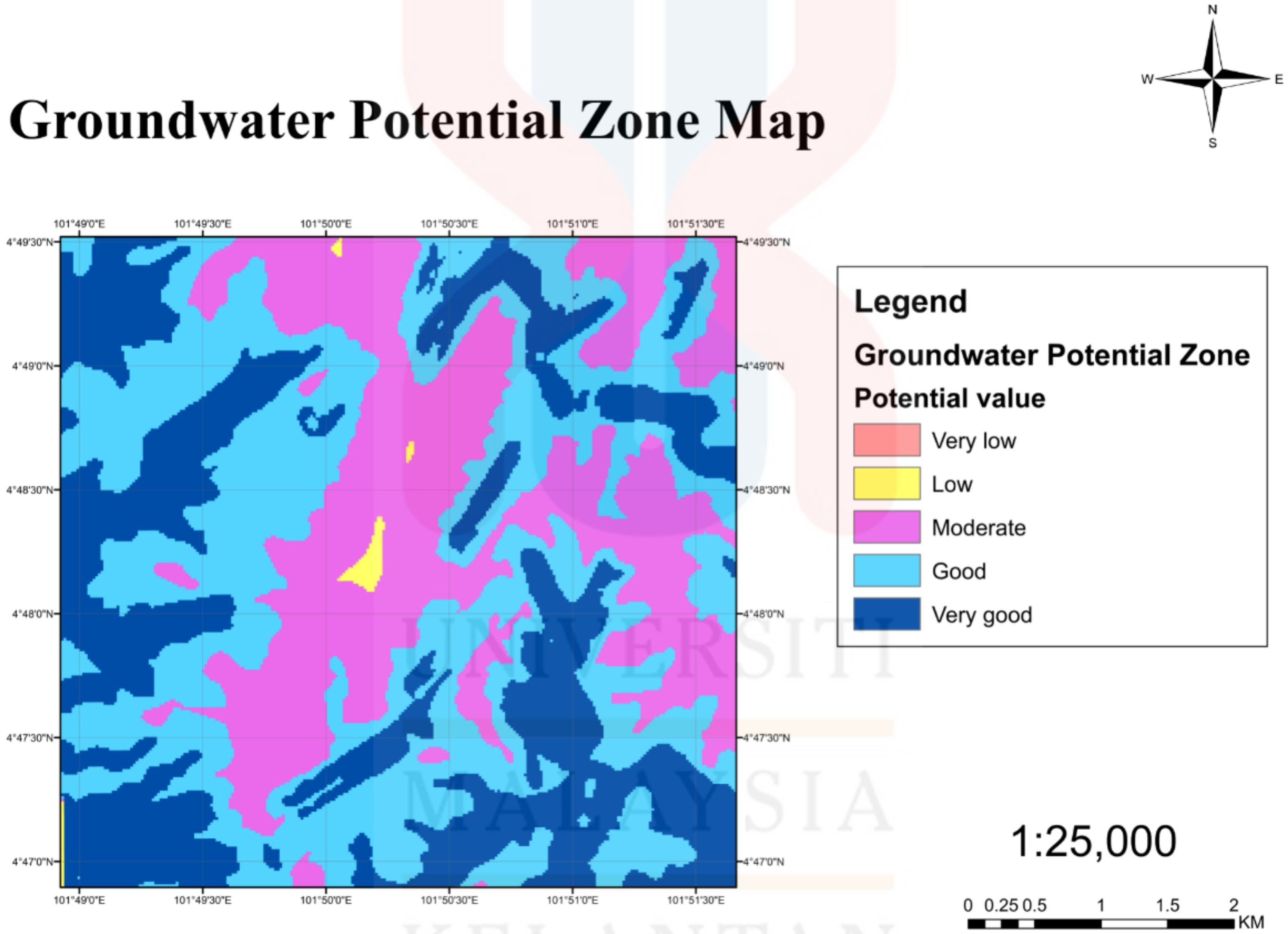


Figure 5.7: Groundwater Potential Zone Map

5.5 Reclassify of Raster

After all the parameters were produced from the DEM data, all the parameters were converted into raster data sets. The class were made based on its importance. The sum of all factors must be equal to 100 percent. The reclassify of raster data is very importance in order to generate the groundwater potential zone map using weighted overlay method (WOM). Table 5.1 shows the reclassify raster data sets.

Table 5.1: The reclassify data with scale and influence

No.	Theme	Influence (%)	Class	Weighted
1.	Slope	30	<5°	8
			5° < 25°	7
			15° < 25°	6
			25° < 35°	5
			35° < 60	4
			> 60 °	3
2.	Lineament density	25	Extremely high	9
			High	8
			Moderate	7
			Low to moderate	6
			Low	5
3.	Drainage Density	20	Very low	4
			Low	5
			Moderate	6
			High	7
			Very high	8
4.	Landuse/ Land cover	15	Agriculture	9
			Mix plantation	8
			Bush forest	7
			Forest	6
			Barren land	5
5.	Lithology	5	Mudstone	7
			Granite	6
			Quartzite	5
			Slate	4
6.	Geomorphology	5	Mountainous area	5
			Hilly area	7

Table 5.2: Integrated Weight Range for Various Groundwater Potential Zones

Groundwater Category	Lower and Upper Weight Table
Very good	441-521
Good	394-441
Moderate	352-394
Low	313-352
Very Low	258-313

5.6 Groundwater Potential Zone and Assessment

Based on the Groundwater Potential Zone map that has been produced, the study area was divided into 5 classes which are very good, good, moderate, low and very low. The software generated the groundwater potential zone map automatically based on its importance.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This chapter concluded all the result from beginning until the assessment of groundwater potential zone using GIS and remote sensing method. It is concluded that the objectives of this research project is achieved.

The first objective is to produce a geological map of Lojing, Gua Musang with 1:25000 scales. The objective was achieved by the geological mapping that had been done in the study area. All the geological aspects including geomorphology, stratigraphy, structural geology, petrography and historical geology were discussed in chapter 4in detailed. Generally the study area was classified into 4 main lithologies which are granite, meta mudstone, quartzite and slate. As the study area is in intrusion zone, there are many geological structures that found including major fault, fractures and veins.

The second objective is to identify the parameter for the potentiality of groundwater resources by using integrated GIS tool. Meanwhile, it is for the most imperative contributing parameters that demonstrate groundwater potential, for example, geology, soil, drainage, topography and inclines through GIS module.The study on the potential of groundwater by mapping process have been increasingly implemented by researchers all over the world. This is because of the highly increasing demand for water either for urbanization or industrialization.

This study depend on the GIS, that were able and have the ability to store also analyzing many or various type of data that can be view in different layer forms. In addition, surface data like the availability of the outcrop and the interpretation of the crack and other geological structure that formed on the rock, can give a clue or sign about the water potential of the area.

This research also has describe the importance of structural elements, like crack, lineaments and joints to potential zones for groundwater source. Those structures that were cause by plate tectonic activity that occur for millions of years. It is not a coincidence that the potential zones for groundwater that generated from the map are well correlated with the area that have a high density of lineaments in the study area.

The third objective is achieved by generating the groundwater potential zone map with the scale 1: 25000. The groundwater potential zone map was generated and created by using the GIS and remote sensing method which is weighted overlay method in ArcGIS Software. There were a few or several parameters were chosen to be overlay in order to generate the map includes drainage density, slope, aspect, lithology, landuse and lineaments density. The DEM data is obtained from the USGS website.

As a result, the parameters were overlay by using the weighted overly method, then after that the groundwater potential zone map were produced. The groundwater potential zone map were divided into the specific classification.

6.2 Recommendations

There are a few or several recommendations suggested for the future research. After conducting this research, there were several improvement need to be done in order to produce a better result. One of the recommendations is to use a higher quality of DEM data. This is because when using the lower quality of data, the image that has been produced is not sharp enough and usually will not produced a good quality of map. Besides that, it has a very low resolution. The USGS website does not provide a free high quality of data to be downloaded. The higher quality of data can be obtained from any agencies such as Jabatan Mineral Geosains (JMG). An initiative by approaching the agencies or other agencies to get the higher quality data should be taken.

Besides that, the uses of other software should be increased. Instead of using the software like ArcGIS, other software such as Drastic software or Arc Hydro can be used in. This can make variations of software in geological study. In addition, future researcher can use software such as ArcScene software to generate the 3D-topography of the study area given to show the changes of vegetation in detail and more likely to understand. By using other software, it helps in generating, more evidences to support the validation of the research project.

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APPENDIX

Figure A.1: Conjugate joint

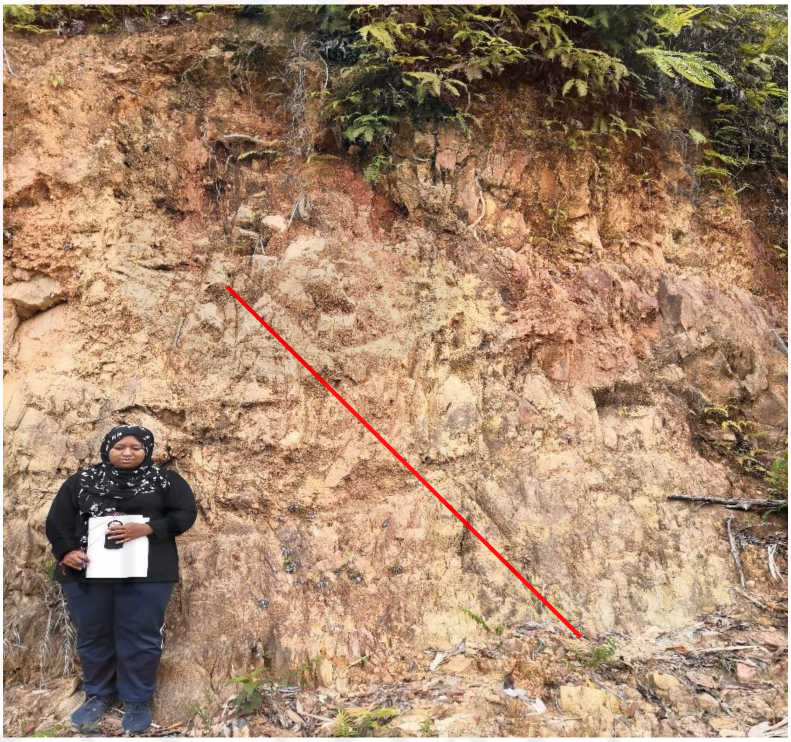

Figure A.2 : Minor fault