GEOLOGY AND DEMARCATION OF POTENTIAL AQUIFER ZONE IN KARSTIC TERRAIN USING SURFACE GEOLOGICAL MAPPING IN KUALA NERUS AREA, GUA MUSANG, KELANTAN

by

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DECLARATION

I declare that this thesis entitled "title of the thesis"is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ________________________________

Name : ________________________________

Date : ________________________________

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ABSTRACT

The study took place in Kuala Nerus, Gua Musang and its surrounding area. The study area consists of carbonate rocks, metamorphic rocks, sedimentary rocks and volcanic rocks that are under the Gua Musang Formation. The focus of the research is to produce an updated geological map of the study area with the scale of 1: 25 000 and to identify any potential aquifer zone in a karstic terrain within the study area. In order to do so, method such as geological mapping and geomorphological investigation are conducted. This method involves field visits, sample collecting and data analysis such as joint and fracture analysis. In determining a karst aquifer, geomorphological data analysis such as sinkhole, cave, joint and other conduits that can lead to the transportation of water to the earth in or near a karstic terrain are conducted. Laboratory work such as using the petro-thin for petrography purpose also involved. Result of this research is the finding of three aquifer zone in Kuala Nerus area, Gua Musang. All three aquifer are different from each other in term of the size, surrounding lithology and geomorphology resulting in the finding of three different karst aquifer that can hold different amount of water. So this research determine which aquifer has the most potential to be utilized. This result will help in the future research.

GEOLOGI DAN PENANDAAN ZON AKUIFER DI KAWASAN KARST MENGGUNAKAN KAEDAH PEMETAAN GEOLOGY DI KAWASAN KUALA NERUS, GUA MUSANG

ABSTRAK

Kajian ini mengambil tempat di Kuala Nerus, Gua musang dan kawasan di sekitarnya. Kawasan kajian terdiri daripada batuan kabonat, batuan metamorfik, batuan sedimen and batuan volkanik yang berada di bawah Formasi Gua Musang. Kajian ini tertumpu kepada penghasilan peta geologi dengan sekala 1: 25 000 dan untuk mengenalpasti kawasan yang berpotensi sebagai zon akuifer di kawasan kars di dalam kawasan kajian. Untuk berbuat demikian, kaedah seperti pemetaan geologi and kajian geomofologi dilaksanakan. Kaedah ini melibatkan kerja lapangan, pengambilan sample dan analisis data seperti analisis rekahan. Bagi menentukan kawasan akuifer, Analisis data geomofologi seperti sinkhole, gua, rekahan dan bukaan lain yang boleh membawa masuk air ke dalam tanah di atau berdekatan kawasan kars telah dilaksanakan. Kerja makmal seperti menggunakan petro-thin bagi menyediakan keratan batu untk tujuan petrografi. Hasil dari kajian ini menemukan tiga zon akuifer di sekitar kawasan Kuala Nerus Gua Musang. Kesemua tiga akifer adalah berbeza antara satu sama lain dari sudut saiz, batuan sekeliling dan juga geomorfologi menyebabkan penemuan tiga akuifer yang berbeza dan mampu menyimpan jumlah air yang berbeza. Jadi kajian ini menentukan akulfer manakah yang mempunyai potensi untuk digunakan. Hasil ini dapat menbantu dalam kajian untuk masa hadapan.

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LIST OF ABBREVIATIONS

Kg.	Kampung
km	Kilometre
N	North
S	South
E	East
W	West
NW	Northwest
SE	Southeast
Sg.	Sungai
e.g.	Example

LIST OF SYMBOLS

°	Degree
%	Percentage
°C	Degree Celsius
σ	Sigma
Q	Discharge
M	Injected tracer quantity
Vo	Volume of the injection tracer slug
Co	Concentration of the injection tracer slug
Cb	Background tracer concentration
C	Observed tracer concentration
T	Time
Δt	Time interval between measurements

CHAPTER 1

INTRODUCTION

1.1 General background

The research main focus is to find and earmark sum potential aquifer zone in karstic terrain by applying the geological and geomorphological method that's involved the analysis of the landform mineralogy, lithology and stratigraphy. The method also includes the analysis of geological structure and geomorphology of the karstic terrain.

One of the main purposes of the research is to identify the potential karstic aquifer zone in the study area which could be an alternative water recourse for the people of Gua Musang. Groundwater exploration isn't new in Malaysia. In fact the peoples in the state of Kelantan mostly depend in groundwater supply. 35% of Kelantan population solely depends on the alternative source of water supply (groundwater and Gravity Feed System) especially in rural area (Idrus A.S. Fauziah M.N., 2014). But there's one type of groundwater supply that wasn't as popular and commercialised as other type of groundwater aquifer that is the karst aquifer.

Karst is a terrain with distinctive hydrology and landforms arising from a combination of high rock solubility and well developed secondary porosity (Ford D. a., 1989). The statement by Ford and Williams shows that a karst must consist of carbonate rocks such as limestone and dolostone that was able to be dissolved via chemical reaction with water/rain. The carbonate rocks also must be full of well-developed join and fracture that act as secondary permeability.

In south-west Kelantan the karst is less well-known but are actually more varied in their development (Paton, 1964). This statement showed that there are many different karst landforms in Kelantan and that makes it more complex and challenging on determining the aquifer zone.

The study not only revolve around the process of finding the aquifer but also general surface investigation that can influence the aquifer like the amount of surface water because the source of karst groundwater are generally from the surface water that went through a recharge area such as cave, sinkhole and all other karst landform that leads to the adding of karst water.

The quality of the surface water can determine the quality of the quality of karst aquifer because water flow to the aquifer via secondary and tertiary permeability that contribute to the low filtration because water can move easily to the aquifer.

1.2 Problem Statement

The study area is believed to have a high probability of karst aquifer due to its location that is near an alluvium landform that could act as a recharge factor (near recharge area). However the lack of research activities on this type of aquifer is overlooking the possibility of an alternative water source. With time the present groundwater resources could be emptied and these alternatives water resource can help even out the consumption of water from other aquifer and retain water for the future.

The process of determining the potential aquifer zones in a karstic terrain also a lot more difficult than other aquifer due to its complex systems. It could be simply said as challenging and require a great amount of attention to detail (Ford D. a., 1989).

The vulnerability of karst aquifer to groundwater pollution and contamination due to the accessibility at which surface water can enter the subsurface through groundwater flow system is also a problem that needs to be understood. The study is located near an agriculture area thrust the surface water is prone to the exposure to agriculture chemical.

1.3 Research objective

1. To produce an updated geological map of Kuala Nerus area, Gua Musang, Kelantan.
2. To identify, analyse and earmark all the potential aquifer in Kuala Nerus area, Gua Musang, Kelantan.

1.3 Study area

The study area is located in the district of Gua Musang, Kelantan. It is located about 5 km North East from Gua Musang town. It lies between latitude 4°54’50”N and 4°56’35”N and longitude 101°57’10”E and 102°0’57”E. The area is around Kampung Laling, Kuala Nerus and some of the Renok Land Development project area. The area is about 5km x 5km cubic in size. Inside there are 2 main rivers that are the Renok and Galas River. Figure 1.1 shows the geological map of Kelantan and figure 1.2 shows the study area base map.

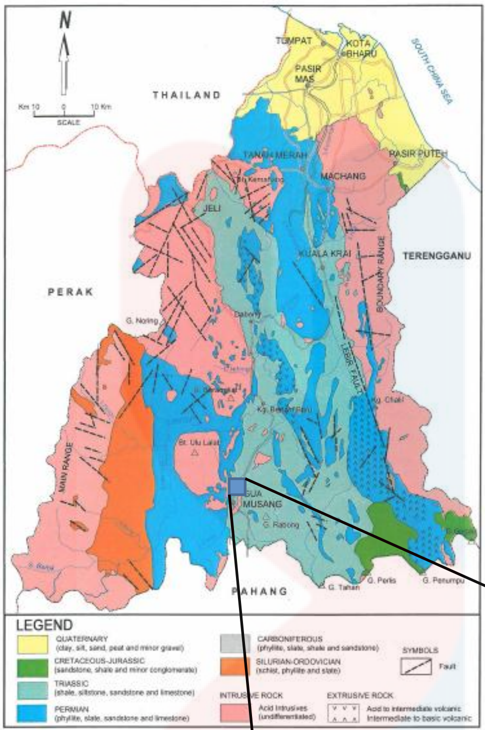

Figure 1.1: Geological map of Kelantan (Nazaruddin, 2015)

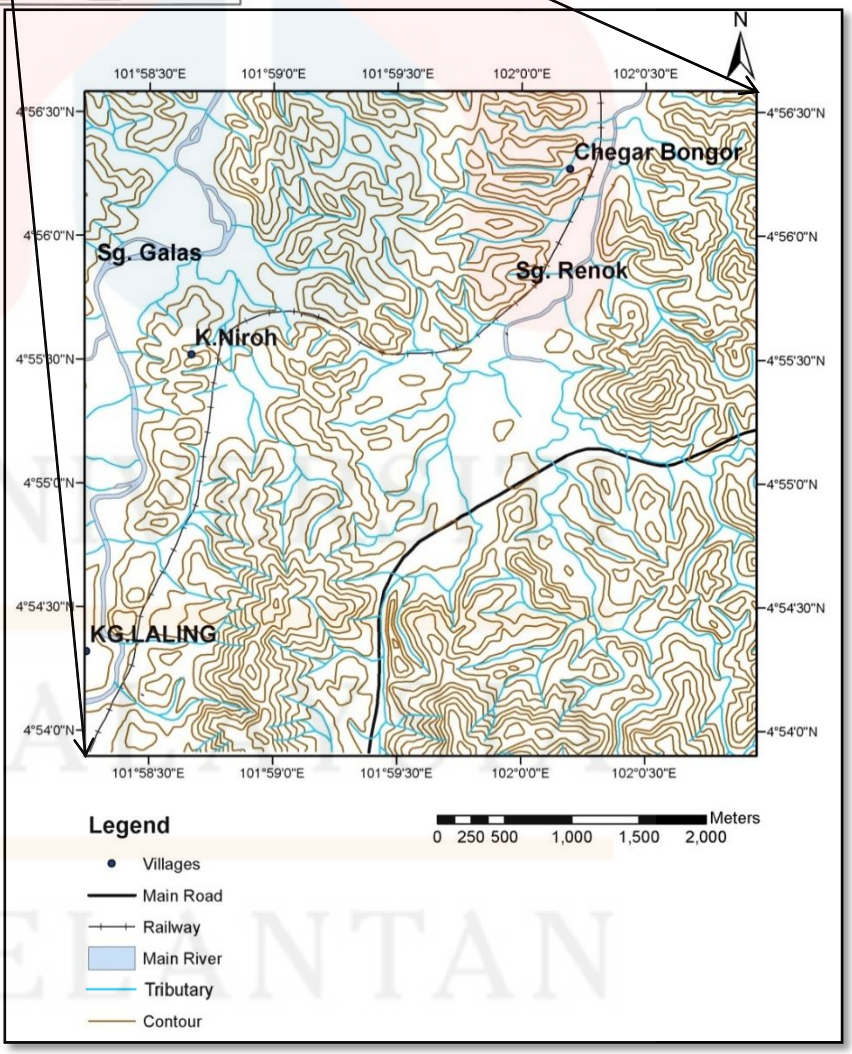

Figure 1.2: Base map of Kuala Nerus area, Gua Musang

1.4.1 Geography

a) People distribution

The states of Kelantan have a population of 1,641,900in the year 2010 and had been increasing to 1,849,700 in the year 2014. Table 1.1 shows the Annual population in Kelantan from 2010 to 2014 Source; Department of Statistic Malaysia.

Table 1.1: Annual population in Kelantan (Department of Statistic Malaysia,2015).

District	Year				
	2010	2011	2012	2013	2014
Bachok	142,100	146,000	149,900	153,800	157,700
Kota Bharu	509,600	522,000	534,500	547,200	569,100
Machang	101,300	103,900	106,400	109,000	111,700
Pasir Mas	212,000	217,300	222,800	228,300	233,800
Pasir Puteh	134,200	137,700	121,100	144,600	148,200
Tanah Merah	133,400	136,700	140,000	143,300	146,700
Tumpat	137,200	177,700	182,200	186,800	191,400
Gua Musang	103,300	106,000	108,800	111,700	114,500
Kuala Krai	120,800	123,700	136,500	129,500	132,400
Jeli	48,000	19,300	50,600	51,900	53,200
Kelantan	**1,641,900**	**1,690,300**	**1,772,800**	**1,806,100**	**1,849,700**

As for the district of Gua Musang, the population was 103,300 in the year 2010 and had increase to 114,500 in the year 2014. The total area of Gua Musang district is 8,214.3 km² and the population had increased by 10.84% from the year 2010 to 2014. Figure 1.3 shows the population of Gua Musang from the year 2010 to 2014.

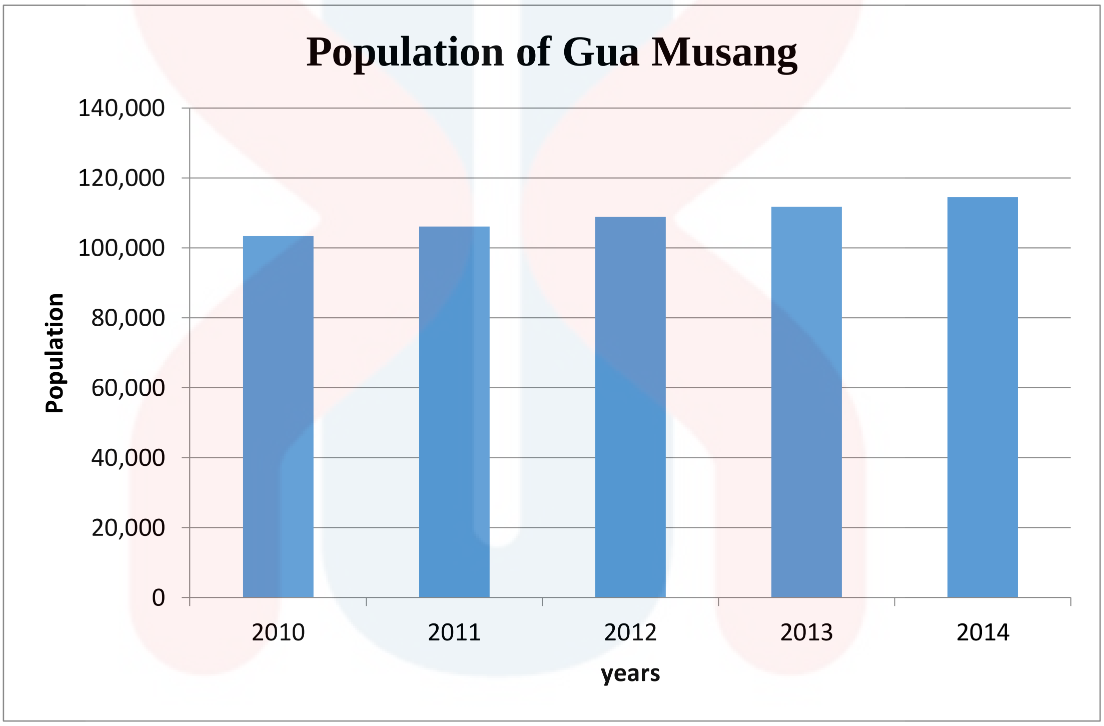

Figure 1.3: The population of Gua Musang from the year 2010 to 2014.

b) Rain distribution

Annual rainfall in Gua Musang is 2020mm in the year 2010 and undergone a decline in the year 2011to 1765.5mm. The average rainfall increase back in 2012 to 2721mm but decrease in 2013 to 2418mm. The annual rainfall in 2014 increase to 2784.5mm. Figure 1.4 shows the annual rainfall in Gua Musang.

Table 1.2 shows the total annual rainfall in Kelantan from 2010 to 2014, Source taken from Department of Statistic Malaysia. This shows that the pattern of rainfall are increasing in one year and decreasing in the next year. So in can be said that the rainfall in 2016 are likely to be higher than 2015.

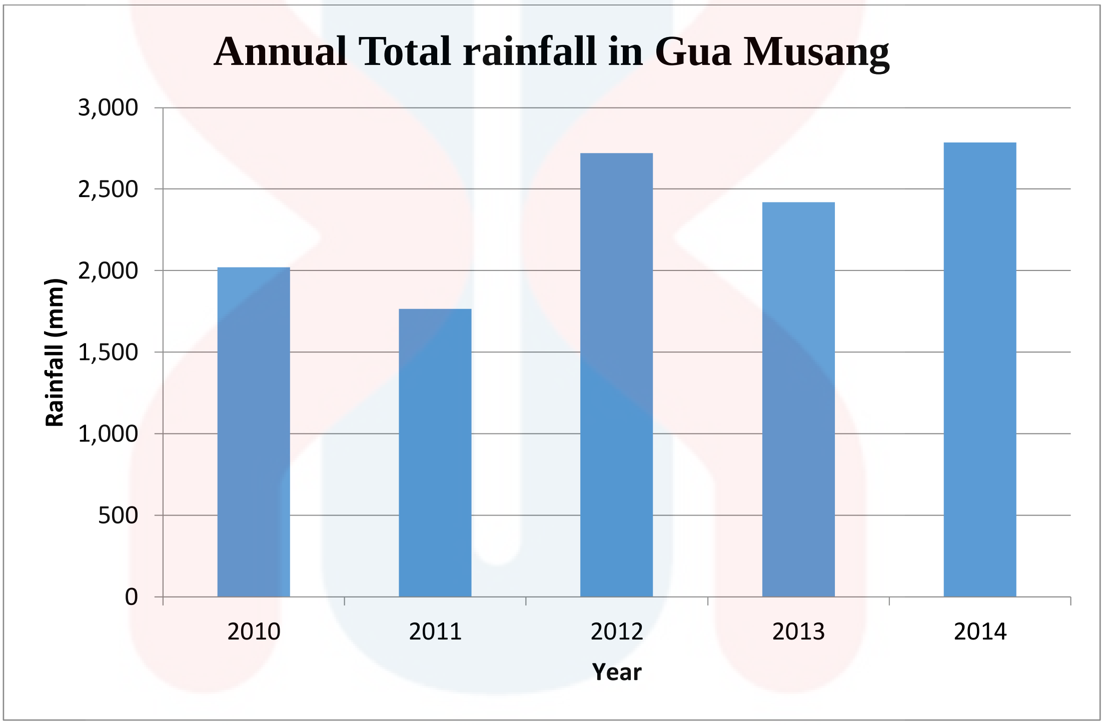

Figure 1.4: The annual rainfall in Gua Musang the from the year 2010 to 2014

Table 1.2: Total rainfall in Kelantan from year 2010 to 2014 (Department of Statistic Malaysia, 2015).

District	Year/Rainfall (mm)				
	2010	2011	2012	2013	2014
Bachok	2713	4149	3136	2841.5	3078
Kota Bharu	2246.5	3033	2741.5	1984.5	2436.5
Machang	2844	4249.5	3136	3730.5	4080.5
Pasir Mas	2717.5	3711.5	2673	2358.5	2782
Pasir Puteh	2902.5	4647	2911	3350.5	3414
Tanah Merah	3258.5	4258.5	3874	3434.5	3999.5
Tumpat	2370	3226	2538	2125	1743.5
Gua Musang	2020	1765.5	2721	2418	2784.5
Kuala Krai	2106.5	2065.5	2191.5	3339.5	1602
Jeli	3103.5	4359.5	3250.5	3592	4094
Kelantan	**26282**	**35465**	**29238.5**	**29174.5**	**30014.5**

c) Landuse

Most of the land use in the study area are palm and rubber frame. Most of this lend use are the influence of the peoples social economic activities that is farming as half of the study area include the Renok land development program properties that encourage the peoples in farming activities. Some other land use includes the houses of the people and a gold mine located near the galas river about 2km from Kampung Batu Dua, Gua Musang, Kelantan. There is also a military post in the study area.

d) Social economy

Most of the people in the study area work as a farmer, mostly due to the influence of the Renok land development project that open a large amount of land for agriculture use. Some of the people who lived in the study area work as businessmen who are the one that is supplying the other people with goods and grocery are for daily lives. Some of the works on the gold mine, but the amount are just a few because the mines are not very big and most of the work is conducted via machine. For the people that serve the military base camp in the study area work as the member of the Malay military to protect and serve the peoples.

e) Road connection

The main road that can be found in the south to south east part of the study area that is the Central Spine Road. That is the only main road in the area. Figure 1.5 shows an image of the main road in the study area. The road is large enough and most of them are in between small hill exposing some hill cutting outcrop in the area. But sadly, most of them are heavily weathered. The other streets are located near the railways as the people lives near the railways. The road and streets can be seen via Google earth.

Besides the main road, the Kuala Nerus area also consist of some minor road and streets that's connects the villages and the land use such as farm and many more. The streets are mostly small yet convenient for daily uses for the people. Because of this, mapping process will be more practical.

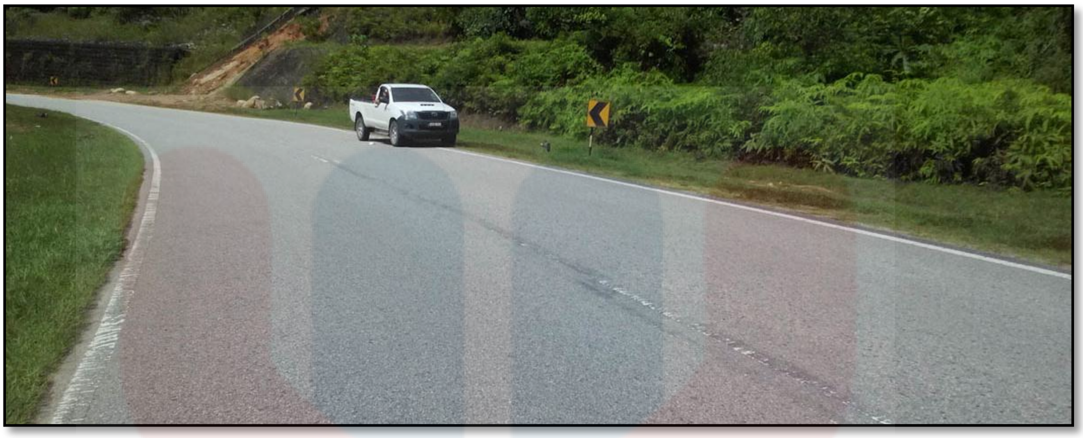

Figure 1.5: The main road in the study area.

1.4 Scope of the study

The study is carried out within the area of 5 km x 5 km of Kuala Nerus which is located in the district of Gua Musang, Kelantan. This research is carried out with the purpose of gaining the general geology information of the study area.

The elevation of the study area is not too high and still able to traverse via foot and cars. The streets are also well connected. But to get to Kuala Nerus area which is a plantation area, the access of cars is limited because of the hill landforms.

In addition, the study area is mostly covered with vegetation and some karst area and outcrop are usually located near or in the river and streams. Thrust traversing along streams and river is a must in order to find a potential recharge area.

The most usually identified karst feature is cave, so the exploration of cave is a must, thus the needs and necessary equipment for cave exploration is a must.

1.6 Significance of study

The research is important because it gives a clear and detail hydrological information of the study area via detail analysis of the mineralogy, lithology, stratigraphy, geological structure and geomorphology that's present in the study area. A detail surface geological mapping of the study area can provide a precise and detail geological information of the location.The study also can determine the possible location of a karst aquifer zone that would be important in future exploration and water management.

The geological study is simply an eye opener to the community and could be a reference to future decision maker to start exploiting groundwater in karst aquifer to satisfy the increasing water demand in Kelantan or even the whole nation.

1.7 Chapter's summary

As a summary, the research is a part of an initiative a finding a potential alternative water resource for the people of Gua Musang. Karst groundwater never been research before in Gua Musang and because of the large amount of limestone and karst feature, the possibility of karst aquifer is high and the study should be conducted.

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

This chapter will discuss about the past study that have a significant contribution on the research or the same types of research that would leads to an even wider and deeper knowledge and perspective upon the studies. This chapter is where the past study that's investigates both the study area and karst investigation are being summarize.

2.2 Geological review

2.2.1 Regional geology and tectonic setting

a) General background of Peninsular Malaysia

The Malaysians peninsular was a part of Eurasian Plate and Sundaland plate that is situated at the South-East Asian region (Hutchinson C. S., 1996). Peninsular Malaysia was divided into three north-south-trending zones that are known as the Western, Central, and Eastern belts. The classification of the three belts is based on different in stratigraphy, mineralisation, and structure.

b) General background of Gua Musang Formation

Gua Musang is the largest district In Kelantan .it is bordered by the state of Terengganu in the east, the state of Pahang in the south, the state of Perak in the west and the district of Kuala Krai and Jeli in the north.

The heart of Gua Musang, the lithology is mostly argillaceous unit especially the log-grad metamorphic rocks like slate, phyllite, marble that was the product of recrystallization of limestone, conglomerate and sandstone. Some part of the state additionally comprises of tuff that had a volcanic Inception Gua Musang is famous with limestone outcrop that an easily recognisable karst topography. This entire rock unit is known as Gua Musang Formation (Peng, 2009).

2.1.2 Structural Geology

The imbricate structure that shows a high angle faults contact with each other in the East highway can be divided into seven tectonic units (Tjia, 1996). One of the study conducted at the Bentong-Raub Suture Zone shows that it had been undergone prograsive-transpressive deformation (Setiawan, 2003).

Structurally tha states of Kelantan is devided in the west part by the olistrostorm while the East part devided via Lebir Fault Zone (Jatmika setiawan, 2010) The thiny bedded chert that overlies the massive shale that have been deformed via bedding that can be found along the East-West highway and Gua Musang Road. The chert shows isocline fold that had been refolded via the steep North-South reverse dextra fault (Shuib, 1994).

2.1.3 Stratigraphy

The Gua Musang formation that is located at south of Kelantan is believed to be of aged from the Middle Permian to Upper Triassic (Hutchinson a. T., 2009). It is also stated that the predominantly Permian sedimentary rock form extensively on the eastern side of Kelantan making it in the area of Gua Musang district (Department of minerals and geoscience of Kelantan, 2003).

One of the major parts of the research is the Karst area that is consist of limestone. The Gua Musang formation is estimated to be 650 m thick made out of crystalline limestone interbedded with thin bade of shale, tuff, chert nodules and subordinate and volcanic (Peng, 2009) .

The Gua Musang Formation is composed of about 900m thick mainly of limestone with interbedded of shale and volcaniclastic (H.Yin, 2000). the age of interbedded limestone with shale is believed to be Middle Permian , state the department of minerals and geoscience of Kelantan.

The most important geomorphology in Gua Musang Formation is the karst topography resulted by desolation of limestone (Yin, 1965).The carbonate rocks comprises several shallow marine agitated water facies including grainstone, packstone, wackestone and mudstone (Mohamed, 2007).

2.3 Research specification review

2.3.1 Karst Topography

Dissolution of soluble rocks and the routing of the water (from rain or snowmelt) underground via caves rather than at the surface in river channels are how karst landforms are created (Ford D. , 2009). surface water that moves in this landform can be transported into groundwater in the matter of minutes (Ford D. P., 2007). The main agent for landscape changes in karst terrains is water (White W. , 1988).But the process take a long time in order for the landscape to change.

One of the features of karst topography is sinkhole. It occur via the dissolution process that can lead to the formation of opening in the bedrock and with time, can extend to 100m or more in depth (Fleury, 2009). The gap will act as collector for insoluble surface material that was washed through the drain that leads to the formation of sinkhole (White et all, 1995).Sinkhole development can be influence by "any mechanism that increase the head differential between the artesian water in the limestone and the perched water in the surface sands (Beck, 1986) ". The size of sinkhole can be very big as for hundreds of meter in depth to small as less the a meter (Ford D. P., 2007).

Another feature that is commonly found in karst area is cave. The definition of cave is a natural opening in the earth that is large enough for human to enter (Palmer, 2007). Caves are commonly formed due to karst processes. Water drainage through caves will continue through the passage terminations, sometime to a spring outside (Ritter, 1995).

2.3.2 Karst Hydrogeology

In a true karst landscape, surface water is absent, all water is circulating through fissures underground (Sweeting, 1973).The area of Kuala Nerus is covered by vast of stream and drainage system. The largest system in the area is the Galas River. During dry season the small stream often dry out but as the wet season approach and rainfall heavily, the small river became full of water and became one of the sources of groundwater especially in karst aquifer. Conduits are a feature of karst aquifers that act as networks of pipes carrying water rapidly through the aquifer that makes them more diverse then other aquifers (White W. , 2005). At least 96% of the storage or volume of groundwater in all karst aquifers was in the matrix portion of the rock base on previous study's (Worthington et all, 2001). The lake in natural filtration as water washed down the aquifer through cracks (topsoil can act as filter, but it is not very effective) make the aquifer prone to pollution (Field, 2002). Thus a proper precaution steps need to be done in order to preserve the aquifer.

A standout amongst the most well-known strategies utilized as a part of karst hydrogeology examination is tracer technique. It is an intense method for such examinations, especially in karst zones. In hydrogeology, a tracer is any sort of substance in the water or property of the water that can be utilized to get data on the groundwater stream and transport of matter (Nico Goldscheider, 2007). There are many types of tracers reviewed by Käss (Käss, 1998). The "ideal conservative tracer" is a substance that is inert, is missing from however promptly dissolvable in water, simple to distinguish quantitatively, non-poisonous, undetectable, reasonable in price, and simple to handle (Käss, 1998). Figure 2.1 shows the list of the most important groundwater tracers.

Table 2.1: Properties of the most important groundwater tracers. The detection limits for fluorescent dyes represent an order of magnitude and are valid for clean waters and a modern spectral fluorimeter. The limits for salts strongly epend on the analytical method. The toxicological evaluation is based on Behrens et al. (2001).

	No.	Tracer	Detection limit (µ g/L)	Natural background	Toxicology	Analytical interference with	Other specific problems
Fluorescent dyes	1	Uranine	10^{-3}	Absent	Safe	2, 6	Strong sorption at low pH
	2	Eosin	10^{-2}	Absent	Safe	1, 4	Very sensitive to light
	3	Sulforhodamine B	10^{-2}	Absent	Ecotox. unsafe	4, 5	
	4	Amidorhodamine G	10^{-2}	Absent	Safe	2, 3, 5	
	5	Rhodamine WT	10^{-2}	Absent	Genotoxic	3, 4	
	6	Pyranine	10^{-2}	Absent	Safe	1, 2	Not reliable (degradation)
	7	Naphthionate	10^{-1}	Absent	Safe	8, DOC	
	8	Tinopal	10^{-1}	Absent	Safe	7, DOC	Strong sorption
Salts	9	Sodium	*Dependent*	High	Safe	–	
	10	Potassium	*on method:*	Moderate	Safe	–	
	11	Lithium	*0.1 µg/L*	Very low	Safe with restr.	–	
	12	Strontium	*to 1 mg/L*	Moderate	Safe with restr.	–	Strong sorption
	13	Chloride		High	Safe with restr.	–	
	14	Bromide		Low	Safe with restr.	–	
	15	Iodide		Very low	(Not evaluated)	–	Chemically unstable
Particles	16	Dyed spores	*Detection*	Absent	Safe	Natural particles	Not quantitative
	17	Microspheres	*of single*	Absent	Safe	Natural particles	Time-consuming analysis
	18	Specific bacteria	*particles*	Absent	(Not evaluated)	(Other bacteria)	Time-consuming analysis
	19	Bacteriophages		Absent	(Not evaluated)	–	Time-consuming analysis

Fluorescent dyes are the most common and broadly utilized tracers in light of the fact that it is sensibly conservative, harmless, cheap and exceedingly recognizable (Nico Goldscheider, 2007). Two sorts of manufactured water tracers are utilized: water-solvent substances and particles. Fluorescent colors and salts are the most broadly utilized water-dissolvable tracers. Radioactive tracers have to a great degree of low background concentrations and identification limits, however it have high analytical cost, requesting security necessities and stringent lawful confinements (Behrens H. , 1998). Numerous natural and manufactured substances that contain aromatic functional groups(carbon ring structures) are known to be fluorescent; they retain light at specific wavelengths (retention, excitation or elimination) and re-emanate light at higher wavelengths (fluorescence or emission) (Nico Goldscheider, 2007). Most fluorescent dyes are detectible instrumentally at fixations up to 1000 circumstances lower than the edge for visual discovery, permitting quantitative detection at sub noticeable levels (Nico Goldscheider, 2007).

A number of salts have also been used as tracers (Käss, 1998) Salts break up in water into anions and cations, in this manner expanding the particular electrical conductivity (EC). Most anions are moderate tracers since they demonstrate low sorption properties and cations are inclined to ion exchange (receptive tracers)(Nico Goldscheider, 2007). Most salts have higher detection limit, foundation focuses together with fluctuation in common waters than fluorescent dyes and Salts demonstrate minimal systematic impedance with fluorescent dyes and can be utilized as a part of consolidated tracer tests (Nico Goldscheider, 2007).

Tracer tests can give great data on groundwater development and contaminant transport, however they can take numerous months to execute, and can come up short if inadequately execute (Nico Goldscheider, 2007). The initial steps are Preliminary examinations and lawful viewpoints. Legitimate directions for groundwater following tests differ with nation and purview (Nico Goldscheider, 2007) . In a country like Switzerland, it is sufficient to inform the authorities and give the result to the national database (Schudel, 2003). Confirmation of natural and human wellbeing is frequently of vital significance in getting authorization for a tracer test (Nico Goldscheider, 2007).

Next is the determination of the tracer sort and infusion amount. Generally, tracers ought to be "toxicologically protected" or "safe with limitations" (Behrens et al. 2001). Determination of the injection points and injection methods is the following stapes. Fruitful injection and translation of such tests requires information of the hydrology of the well, e.g. profundity to water table, position of the well screen(s), hydrostratigraphy, and hydraulic response of the well (Flynn et al. 2005). The more ensitivity of tracer analysis, the more prominent the endeavors that are required to avoid autocontamination (Smart, 2002) in which the water tests turn out to be incidentally contaminated with the infused tracer. Figure 2.2 shows the ways of injecting tracers.

Figure 2.2: Left: Injection of of uranine from a plastic container into a karst shaft. Right: Injection of naphthionate, dissolved in a tank, into an observation well in the confined karst aquifer of a mineral springs (Nico Goldscheider, 2007).

Finally is Selection of the testing area and examining strategies. The examining technique relies on upon the targets of the tracer test, the hydrogeological environment and the assets accessible. Inspecting locales (where tracer is foreseen) and control area (where it is not, e.g. upstream of tracer infusion) should be recognized and their fluorescence design built up. Inspecting site is utilized prior to injection to establish spatial background (Nico Goldscheider, 2007).Figure 2.3 shows tracers' selection base on objectives of trace use.

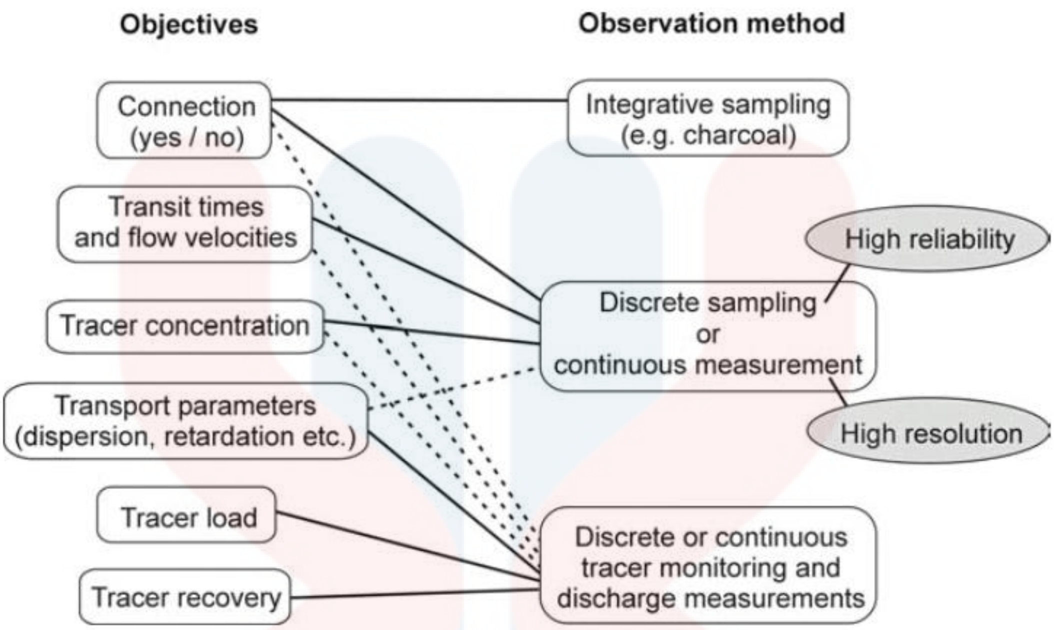

Figure 2.3: The selection of appropriate sampling methods relies on upon the objectives of the tracer test. Integrative sampling is adequate to demonstrate underground associations while the computation of the recovery rate requires discrete examining or consistent estimation, and simultaneous discharge estimations. (Nico Goldscheider, 2007)

Tracer method will also help in determining the hydrogeological perimeter such as discharge via the data that was collected during the field study. From these data, discharge can be calculated using the relationship:

$$Q = \frac{M}{\int_0^t C - C_b \mathrm{d}t} = \frac{V_o C_o}{\int_0^t C - C_b \mathrm{d}t} \approx \frac{V_o C_o}{\sum_{i=1}^{n} (C - C_b) \Delta t}$$

where Q is discharge, M is injected tracer quantity, Vo and Co are the volume and concentration of the injection tracer slug, respectively, Cb is the background tracer concentration in the stream before injection, C is the observed tracer concentration, and t is time.

CHAPTER 3

MATERIALS AND MATHODS

3.1) Introduction

The research involves the investigation of the study area general geology that composes of the gathering of data and analysis of the area's lithology, geological structure and geomorphology. All of the data can be obtained by conducting geological mapping and its analysis. Analysis of geological map also can give significant information regarding the zonation of karst aquifer.

Once the production of geological map is completed, the research can continue with the geological map data analysis. The result of the analysis will show the overall geological future of the study area and the potential aquifer zone.

The use of other method like geomorphological analysis helps in karst aquifer investigation. This will show the characteristic and future of the aquifer. From the data, we can analyse and compare different types of aquifer in the area.

While conducting field activities, sample such as rocks need to be taken for lab study. Lab investigation can give more accurate result and will help in supporting the field data interpretation. The flow of the research can be illustrated via research flow chart.

3.1.1 Research flow chart

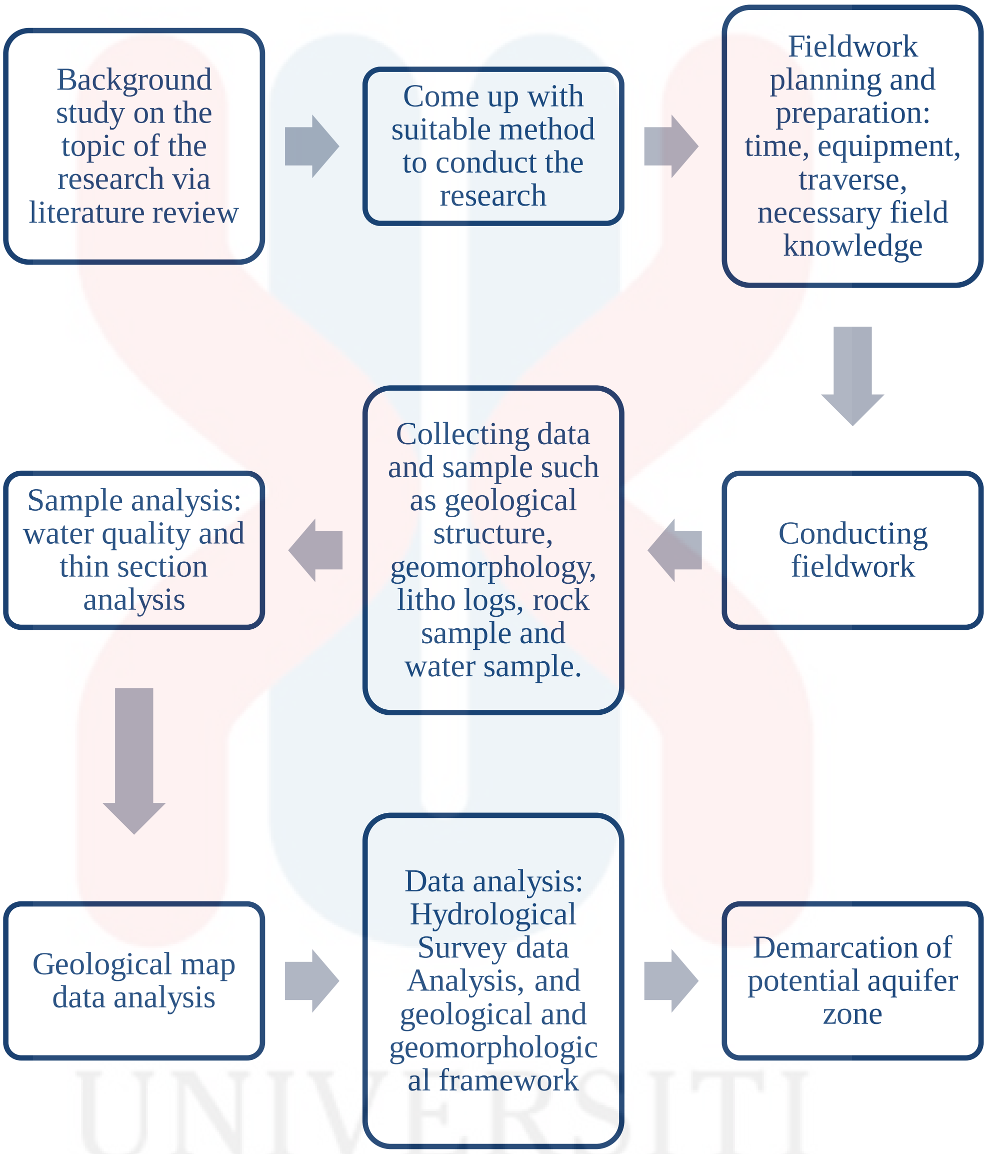

Figure 3.1: Research flow chart

3.2 Preliminary research

Preliminary researches are the survey that is conducted before the actual and detail research are carried out. This involve in the collecting and analysing of useful and beneficial information about the research that can give a significant boost for the actual field work, laboratory activities and data analysis.

It is also important because it can give the researcher a batter understanding regarding the research topic and method to carry out the investigation. A good understanding on the topic of the research is important because it helps the researcher to be alert and stays on topic throughout the research activities.

Producing a base map of the study area via the use of GIS application software ARC GIS 10.2 really helps in understanding the study area because it shows the topography of the area, the highest elevation, the drainage pattern, and liniment. All of the characteristic will helps in understanding the geology of the area. Other than that, base map also showed the roads and streets or even railways that could help us to plane our traverse for the actual field works.

The aerial photo taken via Google earth program was also useful to provide a 2-dimensional plan view from the top of the research sites that will gives information such as roads and land use.

Preliminary research also can be done via literature such as books, journal and other literature resources that gives useful information about the research.

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3.3 Materials and method

3.3.1 Materials

Basic materials needed for research:

1. Base map of study area
2. Topological map of study area.

Equipment use on field:

1. Hammer
2. Compass
3. Hand Lenses
4. Note book
5. Global Positioning System Device (GPS)
6. Hydrochloric acid
7. Measuring tape
8. Sample bag

3.3.2 Methods

a) General Geological mapping

The base map or topographic map helps to predetermine the type of rocks could be present in the study area and also help to give a view of the geomorphology of the study area via contour structure that was present in the map. The general field mapping is to be conducted on a 25 square kilometre study area. During field work, the pinpoint or coordinate of the outcrops of various lithology and its own structure can be marked using Global Potential System (GPS) device. The rock sample can be taken for further study.

b) The geological and geomorphological framework

Introduction

The geological and geomorphological framework involves the study and detail analysis of the study area's mineralogy, lithology, stratigraphy, geological structure and geomorphology. All of the above are important to understand the hydrogeology of Karst topography.

Mineralogy

The study of mineralogy can determine the karstifiability (chemical solubility) of the landform. As the lithology karstifibility is determine, it is possible to interpret the hydrogeological properties of the area.

Lithology

Carbonate rock's lithology haves its effect in its Porosity, Permeability, and Karstifiability. The difference in lithology can result in different in porosity and permeability such as consolidated and unconsolidated sedimentary rocks.

Stratigraphy

The study on stratigraphy includes analysis of the paleo-envirenment and analysis of the different facies of the study area. The degree of groundwater also can influence by stratification, it is call Stratigraphic flow control.

Geological structure

A detail analysis of geological structure such as Fold, Faults, join, bedding planes, and fracture helps to understand the porosity of lithology and to pinpoint the possible location of the aquifer because all of the structure is the cause of secondary porosity.

Geomorphology

Other than geological structure, karst feature that is due to carbonate dissolution such as cave and sinkhole helps to determine the possible location of a karst aquifer.

c) Hydrological Survey and Analysis

Introduction

The application of this method is more focus on the water itself, how to determine its location and where it's flowing to. The analysis can be done via potential recharge area survey and monitoring water on caves.

Potential Recharge area survey

Conducting a survey or analysis on potential recharge area can gives some information about the karst hydrogeological system. It also help on determining the ways of recharge of the aquifer such as autogenic recharge, allogenic input , single point recharge such as sinkhole and sinking streams or all of those recharges can occur in the study area.

Monitoring Water in Caves

Cave gives us a view of the Karst hydrological system. Caves exploration will help in understanding the conduit network geometry that is essential to understand the groundwater flow (Nico Goldscheider, 2007). The method is focus on determining the groundwater flow thus can lead to locating the potential Karst aquifer.

3.4 Field Study

The field study involves the gathering of date on sites. It's more focus on analysing the geological and geomorphological feature of the study area. It also includes the identifying and analysing the sedimentary and stratigraphy of the location if its structure is present and available.

The field study includes most of the method stated on the material and method part. The methods are:

- General Geological mapping
- The geological and geomorphological framework
- Hydrological Survey and Analysis

3.5 Laboratory Investigation

The research didn't involve a lot of laboratory activities, the only laboratory activates are the thin section analysis to identify the type of rocks via petrography.

3.6 Data analysis and interpretation

a) Geological structure

the geological structure data such as fault, fold , joint and fracture can be obtained from the reading of deep and strike that latter can be analyse via constructing rose diagram to gain information of the direction of force that created the structure. From here, we can interpret the geological history of the study area.

b) Mineralogy

Mineralogy data that is obtained via rocks thin section analysis will give a clear result on the name of the rocks and minerals present on the lithology. It is important because it can classified the type of limestone in the potential aquifer, this will helps in the interpretation and the comparison between different aquifer zones.

c) Geomorphology

Geomorphology data, especially the one that's involve karst future such as cave, sinking stream and sinkhole give good indication of a possible aquifer .analysis of a geomorphological feature such a sinkhole can gives an interpretation of the joint and fracture pattern of a karstic terrain, it's also a positive sign that shows that there are water that actually flowing underground.

d) Hydrogeology

Hydrogeology data such as the size of the open conduit or cave, the velocity of water flow and the pattern of water flow, all can lead to a better understanding of the aquifer. From that we can interpreted which aquifer zone are batter the other.

3.7 Report writing

The report writing process will be done after the data collection and analysis via basic geological mapping, geomorphological framework of karst terrain, hydrogeological analysis and lab analysis. The report writing is based on the parameters of the study such as the type of geological structure, the type of geomorphology, groundwater pattern, rock type, weathering process and type of porosity and permeability.

The analysing process compose of identifying the location that have high porosity and permeability that will be influenced by the location geological structure and morphology such as fracture , joint and several karst geomorphology like caves and sinkhole. The permeability of an area also influenced by the mineralogy of the area. If the percentage of calcite is high, it is more likely for it to be dissolved and influence the rate of tertiary permeability. Rate of recharge and discharge also influence the aquifer zone.

The data obtained from the method above were then analysed. Moreover, the classification of carbonate rock and its hydrogeological framework will be analysed and will be demarked on the geological map.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This chapter will be covering most of the geological aspect such as geomorphology, structural geology and even geological history of the study area. This chapter is a compete representation of all the landform and structure in the study area. In this chapter also, we would discussed about the geological history of the study area base on the analysis and interpretation of the geomorphology, geological structure and even sedimentology data.

Geomorphology is a study of landform and nature that makes up for the landscape of the whole area. It can be compose of mountain, valley, lake, rifts and rivers. Geomorphology was concerned largely with erosion surface, their age, origin, and the process that formed all the landscape.

Analysis of structural geology such as lineament, joint, crack and many more geological structure that was found in the field would giving an interpretation of the tectonic activities that had occur in the study area. Understanding the nature and orientation of the tectonic activities can lead to the batter understanding of the study area's geological history and origin.

Petrography analysis also was conducted to determine the lithology of the study area. It is also important in determining lithological boundary in the study area. Petrography also shows the difference within the same lithology in terms of different percentage of primary minerals and presence of secondary minerals that was influenced by weathering processes.

Geological mapping is the key in understanding the general geology and to do so a smart and effective mapping plan is needed. Thus the traverse has to be precise and manage to cover most part of the study area. The traverse cover most part of the study area and during traversing, we manages to take sufficient data such as structural data, geomorphology data and stratigraphy data. Figure 4.1.2 show the travestying during conducting geological mapping.

Sampling such as rock sampling also can be done during geological mapping. Even though we managed to cover most part of the study area, there are some areas that are inaccessible due to safety reason. Figure shows the location of the inaccessible area. The inaccessible area consists of thick forest with steep elevation and a possible threat by wild animals. Figure 4.1.1 shows the condition of the area.

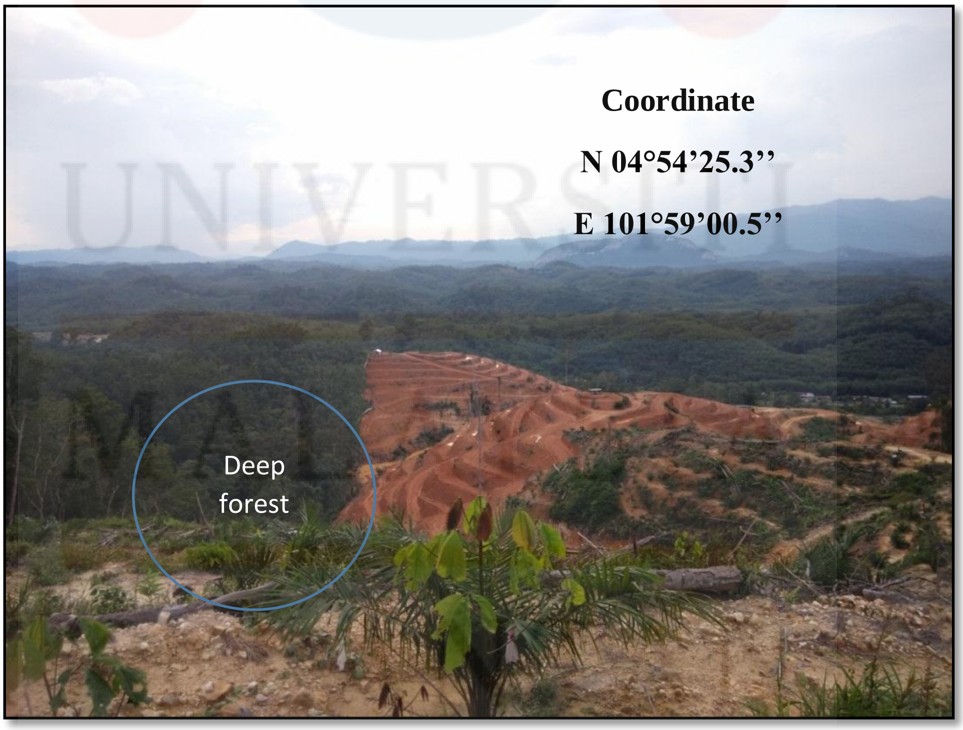


Figure 4.1.1: Inaccessible area

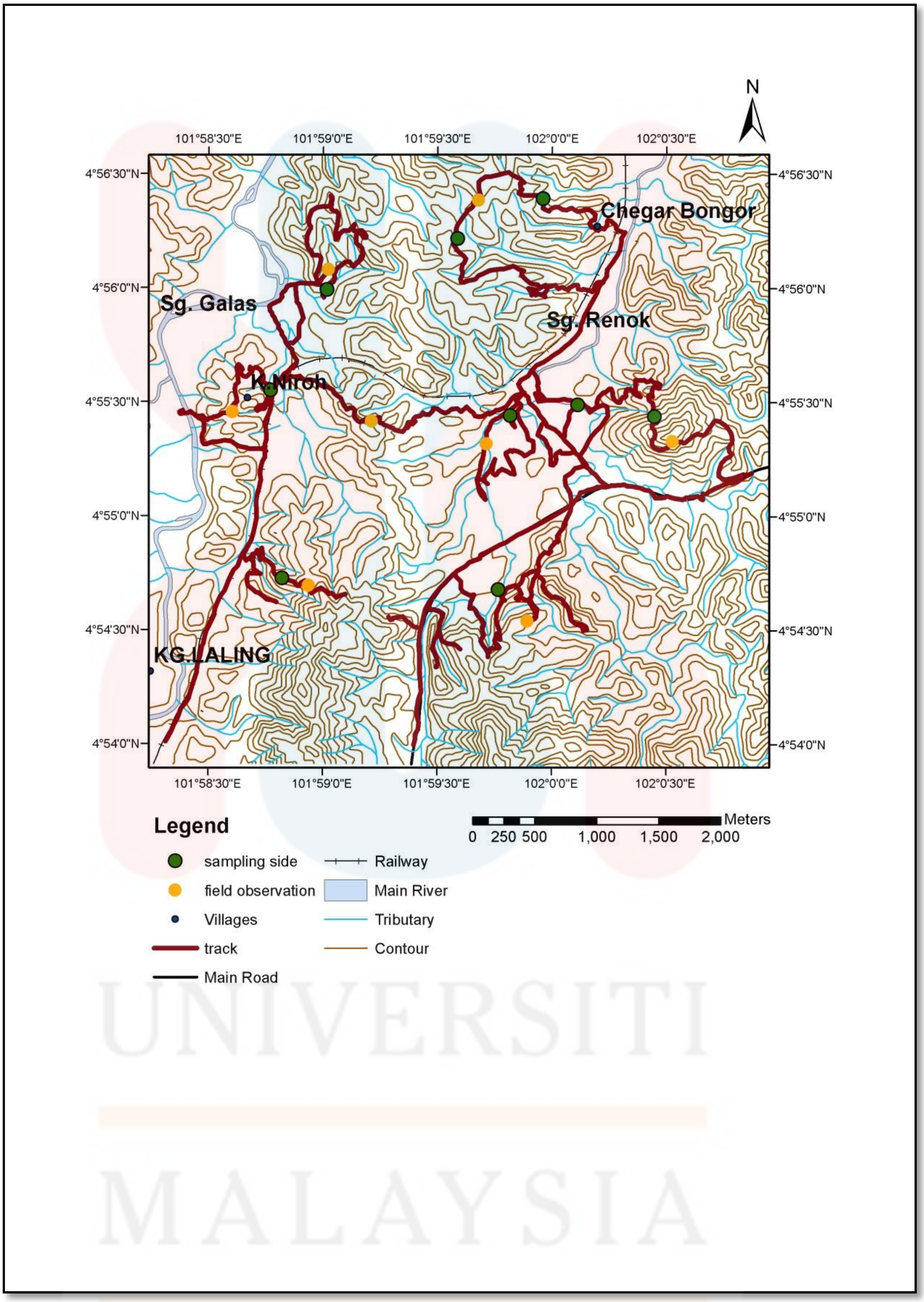


Figure 4.1.2: Traverse map of study area

4.2 Geomorphology

Geomorphology is the study of landform in term of its geometry and related to the process of formation and development of landscape in each area. It study various part of land surface such as mountain, valley, rifts, scarps, lake basin, river channel profiles and pattern that make up the landscape.

Geomorphology process can be influenced by geological structure such as faults, fold, joint and fracture. Topography, drainage system, weathering and erosion also play a role in geomorphology process.

The study area consist of many landform by which are contributed via the presence of many different lithology and compact drainage system that may have contributed to the weathering and erosion process that plays an important role in changing and altering the landform throughout time and creating a whole new landscape.

One of the mane geomorphology that can be studied in the area is karst geomorphology. This is due to the presence of carbonate rocks that are exposed to water and carbon dioxide (carbonic acid) which created many karst future such as cave, sinkhole and etc.

The presence of joint and fracture via tectonic activities may give an added boost in the dissolving process and this will create many enlarged joint and fracture known as conduit and later created caves. Figure 4.2.1 shows the geomorphological map.

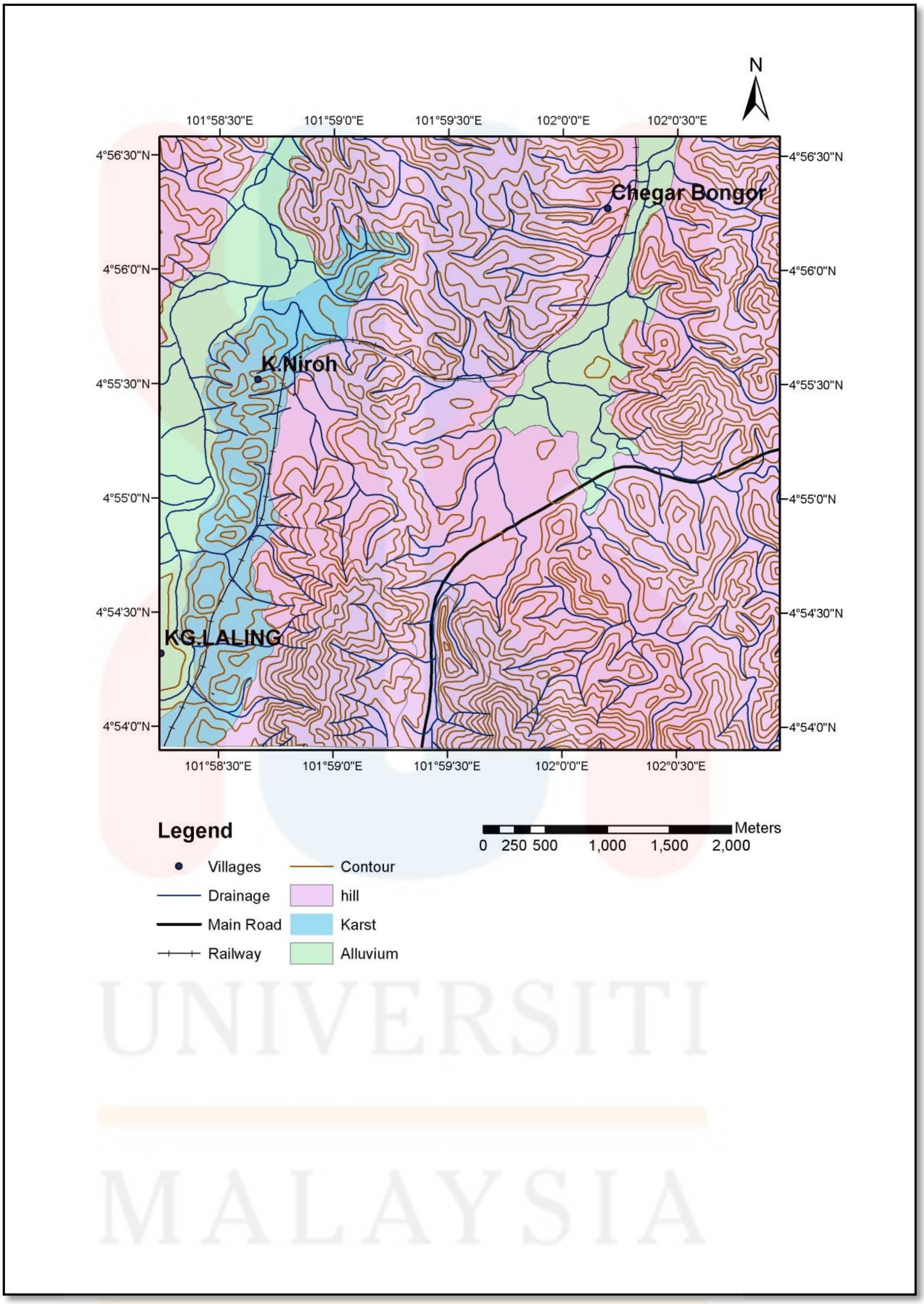


Figure 4.2.1: Geomorphological map of study area

4.2.1 Topography

Topography can be referred to the elevation and relief of earth surface and mostly used to describe the earth surface. It includes a variety of features and landform. Generally, topographic features of Peninsular Malaysia including the study area can be divided into five main category that are low lying (<15m from sea level), rolling (16-30), undulating (31-75), hilly (76-300), and mountainous (>300).

The study area consisted of very wavy surface of land. The area is much undulated with uneven change in elevation pattern of contour. From the study area, the lowest elevation that was detected via GPS during traverse is around 60 meters and the highest elevation that was detected was 290 mitres from sea level. The lowest elevation can be detected around the alluvium area that's located in the middle part of the study area and the highest parts are the contour in the south west part of the study area.

There are no abrupt changes in elevation in the study area, the contour change slightly by 20 meters to 40 meters in height. This type of contour can be found in most part of the study area.

The topography of the area can be influenced by the lithology of the area. For example , the hard and strong volcanic tuff that makes up the hill area in the south west part of the study area makes up the highest elevation in the area compare to the less strong and low resistivity to weathering and erosion lithology such as slate and limestone that makes up of much lower elevation topography. This shows that the resistivity of a lithology can influence the topography of an area. Figure 4.2.2 shows the 3D map.

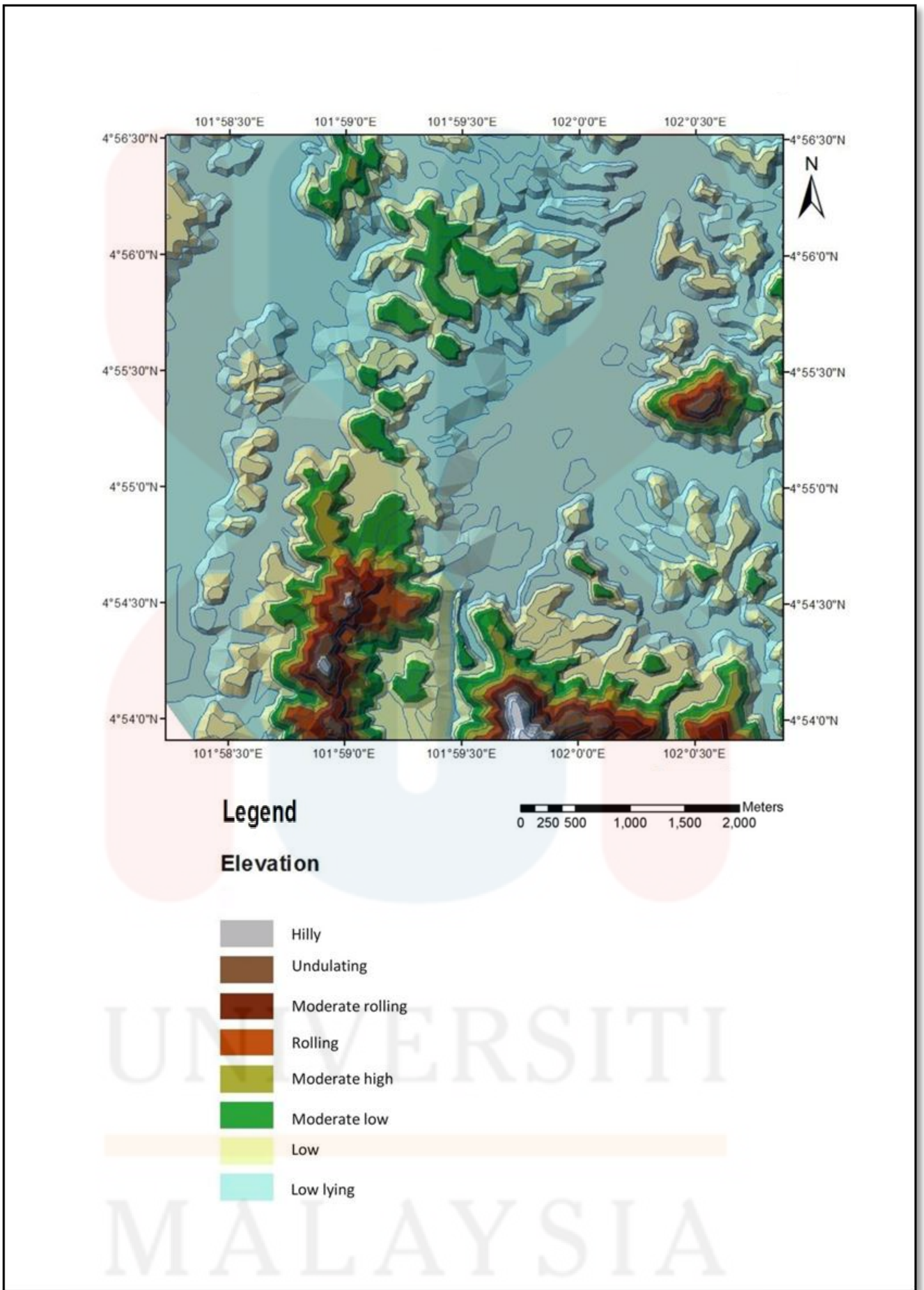


Figure 4.2.2: 3D map of study area

Figure 4.2.3: Geomorphology in high elevation area

Figure 4.2.3 shows the panorama from a high elevation located in the study area. From hear we can see the presence of a cone shaped mountain with high elevation and steep slop. Its morphology may be influenced by its lithology and drainage pattern that contributes to weathering process.

4.2.2 Drainage pattern

The peninsular Malaysia is characterized by dense network of stream and rivers that can be attributed to its prolonged sub-aerial exposure as well as the present of humid tropical climate. There is no single large river that dominates the overall drainage pattern that is consisting of several drainage basins. Most of the rivers serve as states boundaries, for example, the Kelantan River as 11,922 km comprises the entire state of Kelantan.

There are some factor that control the pattern of drainage, some of them are type of rock, distribution of rocks and location of rock at land surface. The resistivity of rocks and weakness of planes in rocks such as bedding plane, fault, joint, fracture can influence the shape of drainage pattern. Other factor, for example, folding, precipitation, and disintegration likewise helped in the arrangement and forming of drainage pattern. The sort of drainage that was controlled by the slop or structure was dendritic, parallel, trellis, rectangular and reticulate (Zhang, 2012).

There are two main rivers in the study area which is Galas River and Renok River, most of the drainage system in the study area is form the hill area. Some of the drainage had undergone changes due to human activities such as construction of bridges. The water flow from high elevation to lower elevation until will arrived at the main river either the Galas River or Renok River. Then both river flows to the north part of the study area. All of the drainage patern can be seen in figure 4.2.4.

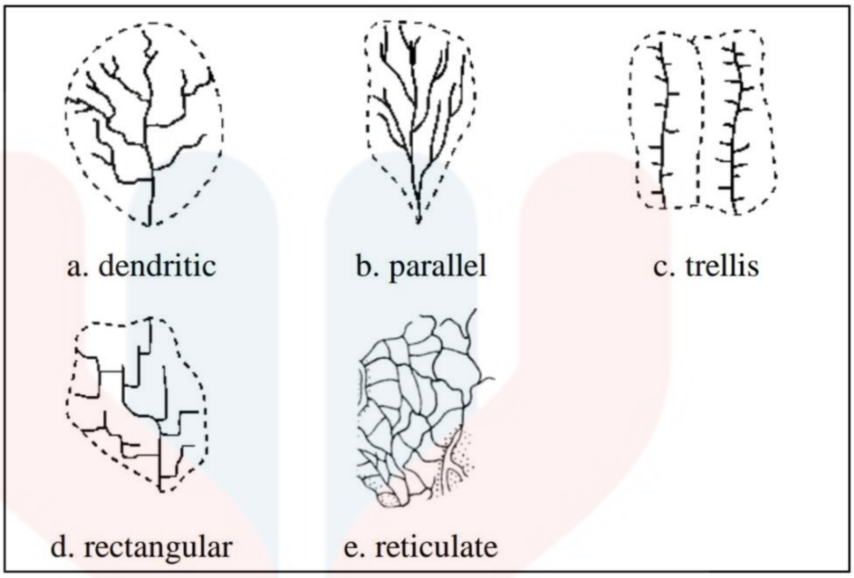


Figure 4.2.4: Drainage network patterns (Zhang, 2012)

Dendritic pattern occurs mostly in horizontal and uniformly resistant and unconsolidated sediment. It can be associated with pinnate drainage, which associated with steep slopes special dendritic pattern where tributaries are more or less parallel and joining the main river at acute angle. This dendritic drainage pattern was mostly found in region of very slight slope that had a little or no influence from structural factor and most commonly at mud flats region (Twindele, 2004) Figure 4.2.5 shows drainage pattern map where's A is radial drainage, B is sub-parallel drainage and C is dendritic drainage).

Another drainage pattern is the radial drainage pattern. This type of drainage pattern are for river that rising by the crest of a rise that guided by slop and follow to all quarters of the slop (Twidale, 2004) This type of pattern are typical for volcano , isolated hills and elevated domes. And in the study area, the morphology is isolated hills. There are also sub parallel pattern. This pattern is due to lack of structural interference because drainage flow with the gradient.

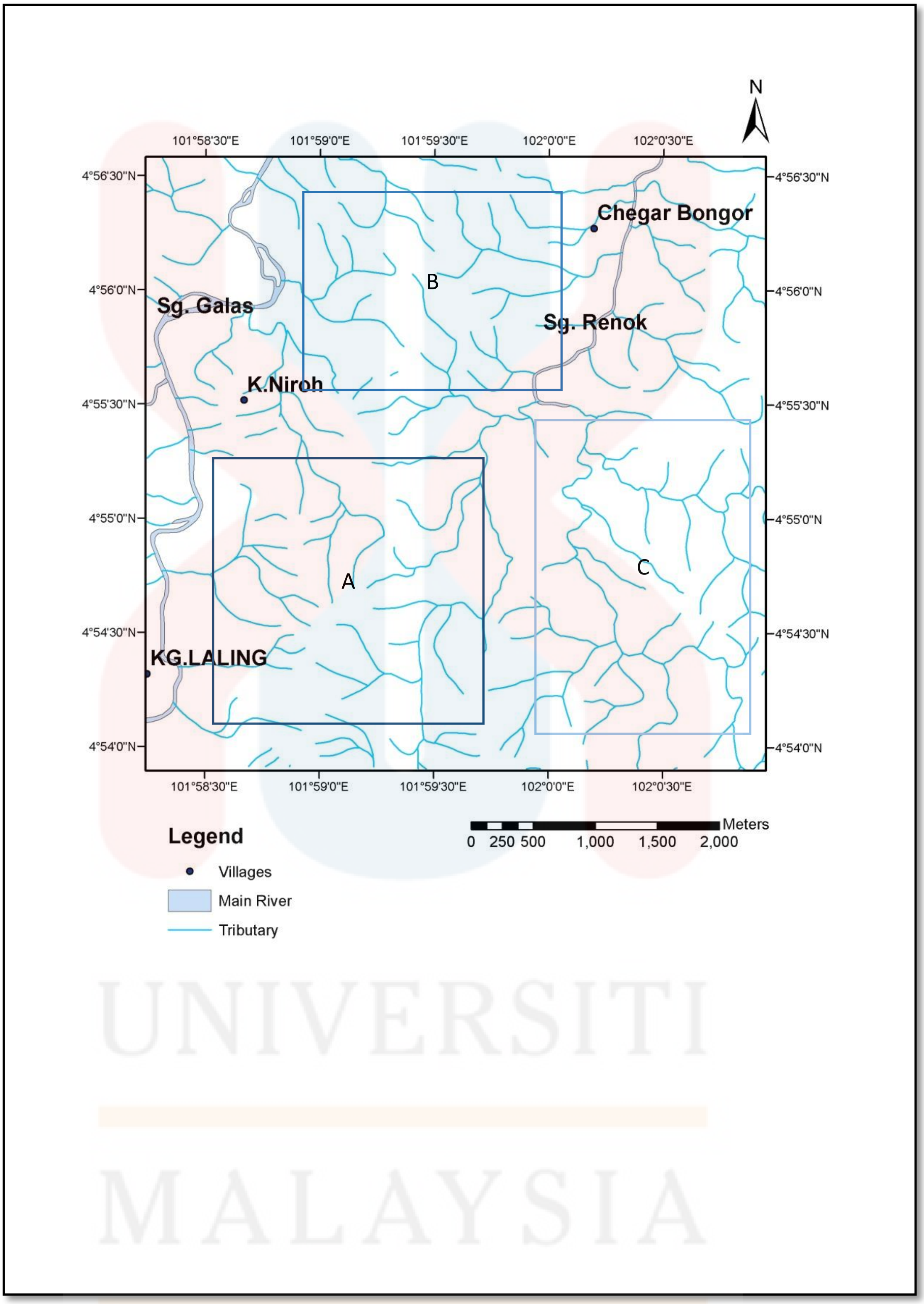


Figure 4.2.5: Drainage map of study area, A(Radial drainage), B(Sub-parallel drainage), C(Dendritic drainage)

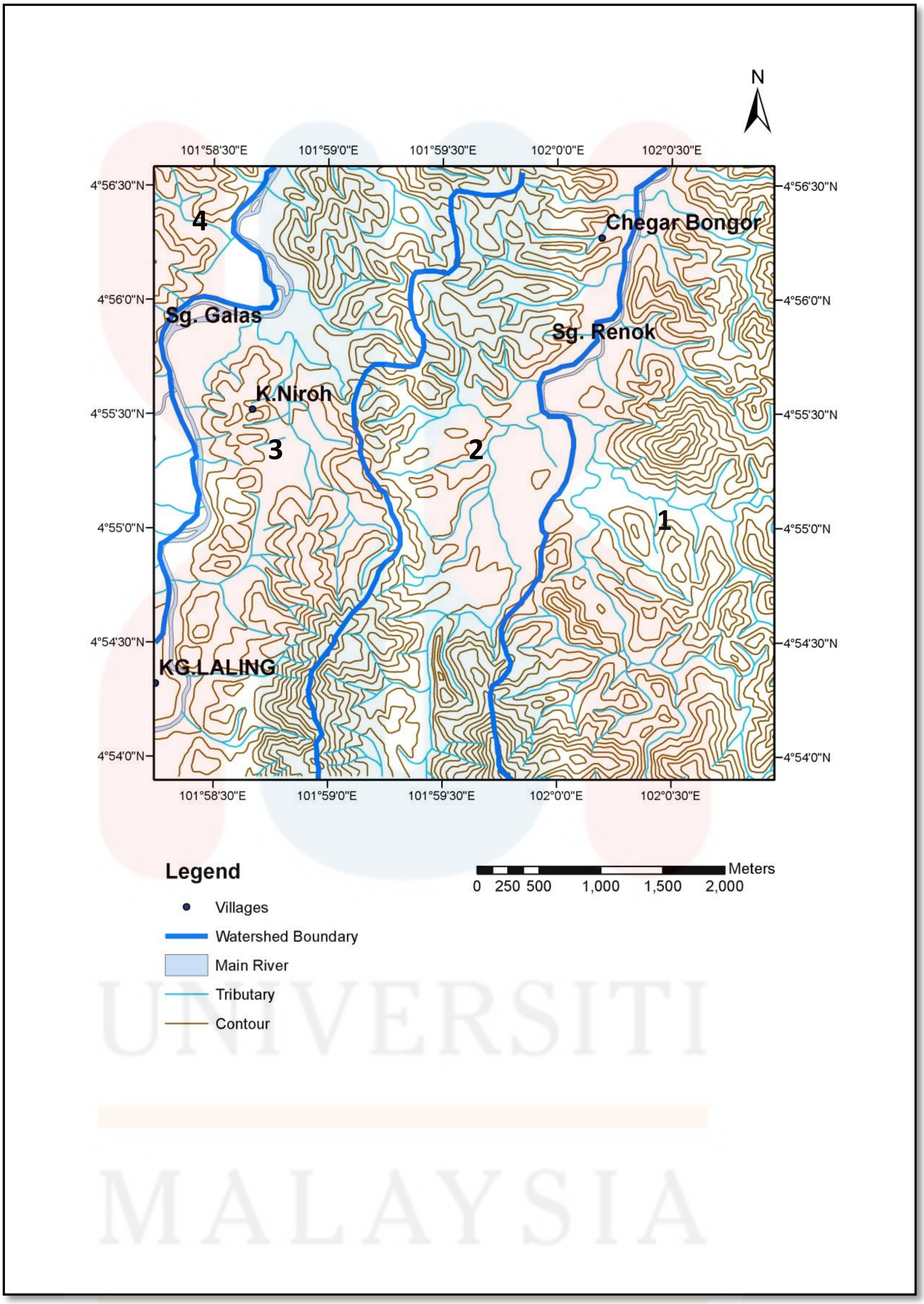


Figure 4.2.6: Watershed map of study area

Figure 4.2.6 shows the watershed of the study area. And from it we know that there are 4 different boundaries in which the water moves. The First (1) is from the eastern part of the area flowing under one direction to Sg.Renok. Next (2) is from the middle part of the area moving to the east also to Sg.Renok. Third (3) is from the middle part of the area moving to the west to the Sg.Galas. Lastly (4) is the movement from the contour in the farther western part moving to the east to Sg.Galas.

4.2.3 Weathering

Weathering is the process where rocks, soil and minerals are broken down through contact with the Earth's atmosphere, waters and biological organisms. Weathering occurs on the sites or also known as in situ weathering. It occur with little or no movement, and thus making it different with erosion, that involves the movement of rocks and minerals by agents such as water, ice, snow, wind, waves and gravity.

To simplify, weathering process is a degradational process that was influenced by weathering agents that is water, wind, gravity, and glaciers. Etch weathering agent contribute to the degradation of rocks in different ways thus making weathering process to be differentiated through three types of weathering process. The three processes are physical weathering, chemical weathering and biological weathering.

Most of the processes that make up the geomorphology of Malaysia are influenced by weathering process. The ages of most of the outcrop hear in Malaysia are really old (The Machinchang Formation is the oldest rock formation in Malaysia are formed in Late Cambrian age). So the rocks in Malaysia are bound to be heavily weathered and thus influence the formation of many geological landforms such as karst morphology, water fall, and may more.

Weathering process in Malaysia are influence by the presence of weathering agent and base on the climate of our country it since that water play the major weathering agent because of the tropical weather and high precipitation rate in Malaysia, followed by wave, wind and gravity. And base on our climate it seems that ice can't be the weathering agent.

In the study area, physical weathering occurs as the fragmented and disintegration of rocks into smaller pieces without changing the rocks mineral composition. The examples are a granular disintegration, exfoliation, and joint block separation.

Chemical weathering that occurs in the study area is caused by water, temperature, oxygen, and hydrogen. It also causes dissolution of grain within stone producing potholes, cavern and karst. This process generally occurs in the soil where water and minerals are in contact. The agent for this type of weathering is water, oxygen and carbon dioxides. The other example of chemical weathering is oxidation and carbonation. This type of weathering is very common in the limestone area. This type of weathering contributes to the formation of karst geomorphology in the study area.

In addition, biological weathering is another type of weathering that causes by the presence of vegetation including root wedging that form on rock crack and fracture.

Figure 4.2.7: Chemical Weathering in study area.

Figure 4.2.8: Physical Weathering in study area.

Figure 4.2.9: Biological Weathering in study area.

Figure 4.2.7 shows the effect of chemical weathering process. Chemical weathering in the figure alter the minerals and produce secondary minerals (change in colour). Figure 4.2.8 shows the effect of physical weathering process.

Physical weathering in the figure is due to water activities. In this case the result is a pothole. Figure 4.2.9 shows the effect of biological weathering process. Biological weathering in the figure is due to biological activities such as plat root of animal borehole. Plant root can alter the rocks in terms of its physical and chemistry.

4.2.4 Erosion

Erosion is the natural process which involves the wearing away and removal of land surface by the action of transporting medium or its entrained debris. The agent of transportation can be water, wind or gravity. In the wet area such as

Malaysia, there are two type of erosion process that is by flowing water and ocean current.

From the observation on the study area, there are two types of erosion which is sheet erosion and rill erosion. Sheet erosion is the removal of the surface layers of soil by the wind and water. It can be found in the plantation area around Kuala Nirus where the vegetation is removed by human for re-planting of vegetation. This activities exposed surface of rocks for erosion by the action of wind and water. Another type of erosion is the rill erosion. Rill erosion is a sets of small narrow channels which are less than 0.5 metres deep that formed by the concentration of surface runoff or the formation of small rivulets running down slope. Figure 4.2.10 shows the rill erosion and figure 4.2.11 shows the sheet erosion process in the study area.

Figure 4.2.10: Rill erosion

Figure 4.2.11: Sheet erosion

4.2.5 Karst geomorphology.

Karst is the term used to describe a special style of landscape containing caves and extensive underground water systems that is developed on especially soluble rocks such as limestone, marble, and gypsum. Karst landscapes are characterized by fluted and pitted rock surfaces, shafts, sinkholes, sinking streams, springs, subsurface drainage systems, and caves. The unique features and three-dimensional nature of karst landscapes are the result of a complex interplay between geology, climate, topography, hydrology, and biological factors over long time scales.

Limestone purity (%CaCO2) is one of the most important controls on karst development, the purer the limestone, the higher its potential for karst development. Karst development in carbonate rocks requires a calcium carbonate ($CaCO_3$) content of 70% or greater (Ford D. P., 2007) . Karst systems are distinct from non-karst systems because of the processes of karst dissolution, the permeability of the solutionally developed landscape surface, the presence of a well-developed and open subsurface, fewer surface streams, and an overall calcium-rich environment (White, Culver, Herman, Kane, & Mylroie, 1995).

Here are some of the surface karst features that can be found in the study area. The first feature is sinkhole. Sinkholes are circular or enclosed depressions of various sizes. Sinkholes can be broad, shallow, and barely noticeable to tens or hundreds of feet in diameter. Depths of sinkholes can range from a few feet to several hundreds of feet. There are two type of sinkhole that can observed in the study area that is solution sinkholes and collapse sinkholes.

Solution sinkholes develop when the rock is exposed at the surface or very close to the surface. Water drains downhill and enters the rock where the water can easily enter the subsurface and begins to enlarge vertical pathways. Over time, soil slowly drains into the enlarged openings in the underlying limestone bedrock. Eventually, these sinkholes provide a direct connection to the underlying groundwater-flow system. This type of sinkhole is usually found near stream and alluvium area.

Collapse sinkholes are form from the collapse of flooded underlying caves. Collapse sinkhole can be found in the study area but only in a very small scale.it is located in a plantation area with a high joint and fracture structure. Figure 4.2.14 shows a Collapse sinkhole.

Next feature is sinking streams. Water is lost or sinks through the stream bed or along the stream bank into the subsurface through dissolved openings in the underlying limestone and are called sinking, losing, or disappearing streams. This type of landform also occurs in the plantation area, this streams act as recharge area for the possible karst aquifer zone in the area. Figure 4.2.12 shows a disappearing stream.

The last karst morphology that can be found in the study area is Karst springs. The location where groundwater appears at the surface is called a spring. This landform represents the aquifer zone discharge. This feature also located in the plantation area. Figure 4.2.13 shows a karst spring.

Coordinate

N 04°56'12.0''

E 101°59'02.5''

Figure 4.2.12: Disappearing stream

Figure 4.2.13: Karst spring

Figure 4.2.14: Collapse sinkhole

4.3 Stratigraphy

4.3.1 Lithostratigraphy

Lithostratigraphy focus on the study of rocks existed in the study area and relates it with its age. This part of analysis was done via geological mapping and preliminary research that is by the help of literature review. In this part, we also manage to understand more on the ages and depositional environment of the rocks. It is very important to understand the lithology of the study area and identifying the lithological boundary in order to create a detail geological map.

The area around Kuala Nerus, Gua Musang consists of many lithology. The lithology of the area consists of limestone, clastic sedimentary rocks, metamorphic rocks, and volcanic rocks. In this part, we have identified and interpreted etch lithology from the field data to petrographic analysis.

a) Limestone

Limestone can be found on the Western part of the study area, from Kampong Laling all the way to Kuala Nerus area. The outcrop is musty consist of small karst feature such as karst stream and karst pavement. The areas are not consisting of large and towering karst hill so finding the outcrop and determining lithological boundary are very difficult.

Limestone can also be found in the alluvial part of the area. Limestone can be found in the alluvial part in the eastern part of the study area. This outcrop consist various karst morphology such as sinkhole and karst stream due to its location in an alluvial plane. Figure 4.3.2 shows the limestone's hand sample.

The weathering processes are moderate and most of the area consists of soil and no other lithology can be found near the limestone that is exposed on the drainage system. The weathering process in this lithology is consisting of physical and chemical weathering via water activities. Limestone is prone to be dissolved by water. Biological weathering also occurs and throughout time can lead to disaster such as sinkhole to occur.

The grain size of the limestone is very fine and in some places is very dark in colour. The limestone in the alluvial plane are darker in colour, this may be influenced by the presence of organic materials such as organic carbon. This can be confusing but acid test shows that the rocks are a limestone. The limestone in the western part that is in Kuala Nerus is lighter in colour. Figure 4.3.3 shows the limestone thin section.

Base on the petrographic investigation, it is identified that the limestone in the study area are classified as grainstone due to its lack of mud and is grain supported. Figure 4.3.1 shows the limestone outcrop in study area.

Figure 4.3.1: Limestone outcrop

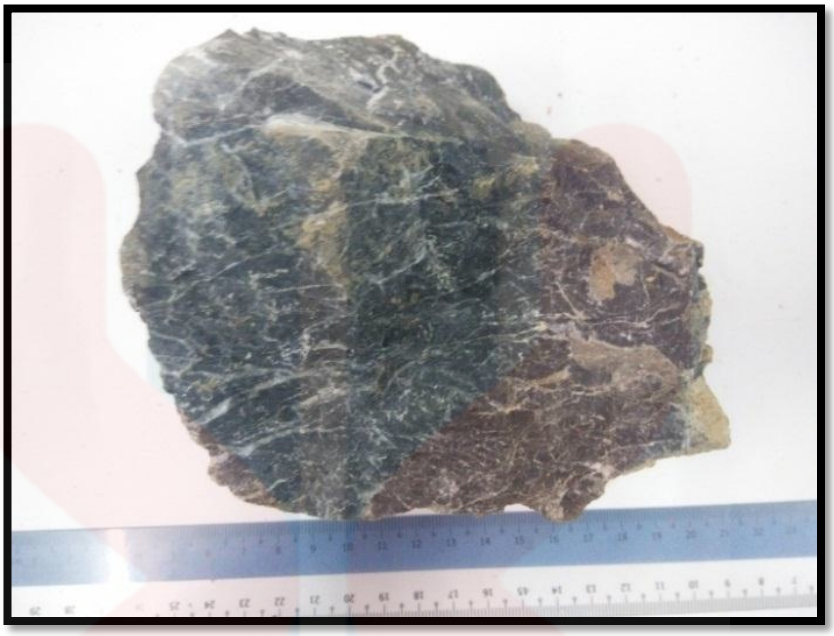


Figure 4.3.2: Limestone hand sample

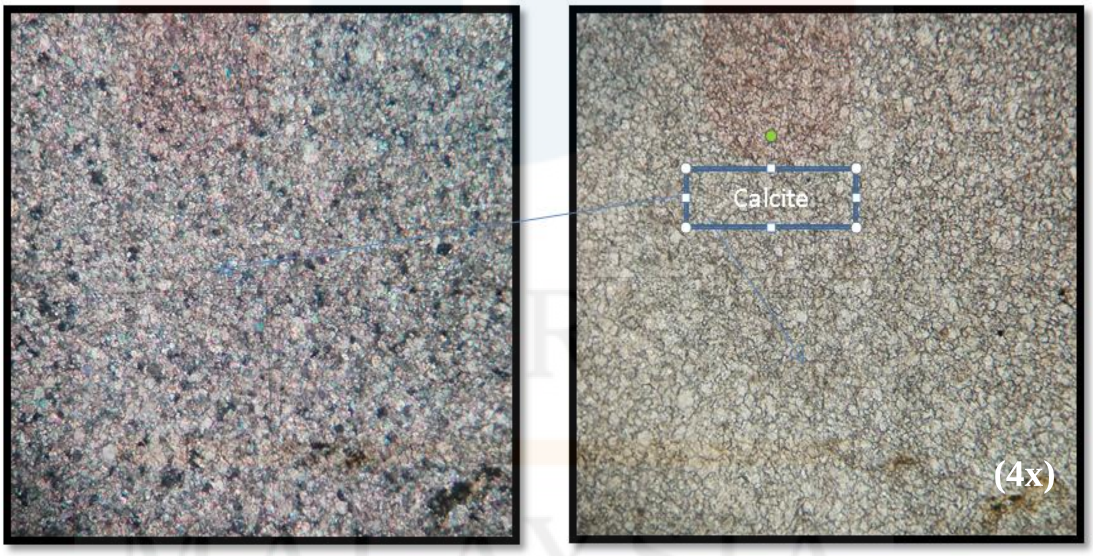


Figure 4.3.3: Limestone thin section

b) **Metamorphic rocks**

Metamorphic rocks are made by either heating up or squashing the earth's crust. They are often found in mountainous regions. A metamorphic rock is a result of a transformation of a pre-existing rock. The original rock is subjected to very high heat and pressure, which cause obvious physical and or chemical changes. They can be formed by pressures deep inside the Earth, by tectonic processes such as continental collisions, or when they are heated up by an intrusion of hot molten rock called magma from the Earth's interior.

Metamorphic rocks cover most of the study area. Approximately around 60 present of the study area consists of metamorphic rocks. The metamorphic rock is slate. Slates are metamorphic rocks that formed from shale or mudstone via metamorphism. Slate in the study area is highly weathered and eroded. Figure 4.3.4 shows slate in drainage area and figure 4.3.6 shows the slate with Iron oxide due to chemical weathering. The exposed slate looks almost the same as shale and mudstone. Figure 4.3.5 shows the highly weathered slate in hill cutting area. The rock also weathered to the extent that it became very soft and breakable like other clastic sedimentary rocks. The only indicator for it is the presence of lamination. Some moderately weathered rocks can be found but due to its location by the river, some chemical weathering such as ion oxidisation also occurs. The grain size is very fine and mostly brownish in colour .Figure 4.3.7 show Hand specimen of slate.

Figure 4.3.4: Slate in drainage area

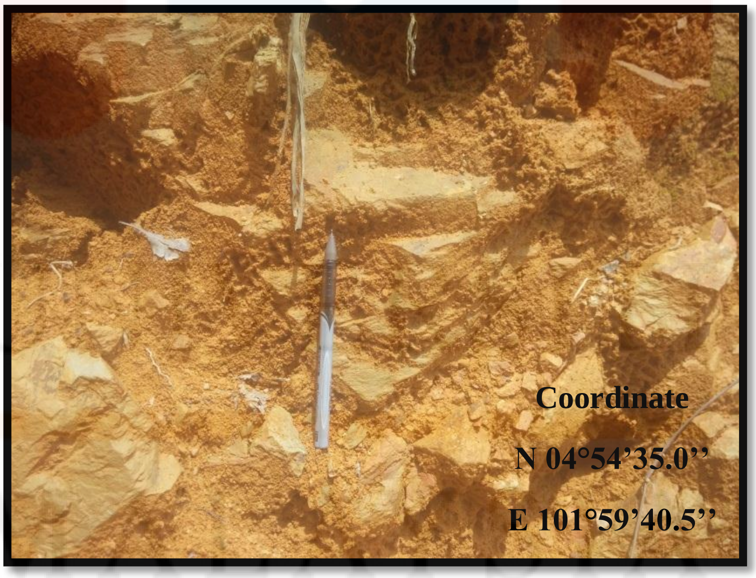


Figure 4.3.5: Highly weathered slate in hill cutting area.

Figure 4.3.6: Slate with Iron oxide

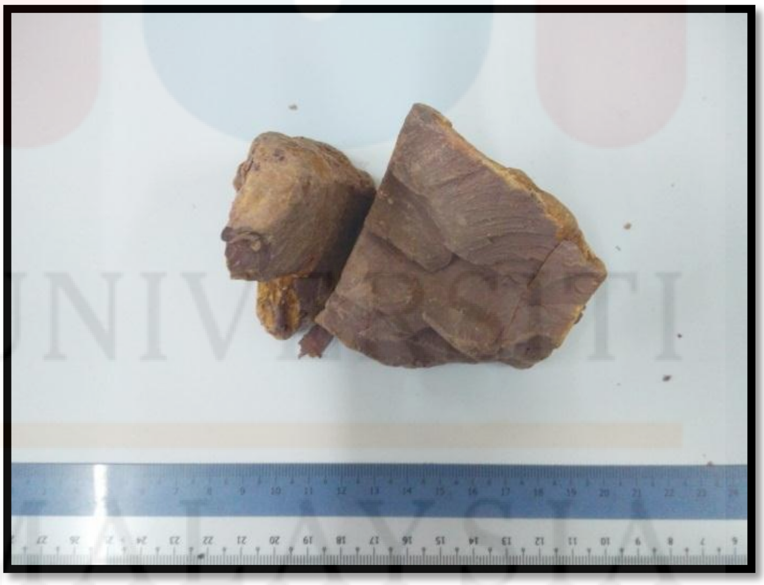


Figure 4.3.7: Hand specimen slate

c) **Clastic sedimentary rocks**

Clastic sedimentary rocks are sedimentary rocks that consist of clastic materials that was formed by weathering of rocks and compacted into rocks. Clastic sedimentary rocks cover the northern part of the study area and it cover around 15 present of the area. The area consists of rubber plantation owned by the people of Kampung Chegar Bongor. The plantation and road help to expose the lithology. The rate of weathering is moderate. The rocks in the area are shale and mudstone. Both lithology can be found throughout the area and in some places the rocks are interbedded with each other.

Shale

Shale in the study area are light to dark brown in colour and moderately weathered, it compose of silt to mud size grain and it brakes along thin laminae or parallel layering. This is called fissility. Figure 4.3.8 shows hand specimen shale.

Figure 4.3.8: Hand specimen shale

Mudstone

Mudstone in the area is darker in colour. From light grey to black. Mudstone compose mostly of mud size sediment and compare to the shale, mudstone didn't have fissility and often found interbedded with shale. Figure 4.3.9 shows the hand specimen mudstone.

Figure 4.3.9: Hand specimen mudstone

d) Volcanic rocks

The volcanic rock in the study area are volcanic tuff, the outcrop are a hill by the elevation of 280 meter from sea level and is exposed by agricultural activities. The volcanic tuffs are highly weathered and eroded. High erosion rate in the area is due to the agricultural activities resulting in a land slide and rock fall. Figure 4.3.10 shows the hand specimen tuff.

Volcanic tuff is volcanic rock that is formed as a result of volcanic eruption. Base on the texture of the rock we can says that the rocks are a welded lapilli-tuff that was formed in a sufficiently hot condition that allow the pyroclastic material and ash to be weld together. Figure 4.3.11 shows the thin section of tuff.

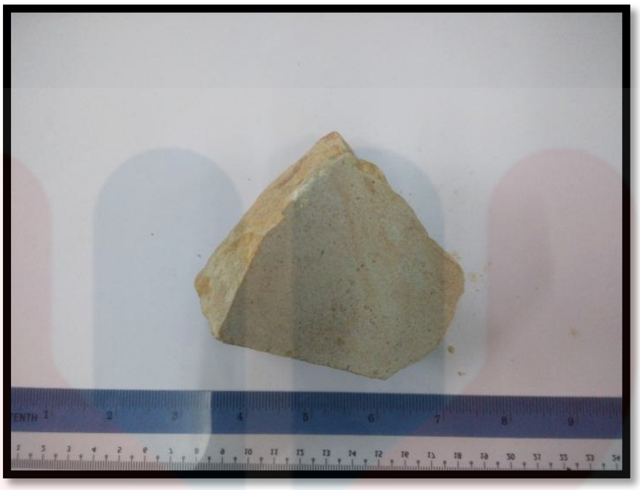


Figure 4.3.10: Hand specimen tuff

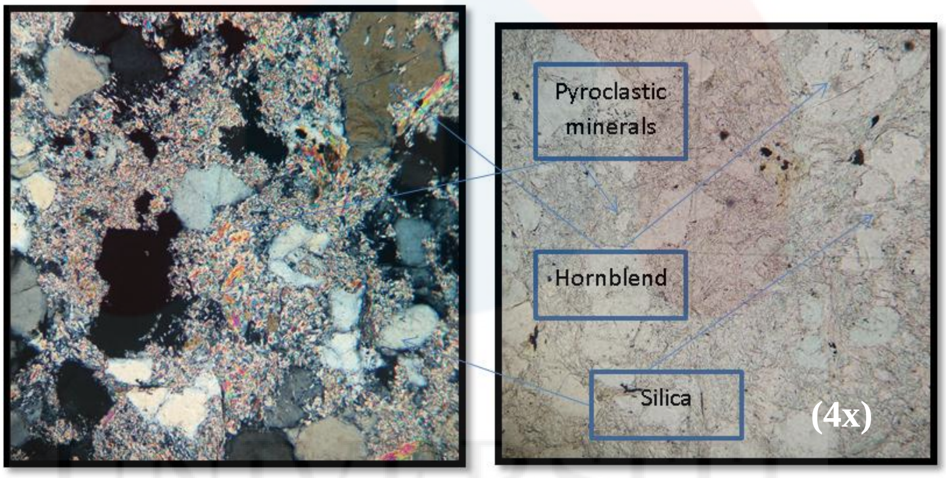


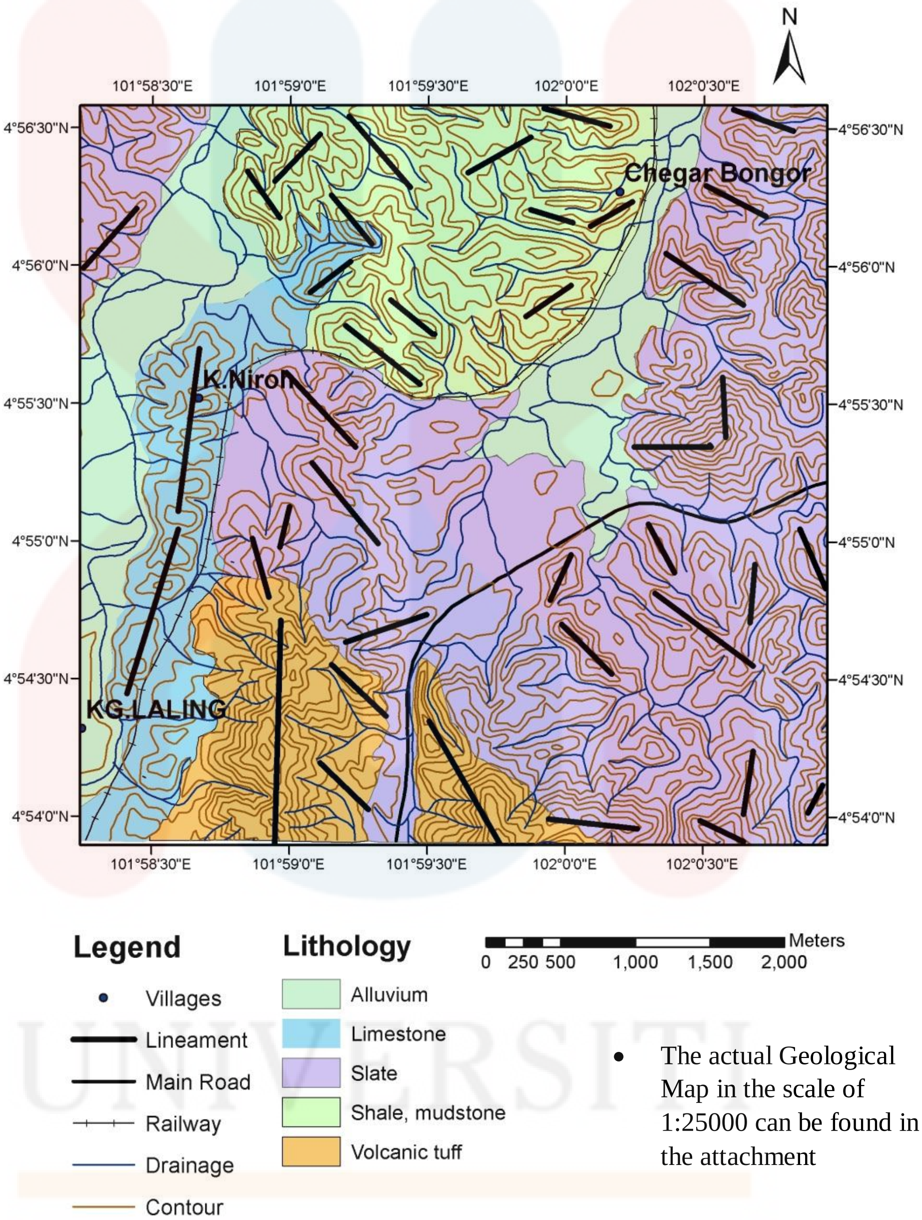
Figure 4.3.11: Thin section of tuff

Base on the lithology, the study area there are 4 types of rocks that is volcanic tuff, clastic sedimentary rock, metamorphic rock and limestone. The age of etch lithology can be indicated. It is difficult to identify the age of the rocks in study area because of the high weathering activities and lacks of fossils that can be found.

Base on the literature review, it can be said that the oldest lithology is the volcanic rocks, followed by clastic sedimentary rocks and metamorphic rocks and lastly the limestone. Figure 4.3.12 shows the geological map of the study area. Table 4.3 shows the lithostratigraphic column of the study area.

Table 4.3.12: lithostratigraphic column of the study area.

ERA	PERIOD		TYPE OF ROCKS
Cenozoic	Quaternary		Alluvium
Paleozoic	Permian	Late	Limestone
		Middle	Slate
			Shale, Mudstone
			Volcanic Tuff



- The actual Geological Map in the scale of 1:25000 can be found in the attachment

Figure 4.3.12: Geological Map

4.4 Structural geology

Structural geology is the study of the process and product of rocks deformation and no geological, geophysical and geochemical study can be done without the input of structural geology. It is because structural geology gives information on the present and past of any mountain belt and also sedimentary basins.

4.4.1 Lineament Analysis

Lineament is the line feature that is mapped on a surface where the line aligns the topography of the map. When the topographic map is viewed under 3D image, the lines are observable whether they are straight or slightly curved. Figure 4.4.4 shows lineament base on terrain image.

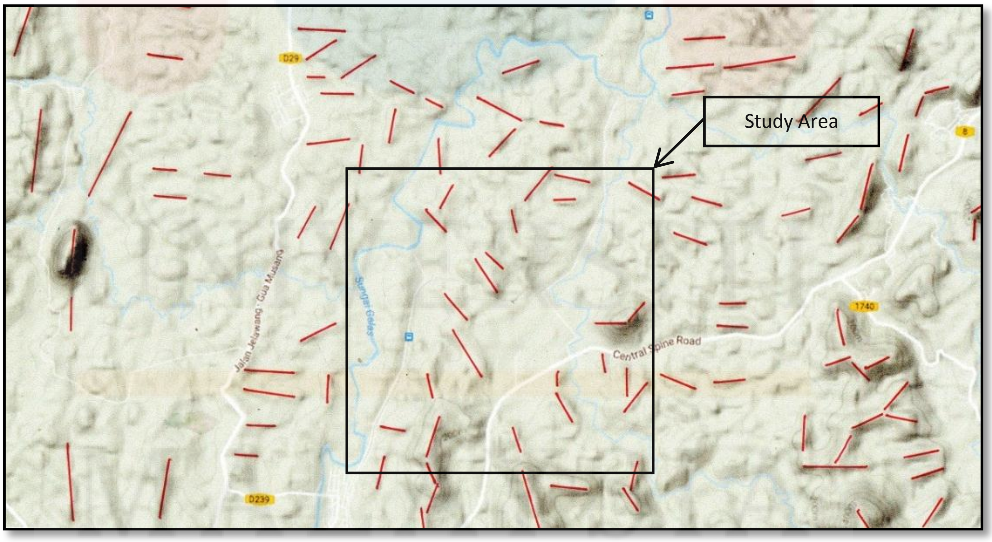


Figure 4.4.1: Lineament base on terrain image (Regional).

Lineament data:

Table 4.2: Lineament bearing reading

2	20	330	322	271	39	70	40	343	12
6	278	30	80	210	60	17	356	345	5
20	285	320	20	268	140	60	348	320	65
280	282	355	25	30	65	43	326	347	275
275	40	300	320	3	71	77	13	21	280
272	70	303	325	65	350	85	280	337	230
23	300	324	321	33	36	273	324	22	270
24	41	60	325	64	15	275	357	353	9
7	345	272	80	77	14	87	272	282	354
8	320	60	60	105	20	300	43	12	20

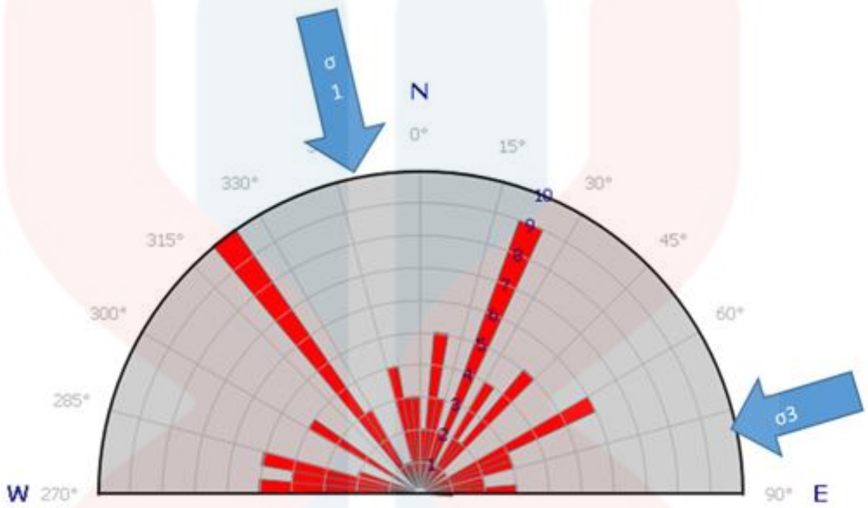


Figure 4.4.2: Rose diagram for lineament analysis

The rose diagram represents the bearing data from the lineament that was tanked from terrain map. This represents the regional tectonic force. The main force (σ1) from the regional tectonic activities is 350°. The force came from north- west of the regional area. σ3 are the tensional force and it is always perpendicular to the main force.

4.4.2 Joint analysis

Crack analysis was done in two areas. Around 100 reading are taken from etch area. Both reading were plotted in separate rose diagram.

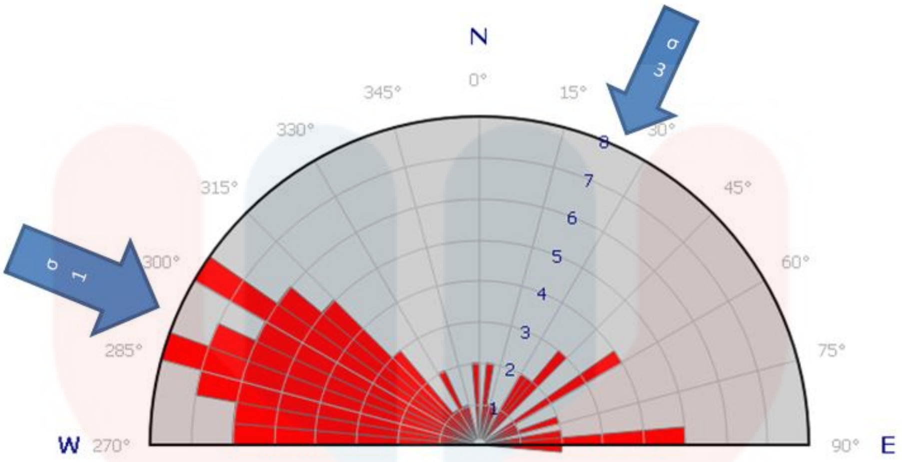


Figure 4.4.3: Rose diagram for joint analysis site 1

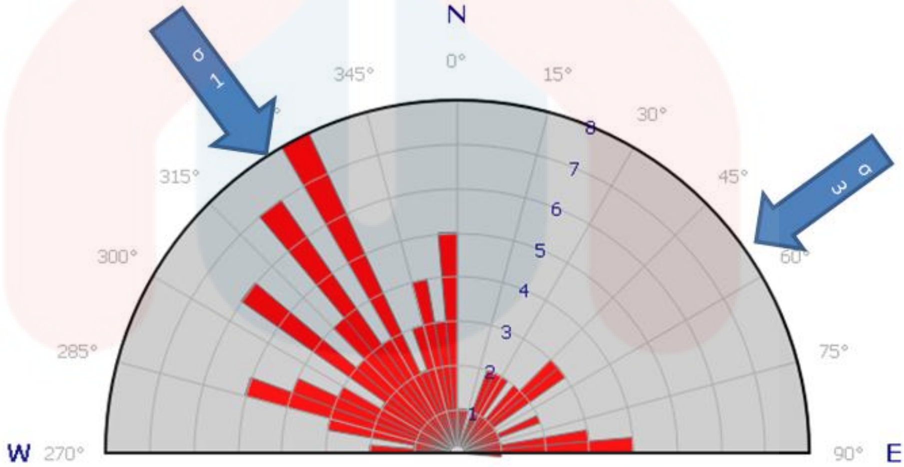


Figure 4.4.4: Rose diagram for joint analysis site 2

Figure and figure shows Rose diagram for joint analysis site. Both rose diagrams shows quite similar main force direction, which were North West (NW) to South East (SE) (NW-SE). Figure and figure shows the joint analysis site.

Figure 4.4.5: Joint analysis site 1

Figure 4.4.6: Joint analysis site 2

Joint data

Joint site 1:

Table 4.3: Joint site 1 strike reading

105	280	250	270	235	265	279	275	266	172
120	160	118	307	284	217	332	291	283	120
220	249	292	286	272	271	285	290	294	289
188	278	277	292	270	295	319	214	300	282
197	276	280	326	311	305	273	289	303	320
240	275	285	306	316	358	314	281	249	308
220	220	223	318	312	297	338	296	300	333
249	237	217	213	301	312	300	293	289	294
250	260	271	194	177	262	288	303	314	303
274	267	265	264	186	252	282	56	59	302

Joint site 2:

Table 4.4: Joint site 2 strike reading

109	20	249	394	31	310	106	355	106	127
356	309	340	331	127	280	143	139	111	104
338	346	335	331	312	324	175	140	103	82
323	50	330	51	310	270	49	97	27	89
322	350	348	296	316	46	167	135	85	190
332	328	352	105	340	40	80	56	78	353
356	343	307	299	326	50	105	28	94	126
8	329	316	23	267	82	140	143	128	67
333	331	40	110	254	95	152	114	134	152
355	349	300	35	183	114	64	127	49	115

4.5 Geological History

Base on lithology of the study area, we can interpreted the past environment base on the possible depositional environment of the rocks. The first lithology is limestone, most limestone form in shallow, calm, warm marine waters. That type of environment is where organisms capable of forming calcium carbonate shells and skeletons can easily extract the needed ingredients from ocean water. When these animals die, their shell and skeletal debris accumulate as sediment that might be lithified into limestone.

Next lithology is clastic sediment such as shale and siltstone that are formed from mechanical weathering debris. Both rocks are formed in ancient marine environments. They are "mudrocks" composed of silt and clay particles slowly deposited through suspension in calm waters. Silica and calcium carbonate from marine creatures provides the cement necessary to eventually form the rock. As the marine environment dries during various epochs of climate change, sedimentary rock is left behind.

Next lithology is volcanic tuff. It is an igneous rock that forms from the debris ejected by an explosive volcanic eruption base on the texture of the rocks, it shows that the volcanic are compose mostly of volcanic ash and small debris. Lastly, the lithology that's compose of metamorphic rocks such as slate. This shows that there are metamorphism processes that occur in the study area. Base on stratigraphy, the oldest rock is volcanic tuff, followed by clastic sedimentary rock and metamorphic rock the lastly the limestone.

The structural analysis of the study area leads to a suggestion that the area had undergone many tectonic activities that the main force came from north-western part of the area.

Base on stratigraphy and the lithostratigraphic column the first rock formed in the study area is volcanic tuff via volcanic activities that later on submerge into ocean due to tectonic activities.

Next is the formation of the clastic sedimentary rocks in the calm ancient marine environments. In the area the clastic sedimentary rocks is shale and mudstone that interbedded with one another.

Metamorphism occurs and formed slate from shale and mudstone via tectonic activities. Then limestone formed in the shallow, calm, warm marine waters where organisms capable of forming calcium carbonate shells and skeletons can easily extract the needed ingredients from ocean water the formation of the lithology are in the Middle Permian period base on the literature review.

CHAPTER 5

Demarcation of Potential Aquifer Zone in Karstic Terrain Using Surface Geological Mapping

5.1 Results and Discussion

This chapter will be covering the analysis and interpretation of the area's geomorphology, structural geology, and lithology in finding and earmark all the potential aquifer in the karstic terrain of the study area.

Base on the result gained from geological mapping, I can indicate that there are 3 potential karstic aquifer zones in the study area. This area met the condition for it to be identified as a potential karst aquifer area. These areas also are different from each other in term of geomorphology, size and even the amount of water that can be stored in the aquifer. The potential area can be seen on figure 5.4.

Each area will be further discussed in this chapter and this analysis and interpretation will include the areas geomorphology, drainage pattern, porosity and permeability, a model that represent all the structure, morphology and potential subsurface aquifer, and estimation of the amount of water that could be extracted from the aquifer.

All three potential aquifer areas have some of karst morphology and geological structure that lead to the estimation of the presence of karst aquifer in the area. But the amount, size and type of the morphology of structure are different in etch area. Table 5.1 shows all the structural and morphological features in all three potential aquifer areas.

Table 5.1: The structural and morphological features in all three potential aquifer areas

Feature	**Potential Area 1**	**Potential Area 2**	**Potential Area 3**
Lithology	Limestone	Limestone and volcanic tuff	Limestone and Alluvium
Disappearing stream (recharge area)	**1** ,(diameter around 1 meter)	-	-
Collapse sinkhole	**5**, (average diameter around 50 centimeter)	**1**,(diameter around 90 centimeter)	-
Dissolved sinkhole	**6,**(average diameter around 30 centimeter)	-	**4**, (average diameter around 40 centimeter)
Spring	**2**, one in the same size as the disapiaring stream and one small spring.	**5**, All in the volcanic tuff hill.	**2**, in the alluvial plane.
Well	-	**1**, 6 Meter in depth	-
Joint and fracture	Lot of joint set in limestone	Lot of joint set in both limestone and volcanic tuff	Joint set only seen on unburied karst.
Karren	Presence all around the area	Only presence in drainage area.	Most can be found near drainage.
Drainage pattern.	Sub-parallel	Sub-parallel	Redial at volcanic tuff and sub-parallel at limestone.

5.1.1 Potential Aquifer Area 1

Potential aquifer area 1 was located in the north-west part of the study area. The coordinate for the area is in the range of N 04°55’45’’ to of N 04°56’15’’ and E 101°58’52’’ to E 101°59’26’’ with average elevation of 98 meters above sea level. The area consists of rubber plantation and some road connection between plantations. The area is covered by vegetation due to the plantation activates but some karst feature can be seen throughout the surface and drainage in the area.

The area consists of sub parallel drainage pattern that are highly dents and interconnected. From the drainage we also found limestone that makes up karst stream via desolation activities. Sinking streams also can be found on the area. This sinking stream is where all the water is lost or sinks into the subsurface through dissolved openings in the limestone. This sinking stream gives indication that this area can be the recharge area for the aquifer. In the area there’s a total of 1 sinking stream.

The area also consists of karst spring. Karst spring is where the water from the aquifer is being discharge. Throughout the area there are a total of 2 karst springs. Both the sinking spring and karst spring are located in the same area. From hare I can interpreted that the aquifer may or May not been in small sized or the aquifer consist of more complex and long conduit that some water may have travel and be stored inside the aquifer while some water came out through the karst spring (even more complex cave system in the subsurface).

The area also consists of six sinkholes. Most of the sinkhole in the area can be identified as Collapse sinkhole. Collapse sinkhole is the result of the collapse of an underlying soil arch above the limestone drain or the collapse of an underlying cavity roof within the bedrock. A collapse sinkhole is a subtype of subsidence sinkholes. This shows that the opening or enlargement of the saluted conduit was too high that it disturbed the stability of the soil on top and resulting it to collapse. The pattern of the sinkhole also gives a clue of the cave system and direction of the opened conduits.

Other than that, the area also consists of highly joint and fractured limestone. Almost all the rocks in the surface show high amount of joint and fracture. This is good because water can enter the aquifer through it (secondary porosity and permeability). This shows the aquifer recharge can came from both secondary permeability and tertiary permeability (opened conduits). From hear we can see that the rate of water flow into the aquifer can be fast (tertiary porosity) and slow (secondary porosity).From hear also we can says that the rate of contaminant are high because water flow very fast and very low filtration for surface water to enter the aquifer. The surface water also can be contaminated by the manure from the plantation. The root of the plant also can encourage weathering process and boost the desolation process via the release of carbon dioxide by microorganism that may live on the root of the plant thus increase the acidity of water that went through the area. Higher amount of recharge can increase amount of water in aquifer, it will also encourage the evolution of karst aquifer that will lead to the creation of a new cave system. Figure 5.1.1 shows the landform of potential area 1.The illustration of the aquifer at area 1 can be seen in figure 5.1.2.

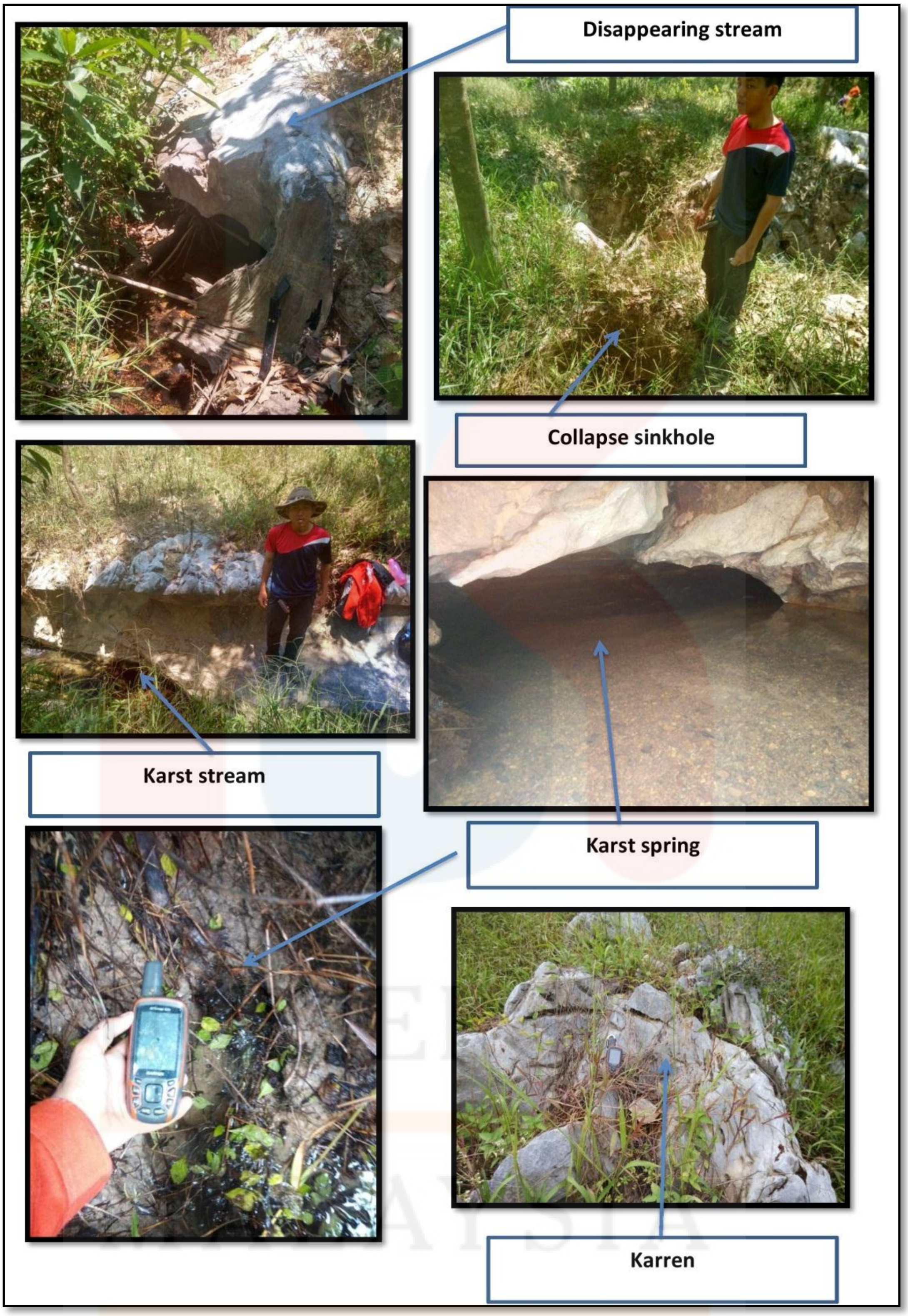


Figure 5.1.1: The landform of potential area 1

Estimated aquifer model area 1

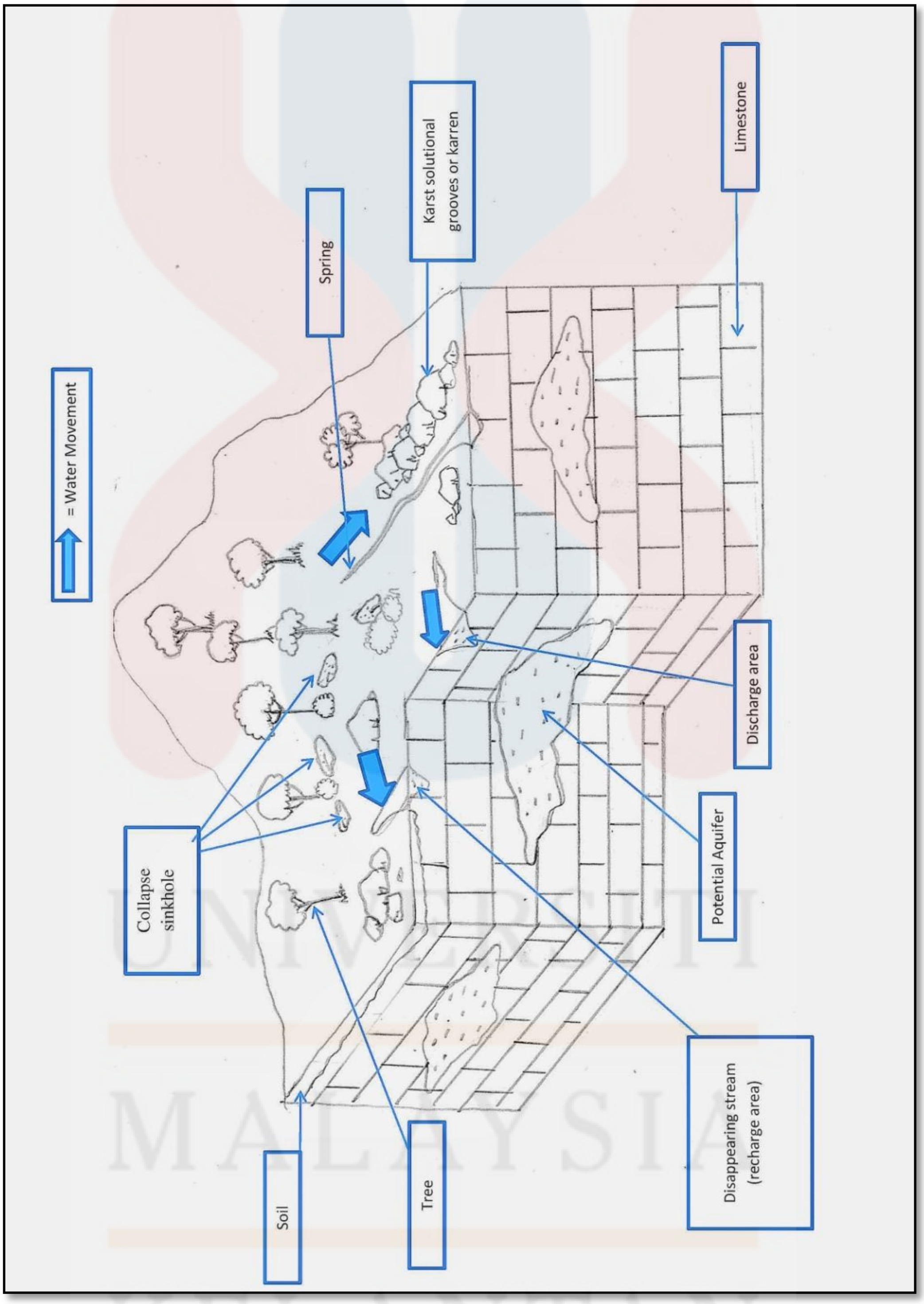


Figure 5.1.2: Estimated aquifer model area 1

5.1.2 Potential Aquifer Area 2

Potential aquifer zone 2 is located in the south-west part of the study area. The coordinate for the area is in the range of N 4°54'20'' to N 4°55'10'' and E 101°57'20'' to E 101°58'57''. The area is located in the rural area near the residential area. The area is a boundary between two separated lithology. One being a volcanic tuff and the other being limestone. The volcanic tuff area consists of high hill of an elevation up to 300 meters from sea levels while the limestone consists of flat area of elevation of 60 meters from sea level that consist of residential area.

The volcanic tuff is exposed due to human activities. Some parts of the hills are cut off for plantation reviling the highly joint and fractured volcanic tuff. The conditions of the volcanic tuff are highly withered and some had been eroded away by the slop. The rocks are mostly covered by loose soil. Almost half the sizes of the lithology are still unharmed and consist of deep forest. Due to the abundant of joint and fracture with the aid of loose soil that are high in porosity and permeability, spring can be found all around the lithology.

Volcanic tuff is very pour in term of Porosity and Permeability because it's a rock made out of volcanic ash ejected from a vent during a volcanic eruption. Following ejection and deposition, the ash is compacted into a solid rock in a process called consolidation. From the consolidation process, the rocks compositions are too tight and compact that it didn't permit water to pass through. But due to the presence of joint and fracture, it had developed a secondary Porosity and Permeability. Secondary porosity is very common in hard rock groundwater. The presence of loose soil acts as a filter to prevent contaminant from entering the aquifer.

Most of the limestone in the residential area is covered with thick soil and the outcrop can only be seen on the drainage area. There are not many geomorphological features in the area besides some small solution sinkhole, one major collapsing sinkhole and Karst solutional grooves or Karren. The downside to this area is that the household wastes are thrown out to the karst drainage system. This can lead to a possible contamination of aquifer. Due to its location that is near to residential area , there are a domestic well being drilled to the dept. of 6 meters, because the water are supplied by karst aquifer , the water level are often changing because karst aquifer water movement depend on the rate of discharge and pressure. The average depth is between 2 to 3 meters below earth surface. This shows that the aquifer is stable.

For this area, the focus is more in the boundary between the two lithology. The orientations of joint of both lithology are almost in the same direction. Figure 5.4 shows the location of potential aquifer area 2 and based on the map, the lineament bearing direction on both lithology are almost in the same baring direction. This bearing direction can shows the joint orientation of the lithology. So the possibility of groundwater from hard rocks (volcanic tuff) to be transferred to the limestone area is high. Base on the topography also, water tends to move with gravity to the lower elevation and follow the water table.

The amount of groundwater that can be result of this aquifer can be high to very high due to the high amount of joint ant fracture from the volcanic tuff. High recharge rate with very low discharge rate also can contribute to high groundwater content. The quality of the groundwater is estimated to be quite good due to the filtration via loose soil in the volcanic tuff area. But there can be a possible contaminant from the residential area. Figure 5.2.1 shows the landform of study area 2. The model for the aquifer can be seen in figure 5.2.2.

Figure 5.2.1: The landform of potential area

Estimated aquifer model area 2

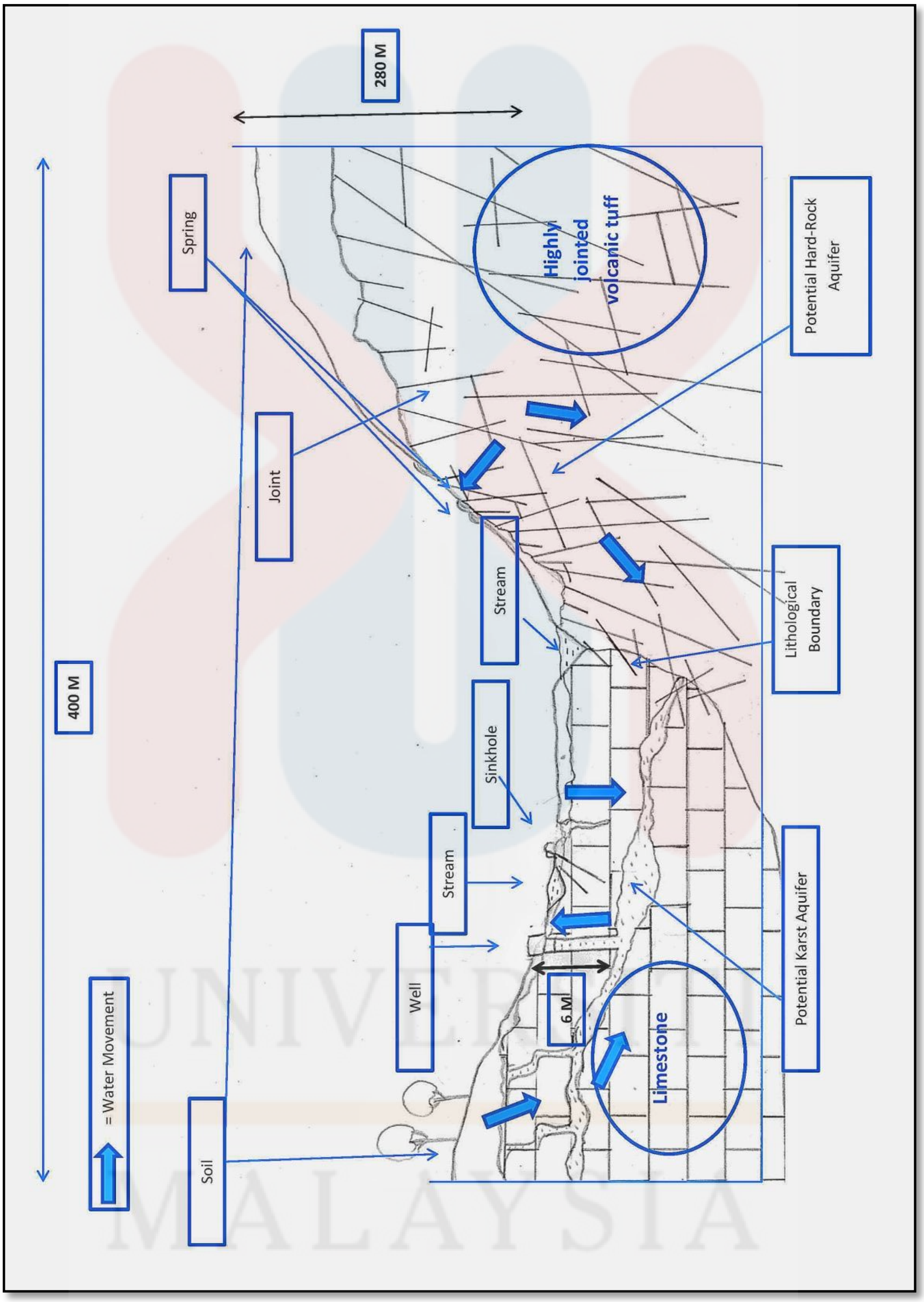


Figure 5.2.2: Estimated aquifer model area 2.

5.1.3 Potential Aquifer Area 3

Potential aquifer area 3 is located in the middle of the study area. The coordinate for the aquifer zone is in the range of N 4°55’26’’ to 4°55’47’’ and E 101°59’35’’ to E 101°59’59’’. The area consists of alluvial plane with some limestone outcrop in the form of karst morphology. Karst feature can be found all around the alluvial plane. Karst feature such as sinkhole (4 sinkhole are found) and Karst solutional grooves or Karren can be found in the alluvial plane. Most of the karst morphology shows that there are layers of limestone under the loose sediment and there is a possibility of an aquifer in the area.

Loose sediment has good porosity and permeability. Water can penetrate and moves in the alluvial plane until meats with any joint and fractured in the limestone and moves towards karst aquifer. This process is difficult to detect in the alluvial plane because the oppend conduit or sinkhole may have been buried during flood. Flood is a normal occurrence in an alluvial plane. That is why we can estimate that the sinkhole in this area can be buried sinkholes. Buried sinkholes are sinkholes that have been filled in over time by natural processes and are no longer visible at the surface. Although no longer visible at the surface, it still functions as a drain for water to enter the groundwater-flow system (Beck, 2005).

The alluvial plane also acts as a boundary between metamorphic rocks and the limestone underneath the alluvial plane. Lithological boundary tends to have some geological structure such as joint and fracture that can increase the porosity and permeability of the aquifer. The estimated size of the aquifer is from medium to high, because the amount of recharge depends in the precipitation. The area gets really wet on flood time but dry after that. Figure 5.3.1shows the landform of potential area 3. An illustration of the aquifer can be seen in figure 5.3.2.

Figure 5.3.1: The landform of potential area 3.

Estimated aquifer model area 3

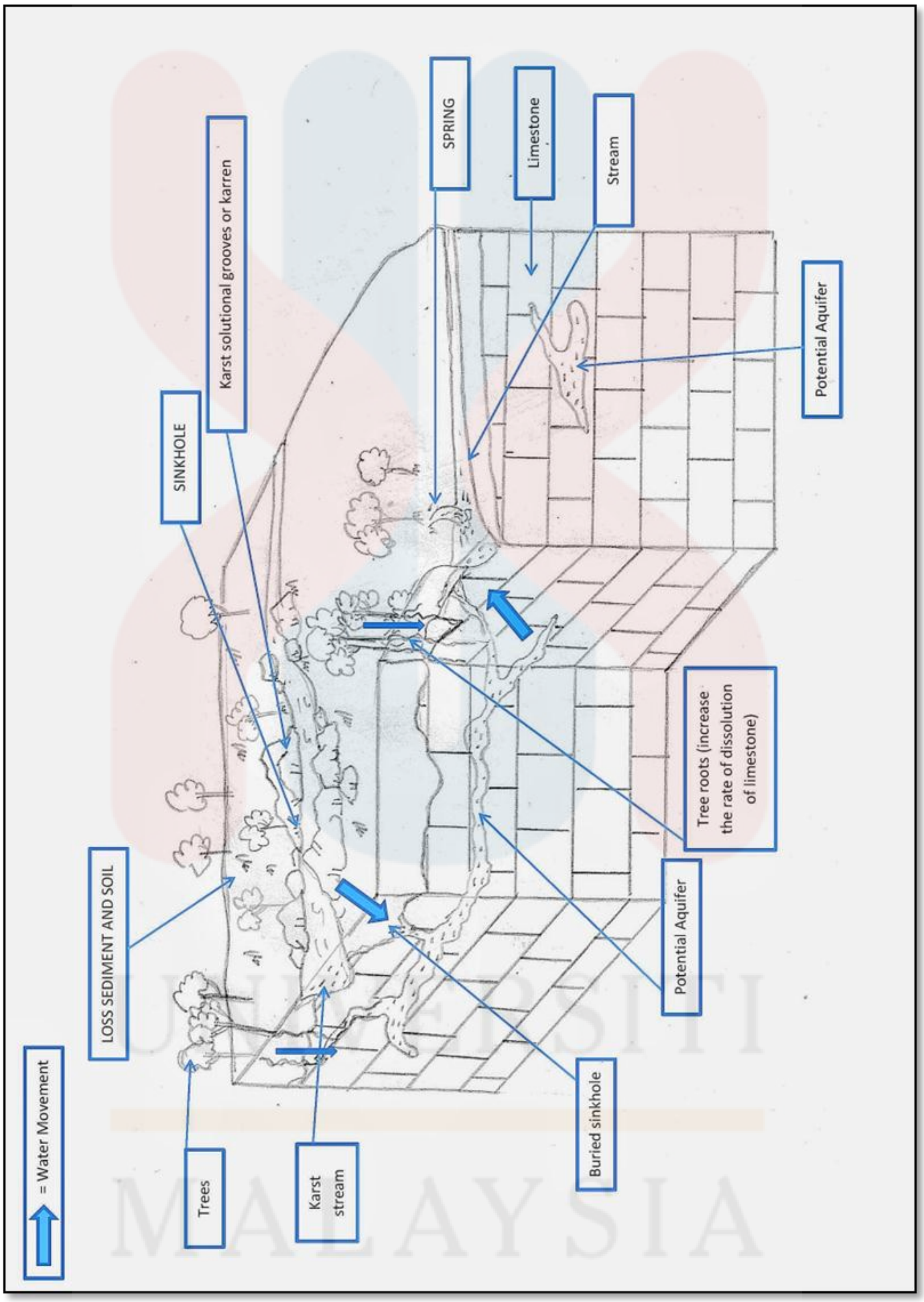


Figure 5.3.2: Estimated aquifer model area 3.

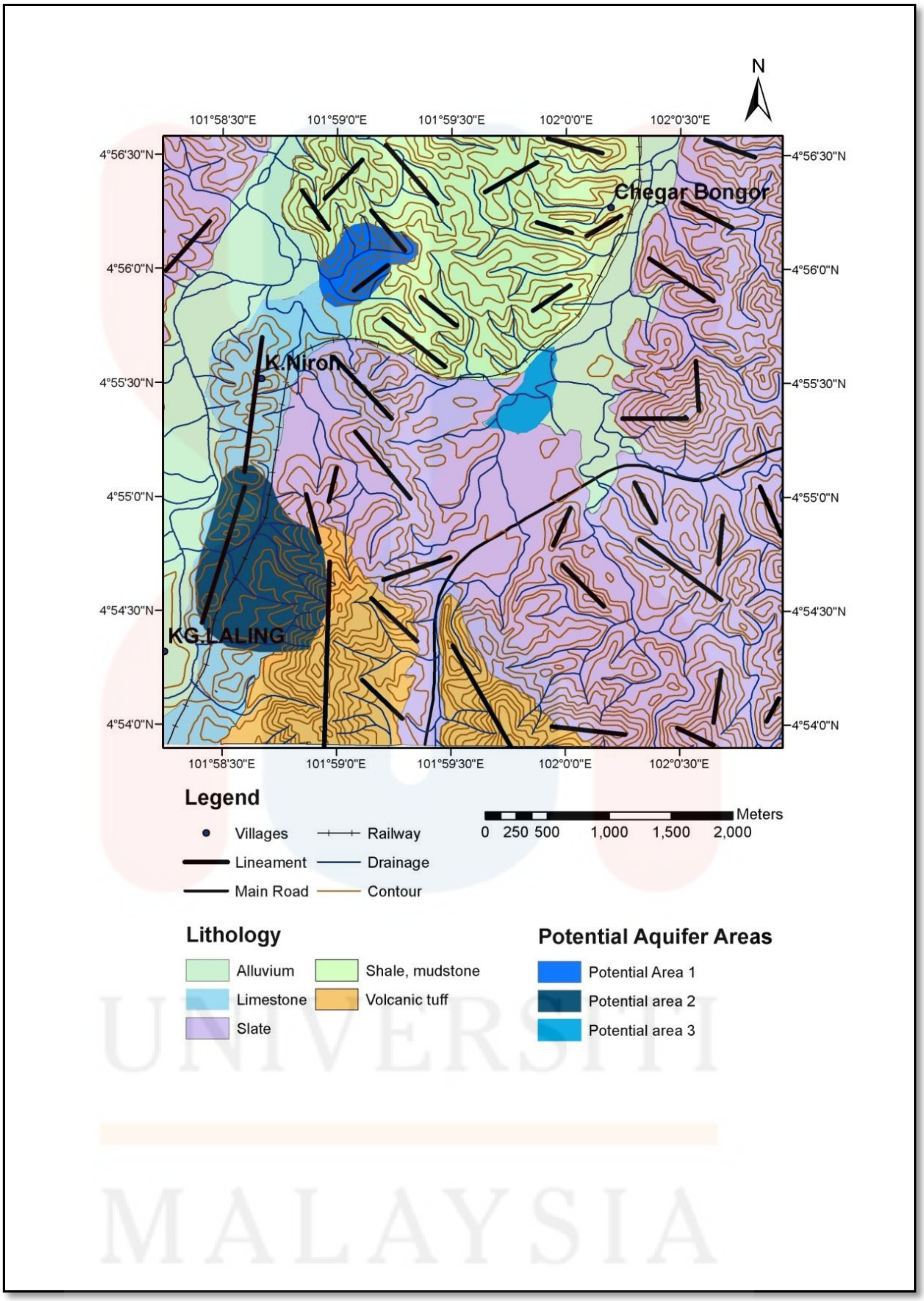


Figure 5.4: Potential aquifer zone map.

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

All three potential zone are different from one another, thus the amount of water that could be stored in etch aquifer are different. All 3 areas have large amount of karst feature. All of this karst feature influence the water intake and outtake in a karst aquifer. The first area consists of the most geomorphological advantages then the other area. It has a disappearing stream and a lot of sinkhole. But the area also has a large amount of discharge.

The areas have two springs and one of the springs sized matched the size of the conduit responsible on recharging the aquifer. This area rate of recharge and discharge is in the ratio of 1:1.5 leading to an assumption that the aquifer may not be able to be in its full capacity.

The second potential area may not have much of a karst feature that act as a recharge as the first area, but it as an advantage in term of recharge directly of another aquifer that is from a hard-rock aquifer. Another advantage is that the area has less discharge area, so the aquifer may contain more water than the first area. The third area depend more on seasonal flood thus its rate of recharge are lower than other area.

This research was conducted in order to identify any possibility and potential for karst area to hold water that can be beneficial for people. By finding and analysing all of the areas, we can indicate that the second area has the most potential followed by the first and lastly the third area.

Figure 5.4 shows the final potential aquifer map showing all the potential area. The colour of the area represents the possible water content of the area. The darker the colour, the larger the capacity of water in the aquifer.

6.2 Suggestion

The research is conducted majorly of surface investigation that applied the study of geomorphology, stratigraphy, geological structure and hydrogeology in the finding of potential aquifer zone. This research only cover the surface and not the subsurface , so a more detail subsurface investigation need to be done in order to get the most out of the aquifer.

Karst aquifer is not like other aquifer, it is complex and unpredictable, and conducting geophysics analysis such as resistivity and seismic investigation can really be of benefits in the future.

Karst aquifers are very fragile and easily contaminated, and some residence in the study area didn’t care about water pollution and contamination as most of the house whole dump and drain are channelled towards the karst stream. From here, there is a possibility that the aquifer can be contaminated. So a better awareness about this aquifer and its benefits to the people can lead to a decline of water pollution in the study area and protect the aquifer.

The actual capacity of the aquifer also is still unknown. So a further study to get the actual value of groundwater that the aquifer holds will be good information in order to further utilize the groundwater resources.

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APPENDIX A

Appendix A (1): Strike and dip data in the study area

Coordinate	Lithology	Strike	Dip
N 04°55’21.3’’ E 102°00’22.2’’	Slate	64°	30°
N 04°54’45.0’’ E 101°59’54.3’’	Slate	241°	33°
N 04°54’38.1’’ E 101°59’53.3’’	Slate	330°	40°
N 04°56’40.0’’ E 102°00’01.2’’	Mudstone	345°	50°
N 04°56’07.0’’ E 101°59’52.3’’	Shale	353°	63°