



Universiti Malaysia
KELANTAN

**GEOLOGY AND GROUNDWATER QUALITY
ASSESSMENT IN KAMPUNG AYER ASAHAN
HULU, TANAH MERAH, KELANTAN**

by

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ACKNOWLEDGEMENT

Alhamdulillah, it is always and will always be the first word to say upon seeing the completion of the thesis. Not always a smooth journey, in fact it is much more of a bumpy journey, but every rainbow comes after storm, every hardship will eventually come to an end and results never betray efforts. Of course, in completing this wholesome thesis, there are many people I would love to specify and being thank to. For giving an opportunity to conduct a research study that never have I ever imagine to carry out, I would love to express my grateful to Universiti Malaysia Kelantan especially my supervisor, Dr. Muqtada Ali Khan for giving me guidance, morale support that I appreciate so much during the days I feel so down for being behind others. Thank you for making me think that everyone has their own journey and being one step behind does not mean I failed. I learned a lot from my supervisor and that I will never forget his advices for future motivational support.

Throughout the completion of my mapping and groundwater quality assessment there are some people I appreciate so much that I want to specify here which are my friends. There are days that I think without their help I would not be able to complete everything by myself. It must be true, cooperation always works like wonder. My utmost gratitude goes to my parents for giving morale support throughout my journey and lending a hand whenever I need to during my geological mapping days. I am hoping that by reading this thesis I worked hard for, readers can gain something from it and find it useful for future references and studies, Insha'Allah.

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Geology and Groundwater Quality Assessment In Kampung Ayer Asahan Hulu, Tanah Merah, Kelantan

ABSTRACT

The main purpose of the study is to update geological map of study area on the scale of 1:25,000 and to assess the groundwater quality in domestic wells in study area. The study area covers around 25.5 km² of the area and lies between latitude from 5° 46'34.58" N to 5° 49'20.56" N and longitude from 102 02'16.57" E to 102° 05'00.06" E. Study area includes some villages and a highway known as Timur-Barat Highway. Some methods were being used in the study such as preliminary study, geological mapping, traversing, field observation, fresh outcrop sample collection, petrographic study and GIS analysis. For groundwater quality assessment, water sample were taken to laboratory for analysis by Atomic Absorption Spectrophotometer (AAS), UV-VIS Spectrometer and by titration method. In-situ parameters such as Total Dissolved Solids (TDS), pH and temperature of the groundwater were taken. Based on the study, the north part of the study area are mostly covered with metamorphic and metasedimentary rocks such as schist, quartzite and meta-mudrock. These rocks can be found in the same area and the schist were composed of mostly quartz minerals. In some areas in the south part of the study area, igneous rocks such as coarse-grained porphyritic granodiorite were found. Granodiorite was mostly composed of quartz mineral along with plagioclase, biotite and microcline minerals. In terms of geomorphology, the study area comprises mostly low hills with elevations ranging from 40m to 160m. Mostly the locations where outcrops are most likely be found were weathered and many places were being developed and currently became cutting areas. Therefore, fresh outcrop were hardly found. Some joints and fault structures were discovered such as reverse fault on a weathered outcrop. Updated geological map can be used by many other beneficiaries for many uses related to development of the area. Based on the result for groundwater quality assessment in study area, most of the groundwater sample consist of major cations and anions within permissible limit under guidance of W.H.O. and Malaysia M.O.H. except for one well labelled as U10 consisting a higher concentration of Ferum ion which is 2.392 mg/l over permissible value of 0.3 mg/l. Although ferum ion does not usually present in health risk, a high concentration of the particular ion should be paid attention to.

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Geologi dan Penilaian Kualiti Air Bawah Tanah Di Kampung Ayer Asahan Hulu, Tanah Merah Kelantan

ABSTRAK

Tujuan utama kajian adalah untuk mengemas kini peta geologi kawasan kajian pada skala 1:25,000 dan menilai kualiti air bawah tanah di telaga domestik di kawasan kajian. Kawasan kajian meliputi sekitar 25.5 km² kawasan dan terletak di antara latitud dari 5o 46'34.58" U hingga 5° 49'20.56" U dan longitud dari 102° 02'16.57" E hingga 102° 05'00.06" E. Kawasan kajian merangkumi beberapa buah kampung dan lebuh raya yang dikenali sebagai Lebuhraya Timur-Barat. Beberapa kaedah telah digunakan dalam kajian ini seperti kajian awal, pemetaan geologi, merentasi, pemerhatian lapangan, pengumpulan sampel singkapan segar, kajian petrografi dan analisis GIS. Untuk penilaian kualiti air bawah tanah, sampel air telah dibawa ke makmal untuk dianalisis menggunakan Spektrofotometer Serapan Atom (AAS), Spektrometer UV-VIS dan kaedah pentitratan. Parameter in-situ seperti Jumlah Pepejal Terlarut (TDS), pH dan suhu air bawah tanah telah diambil. Berdasarkan kajian, bahagian utara kawasan kajian kebanyakannya dilitupi dengan batuan metamorfik dan metasedimen seperti schist, kuarzit dan meta-mudrock. Batuan ini boleh ditemui di kawasan yang sama dan schist terdiri daripada kebanyakan mineral kuarza. Di beberapa kawasan di bahagian selatan kawasan kajian, batuan igneus seperti granodiorit porfiritik berbutir kasar ditemui. Granodiorit kebanyakannya terdiri daripada mineral kuarza bersama dengan mineral plagioklas, biotit dan mikroklilin. Dari segi geomorfologi, kawasan kajian kebanyakannya terdiri daripada bukit rendah dengan ketinggian antara 40m hingga 160m. Kebanyakan lokasi di mana singkapan berkemungkinan besar dijumpai telah lapuk dan banyak tempat sedang dibangunkan dan kini menjadi kawasan pemotongan. Oleh itu, singkapan segar hampir tidak dijumpai. Beberapa sendi dan struktur sesar ditemui seperti sesar terbalik pada singkapan yang terluluhawa. Peta geologi yang dikemas kini boleh digunakan oleh ramai penerima manfaat lain untuk banyak kegunaan berkaitan pembangunan kawasan tersebut. Berdasarkan keputusan penilaian kualiti air bawah tanah di kawasan kajian, kebanyakan sampel air bawah tanah terdiri daripada kation dan anion utama dalam had yang dibenarkan di bawah bimbingan W.H.O. dan Malaysia M.O.H. kecuali satu telaga yang dilabelkan sebagai U10 yang mengandungi kepekatan ion Ferum yang lebih tinggi iaitu 2.392 mg/l melebihi nilai yang dibenarkan iaitu 0.3 mg/l. Walaupun ion ferum biasanya tidak terdapat dalam risiko kesihatan, kepekatan tinggi ion tertentu harus diberi perhatian.

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LIST OF ABBREVIATIONS

ABBREVIATION	WORD
GIS	Geography Information System
GPS	Global Positioning System
AAS	Atomic Absorption Spectrophotometer
mg/l	Milligram per liter
ppm	Part per million
uS/cm	microSiemen per centimeter
W.H.O.	World Health Organization
M.O.H.	Ministry of Health
TDS	Total Dissolved Solids
JMG	Mineralogy and Geoscience Department

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CHAPTER 1

INTRODUCTION

1.1 General Background

Without realising, geological map is being used widely not only in geology field but also in other fields such as economic development. There are many beneficiaries using geological map as a reference. Thus, it shows how important to keep on updating geological map and information of an area. One of the ways to update geological map is by carrying out geological mapping activities. Geological mapping provides various data and information not only lithologies but also geological structures. Geological structures information is significant and is being used by many beneficiaries such as foresters and civil engineers.

Malaysia's current Prime Minister, Datuk Seri Ismail Sabri Yaakob stated that the groundwater usage in Malaysia is as low as 3% out of its nature current capacity which is 5,000 billion cubic metres of groundwater resource besides having a recharge capability of 64 billion cubic metres every year (The Star, 2022). Based on an article, groundwater contributes 70% of water resources specifically in the Lower Kelantan River Basin (Husin et. al., 2020).

Nora Mahpar (2021) stated that, only 71.7% from 1.7 million people living in Kelantan got access to a good water resource. A good groundwater quality helps the residents for domestic uses, agricultural and even for industrial uses. It can affect the residents in terms of poor quality of drinking waters and causing health problems due to the groundwater contamination. Although groundwater quality issue does not only happen in Kelantan, but this state was also recorded to have one of the lowest public water supplies moreover in the rural areas (Idrus et. al., 2014). This shows that Malaysia, particularly in Kelantan needs a water quality assessment in order to help more people residing in Kelantan to get access to a better and cleaner water resources. To foresee the future generation, water supply demand will only get higher and aquifer development as well as conservation will be useful for in the future for many purposes such as domestic uses and industrial uses (Morris, et. al., 2003).

Residents in Kelantan does not receive a proper quality of water resources. In general, groundwater has a composition of minerals and its concentration is highly depending on the subsurface environment, rate of groundwater movement as well as the sources of the groundwater (Prasad et al., 1999). It happens when the groundwater contacted with constituents that resulting in dissolving minerals in the groundwater and carried away together. This is solely the reason how the water resources received by humans are prone to be contaminated. Half population in north Kelantan area prefers groundwater sources for domestic uses (Huda Awang et. Al., 2020). It shows that groundwater quality analysis in this area is a need as this is the source for the residents for domestic uses.

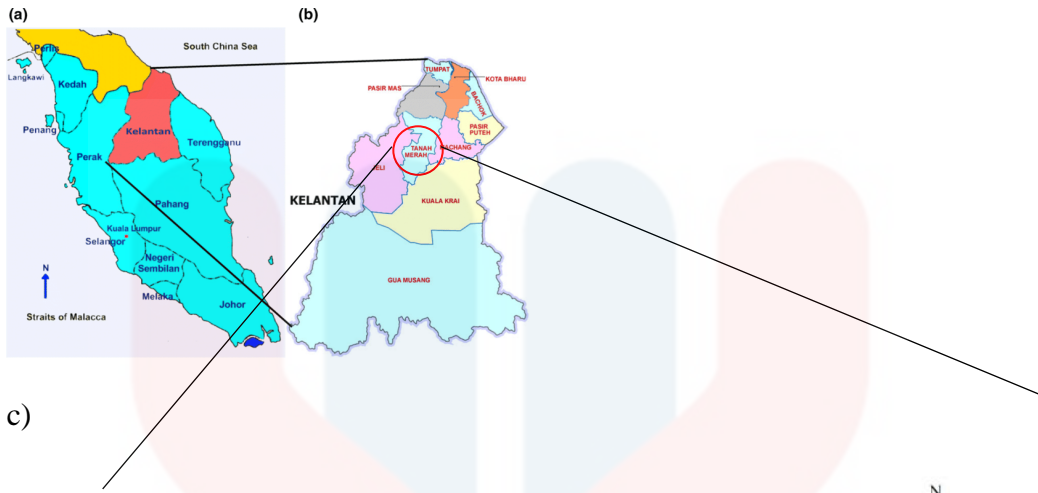
Theoretically, Kelantan state covers around 15,099 km² from the northern region of Peninsular Malaysia. Kota Bharu, Tumpat, Machang, Pasir Puteh, Bachok, Jeli, Tanah Merah, Pasir Mas, Kuala Krai and Gua Musang are a total of ten districts

available in Kelantan. Tanah Merah area, generally covers around 867.6 km². Residents in Tanah Merah prefers groundwater sources for domestic uses. Generally, residents would have a domestic well in their houses. Quality is much more important than the quantity. Therefore, the quality analysis of the groundwater from the domestic wells is significant to be done.

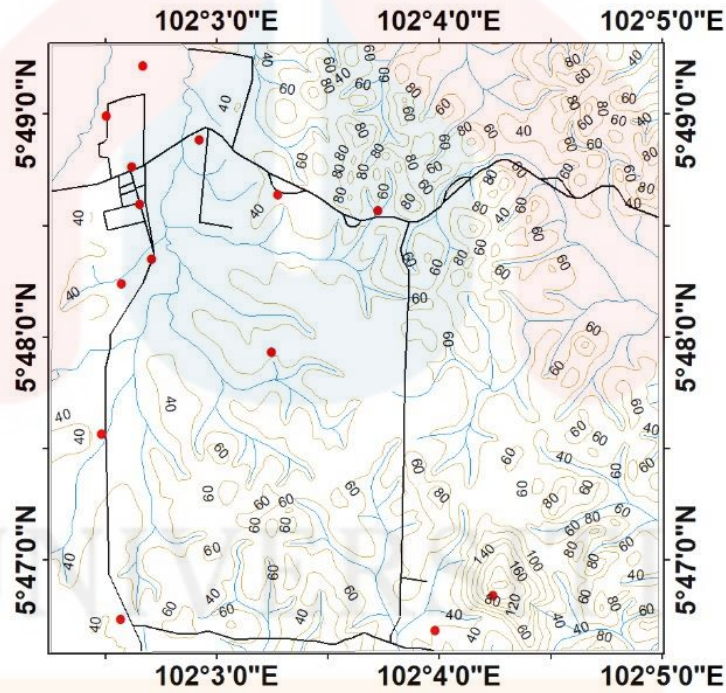
1.2 Study Area

The study area is aligned within latitude from 5° 46'34.58" N to 5° 49'20.56" N and longitude ranging from 102° 02'16.57" E to 102° 05'00.06". Figure 1.1 shows a terrain map of the study area in Kampung Ayer Asahan Hulu, Tanah Merah Kelantan.

Syed Ukasyah (2014) stated that Tanah Merah is known to be one of the areas in Kelantan that is currently developing towards an urbanized area since it was rated to be a runner-up for urban area in Kelantan after Kota Bharu. Though it is in a process of developing, this area uses groundwater supply in their daily activities. Therefore, groundwater quality should be assessed and analysed for the local's usage. The highest elevation in the study area is 160m and the lowest elevation is 40m. Study area including some villages such as Kampung Bechah Tok Kar, Kampung Jelakong, Kampung Ipoh, Kampung Cita Jaya, Kampung Petai Jernih, Kampung Batu Tujoh, Kampung Jenerih and Kampung Lalang.



BASEMAP OF KAMPUNG AYER ASAHAN HULU,
TANAH MERAH, KELANTAN



1:25,000

Figure 1.1: a) Location of study area in the map of Peninsular Malaysia; b) Location of study area in the map of Kelantan; c) Basemap of study area

In terms of accessibility, the study area mostly can be accessed with vehicles. This is because mostly there are roads connected from a place to another and villages to another. Some of the main roads that makes it easier to access around this area are Timur-Barat Highway, Jalan Kampung Bendang Nyior and Jalan Gual Ipoh.

City Population, (2020) stated that a trend in terms of the annual population change that can be observe in Tanah Merah is an increment of 2.7% annually. Compared to 2010, Tanah Merah bear a total of 115,949 people while in 2020, Tanah Merah has a total population of 150,766 people in total. This explains its population density in 2020 which is 170.5/km². University Kuala Lumpur, (2019) carried out a socio-economic study in Tanah Merah. In terms of gender population, out of 2449 respondents, 1655 of them were male domination the percentage of 67.6% and 794 of them were female with a percentage of 32.4%. Based on the data, it still shows that male is dominating in Tanah Merah district. Figure 1.2 shows a population in Tanah Merah residents in terms of gender.

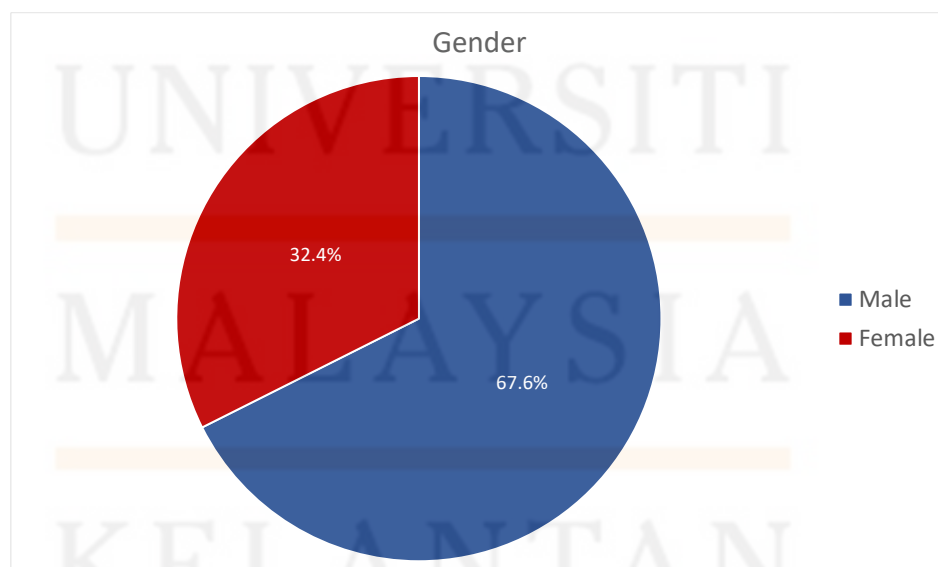


Figure 1.2: Pie chart of gender population in Tanah Merah

Source: City Population, 2020

Figure 1.2 above shows male population is higher compared to female. Figure 1.3 below shows a population in Tanah Merah in terms of ethnic group.

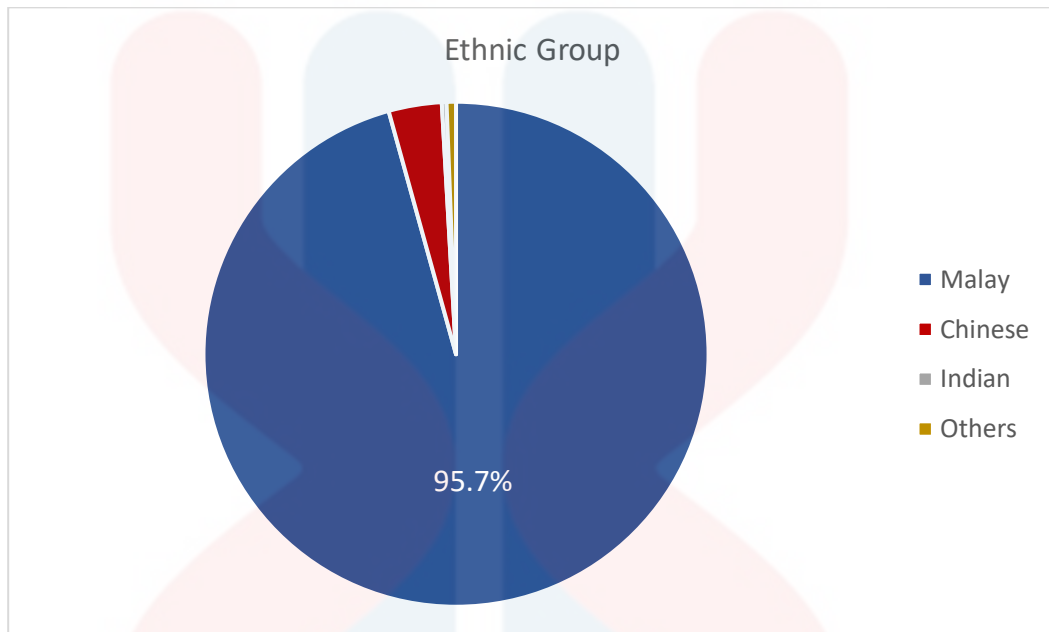


Figure 1.3: Pie chart of population in Tanah Merah in terms of ethnic group
 Source: City Population, 2020

Figure above explains that Tanah Merah district is mostly resided by Malay ethnic with a percentage of 95.7%. University Kuala Lumpur, (2019) stated that in terms of income of residents in Tanah Merah based on the respondents, 0.68% out of the households live survived with more than RM 5,000 income. A majority with a percentage of 99.3% of households live with an income of lesser than RM 5,000.

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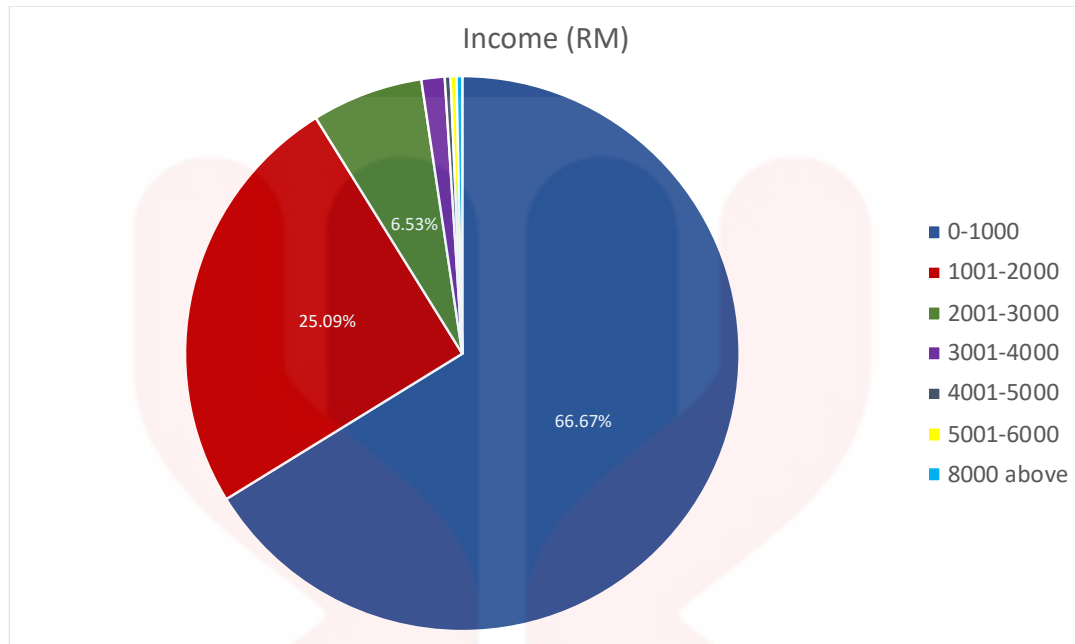


Figure 1.4: Pie chart of population in Tanah Merah in terms of household income

Source: University Kuala Lumpur, 2019

In terms of landuse, mostly the study area is covered with vegetation dominating by palm oil plantation. Since it is mostly village areas, it can be seen that other than vegetation areas, there are also stalls and shops for the residents to acquire their domestic needs. In a simple words, the study area is comprises of human activities for living such as vegetation and business areas. Figure below shows a view of the study area.

1.3 Problem Statement

Tanah Merah covers about 867.6 km² out of 15,099 km² of the whole Kelantan state. Geological map in Tanah Merah specifically in Kampung Ayer Asahan Hulu, has not been recently updated. Therefore, it is significant to update the geological map to help other beneficiaries to use the data as well for the development of the area. Not only policy makers or agencies, students also will gain a lot by referring to updated

geological map for students' further research. This is because geological structures always change over time due to external forces. By helping students for further research, it will be helpful in conserving the geological history of the area and helping future generations to continuously conserving the geological history of the area.

On October 21, 2021, the environment and water minister, Tuan Ibrahim Tuan Man said that among 1.7 million people in Kelantan, only 71.7% of them were recorded to get access to a clean water supply. He elaborated regarding the reason of this issue was because of the treatment plants in Kelantan specifically are not working in a full capacity. Only 21 out of 36 treatment plants were working at a full capacity. Since the population keeps on getting higher from years to years, the quality of water supply should be guaranteed as well along with the technology and development given over time. This is important so that lesser probability of getting diseases in conjunction of bad quality of water supply since diseases such as diarrhoea is famous as a disease for bad quality of water supply.

Shallow wells are often found in the rural areas for their domestic uses despite relying on the surface water only. Therefore, it is significant to know and analyze whether their water resources are suitable for domestic uses. Figure 1.1 shows a terrain map where shallow wells were found in houses for domestic uses.

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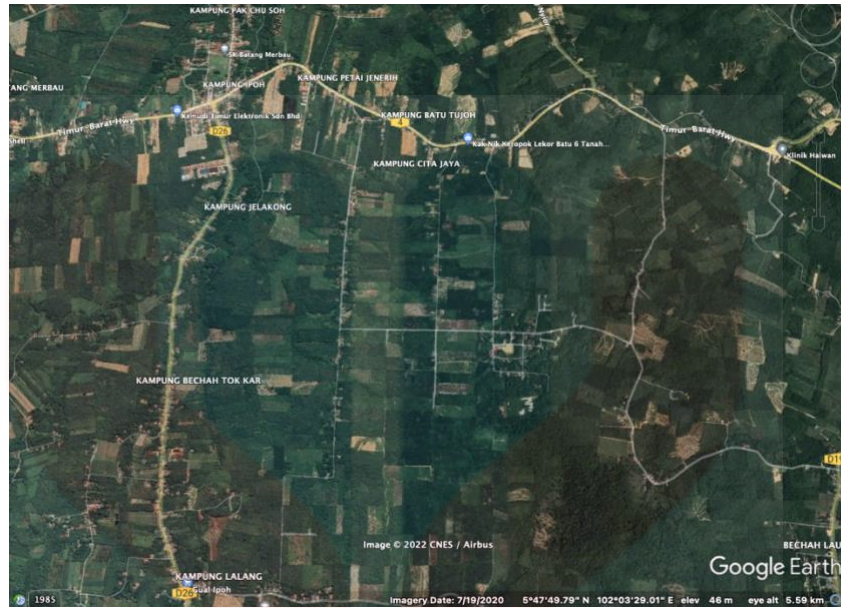


Figure 1.5: a terrain map of the study area

This shows a significant reason to conduct a research in this particular area since most of the residents rely on groundwater resources for domestic uses. Therefore, by analyzing and determining whether the groundwater resource is safe for domestic uses can help preventing side effects of consuming water supply with heavy elements that is not safe to consume.

1.3 Objectives

The objectives of the research are as follows:

1. To update geological map of Kampung Ayer Asahan Hulu, Tanah Merah, Kelantan in the scale of 1:25,000
2. To determine the groundwater quality for domestic uses in Tanah Merah, Kelantan.

1.4 Scope of Study

This research is focusing on the Tanah Merah, specifically in Kampung Ayer Asahan Hulu. This study is more on assessing and analyzing the quality of shallow wells for domestic uses within study area.

Geological mapping will be done in this particular location. This location is picked with an intention to update to the latest geological data in terms of lithology and other geological structures. Therefore, some tools will be used including geological hammer, hand lens, GPS, compass and measuring tape. These are to be used in the field. On the other hand, some outcrop samples will be brought to the laboratory for thorough observation such as mineral composition. Therefore, outcrop samples that has been cut into thin sections will be analyzed under the microscope. Data and information gathered during the geological mapping will be used in generating geological maps including drainage pattern map, lithology map and land use map. Therefore, a software will be used in this study which is the ArcGIS software.

For this study, some water samples from shallow wells will be taken and analyzed its quality whether it is safe to be used for domestic uses. Samples will be taken within the research area, which many domestic wells can be found. Different samples in different locations will be taken in order to get more variables and more accurate data and information. There are also vegetation areas, specifically palm oil plantation. Samples will be kept in a polyethylene bottle and wrapped with aluminum foil just to ensure it is not contaminated. In-situ parameters will be calculated on the field using the YS Multi-Parameter to measure of the parameters such as pH, temperature and electrical conductivity. Laboratory studies will take part next which some of tools will be used in determining the quality of the samples specifically major

cations and anions such as sodium, potassium, chloride, and nitrate. Some of the tools that will be used is the Atomic Absorption Spectrophotometer (AAS), DR900 Colorimeter and some methods such as gravitation method and titration method.

1.5 Significance of Study

Geological map is indeed one of the significant reasons why this research should be carried out. This is because geological map will be very useful not only for locals, but for government and researchers further references. There are many unanticipated beneficiaries of geological maps and data. In terms of geology, geological data resulting from mapping activities is significant for mining and mineral exploration. By having the latest geological data, it will help to locate potential areas for the exploration activities. With geological mapping, data obtained can be used for many things. Without geological mapping, even groundwater analysis research cannot be done perfectly. This is because with geological mapping, information such as lithologies and geological structures can be determined.

Groundwater quality analysis enables researchers to identify if any pollutions occurred in an area. If the water quality is contaminated, the surrounding area might be the reason of the pollution. By identifying the pollution, it is helpful for the residents to use the shallow wells for their domestic uses, agricultural purposes, and industrial purposes. Southeast Asia countries including Malaysia rely on river water, but it is undeniable that the quality of water affects humans in terms of health as well as ecosystems (Yee Ho, et. al., 2022). By analyzing groundwater quality of the area, it can act as a catalyst for development of infrastructure and inhabitants in the area.

Determining the quality of groundwater resources especially in rural areas are significant. Comparing to the urban areas where more clean water resources are supplied, rural areas tend to rely more on groundwater resources that could be acquire through shallow wells. Although shallow wells can easily be find in the rural areas in Kelantan, these areas are prone to contamination a lot since they are exposed to external factors (Wick, et. Al., 2012).

CHAPTER 2

LITERATURE REVIEW

2.1 Regional Geology

The formation of peninsular Malaysia started in the Triassic period where the Indo China plate and Sibumasu plate had a collision among each other. It is a part of Eurasian plate along with Borneo, Java as well as Sumatera. During the Cenozoic Era, tectonic activity was limited to uplift of epeirogenic as well as local gentle down warps and some tilted fault movements (Gobbet D.J. and Tija, 1973). The major components in the Eastern Belt were determined to exist since the Upper Carboniferous to Upper Jurassic and the climax of the activity of magma was believed to happen within the Upper Permian. There are many different types of rocks in Malaysia, including igneous, metamorphic, and sedimentary rocks. Some of these rocks are from the Titiwangsa Range and range widely in granitic composition. Banjaran Titiwangsa is also commonly known as the Main Range of Peninsular Malaysia.

Some other major components mentioned are such as granodiorite, adamellite and granite. These intrusive components were happened during the activity of magma which was within the Upper Permian. Granitic rocks can be broken up into two basic bodies of rock types. The majority of the granite bodies may be found within the Main Range, which can be found somewhere in the western portion of Kelantan. The most

significant mineralization took place during the granitic emplacement and was typically associated with faulting. There are many faults throughout the entire geological structure. There have been no less than three different sets of faults, and towards the beginning of the Cretaceous epoch, the youngest of these faults was projected (Hutchison & Tan, 2009).

2.2 Tectonic Setting

Three parts in Peninsular Malaysia classification which are Central Belt, Western Belt and Eastern Belt. The Eastern Belt was an extension from Kelantan to Johor. Since Peninsular Malaysia can be classified into three major belts, every each of the belts represents different geological characteristics. Bentong-Raub Suture Zone and Lebir Fault Zone are boundaries that separating each belts. Theoretically, Peninsular Malaysia is located on the Sundaland, which is the East part of the Eurasian Plate. In terms of tectonic setting, there are two factors affecting earthquake activities in Peninsular Malaysia which are regional and local. The India-Australian Plate advances northeastward and subducts under the Eurasian Plate in West Malaysia, generating the Sunda Trench, which is part of the broader Sunda-Java-Sumatra Trench. The subduction zone resulted in the formation of active dextral strike slip fault zone in Sumatra Fault Zone. Local tectonics are defined by major faults and fault zones. The alteration of tectonic setting in South East Asian region after massive earthquakes that happened back in December 26, major fault lines were reactivating.

2.3 Stratigraphy

Stratigraphy is more to examining and determining the rock strara, layerings and stratification. This part is significant in determining the age of the rocks in the area and correlate with the geology and the research study.

Generally, in Kelantan, it consists of mostly metasedimentary and sedimentary rocks. As an example in Jeli district such as Sungai Pergau and Sungai Senolek, in terms of lithostratigraphy, mostly phyllite rocks were found in those areas. In terms of granitic intrusions, the central part of the region as those areas such as the Ulu Lalat of batholith. Figure 2.1 shows a geological map of Kelantan.

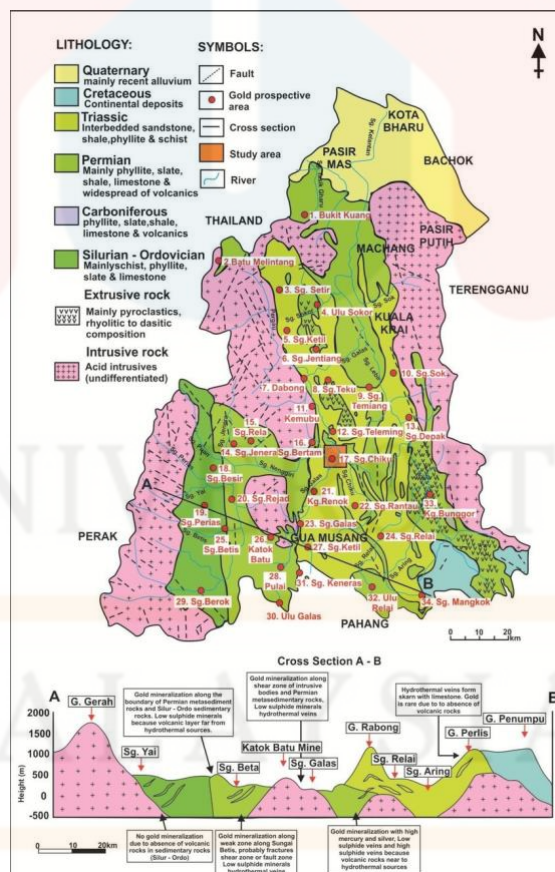


Figure 2.1: Geological map of Kelantan
(Source: Mohd Hariri Ariffin, et. al., 2018)

The geological formation of Kelantan may be separated into three primary chronologies, which are the Paleozoic, Mesozoic, and Cenozoic periods, and they extend in time from the Lower Paleozoic to the Quaternary (Hutchison & Tan, 2009).

In the middle of Peninsular Malaysia, the Paleozoic formation can be seen in Kelantan. Aside from that, the Gua Musang Formation and the Aring Formation in south Kelantan are both made up of Upper Paleozoic rocks. These rocks are made up of marine Permian layers, and arose as linear belts with Mesozoic deposits in the Central Belt. Along with calcareous and arenaceous facies, argillaceous and volcanic facies have successfully colonised the Upper Palaeozoic strata (Lee, 2004). Figure 2.2 shows a classification and correlation of Palaeozoic formation in Peninsular Malaysia.

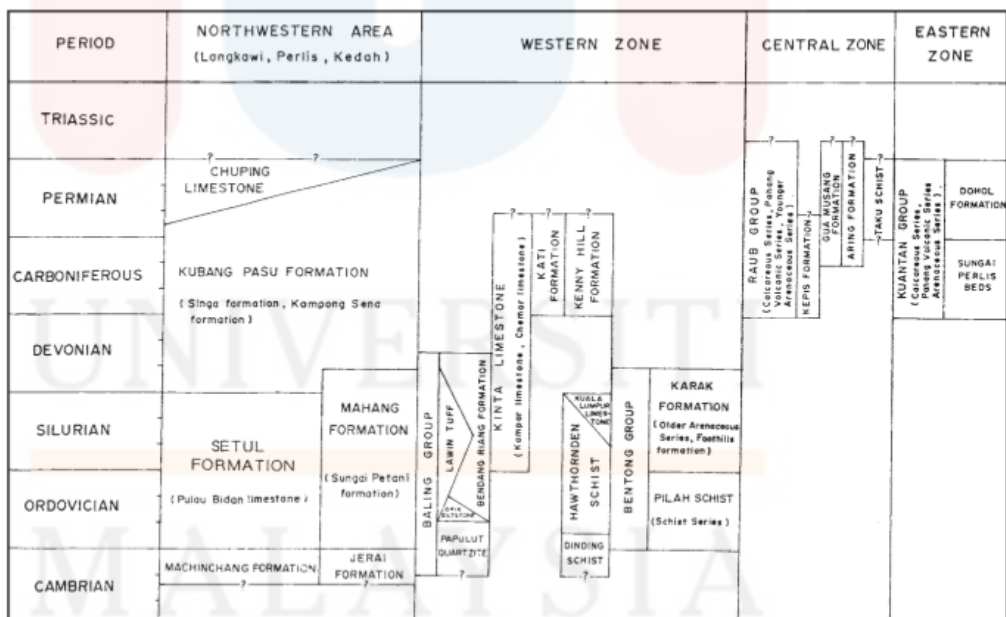


Figure 2.2: Classification and correlation of Palaeozoic formations in Peninsular Malaysia

Source: Foo, 1983

A significant area of the newly created landmass that is now the Peninsula of Malaysia was uplifted and exposed to the subaerial environment at the beginning of the Mesozoic Era. Mesozoic formation has complete control over the middle belt, which forms the uninterrupted north south trending belt extending away from the intercontinental boundaries with Thailand in the north and Singapore in the south. Mesozoic rocks were represented in the Eastern Belt as well including Kelantan. It can be seen as Lesong sandstone, Tebak Formation, Pantii sandstone and Badong conglomerate. Other than that, the Telong Formation is also the most common type of sediment found in deeper marine turbidite. These sediments are often a tuffaceous nature, and the volcanic interbeds can be found in the southern part of the region (Leman, 2004). Figure below shows the distribution and stratigraphic relationships of the Mesozoic strata in the Peninsula Malaysia. Figure 2.3 shows a distribution and stratigraphic relationship of the Mesozoic strata in Peninsular Malaysia.

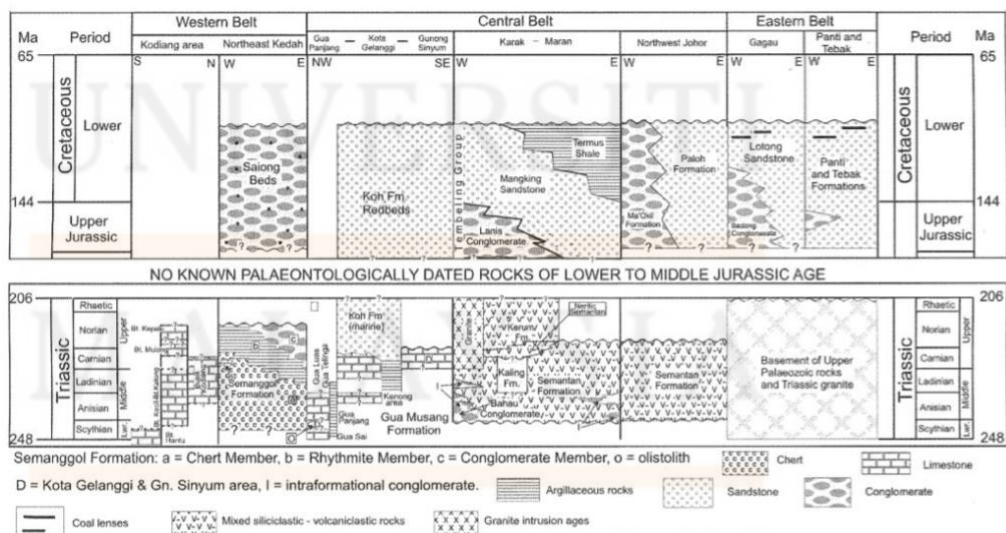


Figure 2.3: distribution and stratigraphic relationships of the Mesozoic strata in the Peninsular Malaysia

(Source: Mazlan Madon, 2017)

Cenozoic formation is made up of sedimentary deposits from Quaternary period. The Quaternary sediment that surrounds the north division of Kelantan is primarily made up of unconsolidated to semi-consolidated boulders, gravel, sand, and silt in addition to clay that lies beneath the coastal and inland plain. To the south-west of it is the well-known magmatic Stong Complex, which is thought to be an injection complex that originated from the hybridization of Palaeozoic rocks by an intrusion of Main Range granite (Macdonald, 1968). In the northern portion, the Main Range granite intrusive breaks through the core sedimentary and meta-sedimentary zone, which is occupied by the foliated Kemahang granodiorite body (Brodie et al., 2007). Figure 2.4 shows the Cenozoic correlation in Peninsular Malaysia.

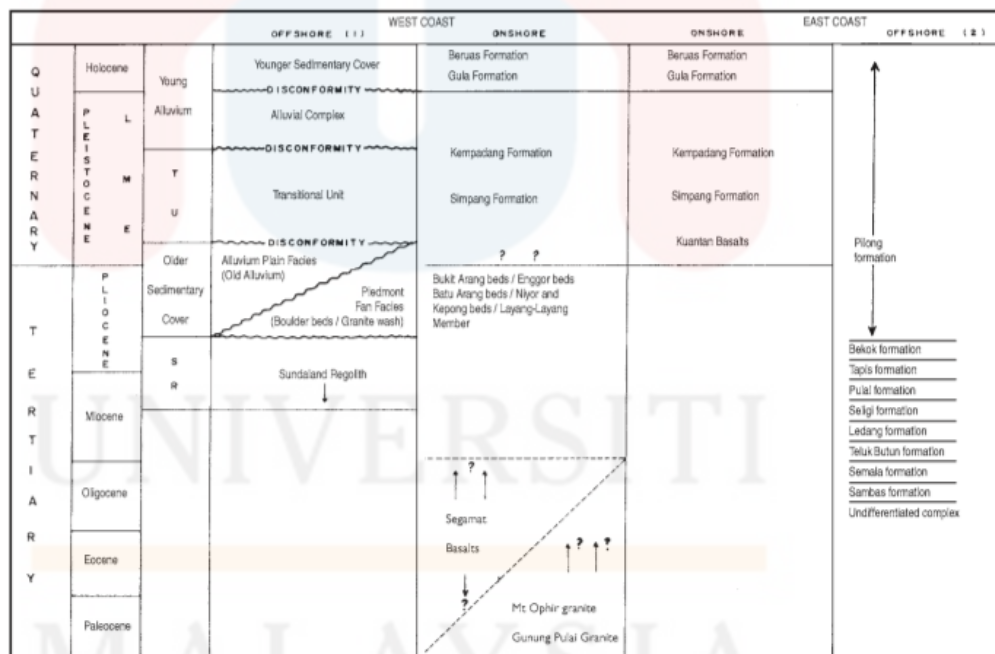


Figure 2.4: Cenozoic correlation chart in Peninsular Malaysia

Source: Suntharalingam, 1983

2.4 Structural Geology

Tanah Merah district is dominated by andesite including andesite flow, andesitic, andesitic tuff and agglomerate. It is made up of extrusive rock, which is a volcanic rock that ranges from intermediate to basic in composition. Malaysia and Thai Working group (2006) stated that based on their findings, these rocks are predominately composed of pyroclastic material, which is primarily composed of andesitic tuff. Additionally, it is possible that the associated sedimentary rocks were deposited at the same time as the pyroclastic material. Agglomerate and andesitic tuff, both of which are sheared quite severely, make up the vast majority of the volcanic rocks (Brodie et al., 2007).

The Palaeozoic sequence is strongly marked by close fold, notably in the Silurian-Devonian succession. This is especially true for the later parts of the sequence. There is a pervasive presence of insignificant structures, such as tight folding on a small scale and comparable folding. It has been discovered that every rock unit contains faulting, and the majority of the faults have a widespread and nearly vertical fracture, with just a very minor amount of displacement taking place within them. Despite this, the majority of the major faults were aligned in a direction running from northwest to northeast (Malaysia and Thai Working group, 2006). In addition, the strata of the Tiang Schist Formation and the Mangga Formation show gentle to steep dipping, and the Manga Formation has gentle folding (Hutchison & Tan, 2009).

2.5 Historical Geology

Kemahang Granite can be found in the research area. This pluton is located in the most northern region of the Central Belt in Peninsular Malaysia. This area is bounded by the Gua Musang Formation (MacDonald, 1968). It is laterally continuous with the Stong Complex to the west and intruded into the most northwestern portion of the Taku Schist. It was formerly known as the Noring Granite, and it extends westwards all the way to Perak. In Malaysia, it covers Bukit Jeli, Bukit Kemahang, Bukit Kusial and other lesser hills. Granite generally forms a mountain range that trends north to south and extends from Narathiwat Province in the eastern coast of the Thai Peninsular all the way to Sukhirin District in the southernmost part of the range. After that, it keeps going until it reaches the town of Jeli on the Malaysian side. (Malaysia, T., and Groups. W, 2006).

This granite is characterised by coarse-grained porphyritic granodiorite. Shearing deformation within granite resulted to the appearance of augen textures near the Stong Complex plutons. When there is metamorphic foliation present, the quartz crystals break up and become partially recrystallized. This is also shown in the microgranite that is located in the most western region of the unit, which possesses highly schistose fabrics (McDonald, 1968). According to Khoo (1980), the formation of clastic granite gneisses results from the development of a shear or fault zone following the initial emplacement of the granite.

2.6 Groundwater

Prime Minister, Datuk Seri Ismail Yaacob stated that nowadays groundwater is only being used in states such as Kelantan, Terengganu, Pahang, Sabah and Sarawak. Despite these states, only 3% of groundwater is being used. Comparing to other countries that make use of groundwater supplies such as United States (50%) and Thailand (80%), Malaysia can actually discover and use more groundwater supply for domestic uses. With reserving and taking care of groundwater quality today, it can be helpful for future generations to get fresh water foreseeing the increasing demands of fresh water supply in the future (Mohammed, et. Al., 2009). Figure 2.5 shows a hydrogeological map of Kelantan.

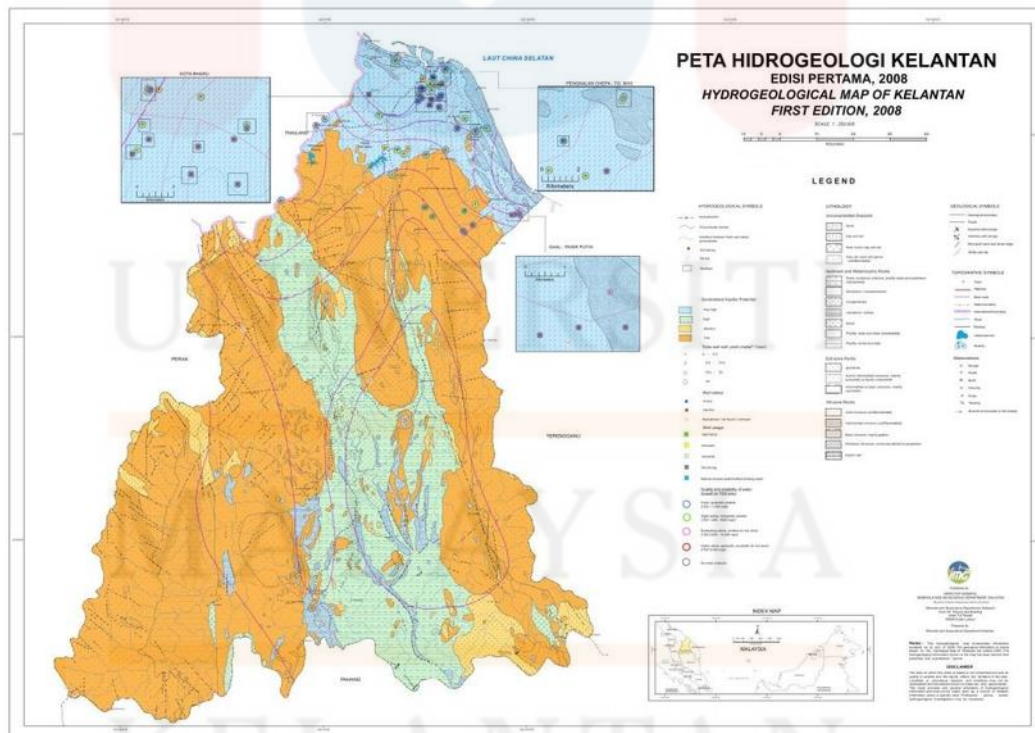


Figure 2.5: hydrogeological map of Kelantan

Source: Ami Hassan, et. al., 2015

The total dissolved solids (TDS) is one of the ways to determine the water quality of a water sample where the water sample will be dried and the TDS is measured (Fetter, C.W., 2001). Different constituents are measured with different tools. As an instance, cations such as sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) are measured using the Atomic Absorption Spectrophotometer (AAS). Gravimetric method is used cations such as sulfate (SO_4^{2-}). Titration method is used for major anions such as chloride while colorimetric method is used for minor anions such as nitrate (NO_3^{2-}) and fluoride (F^-). Though usually nitrate concentration does not exceed 10 mg/litre in drinking water, in some places specifically in a sewage area or industrial locations, nitrate concentration could be higher than expected (WHO, 2008). Table 2.1 below shows a table of Guideline for Drinking Water Quality (GDWQ) from the World Health Organization (WHO). Table 2.2 shows a water classification based on total dissolved solids (TDS).

Table 2.1 shows the Water Quality Guidelines for domestic uses according to WHO

Elements	Value (ppm)
Sodium	≤ 200
Calcium	100
Magnesium	150
Nitrate	50

Table 2.2 below shows the water classification based on the total dissolved solids.

CLASS	TDS (Mg/l)
Fresh	0-1,000
Brackish	1,000- 10,000
Saline	10,000-100,000
Brine	> 100,000

Source : Fetter, C.W., 2001

Other than the physiochemical analysis of the groundwater, some in-situ parameters can be measured on-site. In-situ parameters are including the temperature, pH, water level and conductivity (Anun Pratap Mishra et.al., 2021). This can be measured using the multi-parameter tool.

2.5 Past Research Studies Regarding Groundwater Quality

Some research studies in this field were carried out in the past. Mohamad Abd Manap (2010) stated that groundwater is in demand specifically in areas that did not have sufficient amount of water supply. In Kelantan and Perlis, groundwater is significantly important for general water supply uses (Mohamad Abd Manap, 2010). There were also some other research carried out around the study area. It shows that some of the locations were having a good quality of groundwater resources while some other locations were not. This research study aims to update the data regarding the water quality around the area. Sunita, et. al., (2014) stated that villagers are so far most vulnerable to water contaminants because villagers are relying on water resources from domestic wells and agricultural purposes.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

There are some materials and methods that will be used in conducting this research study and achieve the objectives of the research. This study is divided into two, geological mapping and groundwater sampling for water quality analysis.

In geological mapping, some of the activities that will be carried out includes traversing, geomorphological studies that include outcrop sketching and landform and landuse determination and outcrop sampling. For groundwater sample, there are two activities that will be carried out which is field study and laboratory study. In field study, other than collecting water samples, the in-situ parameters will be calculated such as pH value using the multi-parameter.

In laboratory work, outcrop samples that has been collected during geological mapping will be analysed under microscope for a better view. Other than analysing lithology, the data can be used for map generation. All the data and information will be gathered and compiled into the ArcGIS Software to generate geological maps. For groundwater quality, several methods will be carried out such as titration method, colometric method and gravitation method. These methods are being used since every methods determines different types of elements. After the data obtained from all

methods, the data regarding the elements in the water samples will be converted into percentage and will be plotted into diagrams such as Piper Trilinear Diagram.

3.1 Preliminary Study

Before initiating geological mapping and sample collection, preliminary studies and researches are done. This includes the background of the study area specifically regarding the lithologies, past researches regarding groundwater quality assessments in the study area and the geological structures. This basic data can help to achieve the objectives. Preliminary study also includes survey of study area to see its accessibility towards vehicles, the availability of domestic wells for samplings and to see the possibility of outcrops availability for outcrop sample.

3.2 Material

3.2.1 Geological mapping



Figure 3.1: materials needed for geological mapping

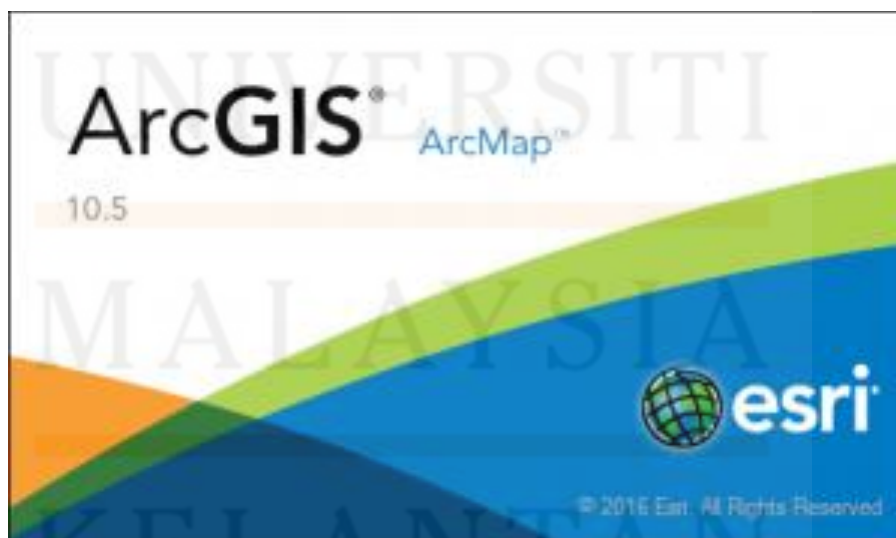


Figure 3.2: ArcGIS software that is being used for map generation

In geological mapping activity, equipment such as GPS, Brunton Compass, hammer, hydrochloric acid and measurement tape is being used throughout the activity along with topographic map with 1 : 25,000 scale.

Some tools are being used in geological mapping such as GPS, Brunton compass, geological hammer, measurement tape, hand lens, hydrochloric acid, fieldwork notebook and sample bags. GPS navigates the way around and using it means it will be related to the latitude and longitude in terms of location. Brunton compass will be used for determining direction and azimuth throughout geological mapping activity. It will also be used in calculating strike and dip of a bedding. This particular acid is being used in order to identify limestone rock, where this rock will react whenever encounter hydrochloric acid. Hammer is being used in order to acquire samples from outcrops and will be kept in sample bags. A measurement tape is used for measurements in centimetres and meters such as outcrop measurements or area measurements. Petrography analysis will be done starting with the outcrop samples that will be obtained will be analysed under microscope for better view regarding the mineral composition, other than analysing the outcrop texture, grain size and other properties of a rock.

3.2.2 Groundwater Sampling

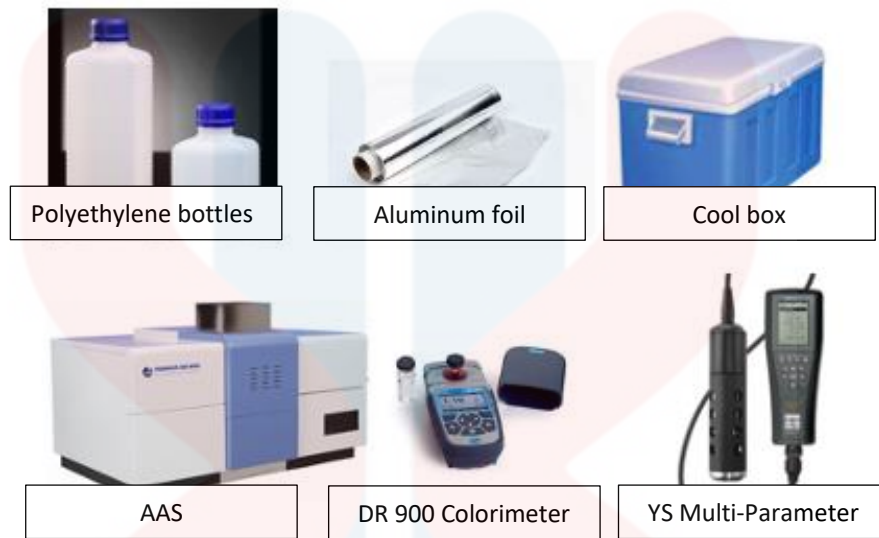


Figure 3.3: materials needed for groundwater sampling

Polyethylene bottle will be used instead of glass materials or teflon materials due to sustainability and price-wise factor. Polyethylene bottles should be cleaned up beforehand before starting to collect samples with it. Aluminium foil is significant to use in order to wrap the polyethylene bottles in order to prevent any contamination of water samples while being stored or transported. A cool box will be used to store water samples throughout the process of transportation from the field to the laboratory. Atomic Absorption Spectrophotometer is specifically being used in order to determine the chemical elements in a liquid sample. The sample will be analysed according to the energy absorbed from its wavelengths. A multi-parameter is used to determine the in-situ parameters such as pH and electrical conductivity. This particular multi-parameter is being used on the field instead of using it in the laboratory. Colorimeter or colometric method is being used in order to determine the concentration of ions specifically nitrate ion (NO_3^-) and fluoride ion (F^-). This particular method uses wavelength scanning as a way to detect the ions available in the groundwater samples.

3.3 Data Collection

In geological mapping activity, it will take around two to three weeks in order to complete the study area which covers 25 km². In geological mapping, traverse, geomorphology studies, outcrop sample collection as well as strike and dip measurements are being carried out. Since the mapping will not cover all Tanah Merah area but only around 25 km², geological map will be generated specifically for the study area. Some of the maps that will be generated are geological map, drainage pattern map, landuse map, landform map, traverse map, watershed map, lithological map and lineament map. These maps are generated using ArcGIS Software using the data obtained from geological mapping.

Data collection for groundwater samples uses polyethylene bottles, aluminium foils and a cool box preserved with ice in it. These are significant in order to preserve the quality of the samples taken in the field. Therefore, unwanted contaminants can be avoided throughout the processes before going to the laboratory analysis. With preserving the water sample in ice around 4°C, contamination will likely can be prevented. Groundwater samples will be taken from shallow wells mainly from household areas since the water is being used daily for their daily needs. Since the study area is not covering the whole Tanah Merah area but only certain areas, a total of 20 samples will be taken around study area.

3.4 Data Analysis

The outcome and data from geological mapping will be compiled into ArcGIS software to generate maps such as geological map, drainage pattern map, landuse map, lineament map, landuse map and landform map. For outcrop samples, the samples will be cut into thin sections before analysing them under microscope. Analysing them under microscope is significant in order to determine some of the crucial features such as mineral composition and textures. These data will be used in lithology map. The maps that will be generated using the ArcGIS Software.

In groundwater sampling, the samples will be taken into laboratory for analysis. Some of the elements need different methods to analyse. Therefore, multiple tools are being used in this study since some elements are crucial to be determined to ensure the water quality for domestic uses. Gravimetric method is being used in order to acquire the sulphate which can be acquired in the form of barium sulphate. This is because sulphate as the product is comes in the form of barium sulphate which is in the hydrochloric acid solution. Barium chloride will be added into the solution that results in the precipitation of sulphate. Titration method is being used in order to determine the acidity and alkalinity of the groundwater samples. For this method to be carried out, equipment such as burette, pipette, volumetric flask, stirrer are involved. Colorimetric method is also being used using the DR 900 colorimeter to determine elements such as nitrate ion (NO_3^-) and fluoride ion (F^-).

The data will then be converted into percentage form and the next step will be plotting step. Piper Trilinear Diagram is being used where all the percentage data will be plotted into the diagram for determination of elements. The data will then being compared to the MOH and WHO values in order to determine whether the elements value in the water samples are in a safe limit for domestic uses.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This chapter comprises more on the geology perspectives during geological mapping such as geography, geomorphology process, weathering, drainage system, and information regarding the study area such as the accessibilities in and about the area. Therefore, some maps were shown within this chapter such as geological map, drainage pattern map, topographic map, and slope map. The localities of sample collection were comprised in a map called as locality map and petrography analysis of thin section were also being discussed in depth.

Geomorphology is concerning more on to the study of Earth surface features. It includes the origins and processes includes that changed and made a variety of different landforms in a specific area over a period of time. The study of geomorphology enables researchers to observe the change and development on an area and relate it to the processes that occur in that area. Some of the geomorphology studies are including a variety of landforms such as mountain, low hills and plains. Whereas these study is affected by some of the geological structures such as topography, drainage system, faults as well as the weathering level in the study area.

Structural geology focuses on the processes that lead and affect the formation of geologic structures. Structural geology comprises as well as to how it plays the role in the change of rock properties in terms of physical and chemical composition. Structural geology may be in a microscopic and macroscopic sizes. For an instance, it can be a small, simple fold that proves deformation process happened in that specific area or it can be a mid-ocean ridge that covers almost the entire Earth.

4.2 Location and Accessibility

Study area is located within latitude of $5^{\circ} 46'34.58''$ N to $5^{\circ} 49'20.56''$ N and longitude from $102^{\circ} 02'16.57''$ E to $102^{\circ} 05'00.06''$ as shown in Figure 4.1. It mainly comprises of a main road known as East-West Highway that is used to access to the location of study area from Jeli as well as Kota Bharu, Kelantan. In this research study, it mainly aims to determine and analyse whether groundwater sources that were currently being used by the residents and industrial or agricultural uses are in a permitted range for uses such as drinking and other domestic uses.

The study area was mostly accessible. There were main roads such as East-West Highway which lies along the study area, Jalan Gual Ipoh and Jalan An Naim. There were also a lot of estate roads for residential areas residing deeper into the study area. Most of the area were accessible for small cars and motorcycles which were some of the transports that were being used during geological mapping activities. Paved roads such as the East-West Highway comprised the south part of study area where it is easily accessible by car. But other than that, there were more estate roads in this study area that interconnects villages to other villages. These roads are mainly being

used by the residents as a route to go to plantation areas where the roads were heavily damaged and its safer to traverse with motorcycle or by walking.

The study area mostly comprised of residential areas in villages and agricultural activities carried out by them. Most of the locations in the study area can be seen to have oil palm plantation and rubber plantation particularly in the early phase of plantation. There were some areas that were in the midst of cutting activities for construction. Some outcrops were taken and was seen during traversing activities. Figure 4.2 shows a traverse map that was done in the study area. The area that was not covered in terms of traversing were mostly agricultural areas that were inaccessible due to prohibited areas.

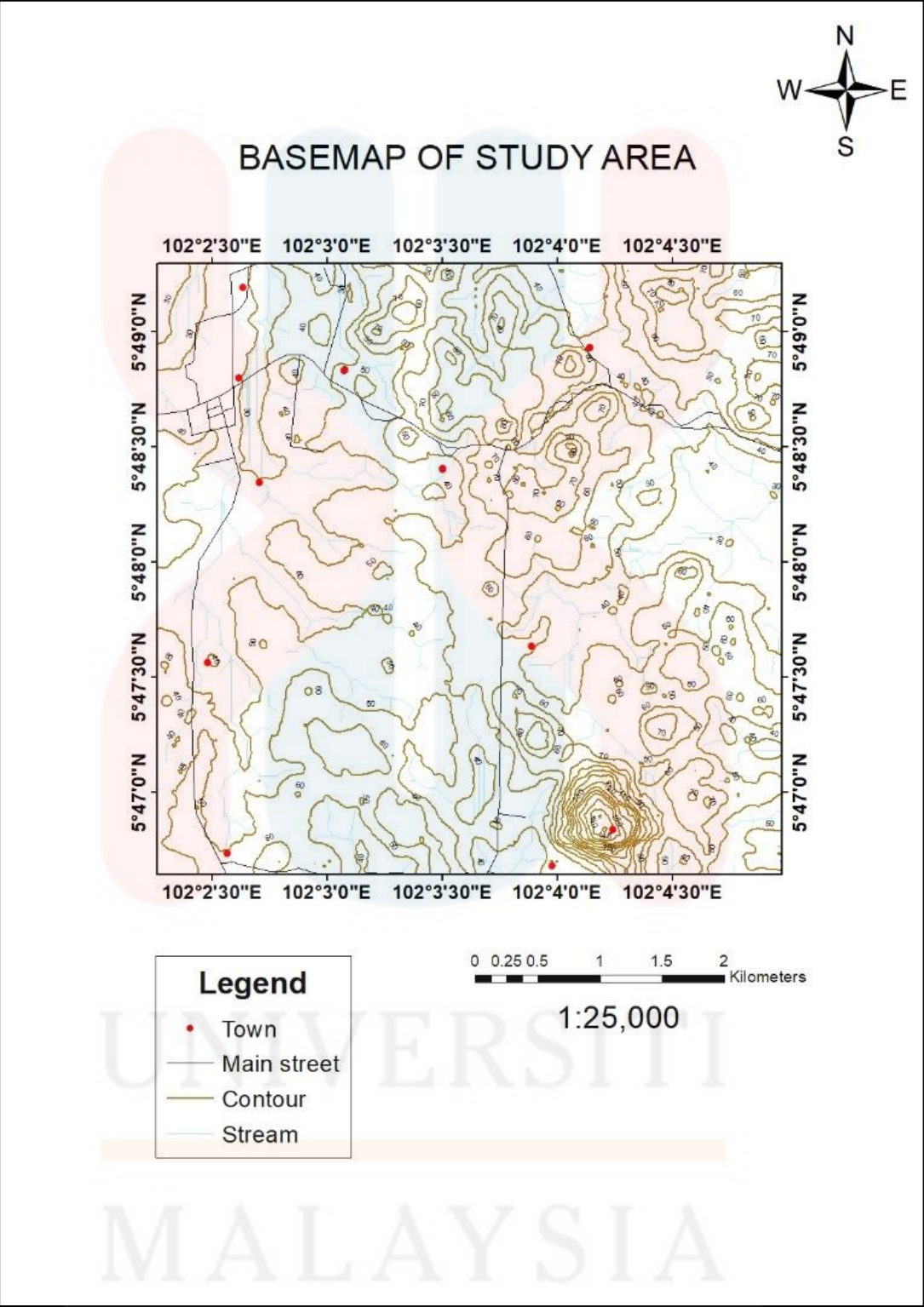


Figure 4.1: Basemap of study area

Source: Generated from ArcGIS (2022)

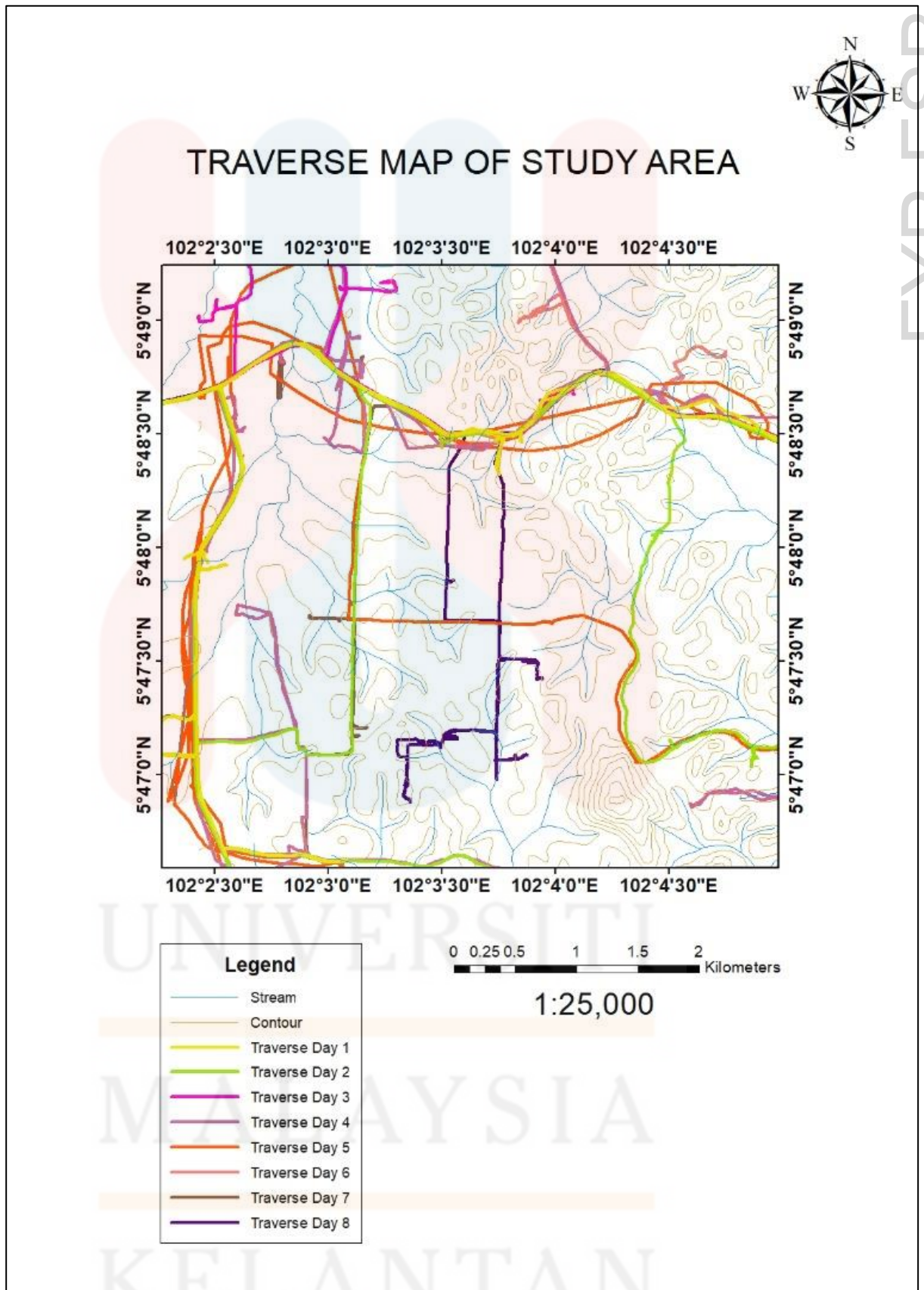


Figure 4.2: Traverse map of study area

Source: Generated by ArcGIS (2022)

4.3 Rainfall Distribution and Climate

The climate of Malaysia is classified as equatorial, showing that it is hot and humid throughout the whole year. Malaysia is a state in Asia that is located just north of the equator. There is no discernible change from one season and the other, and the temperatures remain high and stable. The Northeast and Southwest monsoon seasons both have an effect on the properties of the rainfall. A slight increase between March and August, when highs hover around 32/33 °C (90/91 °F), and a slight decrease between November and January, when highs generally drop to 29/31 °C (84/88 °F), at least in the north, and a slight increase between March and August, when highs drop to 29/31 °C (84/88 °F), but it is felt because of the high humidity. All through the year, the low nighttime temperatures average approximately 23–25 degrees Celsius (73–77 degrees Fahrenheit) and nearly never go below 20 degrees Celsius (68 degrees Fahrenheit). The nation receives a substantial quantity of yearly rainfall during these monsoon seasons, measuring between 2,000 and 4,000 millimeters and experiencing between 150 and 200 days of precipitation (Department of Meteorology Malaysia, 2012).

In Malaysia, there are many hydrological stations developed in order to observe several factors and are divided into different stations. Figure 4.3 shows the hydrological stations specifically in Kelantan where it comprises of different stations such as rainfall stations, evaporation stations agrohydrology stations and others. Based on this, there are approximately 64 stations only for rainfall data collection stations in Kelantan.

Kelantan extends approximately 40 kilometres from west to east and more than 150 kilometres from north to south. With a maximum temperature of only 31 degrees

Celsius on average throughout the year, Kelantan is the coolest location in all of Malaysia. The weather is sometimes nice, but it is also tropically humid due to the high levels of humidity and the high temperatures. It is warm to hot throughout the whole year, and the water temperature, on average, is 29 degrees, making it inviting for bathing. The months of February through April offer favourable travel conditions due to lower average monthly precipitation. The months of October through December have the greatest amount of precipitation.

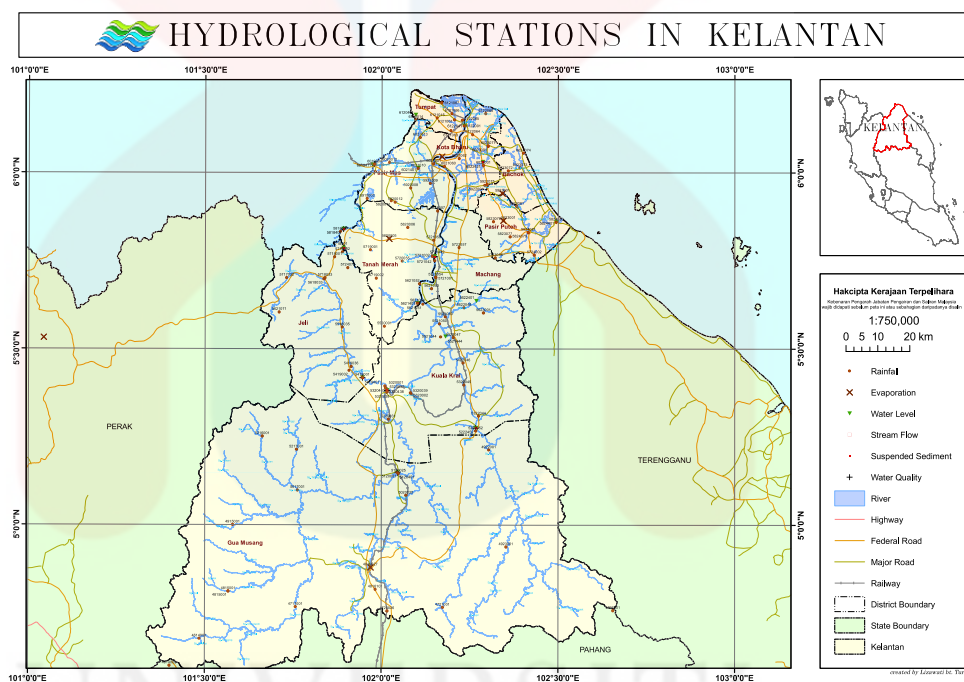


Figure 4.3: Hydrological stations in Kelantan

Source: Department of Irrigation and Drainage (n.d.)

Figure 4.4 shows a graph of data comprising average annual Mean-Temperature of Kelantan in 1901-2020. Despite the fact that there is natural fluctuation, the temperature of the Earth's surface is continuing to rise. The progression of the historical record for Malaysia is depicted in the figure.

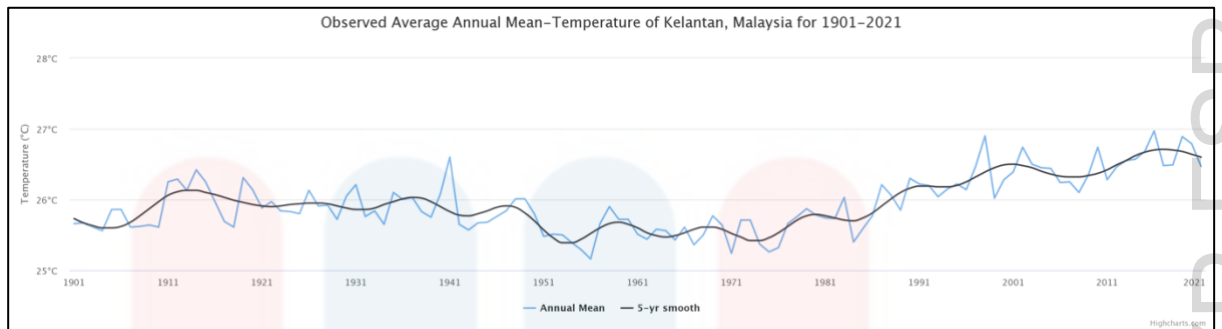


Figure 4.4: Average Annual Mean-Temperature in Kelantan in 1901-2020

Source: Climate Change for Knowledge Portal (2020).

There are several factors on the difference in rainfall distribution in different states moreover in monsoon seasons. This is because during monsoonal seasons, the East-coast of Peninsular Malaysia including Kelantan are receiving extreme heavy rainfalls resulted by the difference in the movement of winds because of the pressure difference between the land and ocean. This could be worse if the heavy rainfalls to combine with the global climatic change that will probably leads to a heavy flood like how it happened on December 2014.

4.4 Landuse

The word "land use" is used to refer to the ways in which humans make use of land. It is a representation of the cultural and economic activities that are carried out in a particular location. There are often vast differences in the uses that are made of public and private property. For instance, the development of urban areas on grounds that are controlled by the government does not happen very often, and the protection of privately owned lands as wilderness areas does not happen very often either. Changes in land use take place continuously and can take place on a variety of scales. These changes can have direct and indirect effects on the quality of the air and water, the function of watersheds, the generation of waste, the extent and quality of wildlife

habitat, the climate, and human health. Land can be used for a variety of purposes, including agriculture, residential or commercial development, mining, industry, or even recreational pursuits. Figure 4.5 and 4.6 shows different agricultural types found in study area.



Figure 4.5: oil palm plantation in study area



Figure 4.6: Early phase of rubber plantation in study area

4.5 Geomorphologic process

Various geological processes, such as temperature fluctuations, freezing and thawing, chemical reactions, seismic shaking, and the movement of wind and water, contribute to the formation of the geomorphologic characteristics of various landforms.

Highest elevation in the study area is 160m and the lowest elevation is 30m. Generally, it comprises low hills and mostly plain areas. Figure 47 shows geomorphology in an area in study area.

*a)**b)**c)*

Figure 4.7 a), b) and c) shows the geomorphology and mountains that can be seen from a coordinate of N 5° 46'54", E 102° 3'21".

4.5.1 Topography

Referring to the topographical map, it can be said that most region in study area are consisting low hills and mostly plain areas. Highest elevation in the study area is 160m and the lowest elevation is 30m. Plain areas dominating almost every part in the study area except at the south-southeast part where low hills 100m to 160m elevations located at. That particular area in south-southeast area shows a more frequent contour lines indicating the steep slope compared to other areas where the contour lines are less frequent showing that other areas have a more gentle slope compared to the south-southeast area. Figure 4.8 is showing the topographic unit of study area.

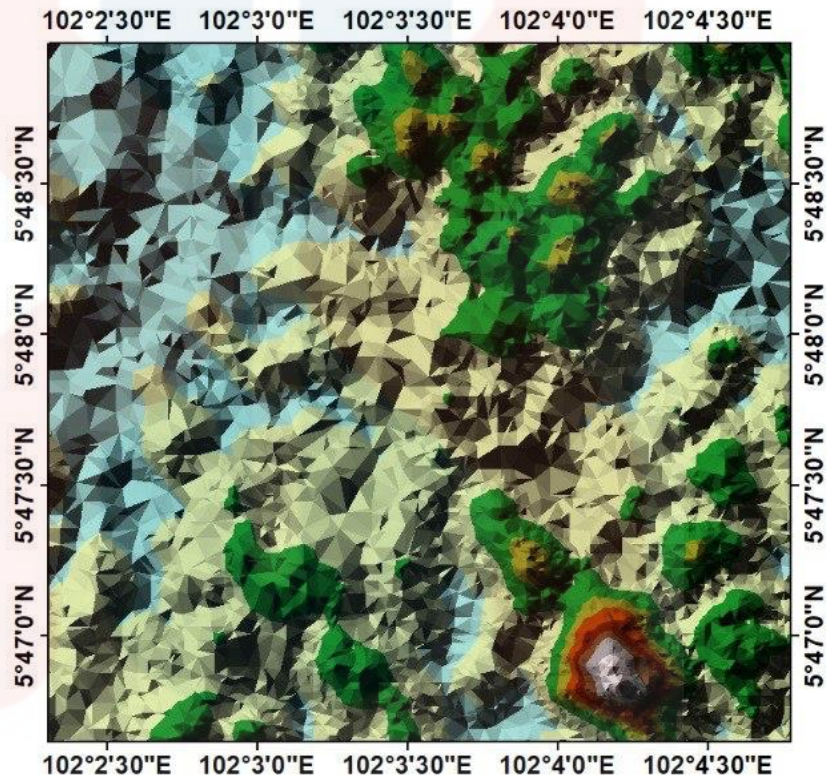
Table 4.1: Topographic Unit and Mean Elevation Standard in Study Area.

Topographic unit	Mean Elevation Above Sea Level (m)	Category of Study Area
Low lying	<15	
Rolling	16-30	Study area
Undulating	31-75	Study area
Hilly	76-300	Study area
Mountains	>301	

MALAYSIA
KELANTAN



3D TOPOGRAPHIC MAP OF STUDY AREA



Legend	
Elevation	
156.446 - 172.901	
139.99 - 156.446	
123.535 - 139.99	
107.08 - 123.535	
90.624 - 107.08	
74.169 - 90.624	
57.713 - 74.169	
41.258 - 57.713	
24.803 - 41.258	



1:25,000

Figure 4.8: Topographic map of study area

Source: ArcGIS Software, 2022

4.5.2 Drainage Pattern

A drainage pattern is the pattern that is generated in a given drainage basin by the streams, rivers, and lakes in that basin. They are determined by factors such as the topography, the predominance of hard or soft rocks in a given location, and the slope of the land. The drainage pattern of a certain drainage basin is the pattern that is created by the streams, rivers, and lakes in that drainage basin. In the eyes of geomorphologists and hydrologists, streams are often considered to be components of drainage basins.

A drainage basin is a geographic region from which a stream receives runoff, throughflow, and groundwater flow. Drainage basins are also known as watersheds. The topographic barriers that separate drainage basins from one another are collectively referred to as a watershed. They are influenced by the topography of the land, the gradient of the land, and whether or not a specific location is dominated by hard rocks or soft rocks. A drainage pattern is a pattern produced by stream erosion over an extended period of time. This pattern shows features of the sort of rocks and geologic structures that are present in an area of the landscape that is drained by streams.

Basic drainage patterns, such as dendritic, parallel, trellis, and rectangular, have specific geologic implications, and modified drainage patterns, which differ from the basic patterns in some regional aspect such as in terms of closer or wider spacing of tributaries, are possible where multiple controls influence drainage. Dendritic drainage patterns are characterised by a network of branches that radiate outward from a central point (Howard, 1967). Figure below shows some for the types of drainage pattern and map of drainage pattern in study area respectively.

Based on Figure 4.12, study area comprises mostly dendritic drainage pattern and some are also rectangular pattern. Dendritic patterns, which are by far the most frequent, emerge in regions where the rock or unconsolidated materials underneath the stream does not have a specific fabric or structure and may be eroded readily in all directions. This is the case in the vast majority of instances. In regions with very little topography and a system of bedding planes, fractures, or faults that create a rectangular network, rectangular patterns have a tendency to emerge and take on a variety of different configurations.

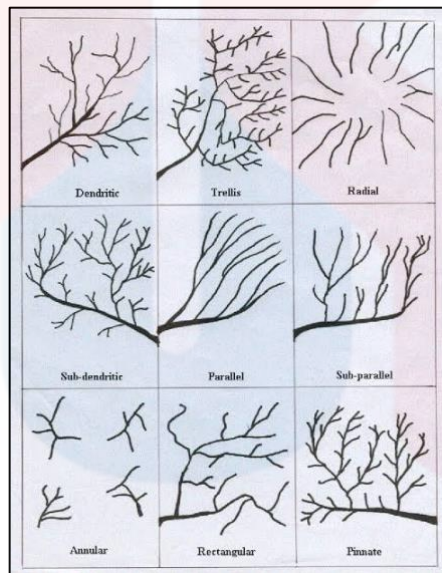


Figure 4.9: Types of drainage patterns

Source: Geology In (2022)

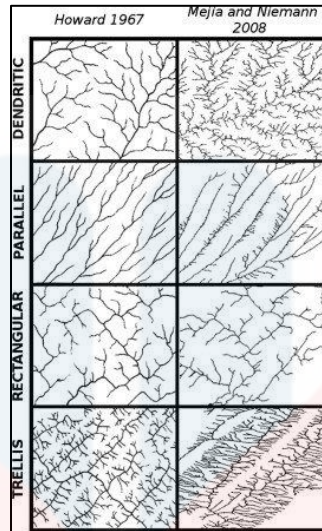


Figure 4.10: Basic drainage patterns taken from Howard (1967) and from Mejía and Niemann (2008)

Source: Devon M. Burr et. al. (2013)



MAP OF DRAINAGE PATTERN IN STUDY AREA

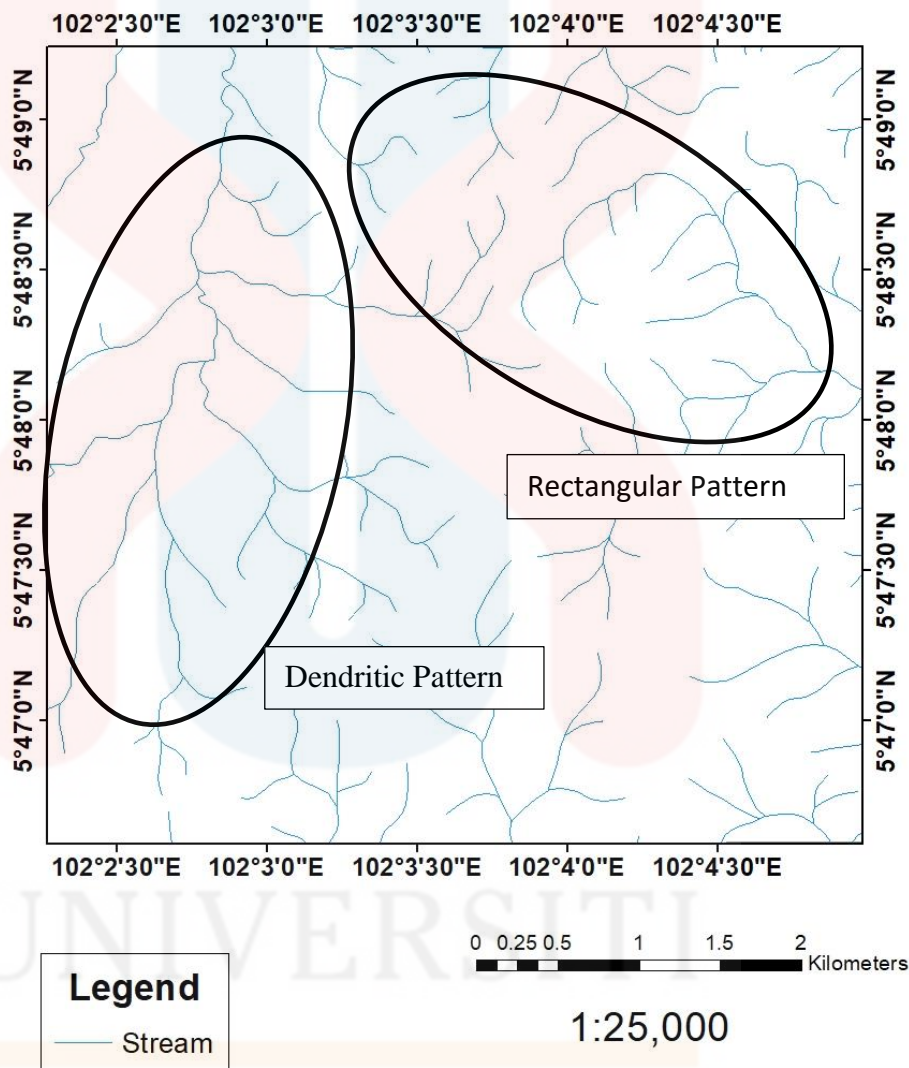


Figure 4.11: Drainage pattern map in study area

Source: ArcGIS Software, 2022

4.5.3 Weathering Process

The term "weathering" refers to the process through which rocks and minerals on the surface of the Earth are broken down or dissolved. Rocks, soil, and minerals, along with wood and man-made materials, may all be broken down via the process of weathering when they come into touch with the air, water, and living species that inhabit the Earth. The process of weathering takes place in situ, which means that it occurs in the same location with very little or no movement. Erosion is the process that takes place when fragments of rock and minerals are carried away from the site where they were originally formed.

Over time, exposed surfaces will get more weathered due to the process of weathering. The amount of time a rock is left exposed to the elements is often a factor in determining how susceptible it is to weathering. There is a wide variety of weathering agents. The components that have a role in the process of weathering are referred to as weathering agents. Water, ice, acids, salts, plants, animals, and changes in temperature are all examples of factors that contribute to the weathering process.

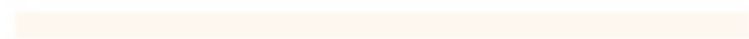
Figure 4.12 shows a table of weathering zones and classification that can be used in clarifying the weathering zones in study area. Generally, mostly in this study area the outcrops found were in Grade IV, V and VI. Grade IV depicts highly weathered outcrop where the materials has altered into soil though the colour and texture remains the same. Figure 4.15 shows an outcrop with a Grade IV of weathering. Whereas Grade V depicts a completely weathered rock and the iron-rich composition is visible while the whole materials are altered into soil. Figure 4.16 shows an outcrop with a Grade V of weathering. Meanwhile Grade VI depicts the residual soil where it

is completely altered into soil and no texture or structures are preserved in this grade.

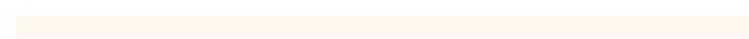
Figure 4.17 shows an outcrop with a Grade V of weathering.



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Komoo, 1995)







Classification	Weathering Zone	Log	Description
Residual Soil	VI		Upper Soil All rock materials changed into soil. No texture or rock mass structure preserved. Homogenic.
Completely Weathered	Vc Vb Va		Zone is rich in Iron Concretion. Unclear texture, less than 25% preserved fabric. Preserved structure. Whole materials changed to soil. Stained. Whole Materials changed into soil. Reddish color, Stained with original material 25-75% fabrics are preserved. Materials disintegrate in water or crushable by hand.
Highly Weathered	IVb IVa		Materials changed into soil preserving original color and textures. >75% preserved texture, easy to disintegrate in water and crushable by hand. Slaking. Material is in transition to IVb condition. Texture & structure intact. Small fragments formed when crush in hand or immerse in water. Geology Hammer does not rebound
Moderately Weathered	III		Color changes in all earth materials (original color increases). Whole texture & structure of rock mass unchanged. Edges of rock material are hard to break by hand. Schmidt Hammer average value is less than 30. Geology Hammer rebounds by hit but does not rings, discontinuity filled with iron oxide.
Slightly Weathered	II		Slightly changes of color in material. Most materials are still fresh. Changes of color on discontinuity clearly exceed 1cm. Schmidt Hammer average value is more than 30. Geology Hammer rebounds and rings. Discontinuity spacing is filled with iron oxides.
Fresh Rocks	I		No changes of forms or color in earth materials. Slightly or no iron stains in discontinuity spacing. Geology Hammer rebounds and rings on hit.

Figure 4.12: Weathering profile classification of rock mass

Source: Komoo (1995)

Physical weathering and disaggregation are what cause rocks to collapse. Water, in either its liquid or solid state, is often a crucial component in the process of mechanical weathering. For example, liquid water is able to infiltrate through cracks and fissures in rock formations. The water will freeze if the temperature drops low enough and its volume increases. The ice is then used as a wedge and elongates the fractures and creates fissures in the rock. The process of erosion is carried out by the liquid water that results from the melting of ice. Alterations in temperature, a phenomenon known as thermal stress, may also contribute to the mechanical weathering of a surface.

Exfoliation is the process that describes how the outer layers of skin eventually peel off in thin sheets. Alterations in pressure are another factor that may lead to exfoliation caused by weathering. The removal of any things that are resting on top of anything is referred to as "unloading." Once the pressure from the rocks on top has been relieved, the rocks underneath are free to expand. The process known as sheeting causes the rock surface to become more susceptible to fracture as it becomes larger. Clay and other materials close to rocks may also undergo a kind of mechanical weathering when they absorb water. Figure 4.14 shows a structure of physical weathering.



Figure 4.13: Weathering structure (exfoliation) on granite outcrop

Differ with physical weathering, chemical weathering is more to the breakdown of rock through chemical mechanisms and it often changes the chemical composition of the rock. There are some processes that could happened in chemical weathering such as oxidation and carbonation. Chemical weathering tend to occur at a warmer and humid regions. It is the first stage in the soil production where the rock may contain iron elements since the rusting effect comes from the reaction between the minerals in it and oxygen in the surroundings. This shows the chemical weathering where the composition of the rocks is altered giving out rusting effect. Other than that, dead plants can also lead to chemical weathering. This is because dead plants produce acids during rotting process that results in the breaking up of the rock.

Biological weathering on the other hand depicts the weathering and disintegrating of rocks due to some weathering agents such as plants, animals and microbes. For an instance, roots from plants that grows within fractures and cracks of the rock may break apart the rock resulting in a biological weathering structure.



Figure 4.14: Grade IV weathering structure in study area



Figure 4.15: Grade V of weathering in study area

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Figure 4.16: Grade VI weathering in study area

4.6 Lithology

Observing the lithology and outcrops in study area, granite mostly can be found. In some areas, hand specimens were obtained for thin section preparation purpose. This is to determine the mineral composition of granite precisely in study area. Based on the study area, mostly it is covered by acid intrusive specifically granite. It mostly comprised of feldspar minerals that makes it a porphyritic texture .

Preliminary studies shows past geological maps and lithological studies information that was found to give not much difference as the updated geological map in terms of lithology and the development of the area. Some noticeable changes can be seen on the increment quantity of volume of agricultural activities and more roads are built to ease the movements of local people residing in and around study area.

4.7 Petrography Analysis

4.6.1 Granite



Figure 4.17: Hand specimen (macroscopic) of alkali-feldspar granite labelled as OC1

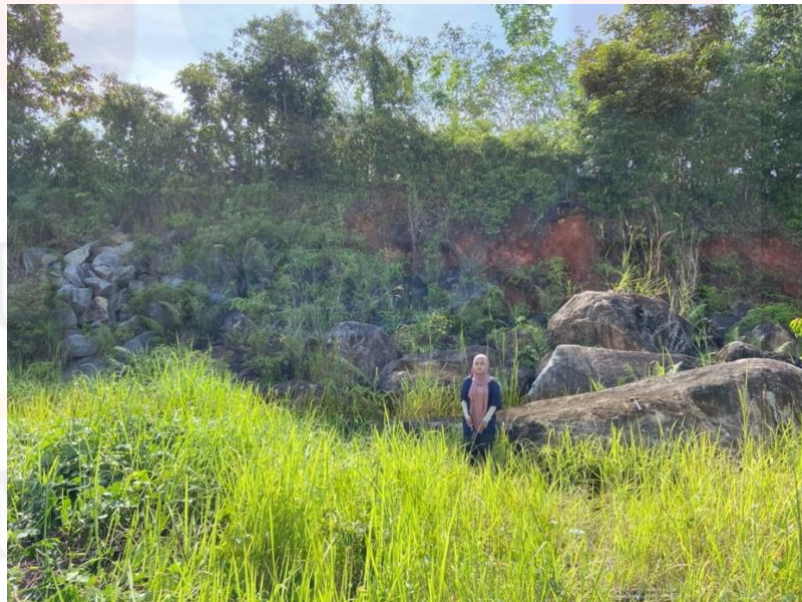


Figure 4.18: Human-scale view of granite boulder

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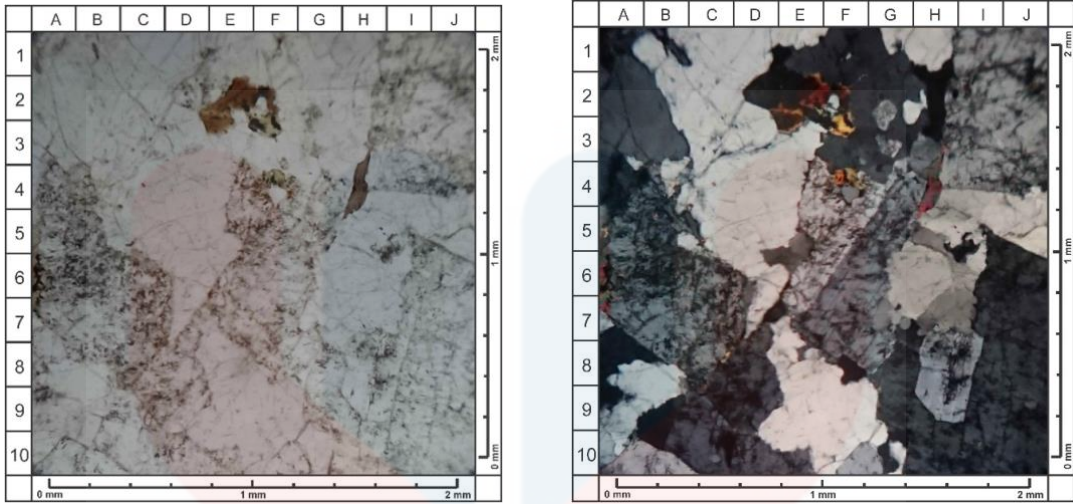


Figure 4.19: Microscopic view of a) Plane-polarized Light (PPL) and b) Cross-polarized Light view of the alkali-feldspar granite boulder.



Figure 4.20: Granite outcrop in study area

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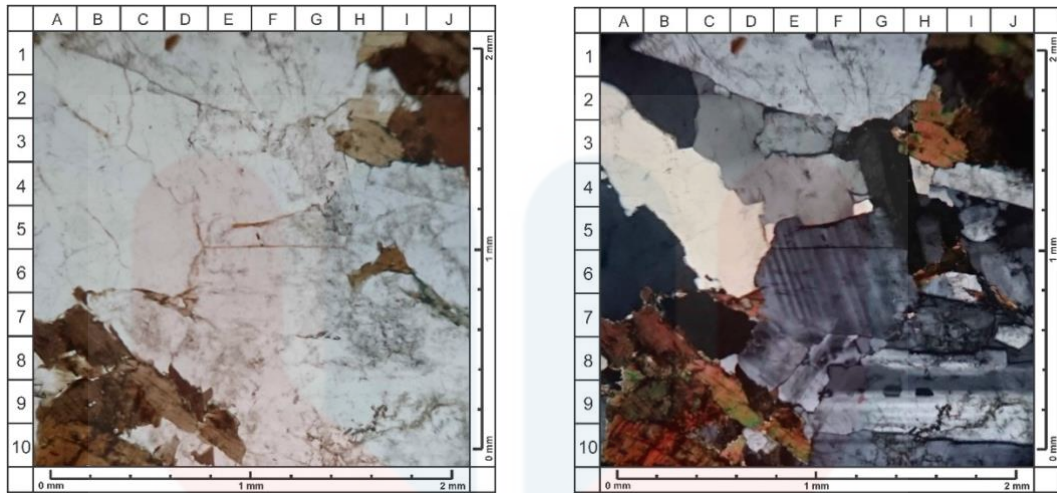


Figure 4.21: Microscopic view a) Plane polarized light (PPL) and Cross polarized Light (XPL) view



Figure 4.22: Granite hand specimen in study area

Acid intrusive rock is referring to granite which can be found abundantly in the study area. It can be seen as an acid intrusive because of its rich composition of silicate minerals such as quartz and feldspar minerals. Granite is an igneous rock belonging to the felsic rock class. This kind of rock crystallises from silicate minerals at very low temperatures and a relatively high silica concentration. It is the lowest temperature in the Bowen series of reactions. Granite in study area are mostly phaneritic texture with a medium to coarse grained minerals.

Quartz mineral can be found abundantly in granite rocks such as alkali feldspar granite and granodiorite in study area. In alkali feldspar granite, quartz mineral dominates around 57% of the total composition while in granodiorite, quartz mineral

dominates around 44% out of the total composition. Quartz minerals can be seen its colourless properties under PPL and interference colour first order in XPL. It has a low relief with no pleochroism and twinning.

Alkali feldspar minerals can be seen to be the second largest percentage of abundance in alkali-feldspar granite which is 40% while in granodiorite rock, alkali feldspar minerals hold up to 5%. Alkali feldspar mineral shows colourless under PPL with a low relief and no pleochroism. Subhedral to anhedral crystal shape while under XPL view, first order interference colour can be observed with Carlsbad twinning can be observed.

Plagioclase feldspar can be determined in the granodiorite thin section where it dominates around 28% of the rock composition. Under PPL view, plagioclase shows colourless features while under XPL view, plagioclase can be seen in its first order interference colours. It shows low relief, no pleochroism with a crystal shape of euhedral-anhedral. Carlsbad twinning can also be observed.

Biotite minerals in alkali feldspar granite and granodiorite is 2% and 12% respectively. It shows greenish brown colour under PPL view with a moderate relief, high pleochroism with a crystal shape of subhedral to euhedral. Under XPL view, biotite mineral shows third order interference colours of greenish orange with no twinning.

4.6.2 Quartzite

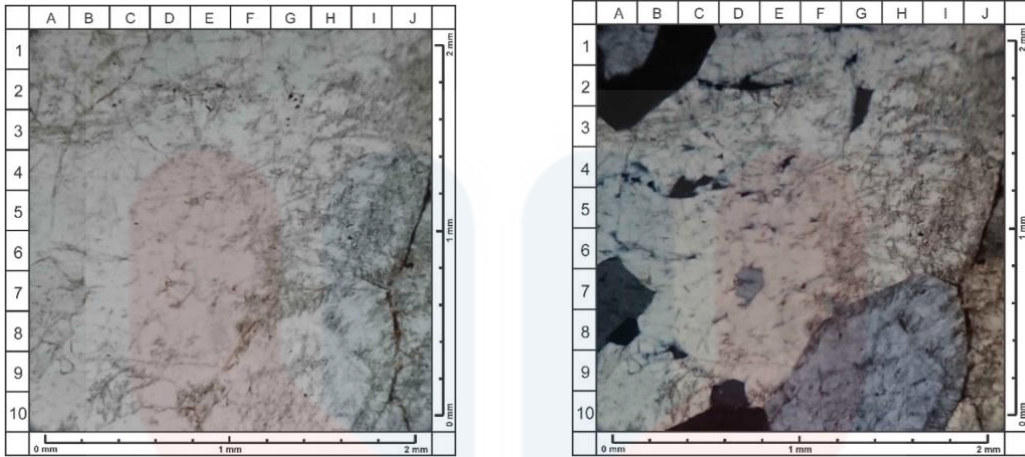


Figure 4.23: View of thin section under a) Plane polarized light (PPL) view and b) Cross polarized light (XPL)



Figure 1.24: Quartzite hand specimen in study area

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Figure 4.25: Quartzite hand specimen in study area

In microscopic view, quartzite can be seen non-foliated with a granoblastic texture with a medium sorting. Most of the mineral composition in quartzite rock is quartz minerals where it covers 99% of the whole composition. Under PPL view, it has a colourless property, low relief with no pleochroism and anhedral shape. On the other hand, under XPL view, it shows a first order interference colour in white.

While the remaining 1% of the composition in comprises of opaque minerals. Under PPL view, it shows a black colour as well as under XPL view, it shows a first order interference colour in black. It shows low relief, no pleochroism and no euhedral shape. Other than that, twinning also could not be determined.

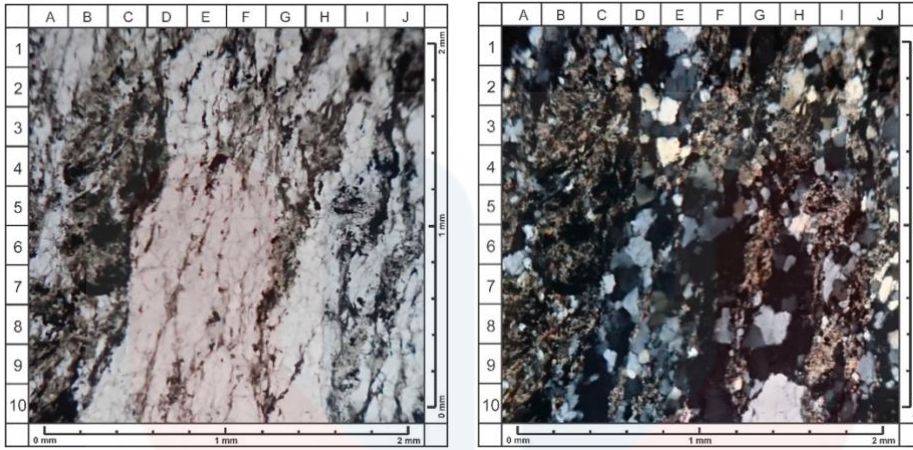


Figure 4.26: Thin section view of schist outcrop under a) Plane polarized light (PPL) and cross polarized light (XPL) view



Figure 4.27: Hand specimen of schist

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Figure 4.28: Outcrop schist with geological hammer scale

4.11 Structural Geology

4.11.1 Lineament Analysis

Lineament can be determined by lining a straight structures in the aerial photographs along structures such as ridge, joints, fault, discontinuities as well as the boundaries of the rock (Muhammad Zikri Zainuddin, 2006). Therefore, lineament analysis can be done when linear straight structures were done. Lineament analysis is categorized into two, positive lineament and negative lineament. The difference in these lineaments are more to the representation of the linear lines. Positive lineament indicates the ridges while the negative lineament depicted by rivers.



LINEAMENT MAP OF STUDY AREA

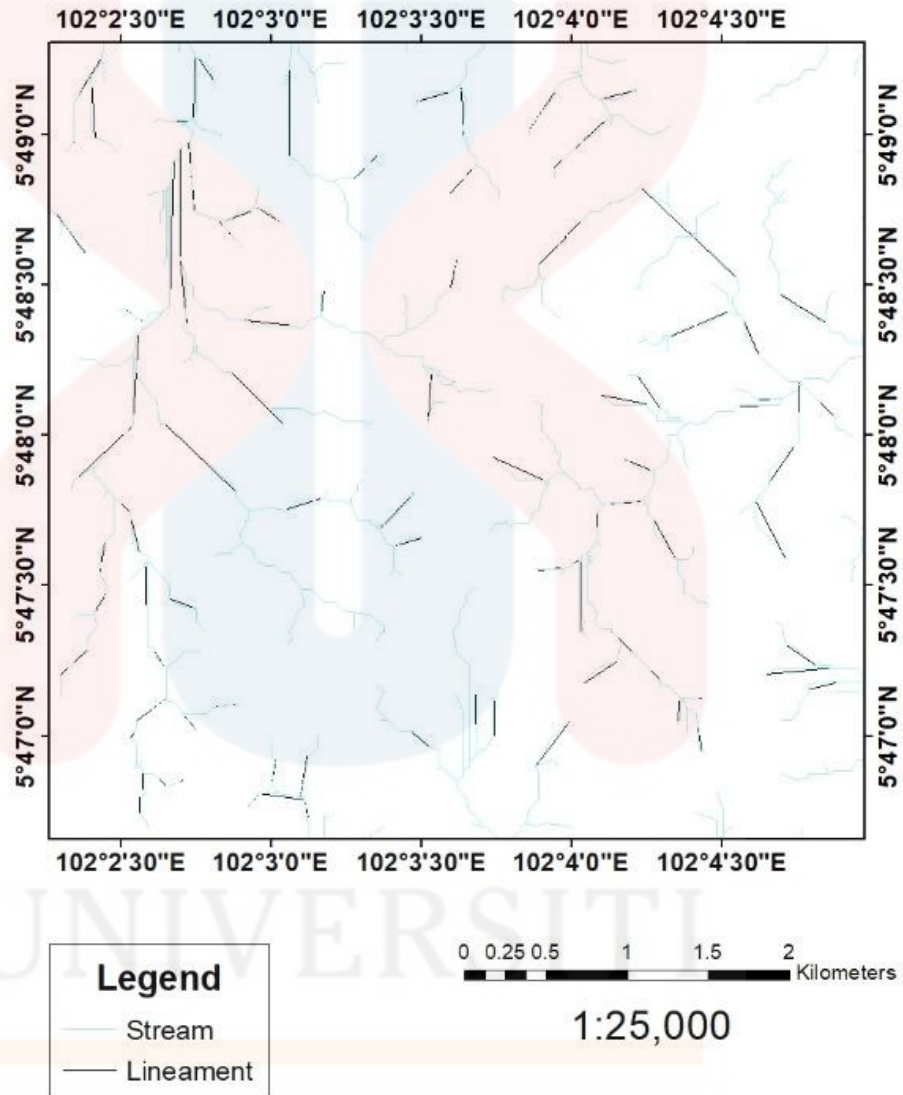


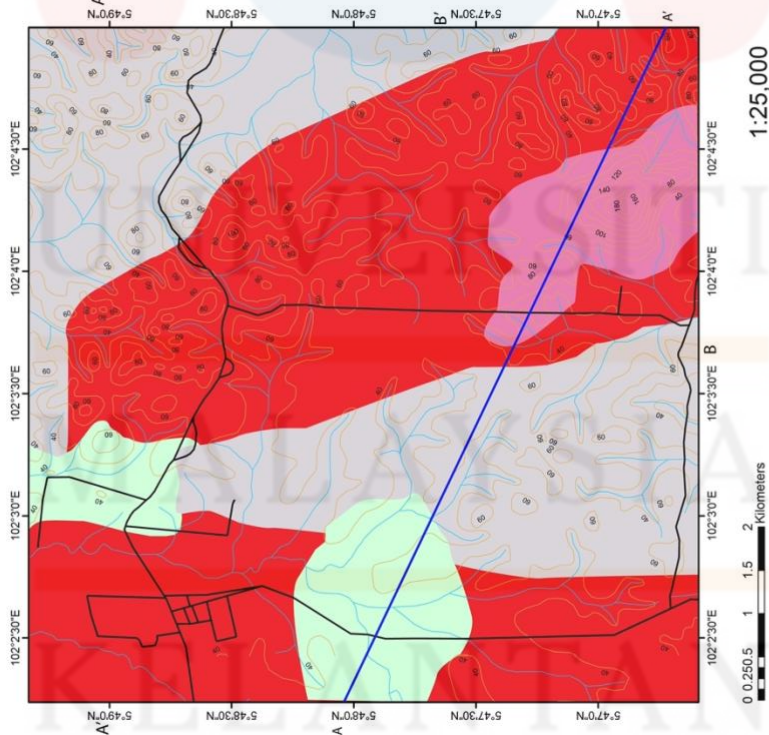
Figure 4.29: Lineament map of study area

Source: ArcGIS Software, 2022



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GEOLOGICAL MAP OF KAMPUNG AYER ASAHAN HULU, TANAH MERAH KELANTAN



1:25,000

0 0.250.5 1 1.5 2 Kilometers

STRATIGRAPHY COLUMN

LITHOLOGY	DESCRIPTION	UNIT	PERIOD	ERA
[Red]	Main feature is alkali feldspar granite	Granite	Tertiary	Cenozoic
[Grey]	Mainly interbedded with schist, quartzite and meta-mudrock.	Schist	Permian	Palaeozoic
[Purple]	Granodiorite has a phaneritic texture where the grain size are visible to naked eye. Fresh samples were obtained	Granodiorite	Tertiary	Cenozoic
[Green]	Mostly weathered outcrops but can be observed through its individual grains and the rock surface.	Sandstone	Triassic	Mesozoic

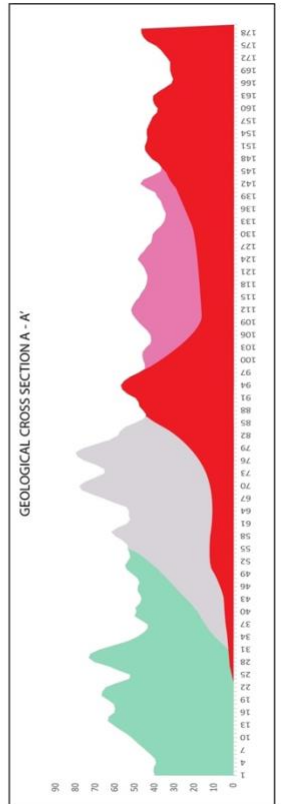
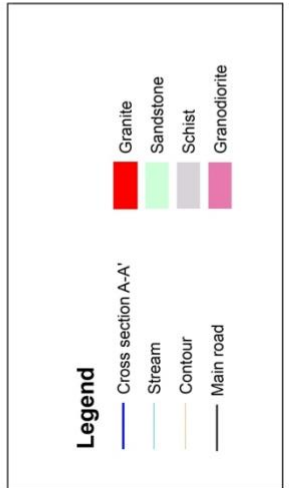


Figure 4.30: Geological map of study area
Source: ArcGIS Software, 2022

GROUNDWATER QUALITY ANALYSIS

5.1 Result and discussion

Groundwater quality can be affected in many ways. It is dynamic that many factors such as human activities can lead to a bad quality of groundwater resources. Human activities involving industrialization such as factories and even urbanization such as building construction will affect groundwater quality if the activities are not being planned properly resulting in a poor waste disposal. This leads to processes such as infiltration of bad components for the groundwater.

A groundwater sample collection was conducted on domestic wells within study area in Kampung Ayer Asahan Hulu, Tanah Merah Kelantan. The parameters and quality of groundwater depends on environmental factors such as industrial areas and agricultural areas.

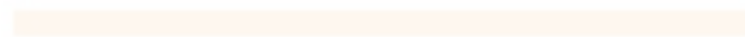
5.2 Hydrogeology of Kelantan

Malaysia is known to have a warm and humid weather where this country has an abundance of rainfall compared to other countries for an instance. Other than that, Malaysia is also recorded to have a groundwater storage and usage at 197 Ml/d (Malaysia Water Guide, 2009). In terms of hydrogeology, Kelantan state mainly

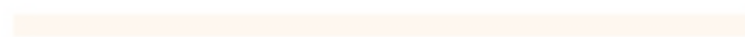
dominated by Kelantan river (249km) followed by two tributaries, Galas river (178km) and Lebir river (91km).



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SAMPLING LOCATION IN STUDY AREA

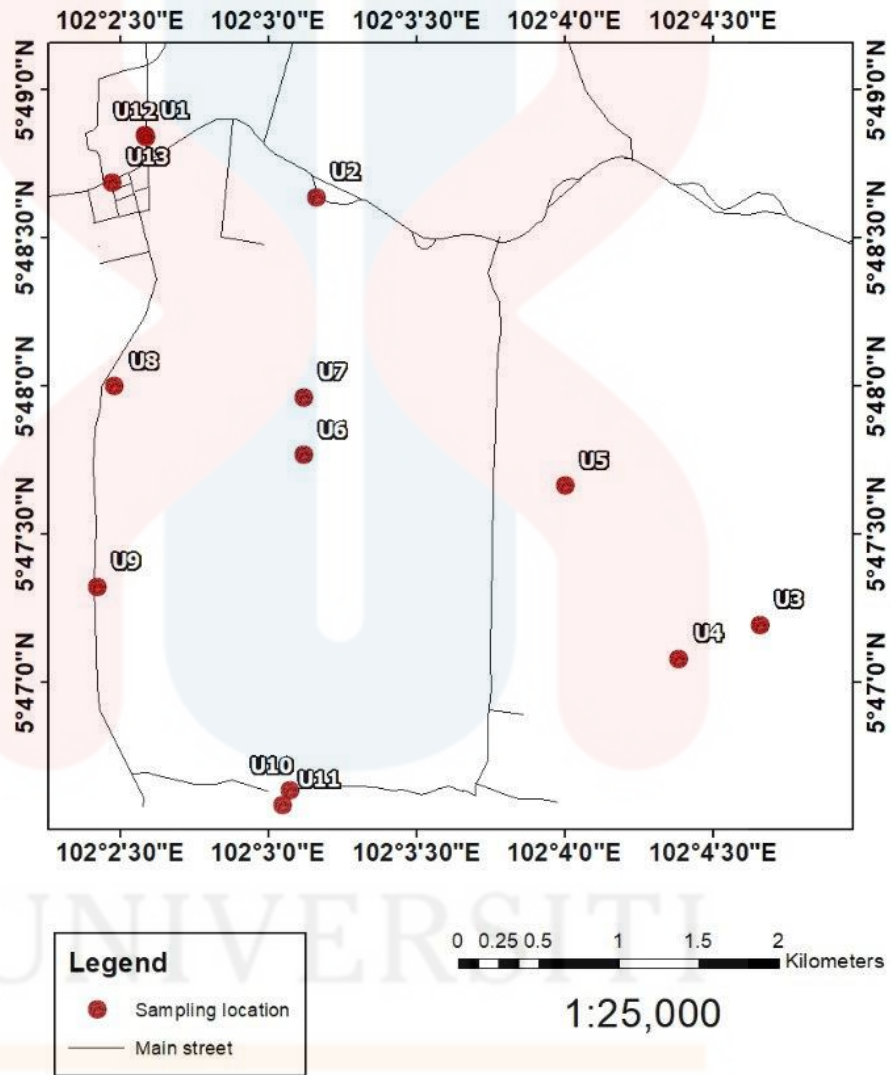


Figure 2.1: Sampling location of groundwater in study area

Figure 5.1: Coordinates and elevation for sampling collection location

Well no.	Latitude	Longitude	Elevation
U1	N 05° 48'50.7"	E 102° 02'35.0"	28m
U2	N 05° 48'38.2"	E 102° 03'09.6"	47m
U3	N 05° 47'11.5"	E 102° 04'39.5"	42m
U4	N 05° 47'04.7"	E 102° 04'23.1"	51m
U5	N 05° 47'39.7"	E 102° 04'00.1"	56m
U6	N 05° 47'45.9"	E 102° 03'07.1"	43m
U7	N 05° 47'57.6"	E 102° 03'07.0"	50m
U8	N 05° 47'59.9"	E 102° 02'28.8"	28m
U9	N 05° 47'19.2"	E 102° 02'25.2"	38m
U10	N 05° 46'38.0"	E 102° 03'04.3"	44m
U11	N 05° 46'35.1"	E 102° 03'02.8"	41m
U12	N 05° 48'50.4"	E 102° 02'35.2"	43m
U13	N 5° 48' 41.2"	E 102° 02' 28.2"	44m

Figure 5.2: Comparison of the Concentration of the physico-chemical parameters of groundwater samples in study area with the Standard Drinking Water Guidelines by W.H.O. and M.O.H.

Constituents	W.H.O. (mg/L) (1993)	W.H.O. (mg/L) (2000)	M.O.H. (mg/L) (2000)	Concentration of groundwater samples (mg/L)
pH	6.5 to 8.5	6.5 to 9.5	5.5 to 9.0	4.27 to 6.66
Hardness	500	500	500	0.506 to 39.7
TDS	1000	1000	1000	24.05 to 123.50
Sodium, Na ⁺	200	200	200	1.127 to 36.89
Potassium, K ⁺	30	12	30	0.489 to 4.437
Calcium, Ca ²⁺	200	200	200	0.001 to 13.07
Magnesium, Mg ²⁺	150	150	150	0.098 to 2.505
Ferum, Fe ²⁺	0.3	0.3	0.3	0.004 to 2.392
Nitrate, NO ₃ ²⁻	50	50	10	0.7 to 6.7
Sulphate, SO ₄ ²⁻	400	200	250	1.0 to 6.0
Chloride, Cl ⁻	250	250	250	4.26 to 28.4
Bicarbonate, HCO ₃ ⁻	380	500	500	0 to 75
Fluoride, F ⁻	1.9	1.5	1.5	0.01 to 0.27

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Figure 5.3: Concentration of elements in groundwater samples

Well No.	Element concentrations (mg/l)									
	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺	Fe ²⁺	NO ₃ ²⁻	SO ₄ ²⁻	Cl ⁻	HCO ₃	F ⁻
U1	5.95 0	2.61 5	3.86 2	0.35 7	0.00 9	3.1	6.0	25.5 6	35.0	0.0 1
U2	4.41 8	1.81 0	1.77 5	0.43 7	0.02 1	1.6	0	14.2	40	0.2 7
U3	1.12 7	0.96 9	2.18 2	0.47 3	0.05 2	1.5	0	4.26	0	0.0 6
U4	29.9 8	2.60 6	4.58 8	2.50 5	0.54 4	0.7	0	7.1	75.0	0.2 4
U5	36.8 9	1.40 1	9.98 3	0.25 0	0.00 5	6.7	0	28.4	35.0	0.0 6
U6	1.33 5	0.94 2	7.78 8	0.22 6	0.00 4	2.4	1.0	11.3 6	40.0	0.0 4
U7	2.14 5	4.43 7	13.0 7	1.50 9	0.46 9	1.8	6.0	8.52	0	0.0 1
U8	2.37 0	1.51 7	4.07 4	1.13 4	0.15 7	1.7	0	7.1	45.0	0.0 7
U9	2.65 9	2.86 3	8.65 9	0.29 3	0.14 9	1.1	2.0	12.7 8	45.0	0.0 7
U10	1.96 6	1.29 6	0.58 7	0.38 4	2.39 2	1.1	0	9.94	0	0
U11	3.09 4	1.16 4	0.49 0	0.25 1	0.06 6	2.3	0	8.52	15.0	0.0 7
U12	19.2 4	0.48 9	0.00 1	0.09 8	0.05 6	2.4	1.0	12.7 8	20.0	0.0 2
U13	9.30 8	2.93 6	4.56 9	0.17 3	0.01 3	1.6	4.0	12.7 8	65.0	0.0 4

Figure 5.4: Physical parameters of groundwater samples

Well No.	Physical parameters						
	pH	Hardness (mg/l CaCO ₃)	TDS (mg/l)	Turbidity (NTU)	DO (mg/l)	Temperature (°C)	Electrical Conductivity (microS/cm)
U1	4.71	11.132	63.05	1.87	5.15	28.3	103.3
U2	4.89	6.270	63.8	3.59	4.78	28.4	67.9
U3	5.47	7.491	24.05	7.05	3.30	28.2	38.9
U4	5.99	22.746	79.95	11.4	4.41	28.0	130.4
U5	5.91	25.975	123.50	12.7	5.02	26.9	197.0
U6	5.71	20.392	59.80	0.62	4.45	28.1	97.2
U7	5.80	39.7	86.15	11.5	3.65	28.1	138.4
U8	6.66	15.126	41.60	12.1	4.19	28.2	68.3
U9	5.82	23.103	66.00	3.35	3.68	28.3	106.5
U10	5.71	7.333	69.80	10.4	4.59	28.1	97.2
U11	4.87	2.375	30.55	2.38	4.48	27.7	49.4
U12	4.27	0.506	40.95	0.93	3.88	28.8	68.0

U13	5.2	12.149	52.65	0.48	2.04	29.5	88.6
	4						

5.3 Physical Parameters

5.3.1 pH

The measurement of the concentration of hydrogen ions in a solution that is based on water is referred to as the pH scale. If the pH of a liquid is lower, then it contains a greater number of hydrogen ions, but if the pH of the liquid is higher, then it contains a smaller number of hydrogen ions. A measurement of an acidity or alkalinity is expressed on a scale that ranges from 1 to 14, and it is abbreviated as pH. The pH of distilled water, which is completely neutral at 7, sits directly in the center of the scale. Everything with a pH lower than 7 is considered an acid, whereas everything with a pH higher than 7 is considered an alkali, sometimes known as a base.

Heavy metals and minerals found in the water are exposed to the body when acidic water is consumed. Acidic water often creates difficulties for pipelines since it is very corrosive and causes destruction. Acidic water may cause the acid in the mouth to work harder and destroy teeth and gums more quickly. It can also readily harm delicate gums. 60% of the public water supply originates from surface or shallow sources, which are known to be highly acidic owing to bedrock deterioration, carbon dioxide, and insufficient natural filtering.

Figure 5.6 below shows the pH of all the groundwater samples taken with the lines depicted the permitted by W.H.O. and M.O.H. The pH value obtained ranges from 4.27 to 6.66 whereas the mean pH value from all the groundwater samples is

5.47. This average pH value shows an acidic property of groundwater. Anthropogenic pollution, which is pollution caused by humans, may also create acid rain, which can cause the water to become acidic. Carbon dioxide is the most prevalent source of acidic water. pH values tend to decrease and become acidic due to the free carbon dioxide and acid generating salts (Willis, 2001).

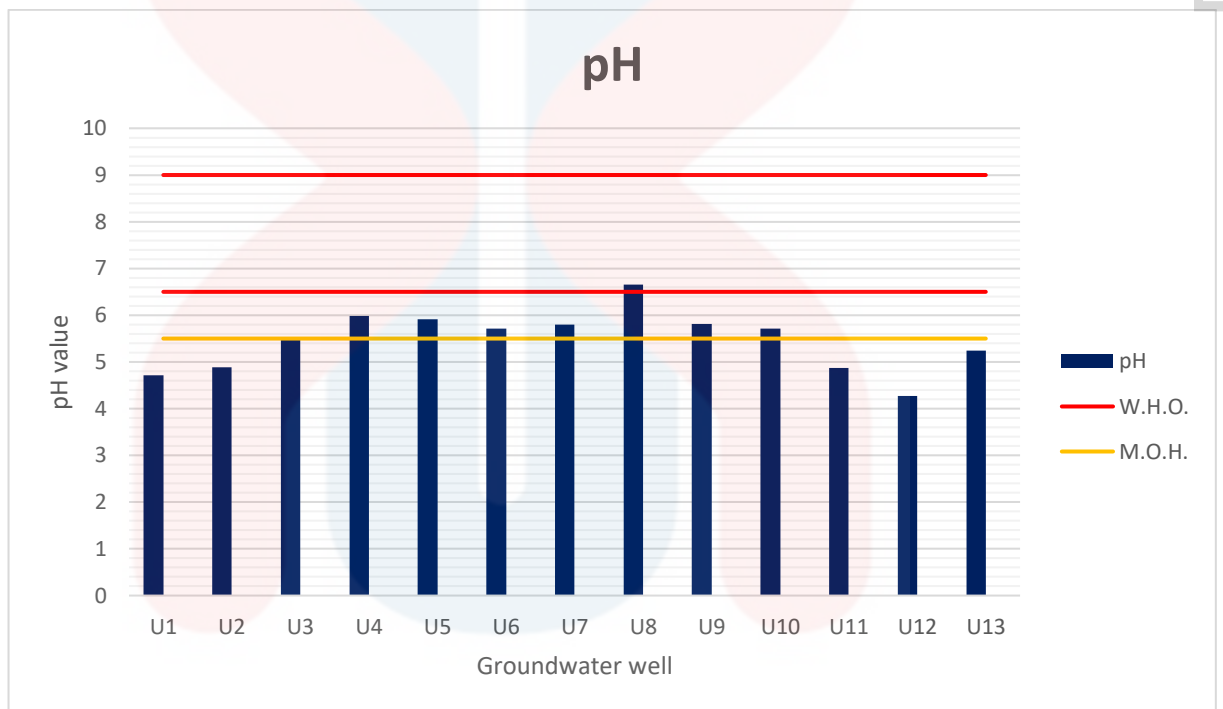


Figure 5.2: pH concentration in groundwater sample in study area around Kampung Ayer Asahan Hulu, Tanah Merah Kelantan

Figure 5.5: pH of groundwater samples according to permissible value from M.O.H. and W.H.O.(Ventakesh & Rajeskar, 2005)

Parameter	Rank	Criteria	Remarks	Class
pH	1	6.50 – 8.50	Acceptable value by M.O.H. and W.H.O.	Well 8
	2	8.51 – 9.20	Acceptable value by	

			M.O.H. and W.H.O.	
	3	≤ 6.49	Rejected value	Well 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12 and 13
	4	≥ 9.21	Rejected value	

5.3.2 Hardness

The hardness of groundwater sample in study area ranges from 0.506 to 39.7. Meanwhile, the mean of the overall hardness values of the groundwater is 14.946 which lies on the soft water classification based on Figure 5.9. Although hard water may not harm and even safe to do as drinking water due to the mineral content in it, it affects other factors rather than the indigestion part such as hair and skin (National Institute of Health, n.d.). The maximum hardness concentration that may be allowed is typically specified by the membrane manufacturer. However, the general rule of thumb in the industry is that the hardness level should not exceed 120 to 170 mg/L. Hard water somehow affects hair and skin because when hard water comes into touch with the body, it may remove its naturally occurring oils on the skin. Meanwhile, hair with mineral deposits, causing the hair to become dry and brittle.

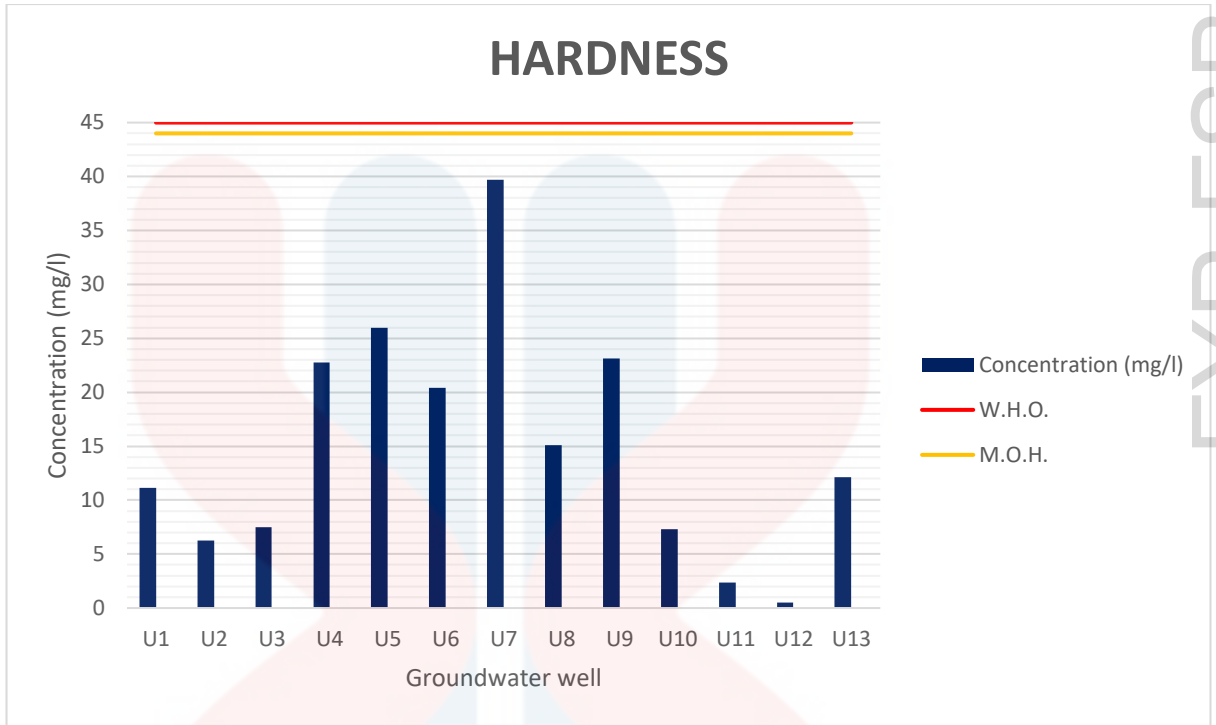


Figure 5.3: Hardness of groundwater sample in study area around Kampung Ayer Asahan Hulu, Tanah Merah Kelantan

Figure 5.6: Hardness Classification comparison between groundwater samples and M.O.H. and W.H.O. (Venkatesh & Rajasekar,2005).

Parameter	Rank	Criteria	Remarks	Class
Hardness	1	≤ 200	Acceptable value by M.O.H. and W.H.O.	Well 1,2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13
	2	201 – 400	Acceptable value by M.O.H. and W.H.O.	
	3	401 – 600	Acceptable value by M.O.H. and W.H.O.	
	4	601 – 1000	Rejected value	
	5	> 1000	Rejected value	

Figure 5.7: Hardness of Calcium Carbonate (mg/l) and its Water Classification

Hardness of Calcium Carbonate, CaCO₃ (mg/l)	Water Classification	Classification of Groundwater samples
0 – 75	Soft	Well 1,2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13
75 – 150	Moderately Hard	
150 – 300	Hard	
>300	Very Hard	



HARDNESS CONCENTRATION DISTRIBUTION MAP IN STUDY AREA

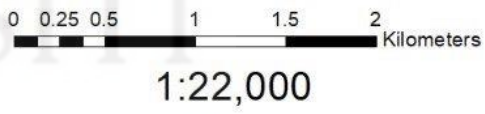
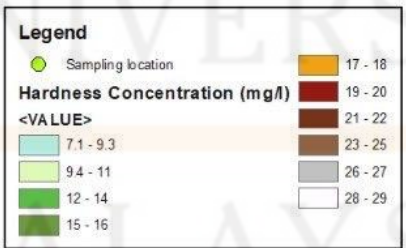
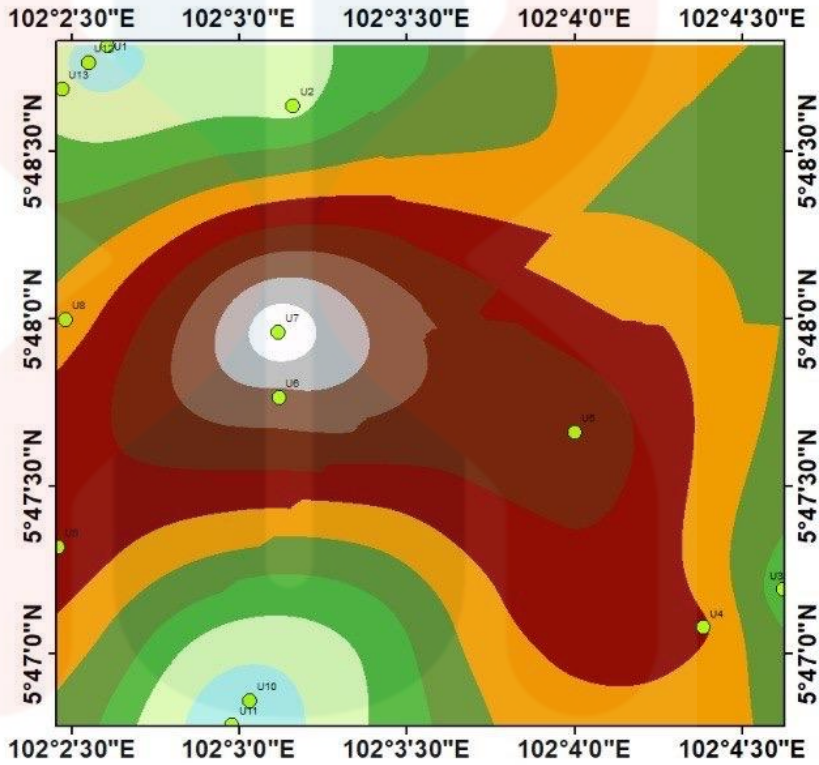


Figure 5.4: Hardness concentration distribution map in study area

Source: ArcGIS Software (2022)

5.3.3 Total Dissolved Solids (TDS)

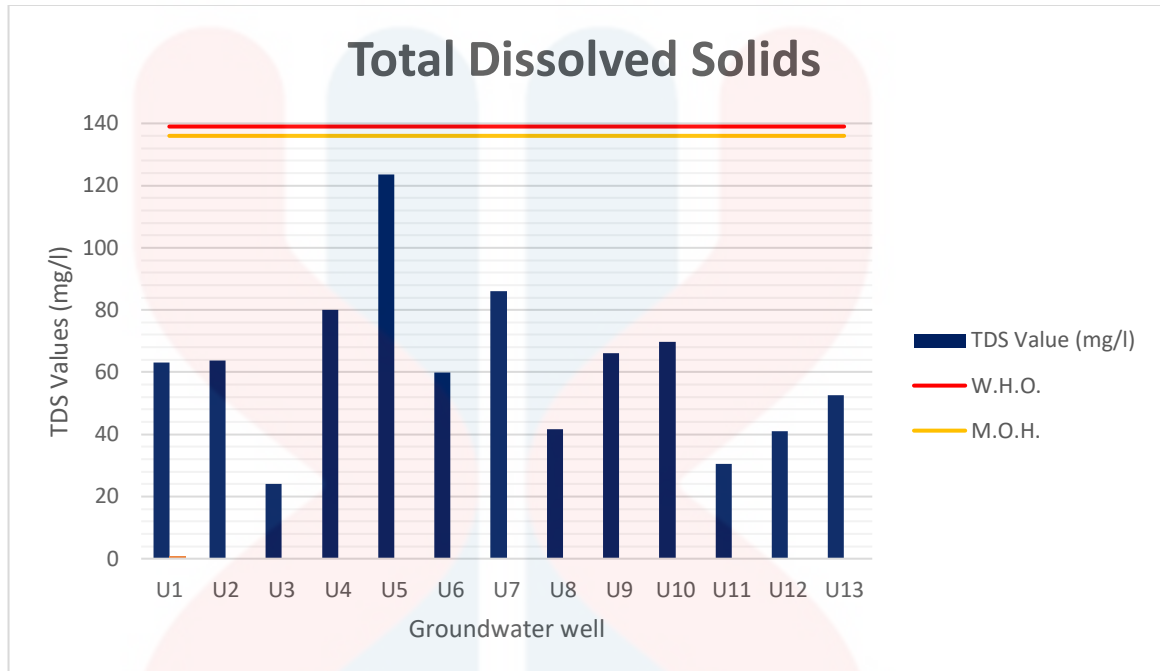


Figure 5.5: Total Dissolved Solids (TDS) concentration in groundwater sample in study area around Kampung Ayer Asahan Hulu, Tanah Merah Kelantan

Based on Figure 5.12, study area mainly has a TDS value ranges from 24.05 to 123.50 while the mean TDS value in the study area is 61.68 mg/l. These values shown in figures below depicts the freshwater properties of the groundwater sample in the study area and its surrounding. This is based on the TDS classification shown in Figure 5.13 below.

The value of the dissolved solids somehow gives difference in the taste of the water mainly more than 1,000 mg/l making it unsuitable for some uses such as drinking purposes (Balakrishnan et. al, 2011). Total dissolved solids value can become high due to the presence and high concentrations of some elements such as bicarbonates, carbonates, sulphates, and calcium.

Figure 5.8: TDS groundwater classification between groundwater samples and M.O.H. and W.H.O. (Balakrishnan et. al., 2011).

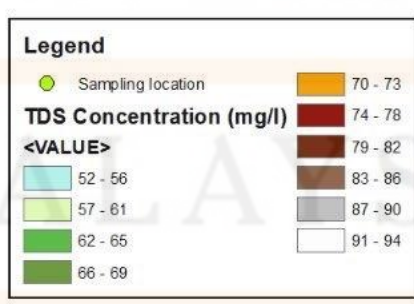
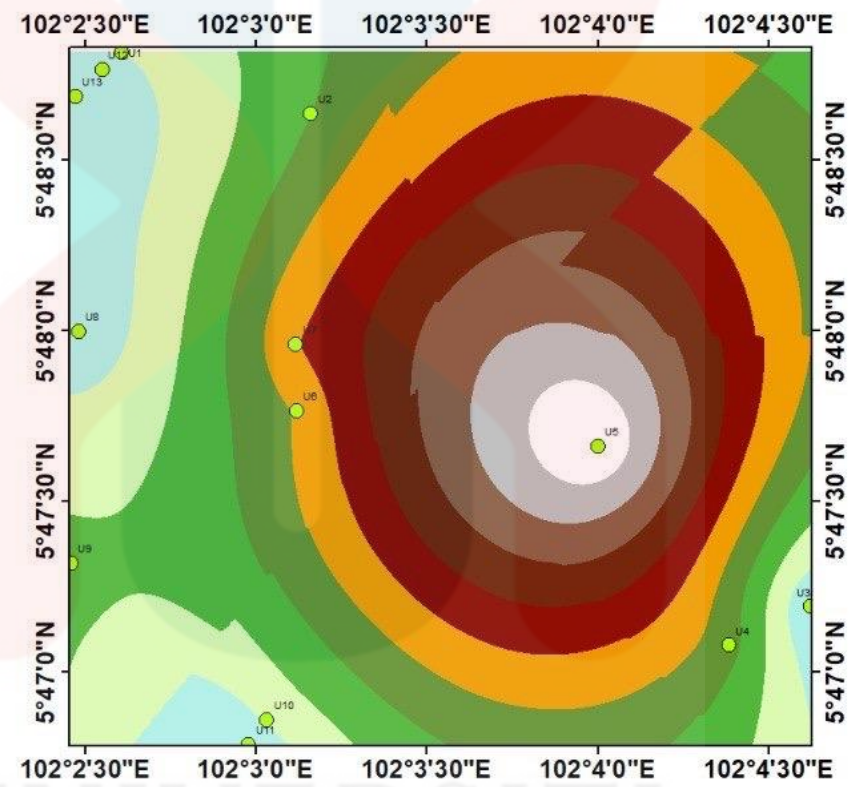
TDS (mg/l)	Category	Description	Classification
< 500	Fresh water	Desirable for drinking purposes	Well 1,2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13
500 – 1000	Fresh water	Permissible for drinking purposes	
1000 – 3000	Brakish water	Permissible for irrigation purposes	
> 3000 – 10000	Saline water	Unsuitable for drinking and irrigation purposes	
>10000	Brine water	Unsuitable for drinking and irrigation purposes	

Figure 5.9: TDS Classification comparison between groundwater samples and M.O.H. and W.H.O. (Venkatesh & Rajasekar,2005).

Parameter	Rank	Criteria	Remarks	Class
TDS value (mg/l)	1	≤ 200	Acceptable value by M.O.H. and W.H.O.	Well 1,2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13
	2	501 - 1000	Acceptable value by M.O.H. and W.H.O.	
	3	1000 – 1500	Acceptable value by M.O.H. and W.H.O.	
	4	1501 – 2000	Rejected value	
	5	>5000	Rejected value	



TDS CONCENTRATION DISTRIBUTION MAP IN STUDY AREA



1:22,000

Figure 5.6: TDS concentration distribution map in study area

Source: ArcGIS Software (2022)

5.3.4 Electrical Conductivity

In terms of electrical conductivity, the values in the groundwater samples in study area are classified to be in the low conductivity class where the range of conductivity in the samples are 38.9 microS/cm – 197.0 microS/cm. Whereas to classify it to be in a low conductivity, the value should be lesser than 500 microS/cm as shown in Figure 5.17. Since the mean average of the electrical conductivity in those 13 groundwater samples obtained is 115.48 microS/cm, it is classified to be in a low conductivity class. A fresh groundwater source tends to have an electrical conductivity value of 150 microS/cm and lesser although there are no specific health guidelines regarding the electrical conductivity in water (LAWA, 2022).

Based on the observation and data tabulated, the highest electrical conductivity value is 197.0 microS/cm, which on the same well, U5 was recorded to have the highest nitrate concentration, 6.7 mg/l. This shows that the nitrate concentration in a groundwater sample plays a role and is directly proportional to the value of the electrical conductivity (Sajil Kumar et. al., 2014).

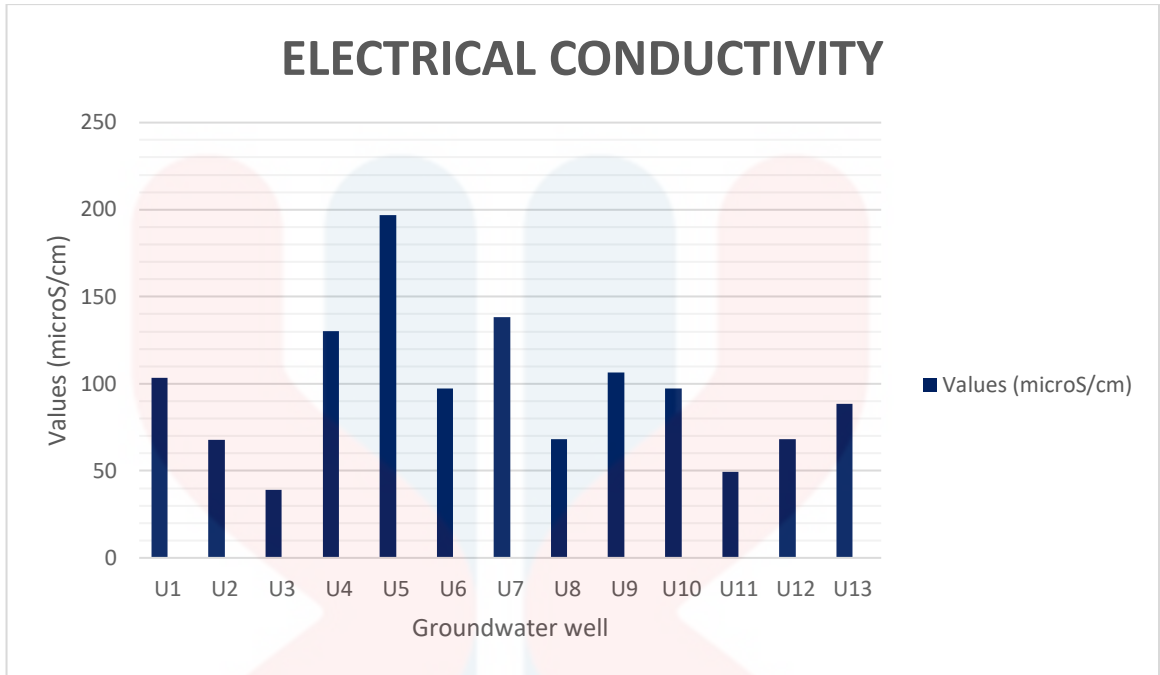


Figure 5.7: Electrical conductivity value in groundwater sample in study area around Kampung Ayer Asahan Hulu, Tanah Merah Kelantan

Figure 5.10: Groundwater sample classification for drinking purposes according to EC parameter

Category	Description (microS/cm)	Classification
Low conductivity	< 500	Well 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13
Medium conductivity	500 – 1000	
Medium conductivity	1000 – 3000	
High conductivity	>3000	

5.4 Major cation concentration

5.4.1 Sodium, Na⁺

Based on data collected, the concentration of Sodium, Na⁺ ranges from 1.127 mg/l to 36.89 mg/l. The mean average sodium concentration in the groundwater samples in study area is approximately 9.27 mg/l.

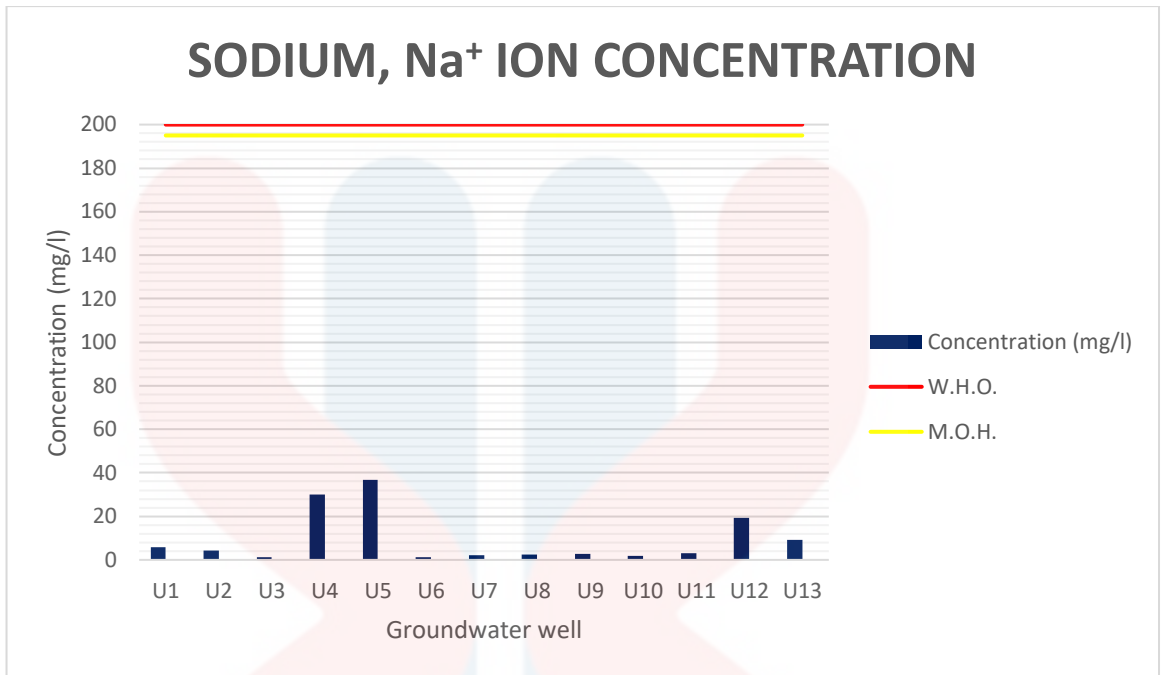
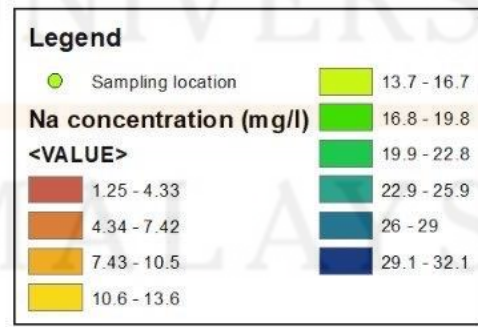
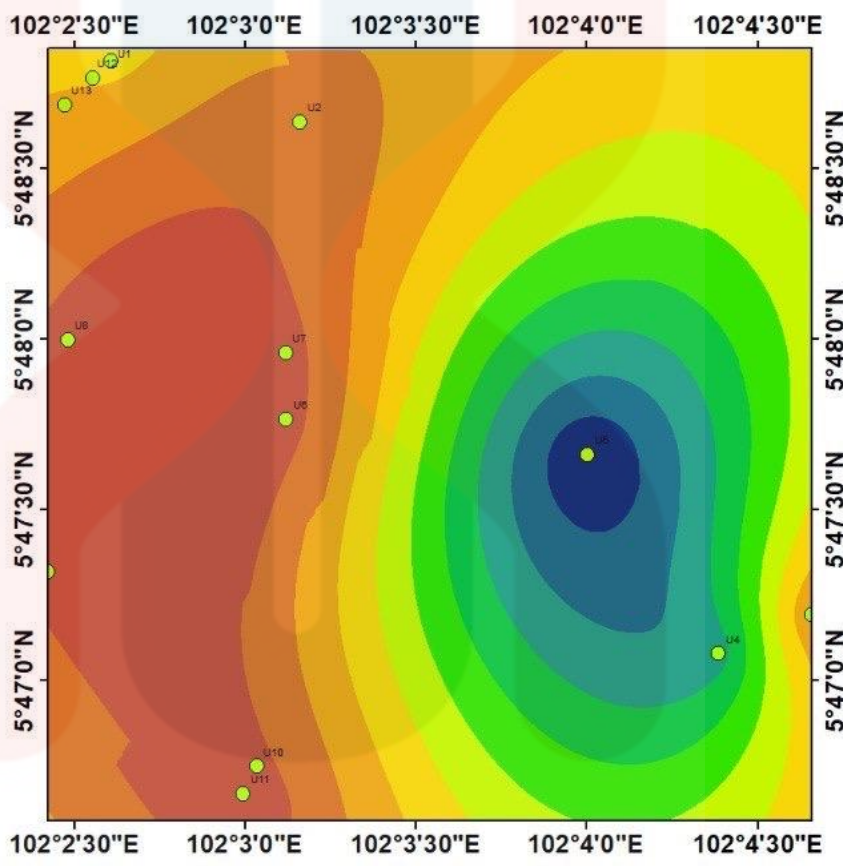


Figure 5.8: Sodium element concentration in groundwater sample in study area around Kampung Ayer Asahan Hulu, Tanah Merah Kelantan



SODIUM CONCENTRATION DISTRIBUTION MAP IN STUDY AREA



1:22,000

Figure 5.9: Sodium concentration distribution map in study area

Source: ArcGIS Software (2022)

5.4.2 Calcium, Ca²⁺

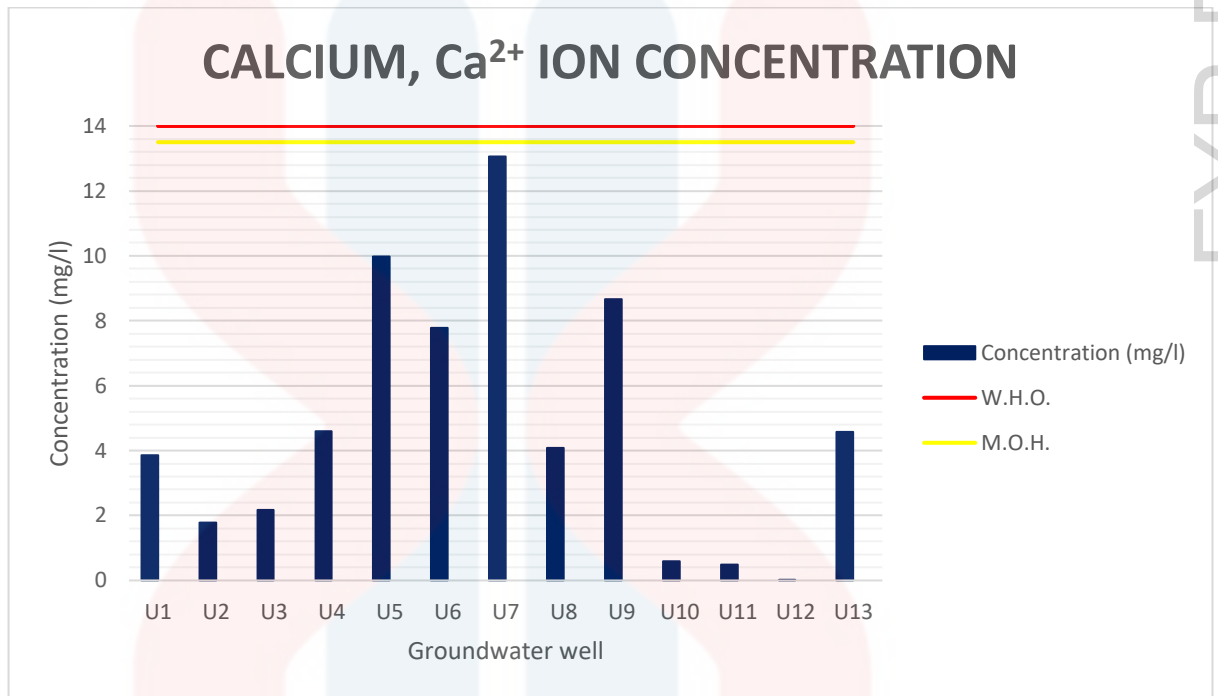
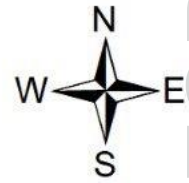


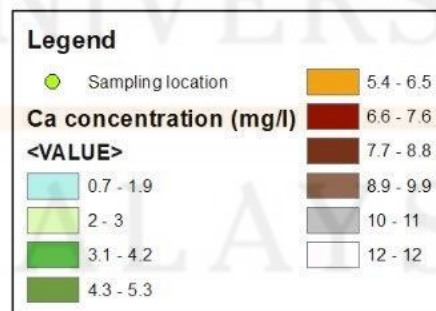
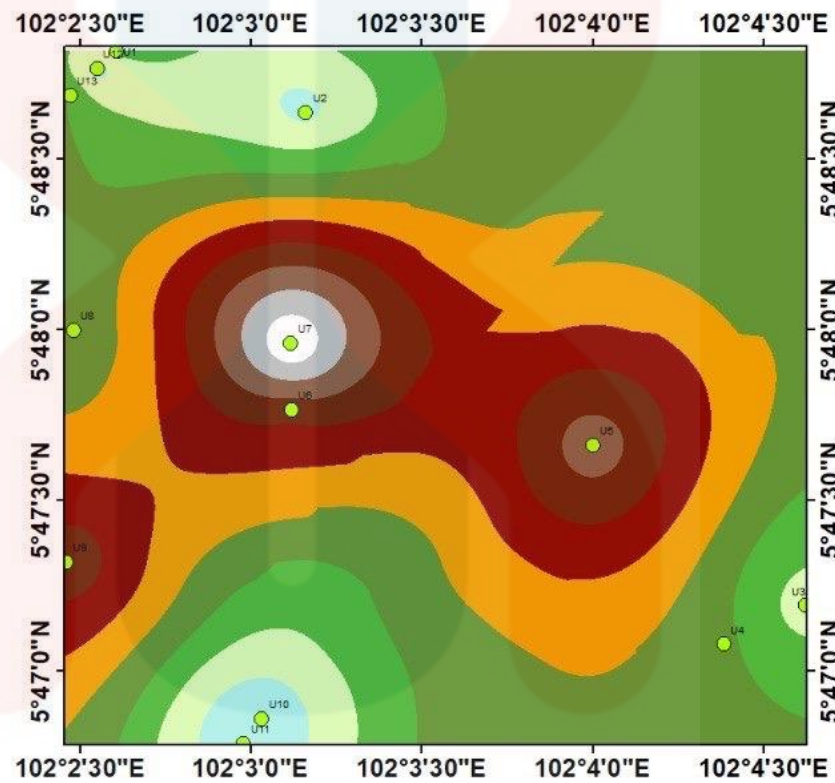
Figure 5.10: Calcium element concentration in groundwater sample in study area around Kampung Ayer Asahan Hulu, Tanah Merah Kelantan

Based on the data present above, the highest calcium concentration acquired is located in U7, 13.07 mg/l. Whereas the lowest calcium concentration acquired is located at U12 which is 0.001 mg/l. Average concentration of Calcium ion in all the groundwater samples is 4.74 mg/l which did not exceed the permissible limit by both W.H.O. and M.O.H.

Calcium concentration may differ in certain areas in study area, mainly due to rainfall difference in certain areas. In southern part of the study area records as high as 9.983 mg/l of Ca concentration while on the northern part of the study area records a Ca concentration as high as 4.659 mg/l. This shows that southern part has higher concentration mainly due to rainfall factors that results in an increment of dilution possibility of calcium concentration.



CALCIUM CONCENTRATION DISTRIBUTION MAP IN STUDY AREA



1:22,000

Figure 5.11: Calcium concentration distribution map in study area

Source: ArcGIS Software (2022)

5.4.3 Potassium, K⁺

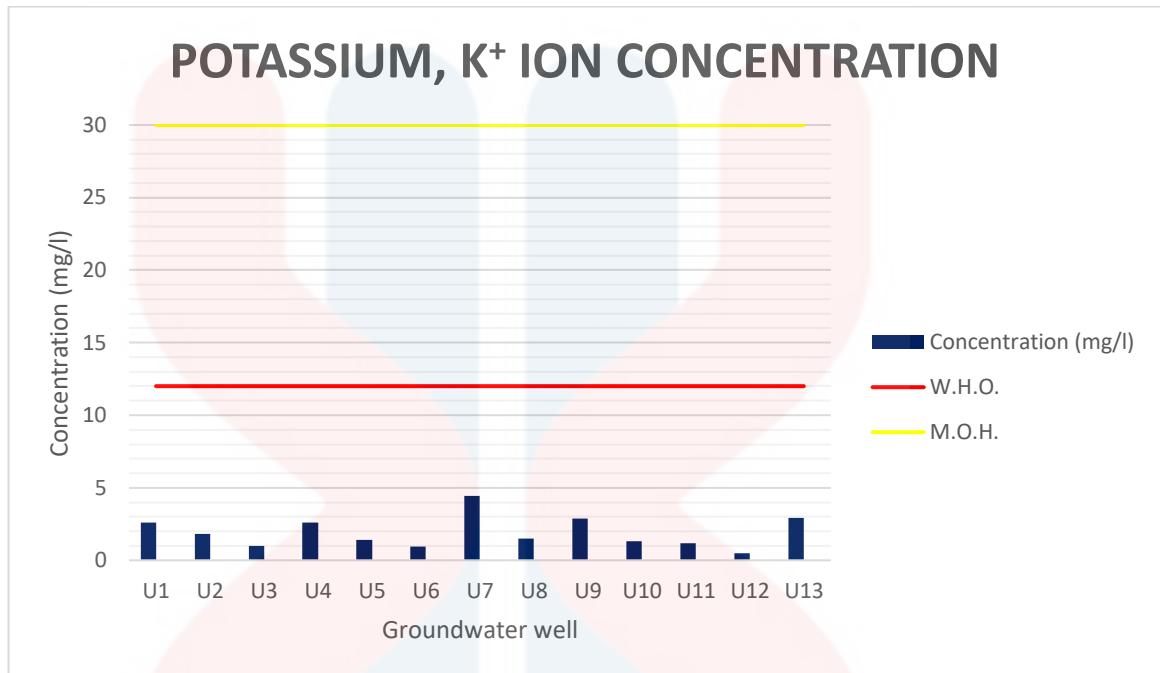


Figure 5.12: Potassium element concentration in groundwater sample in study area around Kampung Ayer Asahan Hulu, Tanah Merah Kelantan

Based on figure above, highest potassium concentration in study area is located in well U7, 4.437 mg/l whereas the well U12 recorded to have the lowest potassium concentration which is 0.489 mg/l. The mean average of potassium concentration in overall wells in study area is 1.93 mg/l which is lower than the permissible limit by both W.H.O. and M.O.H. that is 12 mg/l and 30 mg/l respectively.

The southern part of study area has a concentration as high as 2.863 m/l located in well U9 whereas the northern part of study area has a potassium concentration as high as 2.936 mg/l. The center part of study area, U7 has a potassium concentration of 4.437 mg/l. This is because one of the factors determining the value of potassium concentration of groundwater is the landuse because potassium is being used for fertilizing purposes. In the study area, agricultural activities can mostly be seen mostly on the center and southern part of study area.



POTASSIUM CONCENTRATION DISTRIBUTION MAP IN STUDY AREA

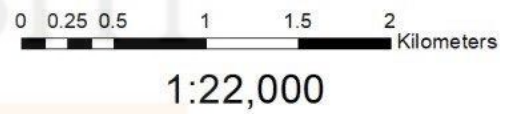
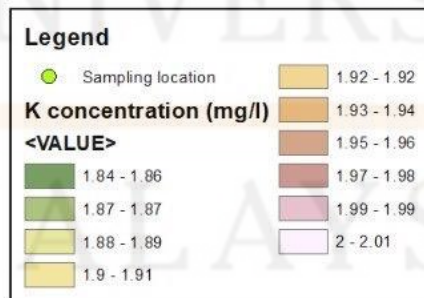
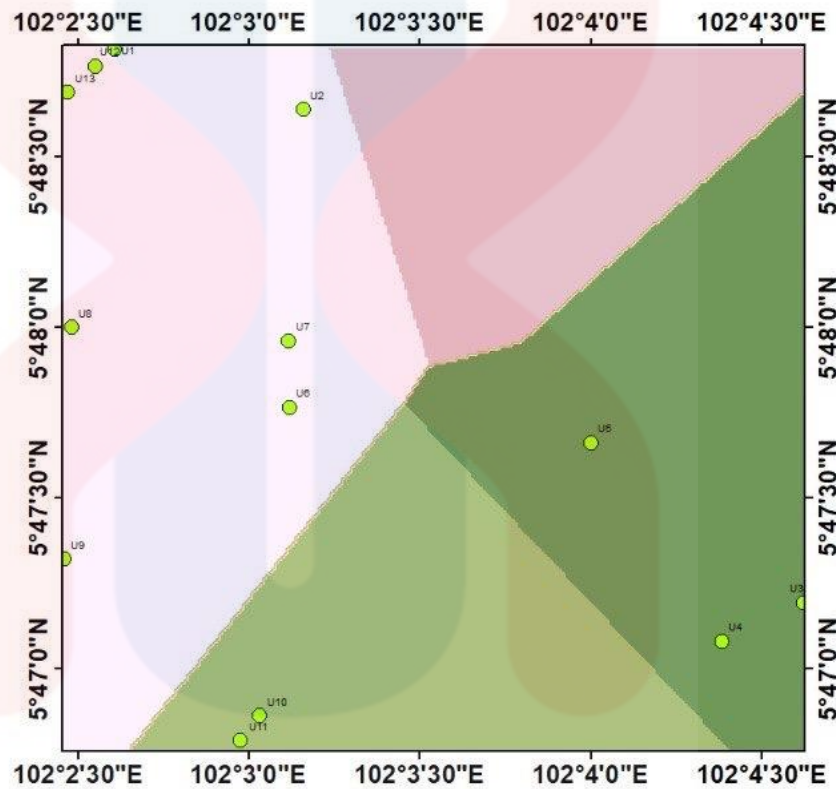


Figure 5.13: Potassium concentration distribution map in study area

Source: ArcGIS Software (2022)

5.4.4 Magnesium, Mg²⁺

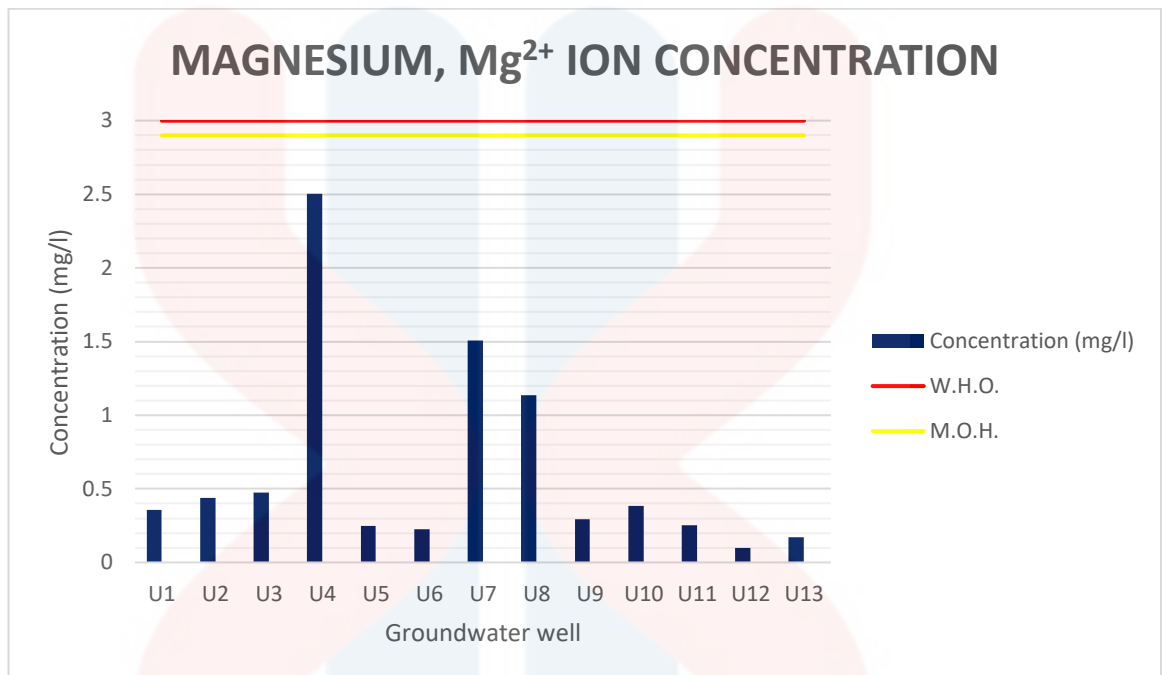


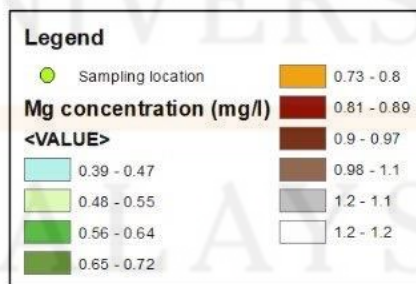
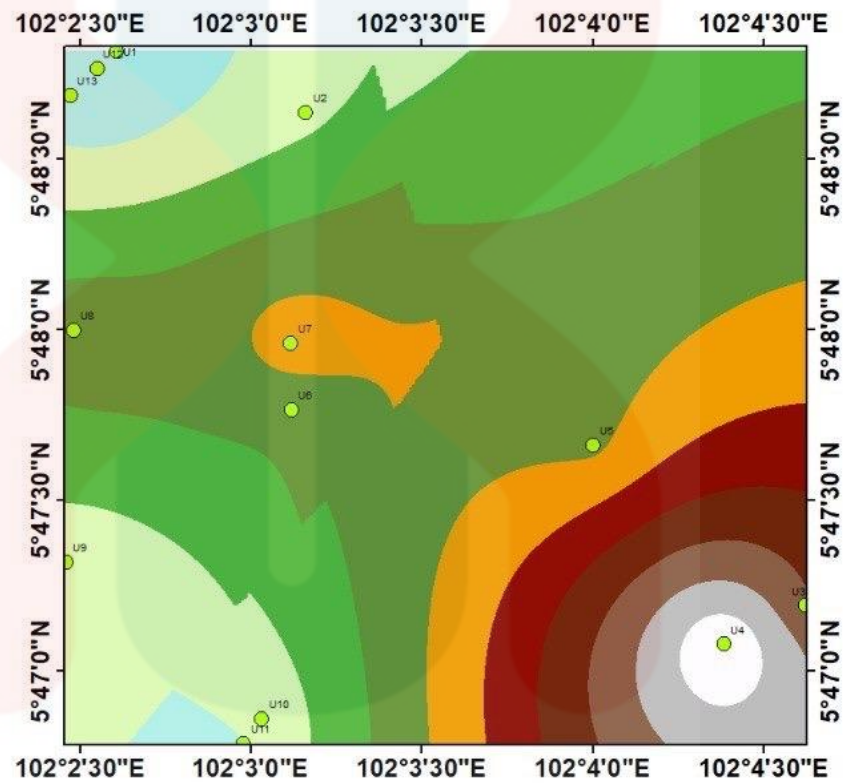
Figure 5.14: Magnesium element concentration in groundwater sample in study area around Kampung Ayer Asahan Hulu, Tanah Merah Kelantan

Based on the figure above, the range of Magnesium ion concentration in study area is as low as 0.098 mg/l located in well U12 and as high as 2.505 mg/l located in well U4. The mean average of magnesium concentration in study area is 0.62 mg/l which did not exceed the permissible limit given by both W.H.O. and M.O.H which is 150 mg/l. This can be said that mostly in study area groundwater samples and in a safe limit in terms of magnesium concentration.

Magnesium concentration also depends on the surrounding activities. In study area, agricultural activities can mostly be found such as oil palm plantation and rubber plantation. This can affect the magnesium ion concentration in groundwater sources. Rather than agricultural activities, tributaries and rivers also have potential to carry together traces of seawater that seeps into soil that will manage to increase the concentration of magnesium (Willis, 2001).



MAGNESIUM CONCENTRATION DISTRIBUTION MAP IN STUDY AREA



1:22,000

Figure 5.15: Magnesium concentration distribution map in study area

Source: ArcGIS Software (2022)

5.4.5 Ferum, Fe²⁺

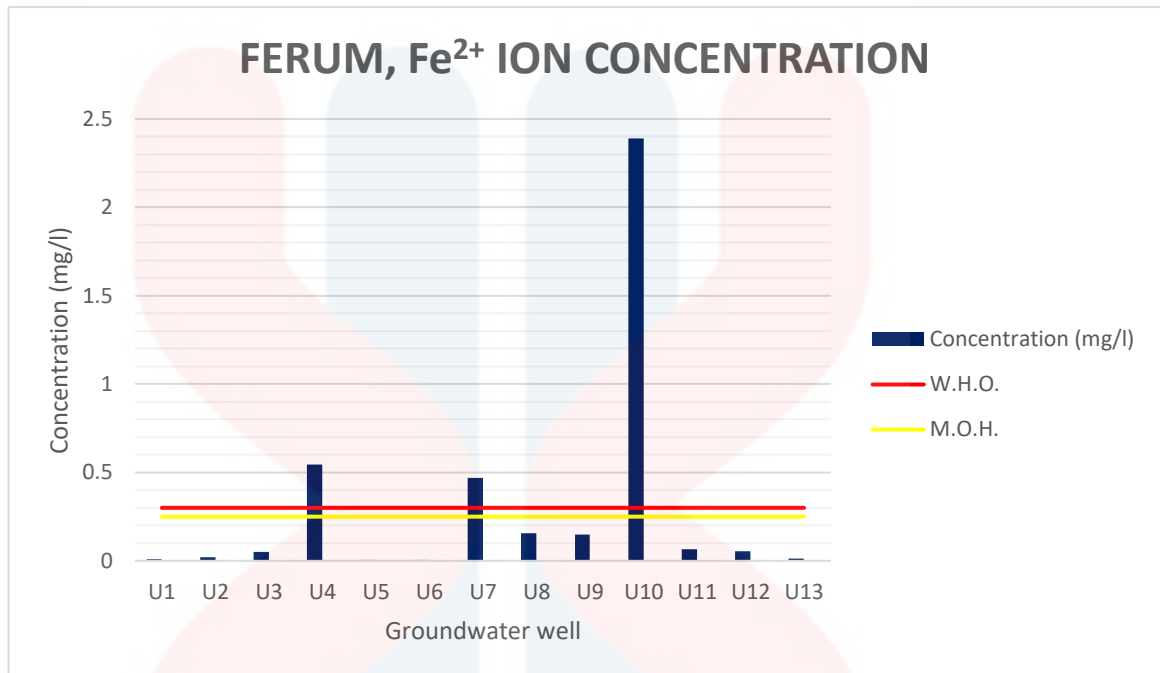


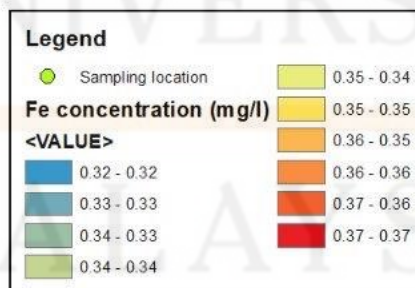
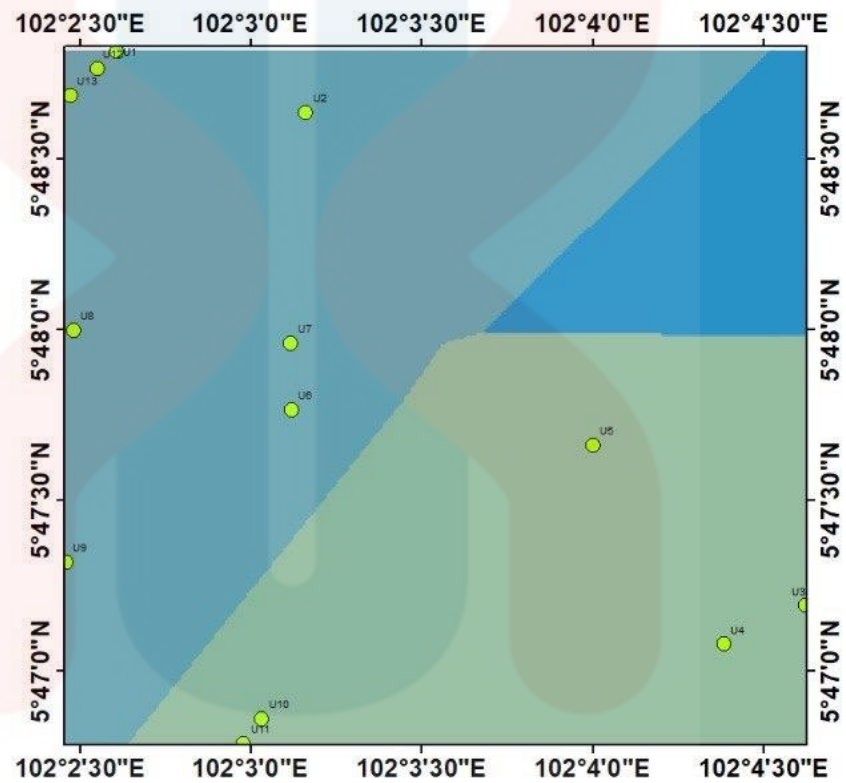
Figure 5.16: Ferum element concentration in groundwater sample in study area around Kampung Ayer Asahan Hulu, Tanah Merah Kelantan

Based on figure above, the range of ferum concentration in all 13 groundwater samples acquired is as high as 2.392 mg/l located in U10 and as low as 0.004 mg/l located in U6. In this concentration it has a mean average of 0.3 mg/l which is exactly the highest permissible limit suggested by both W.H.O. and M.O.H.

Since the study area and locations of groundwater sample collection in more to rural areas and villages, the concentration level can be found as high as 50 mg/l although the permissible limit is only lesser than 0.3 mg/l. This may be due to dissolution process happened between the ferrous borehole and handpump tools since most of the areas are using handpumps nowadays. High ferum composition in domestic well can be seen affected on the unwelcoming taste and discolouration and ruined clothes during laundry activities (Lenntech, n.d.).



FERUM CONCENTRATION DISTRIBUTION MAP IN STUDY AREA



1:22,000

Figure 5.17: Ferum concentration distribution map in study area

Source: ArcGIS Software (2022)

5.5 Major Anion Concentrations

5.5.1 Nitrate, NO_3^-

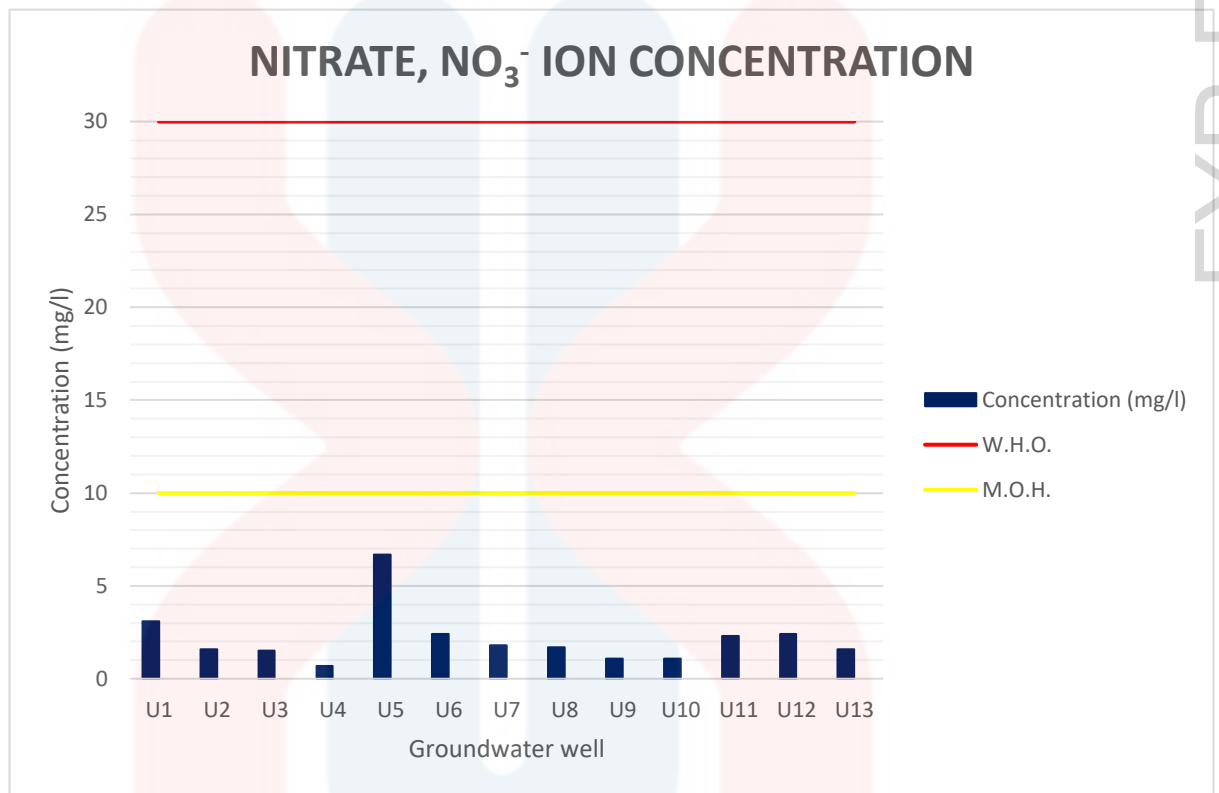
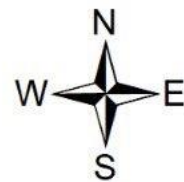


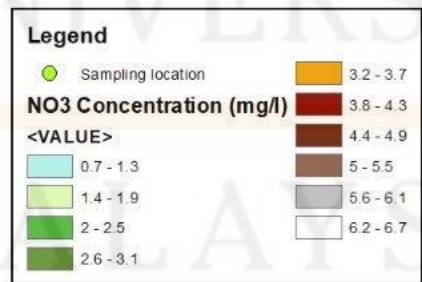
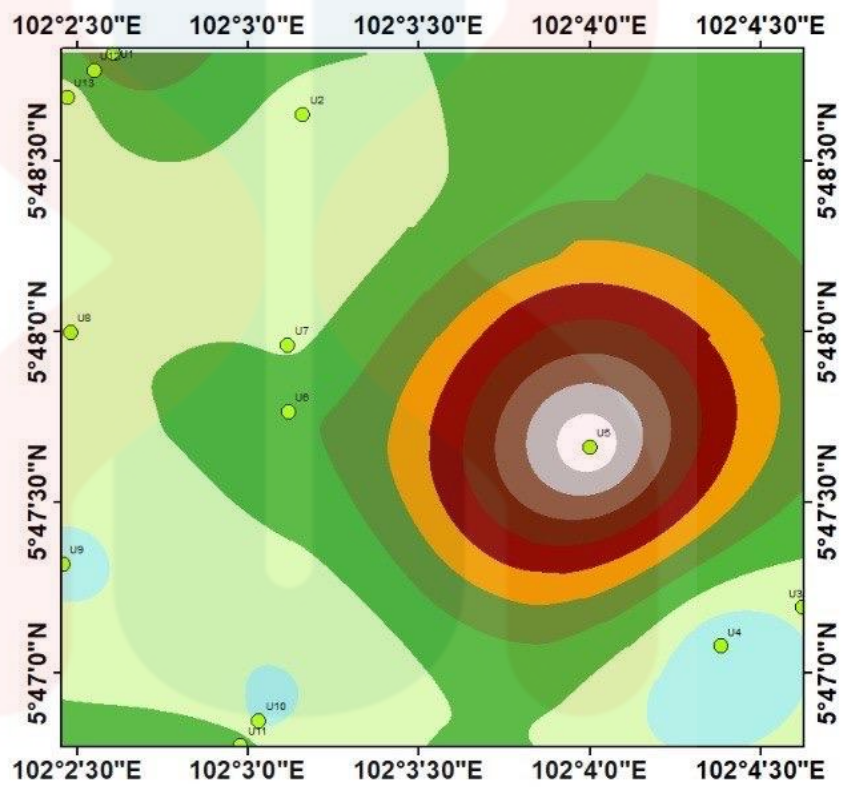
Figure 5.18: Nitrate element concentration in groundwater sample in study area around Kampung Ayer Asahan Hulu, Tanah Merah Kelantan

Based on the figure above, the highest nitrate concentration is located in well U5, which is 6.7 mg/l whereas the lowest nitrate concentration is located in well U4 which is 0.7 mg/l. The mean average of the total 13 wells nitrate concentration is 2.15 mg/l that is not exceed the permissible limit suggested by both W.H.O. and M.O.H. which is 50 mg/l and 10 mg/l respectively.

Agricultural activities might contribute to the increment of the nitrate concentration in a particular areas due to the fertilization of crops process. Although it is something mainstream to be seen in agricultural areas, the high concentration of this ion is practically not good for crops and plantations since it will lessen the fertility of the agriculture (McLay et. al., 2001).



NITRATE CONCENTRATION DISTRIBUTION MAP IN STUDY AREA



1:22,000

Figure 5.19: Nitrate concentration distribution map in study area

Source: ArcGIS Software (2022)

5.5.2 Sulphate, SO_4^{2-}

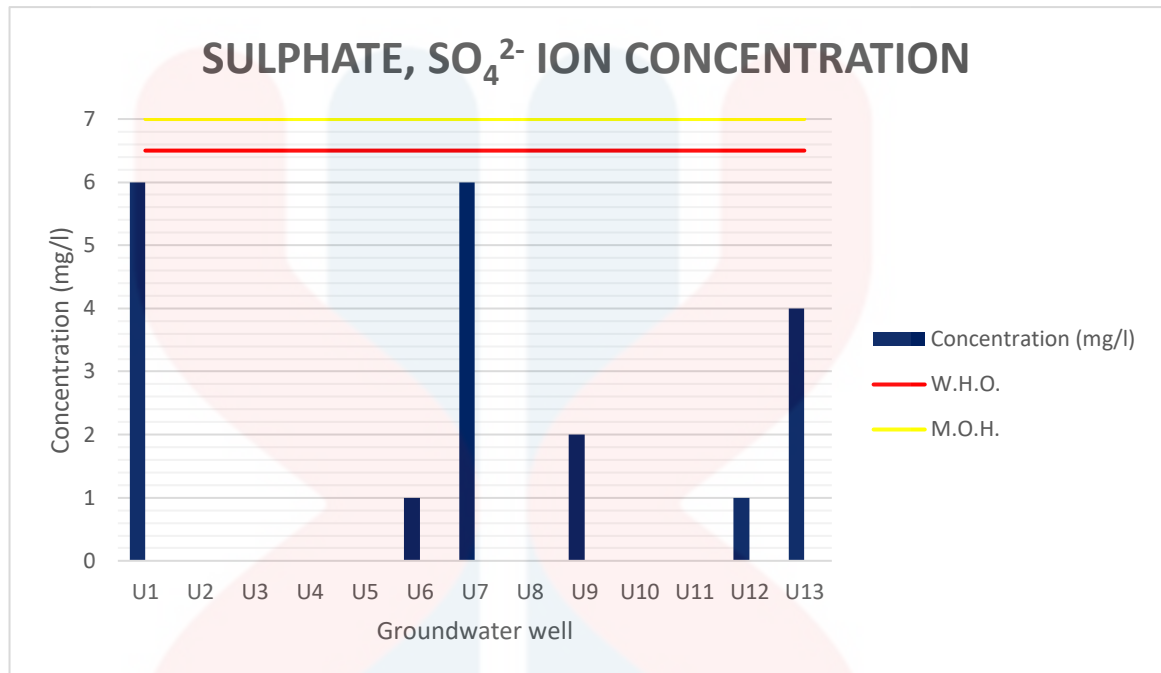


Figure 5.20: Sulphate element concentration in groundwater sample in study area around Kampung Ayer Asahan Hulu, Tanah Merah Kelantan

Based on the figure above, the range of sulphate ion concentration is as high as 6.0 mg/l located in well U7 and as low as 1.0 mg/l located in well U6. Nevertheless, there are also some wells that has a sulphate concentration of 0 mg/l. This wells might have a very little to no composition of sulphate in these wells such as well U2, U3, U4, U5, U8, U10 and U11. The highest sulphate concentration is located in central part of study area which is near to agricultural activities. Geological factors may plays an important role in the concentration of sulphate ion because rocks and soils that comprised of gypsum, iron sulphides and some other sulphured compositions may increase the concentration of sulphate ion (Willis, 2011). In the study area, mostly the values of the sulphate ion concentration did not exceed the permissible limit suggested by W.H.O. and M.O.H which is 200 mg/l and 250 mg/l respectively. This shows that the groundwater samples taken is safe to be used in terms of sulphate composition.



SULPHATE CONCENTRATION DISTRIBUTION MAP IN STUDY AREA

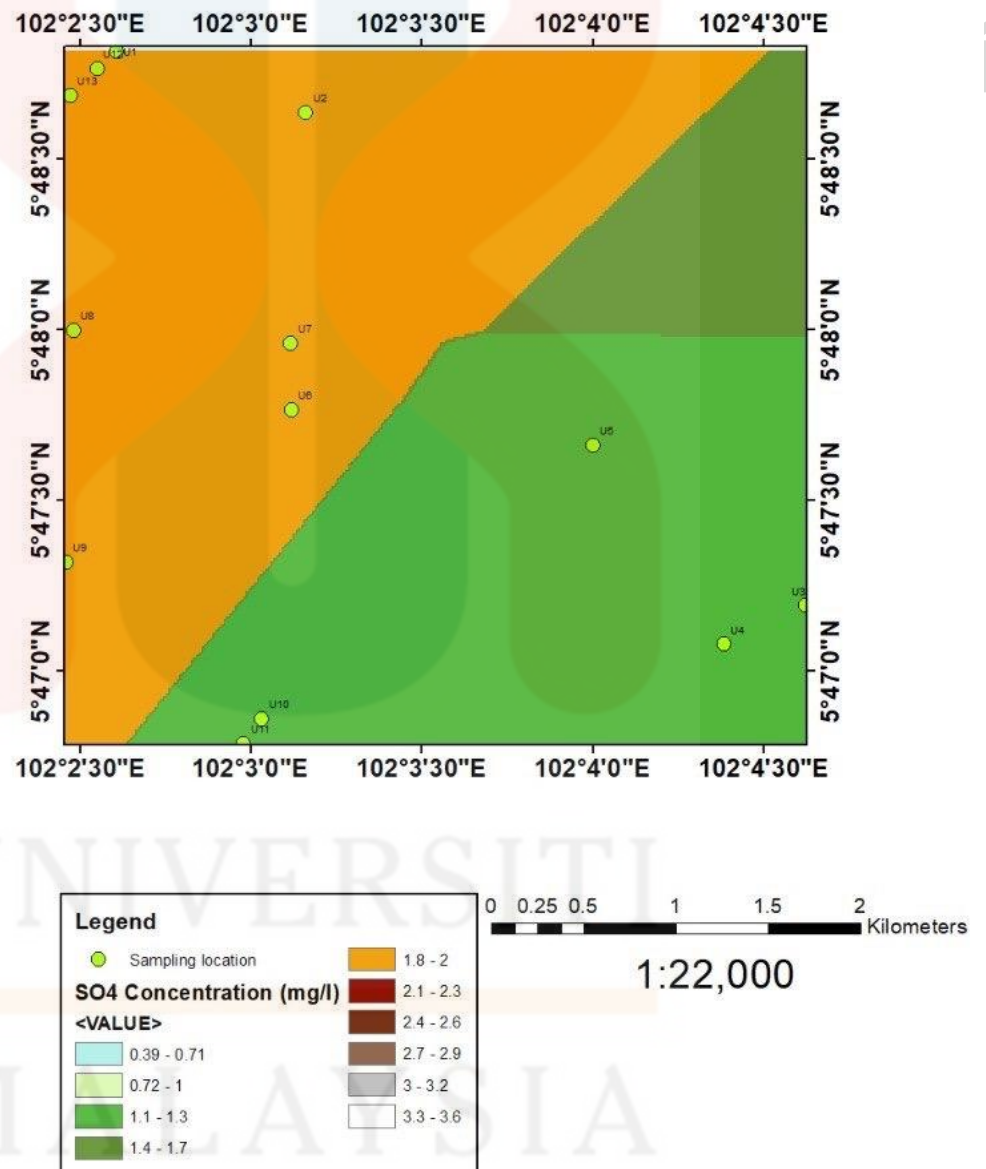


Figure 5.21: sulphate concentration distribution map in study area

Source: ArcGIS Software (2022)

5.5.3 Chloride, Cl⁻

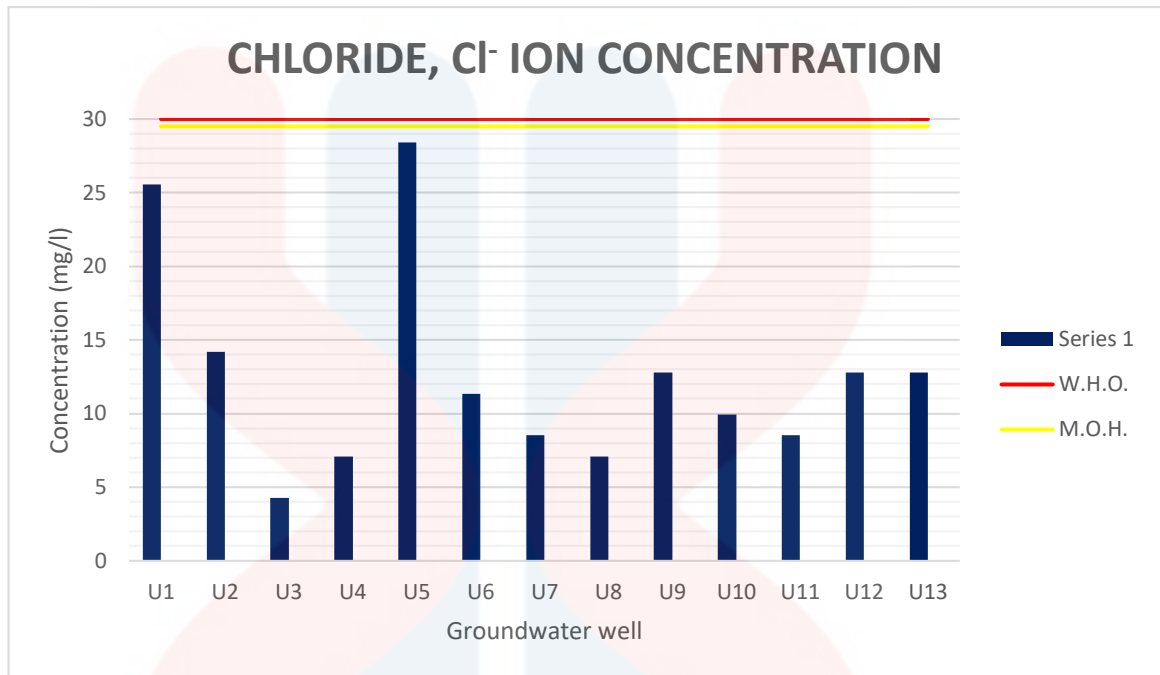
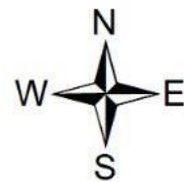
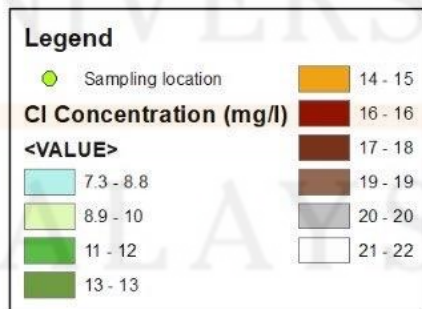
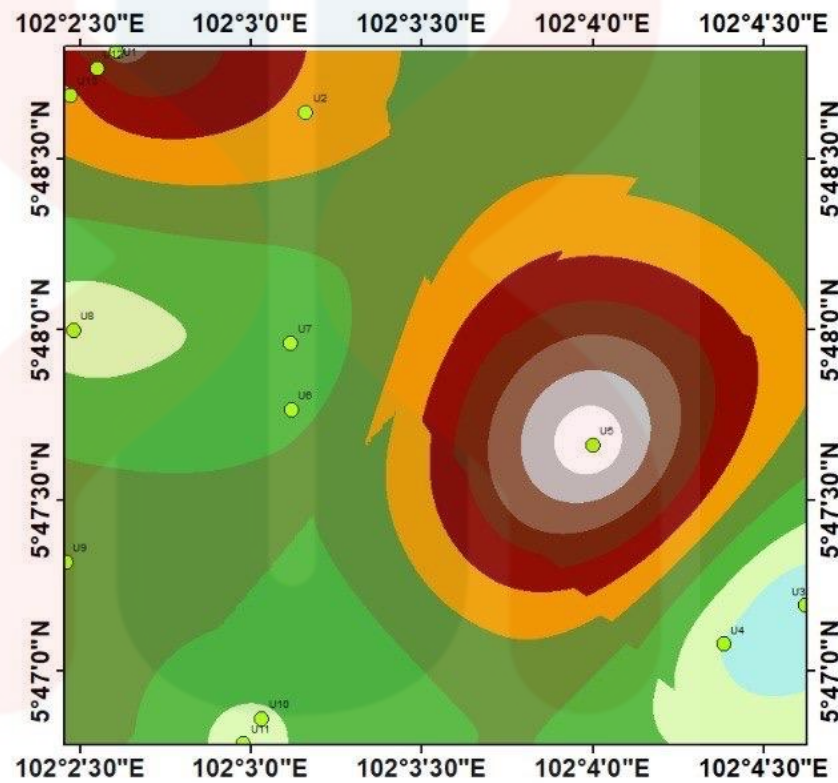


Figure 5.22: Chloride element concentration in groundwater sample in study area around Kampung Ayer Asahan Hulu, Tanah Merah Kelantan

Based on figure above, chloride ion concentration has the highest value in well U5 with a value of 28.4 mg/l and lowest concentration value in well U3 with a value of 4.26 mg/l. The average mean chloride concentration overall in 13 groundwater samples taken from various domestic wells is 12.56 mg/l which is far below the permissible limit suggested by both W.H.O and M.O.H. which is 250 mg/l. Chloride may be present in a groundwater sources due to dissolution process of rocks and soils. Therefore, the groundwater sources in these domestic wells are safe in terms of chloride ion concentration.



CHLORIDE CONCENTRATION DISTRIBUTION MAP IN STUDY AREA



1:22,000

Figure 5.23: Chloride concentration distribution map in study area

Source: ArcGIS Software (2022)

5.5.4 Bicarbonate, HCO_3^-

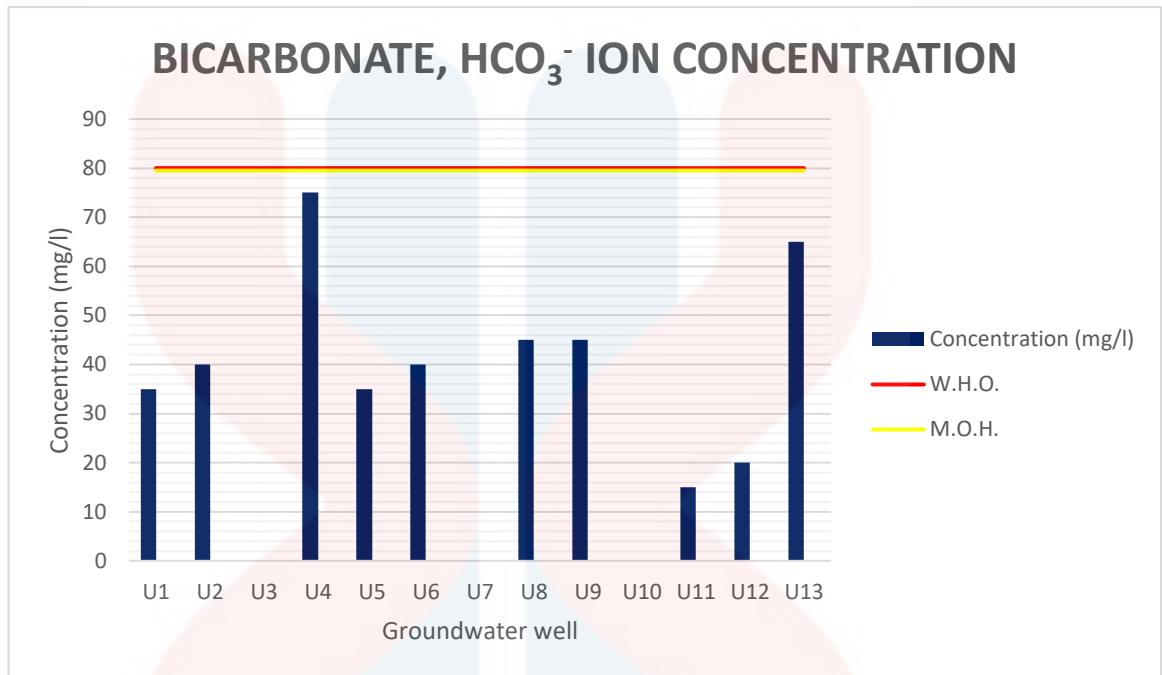


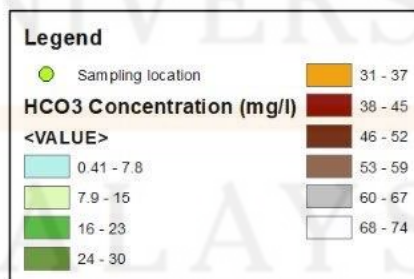
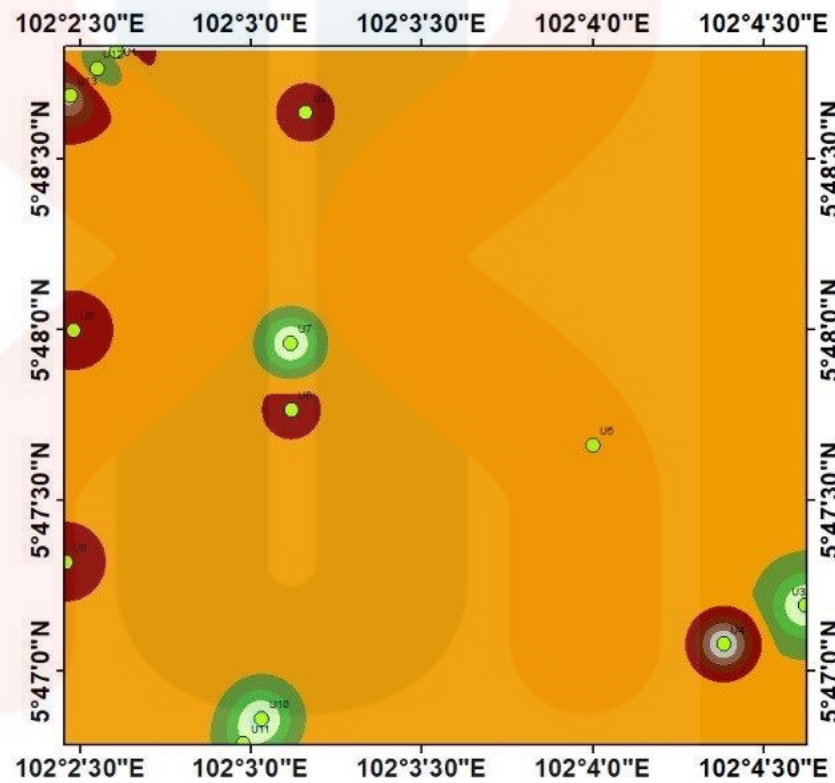
Figure 5.24: Bicarbonate element concentration in groundwater sample in study area around Kampung Ayer Asahan Hulu, Tanah Merah Kelantan

Based on figure above, highest bicarbonate ion content in 13 groundwater samples acquired is located in well U4, with a value of 75.0 mg/l and the lowest bicarbonate ion concentration is located in well U10 which has a 0 mg/l value. Referring to the permissible limit suggested by both M.O.H. and W.H.O. which is 500 mg/l, groundwater samples taken are by far safe to be used in terms of bicarbonate ions.

MALAYSIA
KELANTAN



BICARBONATE CONCENTRATION DISTRIBUTION MAP IN STUDY AREA



1:22,000

Figure 5.25: Bicarbonate concentration distribution map in study area

Source: ArcGIS Software (2022)

5.5.5 Fluoride, F⁻

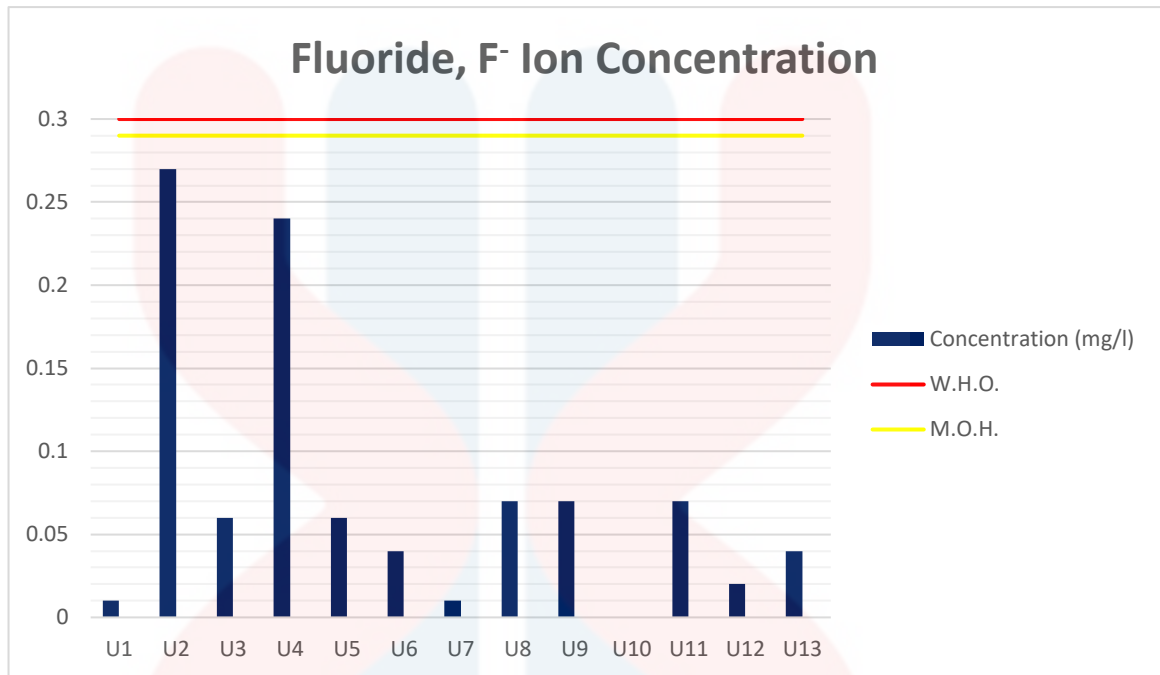
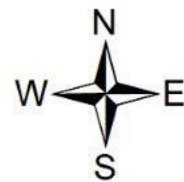
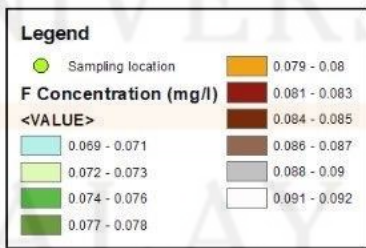
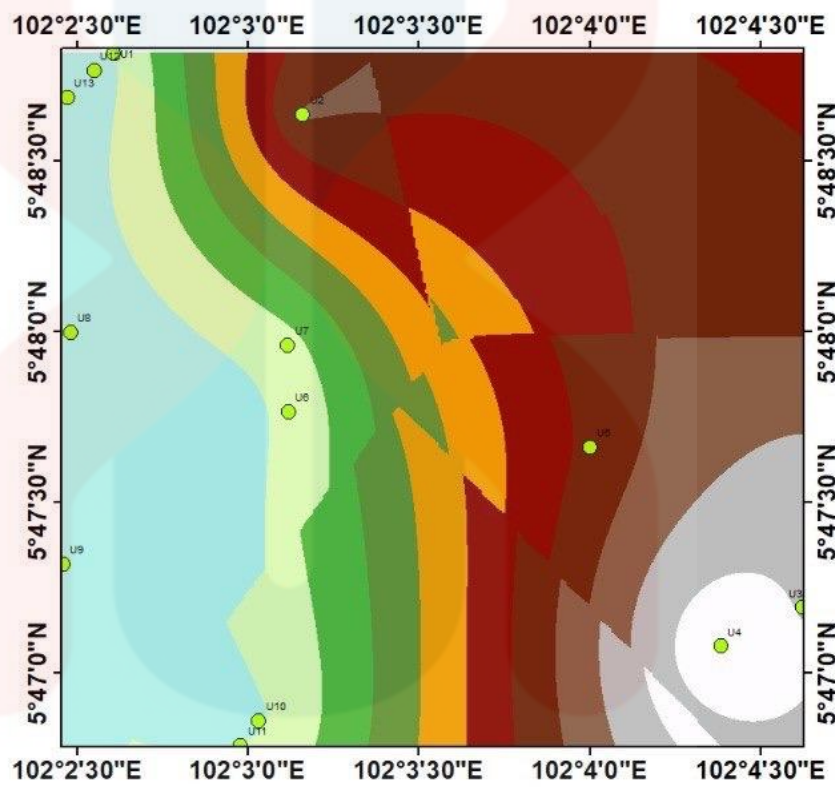


Figure 5.26: Fluoride element concentration in groundwater sample in study area around Kampung Ayer Asahan Hulu, Tanah Merah Kelantan

Based on the figure above, the highest fluoride ion content is located in well U2 with a value of 0.27 mg/l and the lowest value is located in well U10 which is 0mg/l. Meanwhile, the average mean value of the fluoride ion concentration in all groundwater samples taken is 0.07mg/l. By far, W.H.O. and .M.O.H. suggested a permissible limit for drinking water purpose is 1.5mg/l which is far from the values obtained from the groundwater samples. Therefore, in terms of fluoride content, sources is safe to be used.



FLUORIDE CONCENTRATION DISTRIBUTION MAP IN STUDY AREA



1:22,000

Figure 5.27: Fluoride concentration distribution map in study area

Source: ArcGIS Software (2022)

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

To conclude the research, study area mostly comprised of agricultural areas. Within the total area of 25 km² of study area, rubber plantation and oil palm plantation can easily be seen anywhere in study area be it a full-grown plantations and early phase of plantations. An updated geological of the study area is produced through ArcGIS software in the scale of 1:25,000. The study area does not comprise of a variety of topography as the highest elevation is 160m and the lowest elevation is 30m. Therefore, study area is mostly dominated by plain areas. Major rock type can be found in study area is acid intrusive which is granite rocks which can be found mostly in study area.

In terms of groundwater quality analysis, laboratory analysis found that groundwater samples are mostly safe to be used according to the permissible limit suggested by both W.H.O. and M.O.H. This is because by referring and following the limits suggested, many side effects can be avoided such as properties guarantee and health guarantee. Except for ferum ion concentration. Even though there is no specific health or concerns regarding high ferum concentration in groundwater source, some side effects might be a concern to users as well such as its unpleasant smell and colour.

It can be said that most of the groundwater samples taken shows a result of a not too high content of pollutions and contaminations. Contamination of groundwater may be due to the surrounding activities and recharge sources. From this, it can be concluded that the content of major cations and major anions in the groundwater samples are low. Therefore, still safe to be used for domestic purposes.

6.2 Recommendations

Groundwater quality is not something that stays stagnant throughout the years and centuries. It changes every time during monsoonal seasons and depending on the quality of the recharge and the surroundings. Therefore, this research and continuously be done so that users and local people in the study area are continuing to receive a proper quality of groundwater in their domestic wells.

An awareness should be done to the residents moreover to those who are using groundwater and domestic wells for domestic purposes. Residents should acknowledge the importance of doing and carrying out analysis and groundwater monitoring from time to time in order to ensure the water that is being taken and consume daily is safe and do not giving bad effects moreover to the health of the users.

This linked to the responsibility of the government and those who are in charge in developing and monitoring the groundwater quality from time to time. Other than giving acknowledgement and awareness, the higher ups should know that they are playing a big part in maintaining the groundwater quality after the residents itself that consume the groundwater sources every day.

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