GENERAL GEOLOGY AND HYDROGEOCHEMISTRY OF GROUNDWATER AT TERENGGANU RIVER BASIN

by

NUR AMANINA RASYIDAH BINTI SUHAIMI

A research thesis submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Geoscience)

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DECLARATION

I declare that this bachelor degree thesis of applied science (Geoscience) entitled "*General Geology and Hydrogeochemistry of Groundwater at Terengganu River Basin*" is the result of my own research except as cited in the references and this work has been carried out under the supervision of Dr Mohammad Muqtada Ali Khan. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Signature of Supervisor : ______________________________
Name of Supervisor : DR. MOHAMMAD MUQTADA ALI KHAN
Date : 12TH JANUARY 2017

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ABSTRACT

A geological study has been conducted at the study area in order to update the geological map in scale 1:25 000 including the study of igneous, sedimentary and metasedimentary rocks that found in the study area. A base map in a scale 1:25 000 was prepared in order to traverse the study area that is compulsory in 5km² for the study. All the geological studies such as geomorphology, stratigraphy and structural geology have been observed. Generally, the groundwater of Terengganu River Basin is the main source of water for some residential area at Terengganu, the hydrogeochemical characteristics of groundwater in Terengganu River Basin has tendency of contamination by major chemical constituents and the trace element that were anticipated. A study of geochemical process could assist a lot in order to get the precise value of concentration of major chemical constituents and trace elements. All the major chemical constituent and trace element include Bicarbonate Bicarbonate (HCO_3^-), Chloride (Cl), Calcium (Cal), Magnesium (Mg), Sodium (Na), Potassium (K), Iron (Fe), Manganese (Mn), Copper (C) and Zinc (Zn) have been measured by using the Ion Chromatography (IC) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The physical parameters such as pH, Total Dissolved Solid (TDS), electric conductivity and salinity also been observed directly during the fieldwork sampling. All the value and the concentration could be obtained and analysed from this study. Besides, hydrogeochemical facies of the groundwater at the study area such as Alkali-HCO_3, Ca-Mg-HCO_3, Alkali-SO_4-Cl which are the type of groundwater were observed from this study.

ABSTRAK

Satu kajian geologi telah dijalankan di kawasan kajian untuk mengemaskini peta geologi dalam skala 1:25 000 termasuk kajian batu-batuan igneus, sedimen dan metasedimentari yang dijumpai di dalam kawasan kajian. Sebuah peta asas dalam skala 1:25 000 telah disediakan untuk merentasi kawasan kajian yang diwajibkan seluas 5km² untuk kajian. Semua kajian geologi seperti geomorfologi, stratigrafi dan geologi struktur telah diperhatikan. Secara umumnya, air bawah tanah di Lembangan Sungai Terengganu merupakan sumber utama air untuk beberapa kawasan perumahan di Terengganu. Ciri-ciri hidrogeokimia air bawah tanah di Lembangan Sungai Terengganu mempunyai kecenderungan pencemaran oleh bahan kimia utama dan unsur surih yang dijangkakan. Satu kajian ke atas proses geokimia boleh membantu banyak dalam usaha untuk mendapatkan nilai tepat kepekatan juzuk kimia utama dan unsur surih. Semua konstituen kimia utama dan elemen surih termasuk Bikarbonat (HCO_3^-), Klorida (Cl), Kalsium (Cal), Magnesium (Mg), Natrium (Na), Kalium (K), Besi (Fe), Mangan (Mn), Kuprum (C) dan Zink (Zn) telah diukur dengan menggunakan Ion Chromatography (IC) dan Pasangan Plasma Induktif Mass spektrometri (ICP-MS). Parameter fizikal seperti pH, Jumlah terlarut pepejal (TDS), kekonduksian elektrik dan kemasinan juga telah diperhatikan secara langsung semasa persampelan kerja lapangan ini. Semua nilai dan kepekatan boleh diperoleh dan dianalisis daripada kajian ini. Selain itu, fasies hidrogeokimia air bawah tanah di kawasan kajian seperti Alkali-HCO_3, Ca-Mg-HCO_3, Alkali-SO_4-Cl adalah jenis air bawah tanah yang diperoleh dari kajian ini.

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LIST OF ABBEREVATIONS

NE	North-East
SW	South-West
NW	North-West
SE	South-East
IC	Ion Chromatography
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
TDS	Total Dissolved Solid
TSS	Total Suspended Solvent
EC	Electric Conductivity
GPS	Global Positioning System
HCL	Hydrochloric acid
HCO_3	Bicarbonate
SO_4	Sulphate
Cl	Chloride
Ca	Calcium
Mg	Magnesium
Na	Sodium
Mn	Manganese
K	Potassium
Fe	Iron
Cu	Copper
Zn	Zinc
Mg	Milligram
L	Litre

LIST OF SYMBOLS

“	Second
‘	Minute
º	Degree
ºC	Temperature
%	Percentage

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Groundwater is a noteworthy wellspring of clean drinking water everywhere throughout the world. It has been an essential asset particularly in the dry part of the world including North America and European landmass. Groundwater has been utilized as a part of Malaysia for numerous hundreds of years (Ang, 1994). However the use was mostly constrained to the shallow or unconfined aquifers utilizing burrowed wells. Profound tubewells in coarse sand aquifers were created in the previous 20 years for water supply of beach front town, for example, Kota Bharu (Sofner,1989). Late advancement in well penetrating is driven by the improvement of businesses and populace development. Processing plant, for example, material producer, elastic production line also, quarry are starting to utilize groundwater as supplement to surface water.

Groundwater is additionally utilized as a part of fish incubator and cultivating, domesticated animals and farming exercises and in household utilization (Bouwer, 1979). Mineral water businesses are too tapping groundwater yet the amount is moderately little. The part that groundwater has played in the advancement of humanity is limitless. The utilization of groundwater has been expanding and in light of this, groundwater has had a tendency to be used in a sloppy way. This is because of expanding populace and commercial ventures, urbanization, horticulture, generation and assembling divisions. Thus, numerous spots in the world experience the ill effects of an exhaustion or contamination of groundwater, interruption of saline water furthermore, event of area subsidence. These situations have achieved genuine outcomes to living conditions as well as to essential foundations too.

1.2 Problem Statement

Base map of Kuala Terengganu literally lack of the current data for all the geological features therefore it needs to be created and updated regarding to the data that has been collected on my study. Most of the groundwater study is discussed about quality and quantity in fact they supposed to be discussed about how does the hydrogeochemical acts in reservoir in order to get the detail and complete data of their groundwater study. Yet, there is no detail hydrogeochemical study on groundwater in Terengganu.

1.3 Objective

i. To update the geological map of Bukit Jong, Terengganu in a scale 1:25000

ii. To analyze the physical and chemical characteristic of groundwater at Terengganu River Basin.

iii. To identify the groundwater facies at Terengganu River Basin by using the piper trilinear diagram.

1.4 Significant of Study

The research that has been done is come along with the significant about the study of hydrogeochemistry at groundwater. This study is able to clarify the significant correlation between hydrogeochemistry and groundwater. Therefore, this study shows the new results of physical and chemical properties of hydrogeochemical process of groundwater at Terengganu river basin. From the preliminary study, it is a good relevance study for interpreting the characteristic of shallow groundwater hydrogeochemistry.

1.5 Study Area

The study area is located along the Terengganu River basin. The Terengganu River basin is situated between a latitude of 4°40'-5°20'N and a longitude of 102°30'-103°09'E in the north eastern coastal region of Peninsular Malaysia. Terengganu River is the main river in this basin which flows from the upper watershed of Kenyir Lake to the South China Sea as shown in Figure 1.2. The main tributaries feeding the Terengganu River are the Nerus, Tersat, Berang and Telemung Rivers. (Suratman et al. 2009). For the general geology, the mapping is conducted at Bukit Jong, Terengganu. The study area shown in the Figure 1.1 as the placemark of water sampling point from the Google Earth together with the base map of Bukit Jong shown in the Figure 1.3

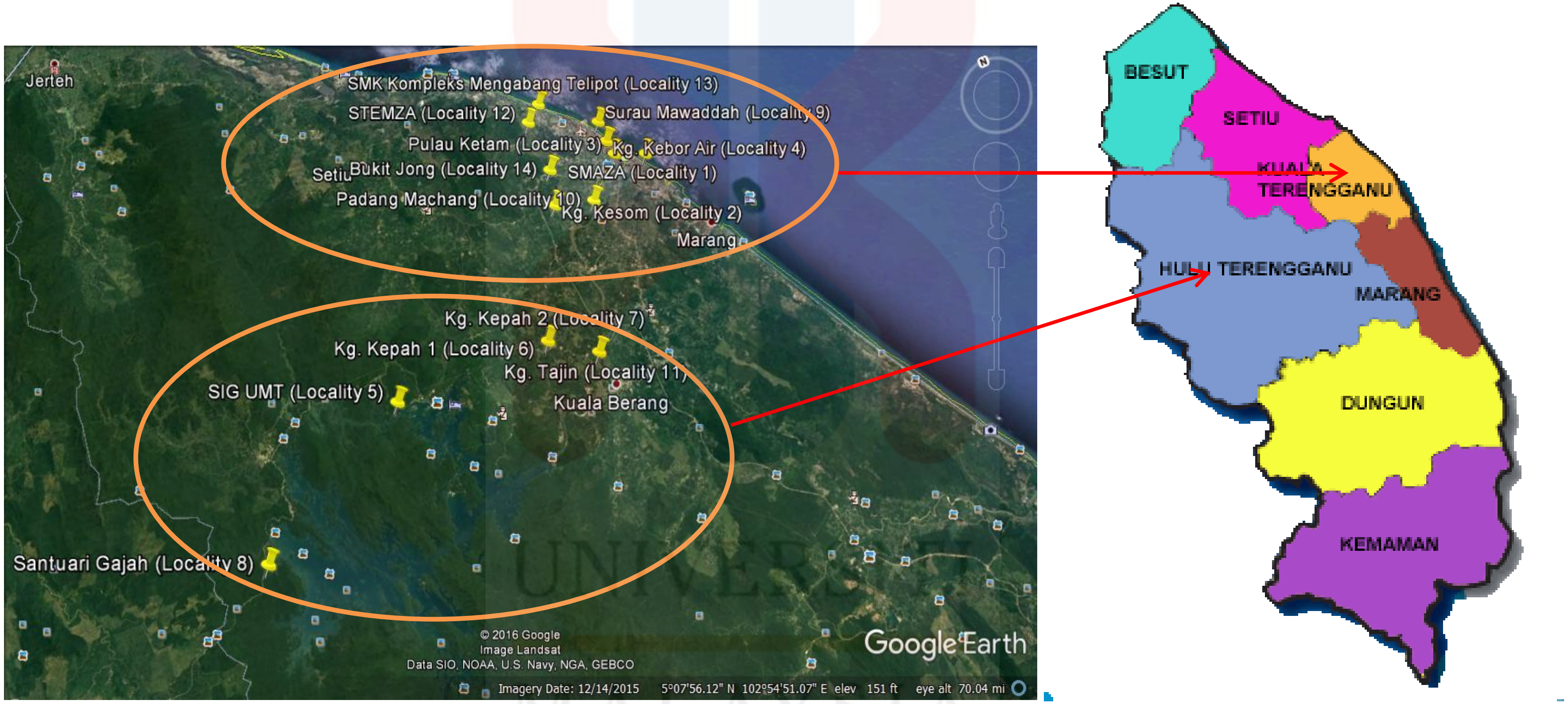


Figure 1.1: Placemark of groundwater sampling point from Google Earth

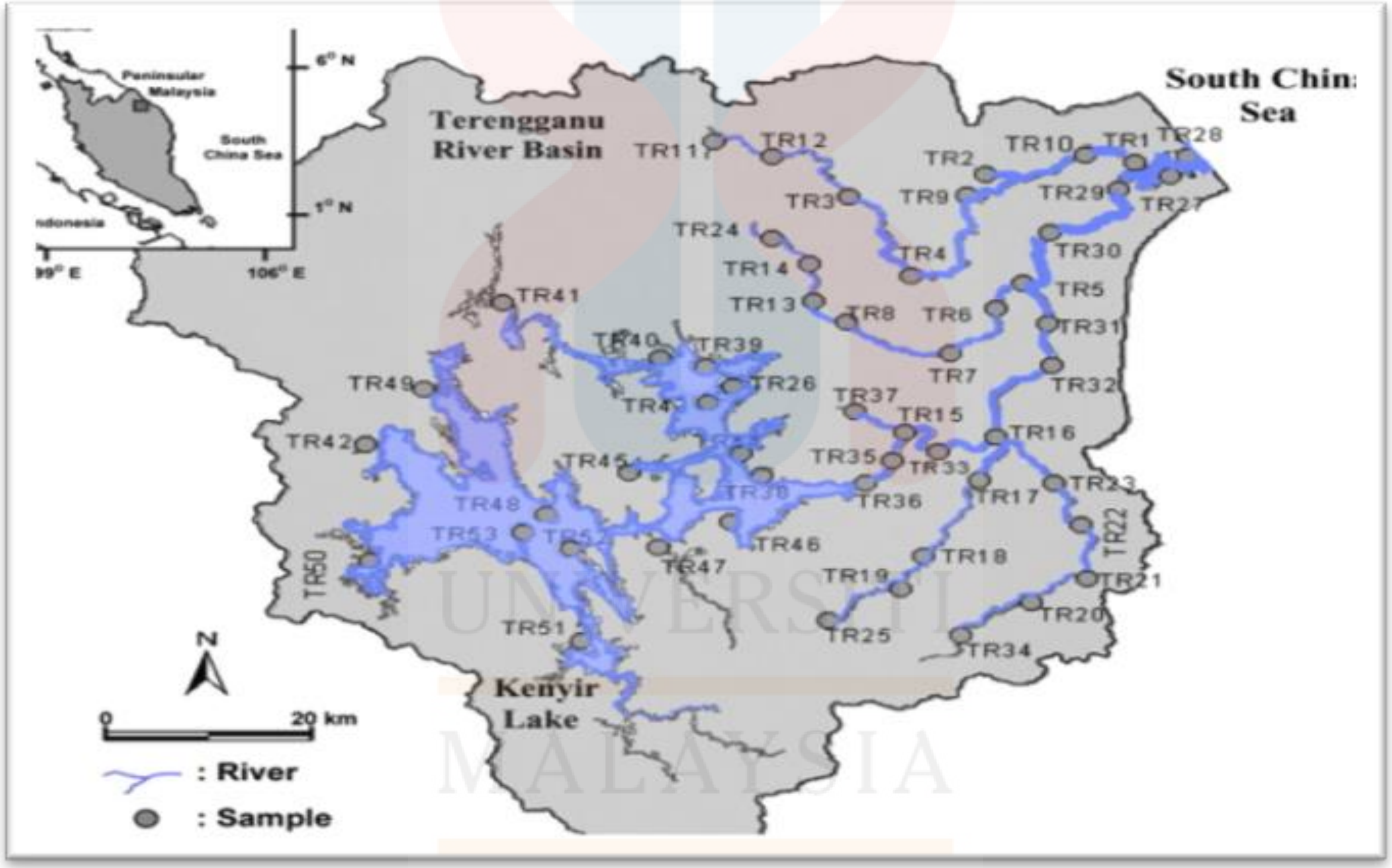


Figure 1.2: Terengganu River Basin

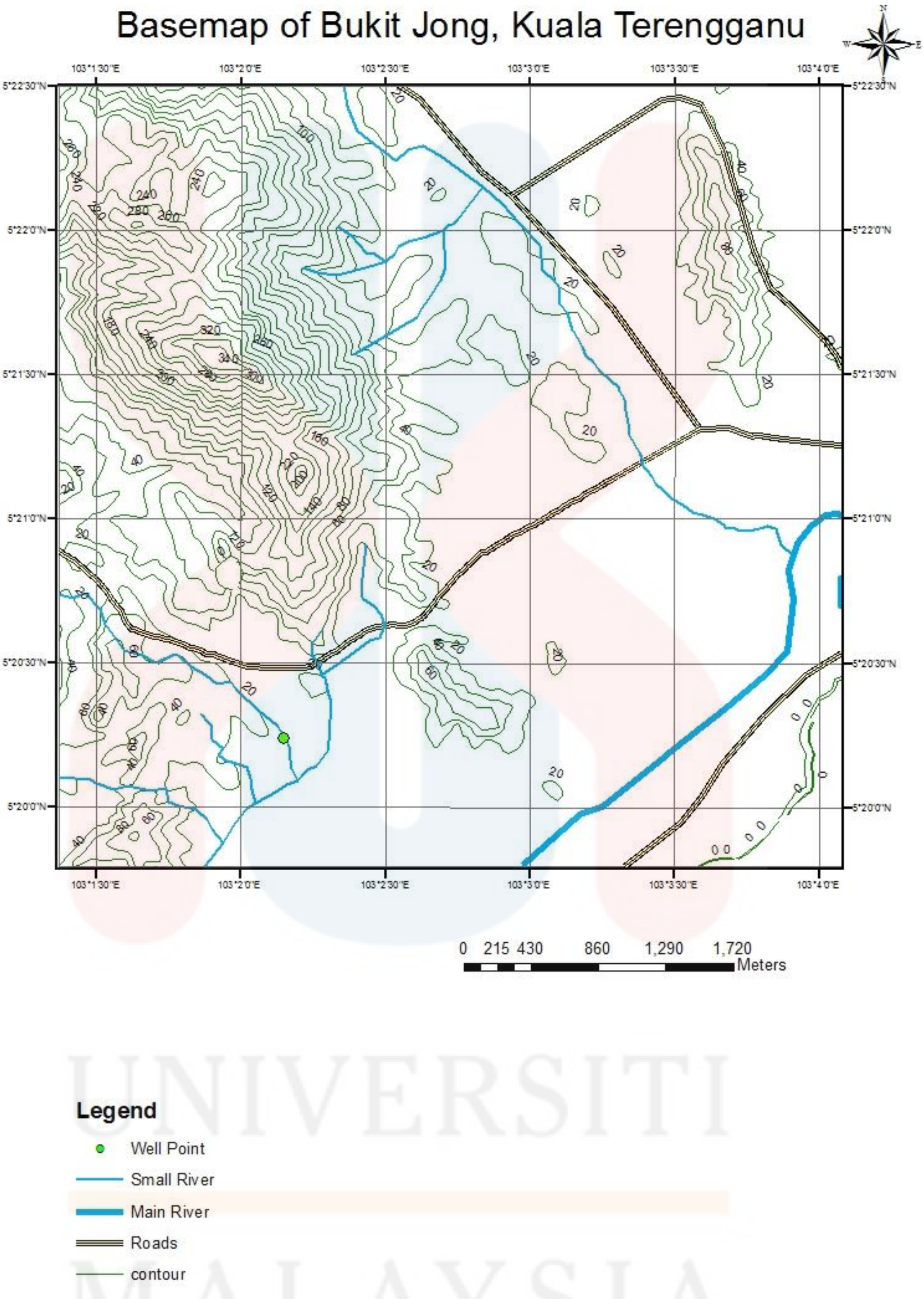


Figure 1.3: Base map of Bukit Jong, Terengganu.

1.5.1 Demography

Malaysia has a population of 25 million today with a growing rate of 2.5% per year. More accuracy based on the census 2010 showed that the total population of Malaysia was 28.3 million, compared with 23.3 million in 2000 as stated in Figure 1.4. Terengganu is one of the states that experienced in the lower rate of growth which total 1.4% from the total population of Malaysia.

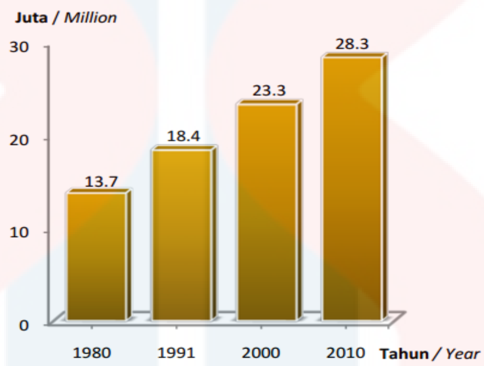


Figure 1.4: Total population of Malaysia

There are approximately 927,000 of total population in year 2004 in Terengganu on which 95% are Malays, 5% are Chinese and the remainder shared among Indian and other ethnics. However in 2010, the total population of Terengganu increase approximately to 1,015,776 according to the table below that source from National Census 2010, Department of Statistics Malaysia.

Table 1.1: Population distribution by states and territories in 2010

State	Population	Area (km²)	Population Density	Urban Population	Bumiputera (%)	Chinese (%)	Indian (%)
Johor	3,348,283	19,210	174	71.9	58.9	33.6	7.1
Kedah	1,890,098	9,500	199	64.6	77.9	13.6	7.3
Kelantan	1,459,994	15,099	97	42.4	95.7	3.4	0.3

Malacca	788,706	1,664	470	86.5	66.9	26.4	6.2
Negeri Sembilan	997,071	6,686	150	66.5	61.3	23.2	15.2
Pahang	1,443,365	36,137	40	50.5	79.0	16.2	4.4
Penang	1,520,143	1,048	1,500	90.8	43.6	45.6	10.4
Perak	2,258,428	21,035	110	69.7	57.0	30.4	12.2
Perlis	227,025	821	280	51.4	88.4	8.0	1.2
Selangor	5,411,324	8,104	670	91.4	57.1	28.6	13.5
Terengganu	1,015,776	13,035	69	59.1	97.0	2.6	0.2
Sabah	3,117,405	73,631	42	54.0	84.8	12.8	0.3
Sarawak	2,420,009	124,450	19	53.8	74.8	24.5	0.3
FT Kuala Lumpur	1,627,172	243	6,891	100.0	45.9	43.2	10.3
FT Labuan	86,908	91	950	82.3	83.7	13.4	0.9
FT Putrajaya	67,964	49	1,400	100.0	98.0	0.7	0.1

1.5.2 Rain Distribution

Understanding the spatial and temporal of rainfall variability is important element in gaining knowledge of water balance dynamics on various scales for water resources management and planning. Basically, Terengganu has tropical monsoon climate which is fairly hot and humid all year around. The temperature is relatively uniform within the range of 21°C to 32°C throughout the year. Along the months of January to April, the weather is basically dry and warm. Humidity is consistently high which approximately 80% in day time.

Terengganu is characterized by two main types of monsoon, the southwest monsoon season which is usually occurred at the end of May or early June and used to be end in September. The wind that used to flow in that particular time is generally south-westerly and light which is below 15 knots. Meanwhile for the northeast monsoon season usually starts in early November and ends in March. Along this season steady easterly or north-easterly winds of 10 to 20 knots prevail. The winds over the east coast states of Peninsular Malaysia may reach up to 30 knots or more during the period of strong surges of cold air from the north.

Terengganu being presented to the coast that gets overwhelming precipitation of around between 2034mm to 2504mm every year which can easily break the bank of the streams and cause overbank release. Approximately, Terengganu is donated an average of 242.6 mm (9.6 in) per month. When the northeast monsoon occur between Novembers to January some areas get suffer by the flood. However in some clear sunny days during the monsoon season, surprisingly east coast is always presented with clear blue sky and cooling wind.

The daily data of rainfall, and stream flow from seven stations of Terengganu Malaysia was collected from Department of Irrigation and Drainage (DID). The Department of Minerals and Geosciences has observed the data for the groundwater level for the period of 2000 to 2012.

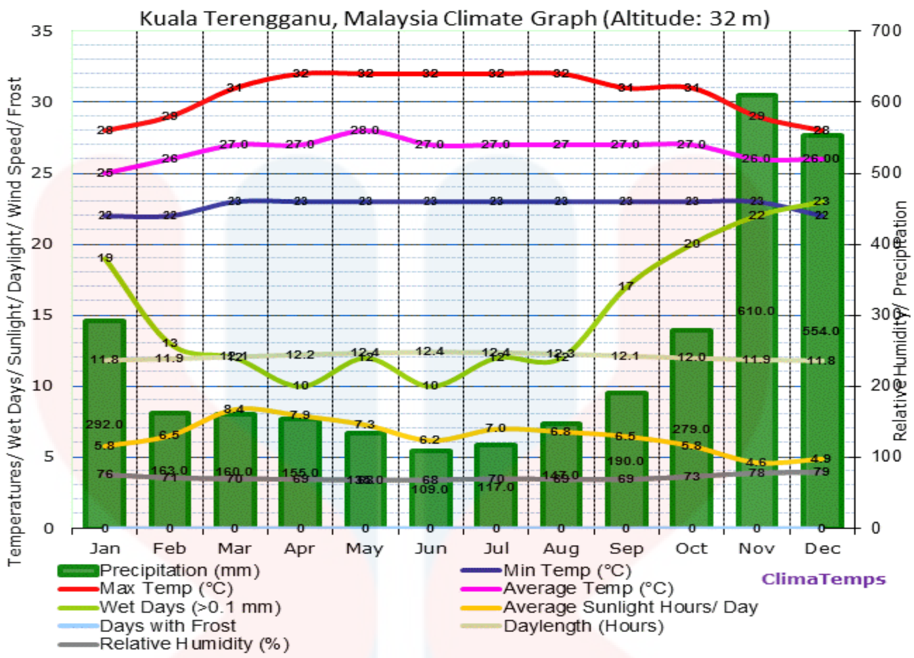


Figure 1.5: Kuala Terengganu climate graph (source: http://www.terengganu.climatemps.com/)

Table 1.2: Rainfall and precipitation table of Kuala Terengganu

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Precipitation mm (in)	292 (11.5)	163 (6.4)	160 (6.3)	155 (6.1)	135 (5.3)	109 (4.3)	117 (4.6)	147 (5.8)	190 (7.5)	279 (11)	610 (24)	554 (21.8)	2911 (114.6)
Precipitation Litres/m² (Gallons/ft²)	292 (7.16)	163 (4)	160 (3.92)	155 (3.8)	135 (3.31)	109 (2.67)	117 (2.87)	147 (3.61)	190 (4.66)	279 (6.84)	610 (14.96)	554 (13.59)	2911 (71.4)
Number of Wet Days (probability of rain on a day)	19 (61%)	13 (46%)	12 (39%)	10 (33%)	12 (39%)	10 (33%)	12 (39%)	12 (39%)	17 (57%)	20 (65%)	22 (73%)	23 (74%)	182 (50%)
Percentage of Sunny (Cloudy) Daylight Hours	50 (50)	55 (45)	70 (30)	65 (35)	60 (40)	50 (50)	57 (43)	56 (44)	54 (46)	49 (51)	40 (60)	42 (58)	55 (45)

(source: http://www.terengganu.climatemps.com/)

1.5.3 Land Use

Terengganu covered a total area of 13,035km2 which is about 4% of Malaysia, and has a land use distribution which categorized as agriculture 22.6%, forest 43%, building 6.5%, industry 0.3% and others 27.6%. The land use contributes a lot as one of the factor influencing recharge.

However, the study area of general geology which is Bukit Jong is now covered by 30% of Quarry and excavated area. Other 40% are covered by the residential and town. Land use of Bukit Jong has been described precisely in Figure 1.7.

Habitat	**Area (km^2)**
Peninsular Malaysia	
Rivers including floods plains	9,111
Peat swamps	4,850
Reservoirs	1,600
Mining pools	164
East Malaysia	
Rivers including flood plains	8,487
Peat swamps	15,150
Reservoirs	22
Total	**39,384**

Figure 1.6: Aquatic ecosystems in Malaysia

(Source: Yusoff and Gopinath, 1995)

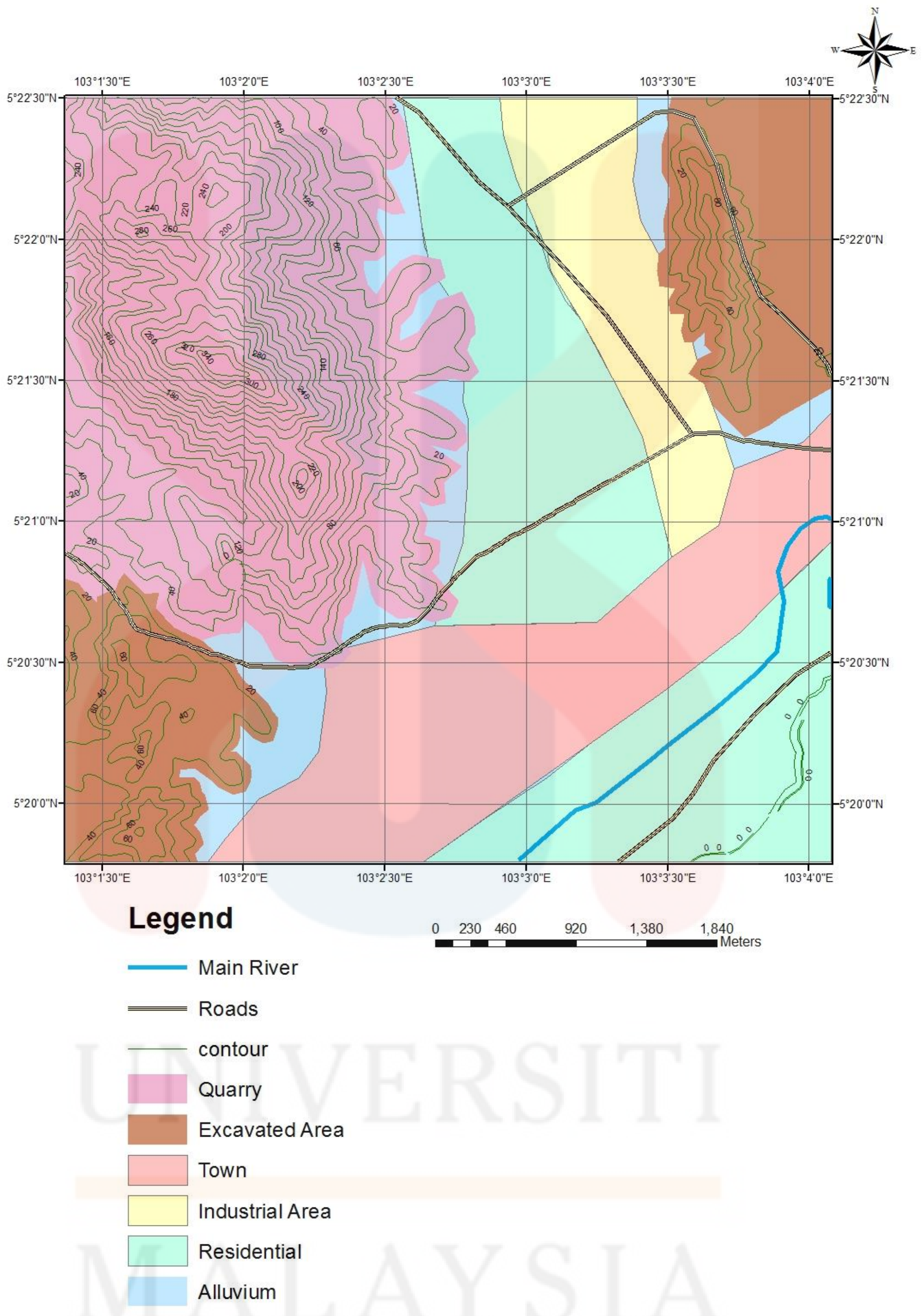


Figure 1.7: Land Use map of Bukit Jong

1.5.4 Social Economic

Terengganu is one of the states of East Coast Economic Region (ECER) of Malaysia. There is some socio-economic backwardness situations are remaining in this state rather than other states of Malaysia. This state is full of natural and mineral resources, islands, beaches, Islamic heritages and cultural attractions. For example, most of the families in Kampung Rhu 10, Terengganu are living by fishing. They generate the income by selling the seafood from their social economic activities. Most of the local people are also expert in making handcraft and batik canting. From that creativity they could generate their family expenses.

1.5.5 Road Connection

Along the way to the groundwater sampling or even rock sampling, there is always a main road connection. However, to reach some location of the wells some of small roads and connection without bituminous have to be pass through. A map traversing has been successful passed through the roads connection.

There is no obstacle to connect with all the roads since the study area is connecting to mostly residential area.

CHAPTER 2

LITERATURE REVIEW

2.1 Regional Geology and Tectonic Setting

Geologically, Peninsular Malaysia is divided into three belts which are Western belt, Central belt and Eastern belt each of which is well defined and recognizable in geology and tectonic history (Hutchinson, 1989). The eastern belt is an amalgamation of continental terranes and underlain with clastics, carbonates, granitic bodies and volcanics ranging in age from Carbonifrous to Quaternary. Phyllite, slate and shale are the common lithologies of the Terengganu River catchment area. Granites are abundant forming elongated north-south trending bodies.

2.1.1 Regional Stratigraphy

Paleozoic sediments of predominantly Carboniferous to Permian age are distributed from east Kelantan through Terengganu and east Pahang into east Johor in the south. In the Group extension to south are Seri Jaya and Kambing Beds while the Sungai Perlis Beds in Terengganu are northwards extension. Most of these sediments are shallow marine argillo-arenaceous deposits together with isolated reefal lenses and volcanics. Carboniferous plant fossil-bearing beds are isolated occurred as well as Permian conglomeratic deposited along the east coast point to restricted terrestrial to paralic sedimentation that alternating with shallow marine deposition in a marginal marine.

2.1.2 Structural Geology

A few noteworthy, in Terengganu State there is existed a north-striking fault on the eighth version of the Mineral Distribution Map of Peninsular Malaysia (Geological Survey of Malaysia, 1988).There is one fault keeps running for around 60 km along the west side of the Besut valley. Another correspondingly long fault cuts over the north partition of the alleged "Lawit Rock" (MacDonald, 1968) and proceeds to the few 35 km more remote southward along the Pertang valley. Basically, "Lawit Rock" used to be found somewhere at Kenyir. In the northwest Malay basin of seaward or offshore of Terengganu and Kelantan, long north-south striking fault are prevailing structures transecting sediment of Cenozoic. Such faults are appeared for occurrence in (Tjia, 1998) and Liew (1996). The local north-south faults in pre-Tertiary crystalline and transformed or metamorphosed rocks of Terengganu State show up as the coastal continuations of those mapped offshore by the companies of petroleum. It is currently known that the major faults of the Malay basin experienced sidelong movements during the Cenozoic (Tjia, 1994), a geodynamic process that might be called "slide-principle tectonics".

2.1.3 Historical Geology

According MacDonald (1967), geological investigation in central Terengganu was made and the map is prepared by him to show the current study area consist of Quartenary alluvium, unchanged of arenaceous sediments. An assemblage of brachiopod, crinoid and tetracoral have found in the metasediment at the area of Bukit Besi indicated as Lower Carboniferous age (Leong, 1970).

2.2 Geomorphology

2.2.1 Lake

Lake is not a common geological feature of peninsula that does not contain of internal drainage like streams and rivers for the East Coast flowing into South China Sea and the West Coast flowing into the Straits of Malacca. Several huge artificial lakes have been created in recent years in order to construct a few dams for the purposes of hydroelectric power generation and water supply or even for flood mitigation. In Terengganu, 155m high of Kenyir Dam is damming the Sungai Terengganu and caused the Kenyir Lake been created and risen with the surface area approximately 369km^2.

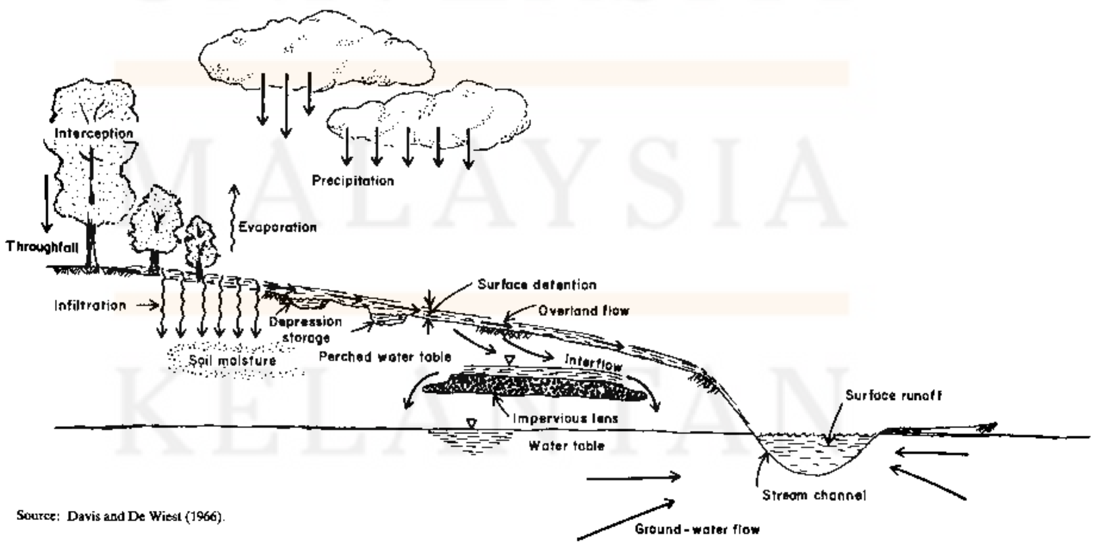
2.2.2 Coastal Plain

The coastal plain of Peninsula vary obviously in width from zero where bedrock form headlands at the coast to 50km and more along the relatively huge stretches of both East and West Coasts. The east coast of Peninsular Malaysia has three main rivers that flow into the South China Sea which are Pahang, Kelantan and Terengganu rivers. The East coast of Peninsula Malaysia is also supported by Quaternary coastal plain where the good countries structure real headlands and extends of precipices. Sand bars were circulated generally along the shoreline which was contributed by the bigger river which is cut over the coast. Solid waves are pervasive amid the North East storm and monsoon. Raised shorelines are a typical element along the Terengganu coast (incorporated into the study region) and additionally somewhere else along the East coast of Peninsular Malaysia.

Generally, it's having been framed by a steady isostatic inspire of the eastern coastline (MacDonald, 1968). The evaluation of sand is predominantly medium to exceptionally coarse. The sand in Bris soils in view of Hanafiah et al. (2004a) is made essentially out of quartz with minor measures of overwhelming minerals. In addition, the coastal plain is tapers southward in north and central Terengganu. Along the coast between Kuala Terengganu and Kemaman are only narrow stretches of sandy beaches due to the stretches comprise of rocky headlands.

2.3 Groundwater Origin and Hydrological Cycle

According to Bouwer (1978) groundwater can be defined as the partition of the water underneath the earth surface that can be gathered with wells, passages or seepage on the other hand that streams normally to the world's surface through leak or springs. Not all underground water is groundwater. Bouwer portrayed that genuine groundwater is achieved just when water starts to stream uninhibitedly into the gap or well. What recognizes groundwater from other underground water is its barometrical weight. Since the air in the opening is at barometrical weight, the weight in the groundwater must be above barometrical weight. Figure 2.1 below shows the hydrologic cycle.



Source: Davis and De Wiest (1966).

Figure 2.1: Hydrologic Cycle

Water in its different structures has recreation. The cycle assumes a critical part in clarifying the source of groundwater. The cycle is outlined in Figure 1. The inflow to the hydrologic framework touches base as precipitation, while the surge happen as the stream flow or keep running off. The most critical procedure is the point at which the precipitation is conveyed to streams by overland stream and interflow or otherwise called subsurface stream and base flow; taking after invasion into soil. Subsurface stream won't just stream horizontal1y yet it will likewise stream vertically. Different components impact water quality in every phase of hydrologic cycle. Amid precipitation, the downpour will respond with dissolvable particles and gasses in the climate. Thus, when it comes to the land surface it is most certainly not without chemicals. The water will penetrate or leak through the dirt into stream framework in the hidden geologic materials.

The soil zone will adjust the science of the water as penetration happens; and additionally by the impacts of geochemical procedures. Soil zone, which is otherwise called zone of air circulation, has the most grounded impact on the science of water that penetrates through it (Freeze and Cherry, 1979). Water that has invaded the soil profoundly enough will achieve the zone of immersion which is the groundwater stockpiling that supplies water to the wells. The thickness of the zone of immersion changes from a couple metre to many meter underneath the earth surface. Elements that decide its thickness are the geography, the accessibility of pores or openings in the developments, the flow and the development of water inside of the zone from zones of energize toward the purposes of release.

2.4 Groundwater in Malaysia

Malaysia is lucky to have high rate of precipitation and is along these lines favoured with inexhaustible surface water assets all things considered that in the past individuals are by and large not inspired by groundwater. In any case, expanding water request combined with precarious supply of surface (waterway) water has guided much consideration of the general population to groundwater. The inquiry on the utilization of groundwater is starting to wind up a critical point of exchange in the general public, both people in general and business groups. Indeed, even the Department of Environment, Ministry of Science and Technology, Malaysia is taking activities to build up a groundwater observing and reporting organized so that the status of the quality and gainful employments of the asset is completely welcomed. The use and improvement of groundwater in Malaysia require appropriate assessment of its quality and maintainability. Despite the fact that present groundwater use is constrained when contrasted with its potential, a more prominent attention to groundwater potential for residential, horticulture and modern water supply can be anticipated. This will prompt increment sought after; and the improvement of groundwater will bring about groundwater reflection from united or hard rock aquifers.

2.5 Aquifer

According to Meinzer (1923), an aquifer can defined as a geological formation, group of formation or part of formation that contains sufficient saturated permeable material to yield significant quantities of water to wells. In order to construct and collect the pumping test information, it is important to get into the essential terminology for this profession. These other fundamental ideas are depicted in numerous ground water course readings. Hydrogeological terms pertinent to the aquifer are portrayed in this area. Geologic unit are depicted by their lithology, inception or mineral substance. An aquifer is characterized as a soaked porous geographical unit that is sufficiently penetrable to yield monetary amounts of water to wells. The most widely recognized aquifers are unconsolidated sand and rock, yet penetrable sedimentary shakes such as sandstone and limestone, and intensely cracked or weathered volcanic and crystalline rocks can likewise be named aquifers (Kruseman et al., 1990).

There are four noteworthy sorts of aquifer; alluvial, sedimentary, igneous and metamorphic (changeable rock) aquifers. An aquifer is a soaked bed arrangement or gathering of development, which yields water in adequate amount to be financially valuable. Aquifer can be classified base on the prevailing subsurface geological composition, hydrological conditions or to groundwater pressure. The significant of the hydrological factor is the recharge mechanism which could be direct or indirect. For the groundwater pressure its will be either equal to or greater than the atmospheric pressure. In an unconfined aquifer the groundwater table forms the upper boundary of the saturation area. Hence, the water table can be defined as a connection of points where the exact pressure corresponding to the atmospheric pressure and the relative pressure. According to hydrological point of view, unconfined aquifer can be simplified as a subject to direct recharge from infiltration. In general, groundwater in the voids of alluvial fill gravels forms an unconfined aquifer. Such an aquifer differs geologically from unconfined type its must be at least three layers of which two are aquifuges with an aquifer in between. If the aquifer is completely saturated, the is confined between the two layers of aquifuges and the extra pressure thus exerted on the groundwater increase its pressure above the atmospheric pressure.

2.6 Hydrochemistry of Groundwater.

A possible circulation of deep seated water from below the permafrost to the surface has brought some light on (Scholz and Baumann, 1997). Experience workers who have recognised and saw the potential of groundwater as geochemical exploration samples have worked dominatingly in northern hemisphere terrains where groundwater is less saline than in Australia (Rose et al. 1985; Langmuir & Chatham 1980). Progress in development of groundwater geochemical methodologies that are appropriate in Australia has resulted from collaborative research between various exploration companies and the CSIRO Division of Exploration and Mining (Giblin & R. Mazzucchelli, 1997). The Okchon dark shale in Korea gives a normal case of regular geological elements enhanced with conceivably lethal components, for example, Arsenic (As), Cadmium (Cd), Copper (Cu), Molybdenum (Mo), Nickel (Ni), Lead (Pb), Uranium (U), Vanadium (V), and Zinc (Zn), (Kim and Thornton, 1993; Lee et al., 1998). The preferable management of groundwater resources requires a comprehension of hydrogeological and hydrochemical properties of the aquifer (Umar et al. 2001).

In addition, the chemical composition of water at the coastal region are separated from wells is frequently anon-preservationist blend of freshwater from an aquifer unit and saltwater from the ocean. In any case, other anthropogenic and common sources, for example, the arrival flow from watering system or the infiltration of brackish waters and wastewater, can likewise add to salinization of groundwater in beach front aquifers (Richter and Kreitler 1993, Cardona et al. 2004). Generally, Malaysia lack of the study of hydrochemistry of groundwater. Therefore, this study will be carried out in order to indetified the geological elements in the groundwater and also gain some knowledge and information of hydrochemistry and hydrogeochmistry of groundwater in Malaysia.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

Methods and materials are definitely a compulsory stage for any study that was conducted in order to achieve the objectives of the study and produce the best result. There are a few stage and step to conduct the hydrogeochemistry study of groundwater. For all the groundwater collection method and the water sample analysis followed standard procedure as shown in Figure 3.1.

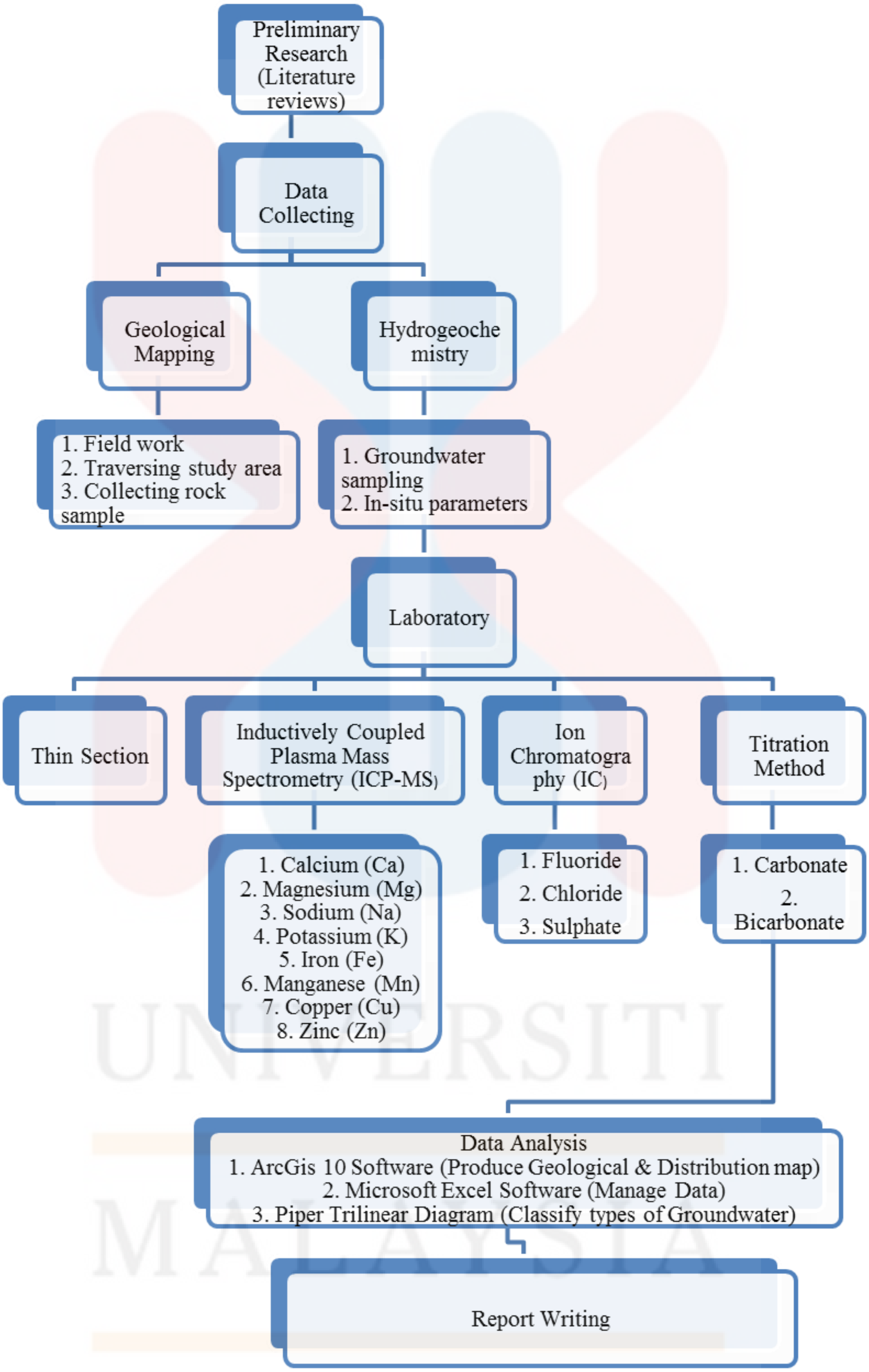


Figure 3.1: Flowchart of overall research methodology.

3.2 Preliminary Research

In order to get a better knowledge and information of geology, hydrology and hydrogeochemistry of the study area, literature review of previous work has been observed. By referring the previous study from the journals, published and previous thesis the literature review completely done. All the map and data of groundwater could be obtained from the previous base map by using ArcGIS Software.

3.3 Materials and Equipments

3.3.1 Fieldwork and Mapping

- Geological Hammer

  The function is for splitting and breaking the rocks. During fieldwork, we are used to obtain a fresh surface of a rock to determine its composition, nature, mineralogy, history, and field estimate of rock strength. In fossil and mineral collecting, we are employed to break rocks with the aim of revealing fossils inside. The geological hammer is also sometimes used for scale in a photograph.

Figure 3.2: Geological Hammer

- Handheld Global Positioning System (GPS)

  A space-based navigation system is provides location and time information in all weather conditions. It is able to accurately triangulate the position based on the data transmissions from multiple satellites. It will give your location in coordinates, together with latitude and longitude.

Figure 3.3: Handheld Global Positioning System (GPS)

- Hydrochloric (HCL) solution

  HCL solution used to test the rock to observe the reaction with the acid then it will be determined the type of rock. Limestone and Dolomite usually the rock type that wil react with the HCL.

Figure 3.4: Hydrochloric Solution

- Suunto Compass

  Direction and navigation usually can be measured by using this compass. Other than that, it also can be used for geologists to perform dip & strike.

Figure 3.5: Suunto Compass

- Hand Lens

  In order to observe closely the rocks or minerals the hand lens could be functioning during the field study.

Figure 3.6: Hand Lens

- Sample bags

  All the rocks sample collected will be stored in the sample bags.

Figure 3.7: Sample Bag

3.3.2 Hydrogeochemistry and Groundwater Sampling

- Polyethylene bottles (250 mL)

  All the groundwater samples will be keep and stored securely into the 250 mL of polyethylene bottles.

Figure 3.8: Polyethylene Bottles

- Coleman box storage

  In order to ensure all the groundwater samples be secured and avoid the contamination, coleman box needed to keep all the samples under control of low temperature.

Figure 3.9: Coleman box storage

- Nitric acid (HNO_3) solution

  The water samples need to be purified. Hence, nictric acid solution could be used to acidify and minimize adsorption of metals to container walls and reduces biological activity.

Figure 3.10: Nitric acid solution

- TSS Portable

The Total Suspended Solvent (TSS) Portable is a handheld measurement instrument for the analytical determination of turbidity and solids in aqueous media. The light scattered sideways by the turbidity particles is measured at an angle of 90°. In the case of solid material, the measurement occurs at an angle of 90° and 120°.

Figure 3.11: TSS portable

- Multiparameter YSI 85

The YSI 85 multi-parameter provides simultaneous measurement of temperature, dissolved oxygen (DO), conductivity and salinity. This combines the specifications and features of the YSI 30 and adds the dissolved oxygen features of the YSI 550. For advanced users, an adjustable conductivity reference temperature and compensation factor can be used, as well as user defined equations for determining salinity.

Figure 3.12: Multiparameter YSI 85

- pH meter

  pH Meter is a scientific instrument that measures scientifically the hydrogen-ion concentration (pH) in a solution that is indicating its acidity or alkalinity.

Figure 3.13: pH meter

3.4 Field Work

Field work or field study is the activities that has been conducted and observed at the study area in order to get all the absolute information. During the field work some of the rock sample has been collected for the laboratory investigation such as thin section of the rock. In addition, the sample will determine the current and the origin of the geological condition and structure. Global Positioning System (GPS), compass and geological hammer was used during the field work. As well as sampling bag and HCL solution is needed during the fieldwork in order to keep the rock samples secure. HCL solution aided in order to determine the type of rock in specification for limestone or dolomite which is the calcite that contain in the rock will react with the HCL solution.

3.5 Sampling

A total of 49 groundwater samples were collected from 14 of tube well which is more than 25.0 m depth that will be monitored as well. To reduce the chance of oxidation, a sampling depth of at least 5 m is ideal (Gray & Noble 2006; Giblin 2001). The sampling locations were chosen randomly. The groundwater samples were filtered through 0.45 µm membrane filter and split into 2 polyethylene bottles 250 mL each, one filled with only sampled water directly while the other samples were acidified with nitric acid (HNO_3) as figuring in Figure 3.15 to a pH of less than 2 to minimize adsorption of metals to container walls and reduces biological activity. The groundwater samples were collected after the well was emptied 3 times and the water was pumped out for about 10 minutes to remove the stagnant water. All groundwater samples are stored at approximately below 5°C.

For in-situ method, multiparameter was used to measure directly the physical characteristic of groundwater that consists of conductivity, Total Dissolved Solid (TDS), Dissolved Oxygen (DO), pH and temperature as well as the depth of water and well as shown in Figure 3.14 and Figure 3.16. Fortunately for pH value there is a pH meter to measure the pH value of groundwater samples accurately.

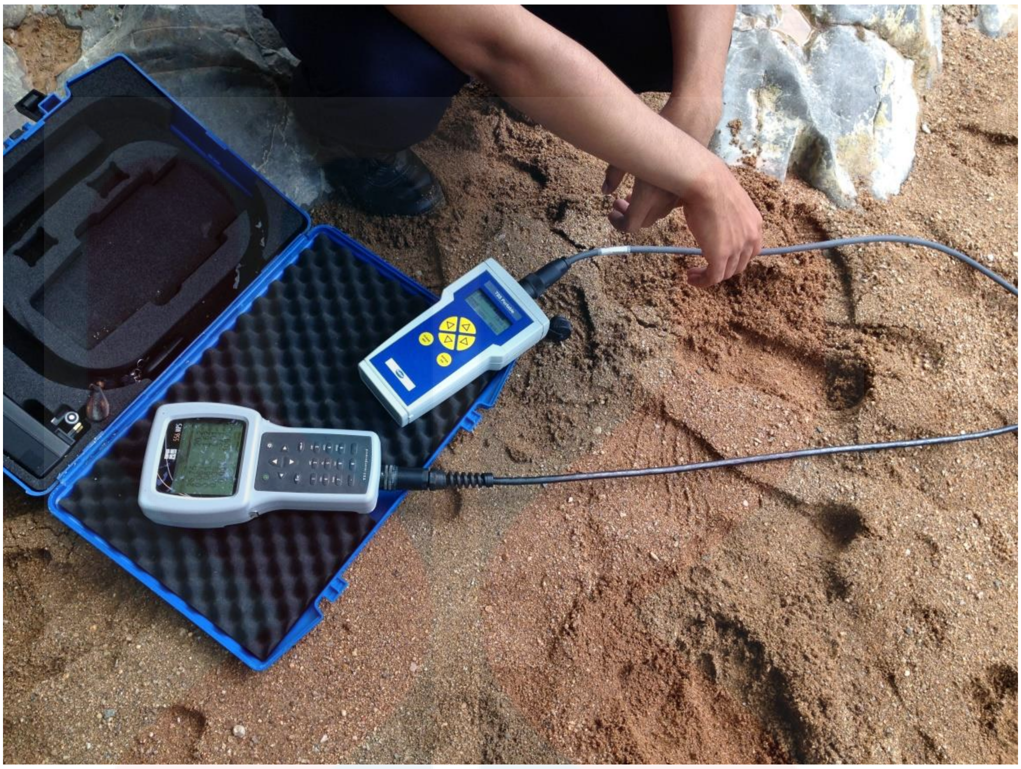


Figure 3.14: Measure the parameters using TSS portable and Multiparameter YSI.

Figure 3.15: Acidified the water sample

Figure 3.16: Measure the depth of water and well

3.6 Lab Investigation

3.6.1 Hydrogeochemistry

The groundwater samples that been collected will be conducted into lab investigation after the sampling method by using the Ion Chromatography (IC) technique in order to measure the quantities of ions that present in groundwater samples. Before the IC technique being conducted, filtration method should be done first to purify the groundwater samples as shown in Figure 3.17. Afterwards, IC methods measure the amount of energy in the form of photons of light that are absorbed by the groundwater samples in value of 15mL. Major anions such as bicarbonate (HCO_3^-), Chloride (Cl), Fluoride (F^-), and Sulfate (SO_4) have been detected through this technique.

Inductively Coupled Plasma Mass Spectrometry (ICP-MS) also will be used to measure quantities of chemical elements present in environmental samples by measuring the absorbed radiation by the chemical element of interest. This is done by reading the spectra produced when the sample is excited by radiation. The atoms absorb ultraviolet or visible light and make transitions to higher energy levels. For major cations (Na, K, Ca and Mg) and minor cations (Fe, Si, B, Ba, Li, Sr, Al, Cu, Mn and Zn) in groundwater can be analysed by using this method.

Next, for the concentration of HCO_3 of the groundwater samples that has been titrated against a known concentration of acid to an end point pH of 4.3 as figuring in Figure 3.18. This should be conducted in the lab investigation by using a burette, stirrer and pH meter, though it is rather time consuming.

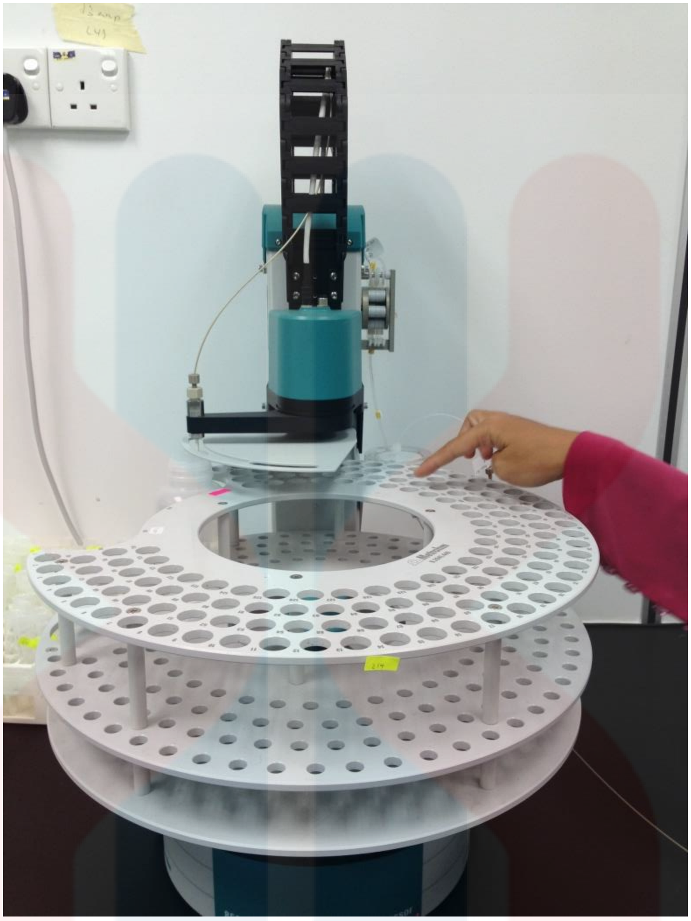


Figure 3.17: Ion Chromatography equipment.

Figure 3.18: Standard Solution for IC.

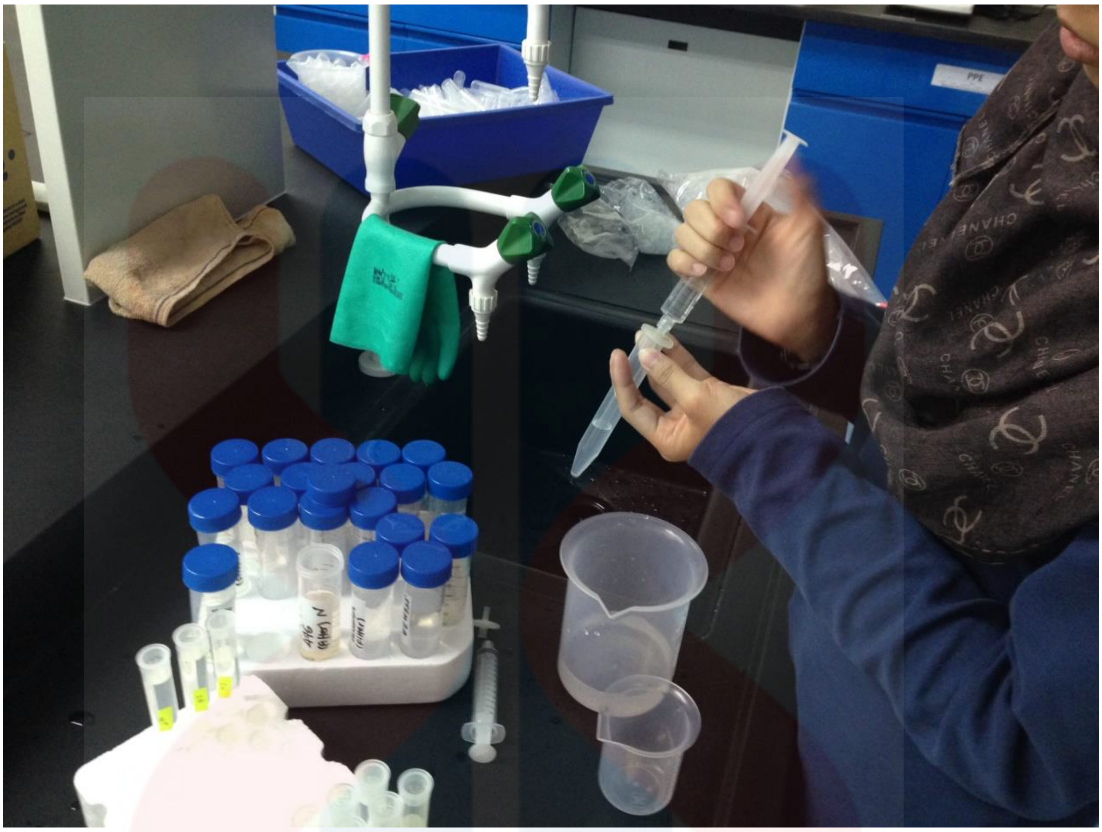


Figure 3.19: Purifying the sample before run the IC method.

Figure 3.20: Titration method to measure the concentration of carbonate and bicarbonate

3.6.2 Thin Section

Thin section analysis is the microscopic examination of the composition and structure of rock. A detailed description of the texture such as grain size, sorting, and grain contacts, sedimentary structures (laminations, bioturbation), framework grain composition and minerals seen in a thin section. There are five main tools that has been used in the process of a thin section. For example, the slab saw, the trim saw, the grinder, the cut-off saw, and the lap wheels.

3.6 Data Analysis

After done all the methodologies for all groundwater samples the data has been analysed. The data of major anions, cations and concentration of HCO_3 were revised and interpreted using the statistics analysis, graphical method and Piper Diagram as in Figure 3.21. For the thin sections, it used for petrological and mineralogical observations that are made in different sizes and using different techniques for curing, polishing and staining in order to get a detailed description of the texture such as grain size, sorting, and grain contacts, sedimentary structures, framework grain composition and minerals. When put between two polarizing filters set at the right angles to each other, the optical properties of the minerals in the thin section alter the colour and intensity of the light as seen under the microscope. As different minerals have different optical properties, most rock forming minerals can be easily identified.

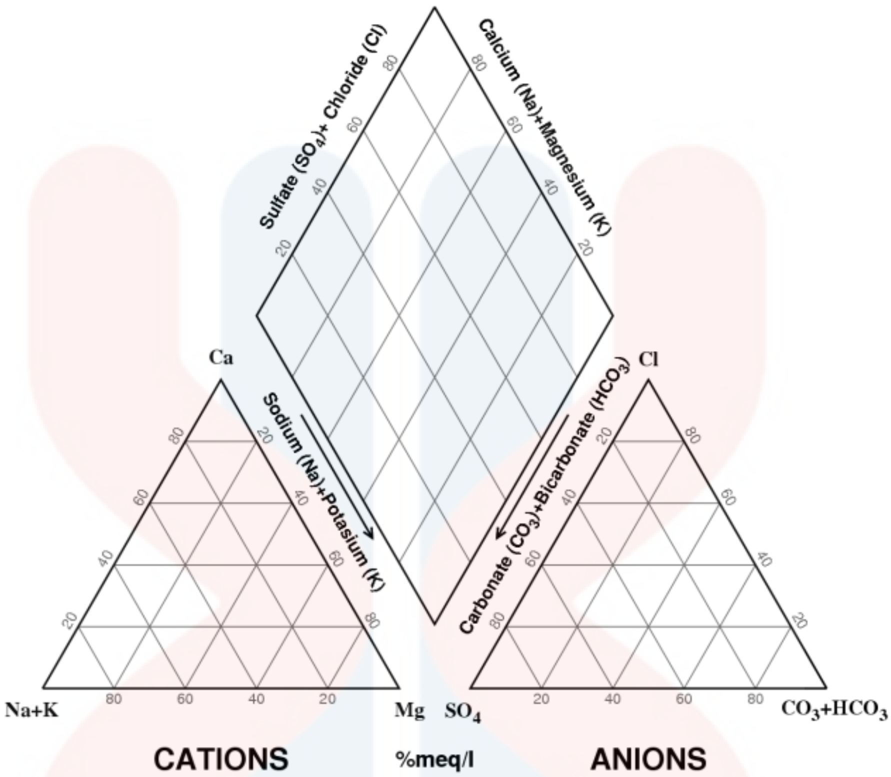


Figure 3.21: Piper Diagram

3.7 Report Writing

Report writing is an essential for the completion of the research and also to ensure that all the objectives of the research be achieved. All the data will be written and elaborated in the report writing as well as the methodologies that been conducted in order to get the data accurately. The law of the report writing must be followed as in presenting the research in proper words into a complete thesis.

CHAPTER 4

GENERAL GEOLOGY OF BUKIT JONG, TERENGGANU

4.1 Introduction

In this chapter, geological study has been conducted at the study area in order to update the geological map in scale 1:25 000 including the study of igneous, sedimentary and metasedimentary rocks that found in the study area. Apart from that, an attempt was also made to find out and identify the environment of the sedimentary and metasediment rocks at the area that has been studied.

As the field work priority, some previous geological works of the study area was have been studied and compiled. A base map in a scale 1:25 000 was prepared in order to traverse the study area that is compulsory in 5km² for the study. Afterwards, the traverse map is prepared as shown in Figure 4.1. The sample's locations are marked by using Global Positioning System (GPS) and shown in the map as in Figure 4.2. The study area consists of igneous rocks at 5° 20' 48.25"N and 103° 1' 53.6"E which flanked by partly metamorphosed sediments on the north eastern part of Bukit Jong.

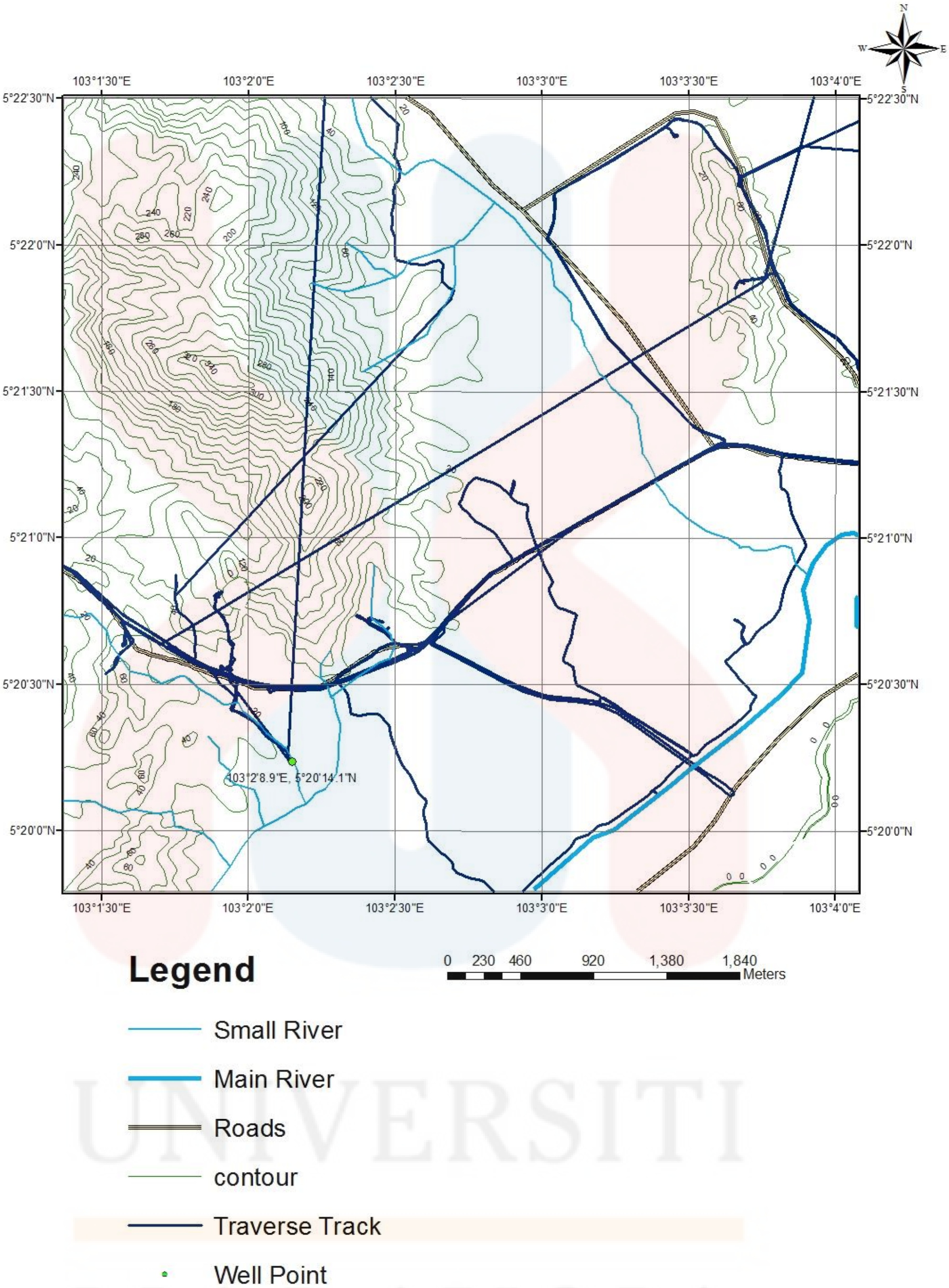


Figure 4.1: Traverse map of Bukit Jong, Terengganu.

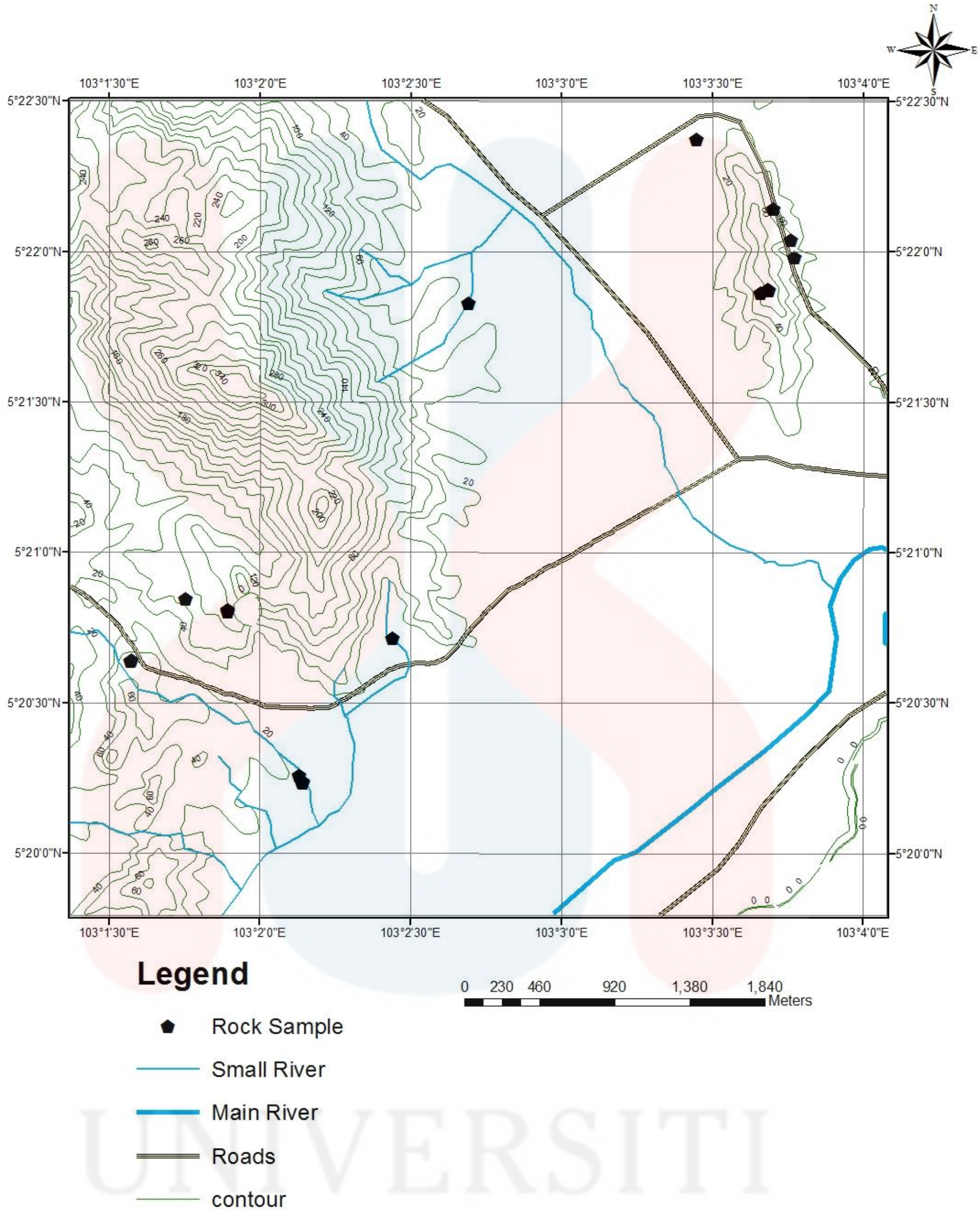


Figure 4.2: Rock sampling map of Bukit Jong, Terengganu.

4.2 Geomorphology

The study of geomorphology is according to the topographic map, aerial photographs and field observations which is traversing the study area by referring the base map in a scale 1:25 000. Basically, the study area is covered by the hill region and lowland region. The hilly country is generally made up of resistant rocks such as metasandstone and quartzite that have been found in the study area. Meanwhile for the lowland area is comprised by the less resistant rock which is more easily to weathered and eroded.

4.2.1 The Hilly Region

These regions are about 50% covered in the study area. The area is basically made up of mountain and consists of ridges and hills that formed of granite as figuring in Figure 4.3 and metasediments in Figure 4.4. The morphology of the area is mainly controlled by the types of rocks, structures and erosions.

The formation of hills that formed of granite is roughly reaching 100 to 300 metres of elevation. The highest point of the study area is located within the granite hill. The hills and ridges that formed of metasediments reach up the height that is not more than 100 metre of elevation.

Figure 4.3: Granite Hill of hilly region.

Figure 4.4: Hill of Metasediment

4.2.2 The Lowland Region

The area that is below than 30 metres of elevation is basically known as the lowland region. Figure 4.5 shows the lowland region is generally occupied with the town area that covered by the residential. Half of the study area is covered by the roads and buildings as figuring in Figure 4.6.

Figure 4.5: Residential area

Figure 4.6: Junction and Buildings at lowland region.

4.2.3 Drainage

Drainage system is also known as a river system that consisted of various patterns formed by the river in the study area. The main river is located at south east of the study area. Figure 4.7 visualize the main river is drained by the southwards flowing of Sungai Nerus. The drainage system is generally controlled by the type of rocks and lineament such as faults and joints. The drainage pattern of the study area is made up of parallel and dendritic pattern as figuring in Figure 4.8. This is due to the main river and a few small rivers located in the study area.

Figure 4.7: Main river of study area, Sungai Nerus

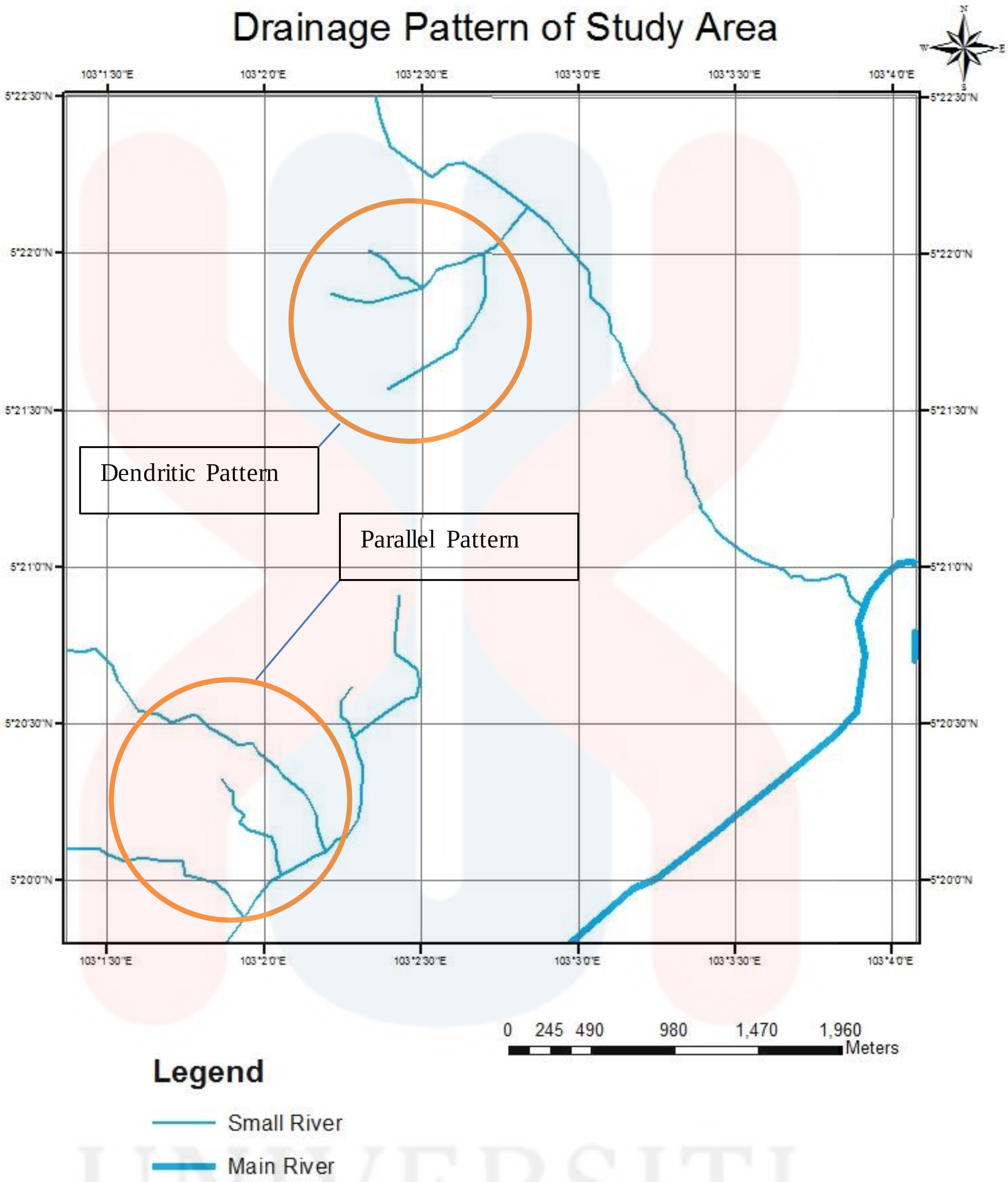


Figure 4.8: Drainage pattern of study area

4.2.4 Topography

Basically, topography is a three-dimensional arrangement of physical elements of a land surface in a place or region. Physical features that make up the topography of an area include mountains, valleys, plains, and bodies of water. Human-made features such as roads, railroads, and landfills are also considered as a part of topography in a region. Figure 4.9 is figuring the topography in the study area can be generally described upon the topography map as the contour shown vary of elevation that refer to the hill and ridges region. The highest of the elevation is 340m which is due to the granite hill and the lowest elevation is 20m. 70% of the study area is covered by the human-made features including roads, buildings and landfills.

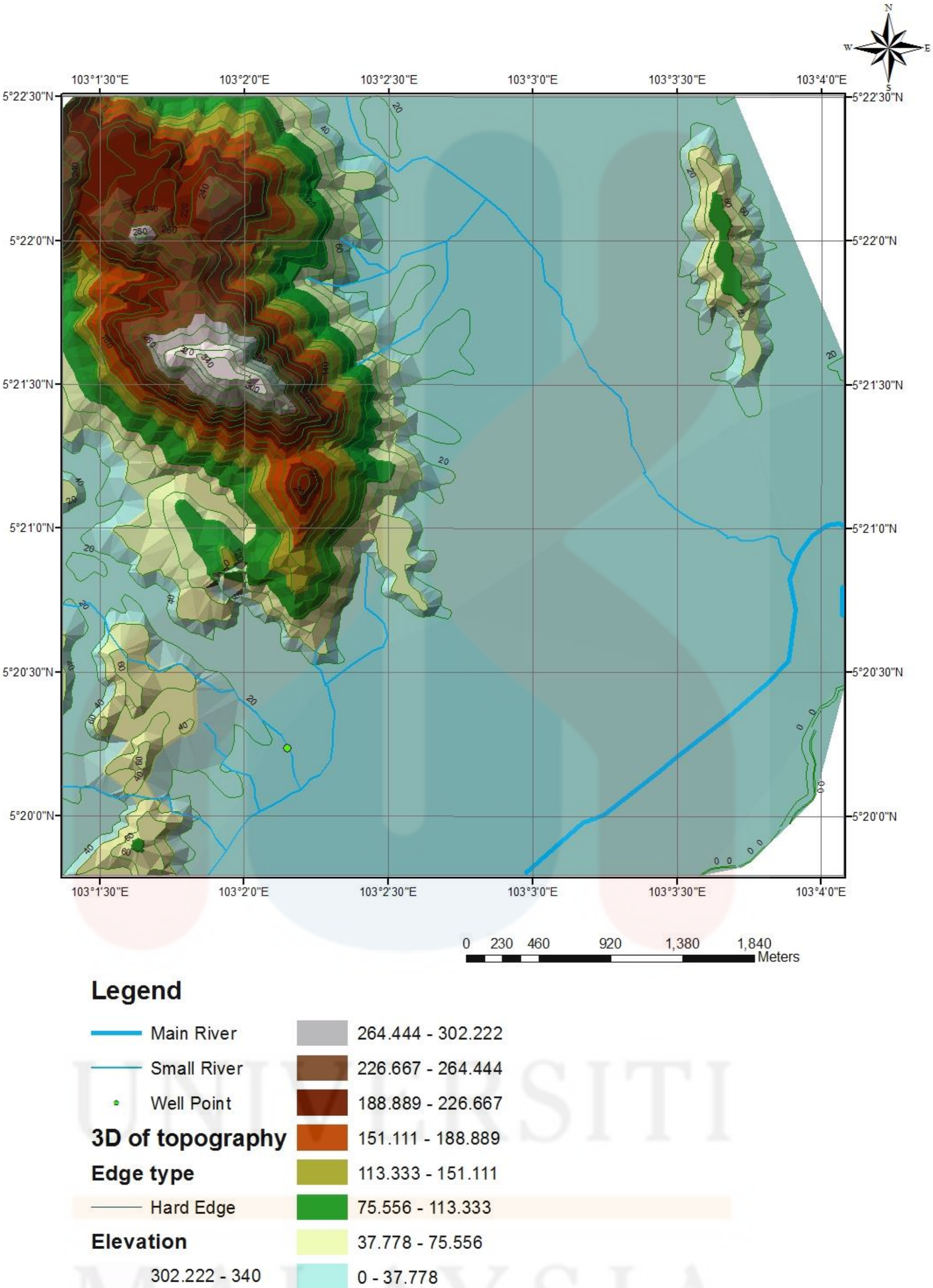


Figure 4.9: Topography map of study area

4.2.5 Weathering

The study area is minor covered by the tropical area which is the rates of chemical weathering and biological weathering is high. Figure 4.10 shows the chemical weathering occurred on the outcrop due to the oxidation. Meanwhile the other half of the area is having the physical weathering due to the residential area and buildings in the certain region of study area. The metasediments are weathered to depth of a few metres. Laterite surface coated the outcrop particularly along beddings and fractures are common occurrence found. Human activity such as excavating as shown in Figure 4.11 also caused the physical weathering on certain outcrops especially sediment and mentasediment.

Figure 4.10: Oxidation type of chemical weathering.

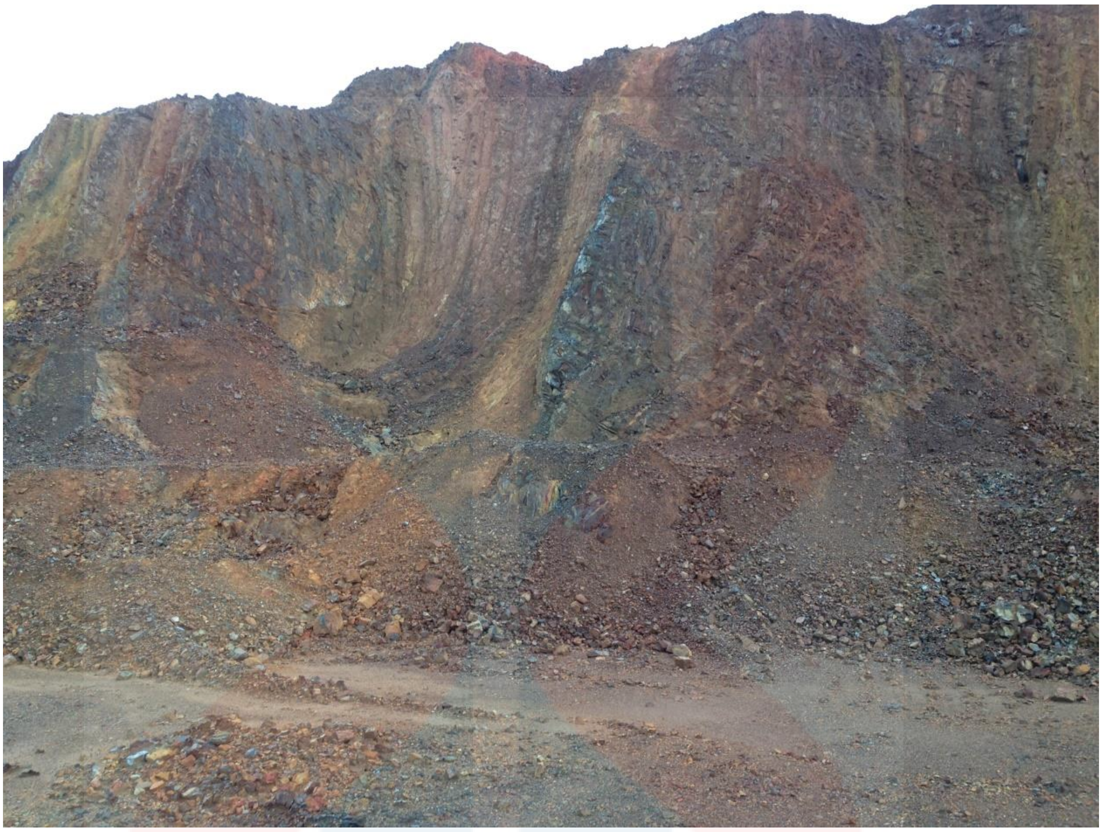


Figure 4.11: Physical weathering of sediment and metasediment outcrop.

4.3 Stratigraphy

A map that published by Jones (1966) been indicated that the metasedimentary rocks in the study area are believed to be Upper Paleozoic age. This Upper Paleozoic metasediments occur extensively through the east coast of Peninsula Malaysia and almost covered the entire Terengganu. The exact age of these rocks and strata could not be determined precisely as the paleontological information is lacked and doubtful. However fossils from several scattered localities beyond the study area indicate that rocks are from the Lower Carboniferous to Permian. According MacDonald (1967), Lower Carboniferous is probably the age of the rocks due to the *Zaphrentid sp.* corals found in black shale. Further 50km north of study area were found the *Pecopiteris sp.* and *Cordaites* sp. plant that indicate the age of Permian (Yau, 1977). *Lepidodendron sp.* indicated of Lower Carboniferous age were found in interbedded of metaquartzite, schist and slate at the south of the study area which is Kemaman, Terengganu (Goh, 1974). According S.M. Zaki (1986) his research and survey has ascertained a more accurate age of the sedimentary rocks based upon the finding of trilobite *Paladin Ophistops* sp.and brachiopod *Brachithyrina Strangways sp.* Both sedimentary and metasedimentary rocks of the study area have been postulated by finding those fossils that they are probably Upper Carboniferous age (S.M. Zaki, 1986). Unfortunately, no fossil found during the current study which probably due to the excavated at the study area.

The granitic intrusion through metamorphism of sedimentary rocks is variable ranging due to the formation of phyllite and slate. However, the contact between the metasediments and the granitic bodies cannot be found and seen. Hence, the exact outline of the aureole could not be determined. Besides, the metasedimentary rocks are highly weathered as well as their mineralogical and texture that indicate low grade of metamorphism according to the assemblages of quartz-muscovite are typical of a low grade metamorphism regardful to the low temperature and confining pressure conditions.

The sandstone being slightly metamorphosed that termed as metasandstone which is having quartz as dominant mineral with clay and mica as matrix as shown in Figure 4.20.

In any case stratified rocks must have at least a pre Late Permian age as the granitoid in the study area has been radiometrically dated to be Late Permian of age (S.M. Zaki, 1986). Bignell (1977) pointed out that in the eastern Terengganu region as the overall concordance between mica ages and whole rock isochorn ages suggest that there was no significant time lag between emplacements and cooling below the argon retention temperature. No event causing wide spread intrusion loss of argon has occurred since 240 to 250 million years ago implying that the area has been relatively stable since Late Permian to Early Triassic.

Paton in (MacDonald, 1967) suggested the intrusion of basic dykes of central Terengganu be shortly after the granitic emplacement. Radiometric dating (K/Ar) for a basic dyke has been done by Bignell (1977) at Sungai Serai Quarry at Kuala Berang that giving an Early Jurassic age which is around 189 million years ago. Thus, S.M. Zaki (1986) believed that the intrusion of basic dykes in the study area is concordant with that Sungai Serai Quarry.

The stratigraphic succession of Bukit Jong has been summarised by S.M. Zaki (1986) as shown in the Table 4.1 and the geological of Bukit Jong has been updated as in Figure 4.12.

Table 4.1: The stratigraphic succession of Bukit Jong

AGE	FORMATION/EVENT	DESCRIPTION
Quaternary	Superficial Deposits (Alluvium)	Unconsolidated sediments and some modern beach sand deposits
Jurassic	Minor Igneous Intrusion	Subvolcanic rocks, cutting the granitoid, basic incomposition.
Triassic to Permian	Major Igneous Intrusion	Medium to coarse grained porphyritic biotite Adammelite
Lower to Upper Carboniferous	Metasedimentary Rocks of Arenaceous and Argillaeous Unit	Arenaceous unit: mainly quartzite, sandstone interbed with shale, in part metamorphosed. Argillaceous unit: shale predominate with minor mudstone and siltstone in part metamorphosed.

(Source: S.M. Zaki, 1986)

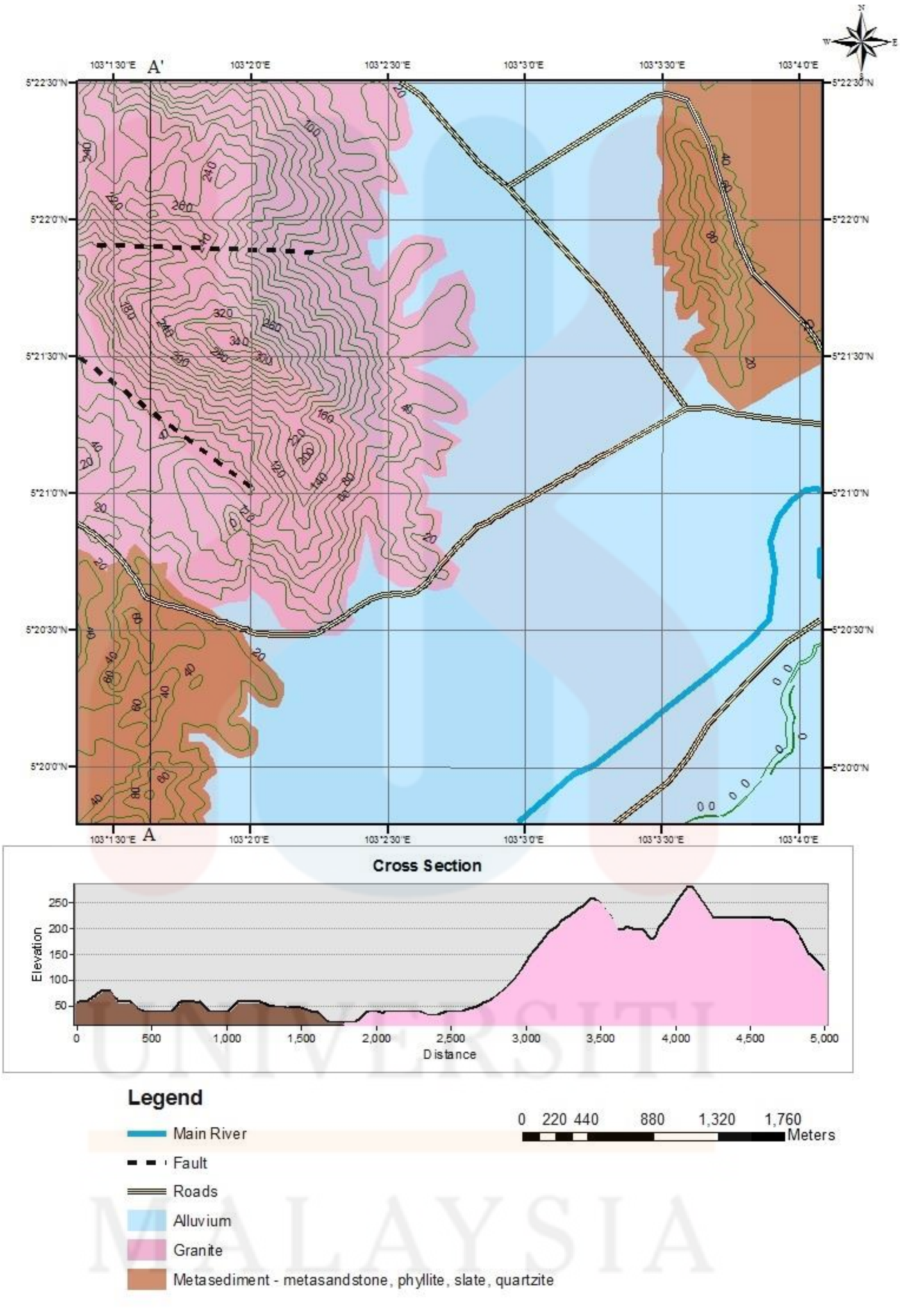


Figure 4.12: Geological map of Bukit Jong, Terengganu.

4.3.1 Igneous Rocks

According to Syed Mohamed Zaki (1986) the igneous rocks in the area have been mapped as Maras-Jerong Granite by J.R. Paton (1967) and part of the Eastern Belt granite mapped by Hutchison (1973) who subdivided the Malaysian Granite into three belts. However, Cobbing (1986) carried out a recent work on the eastern belt granite of Peninsula Malaysia and reviewed the granite in the area and named it as Maras-Jong granite instead of Maras-Jerong Granite. In the study area, granitic rock has been found in the area whereas the Quarry has been developed as shown in figure 4.13.

Figure 4.13: Granitic Body at Bukit Jong Quarry Sdn. Bhd.

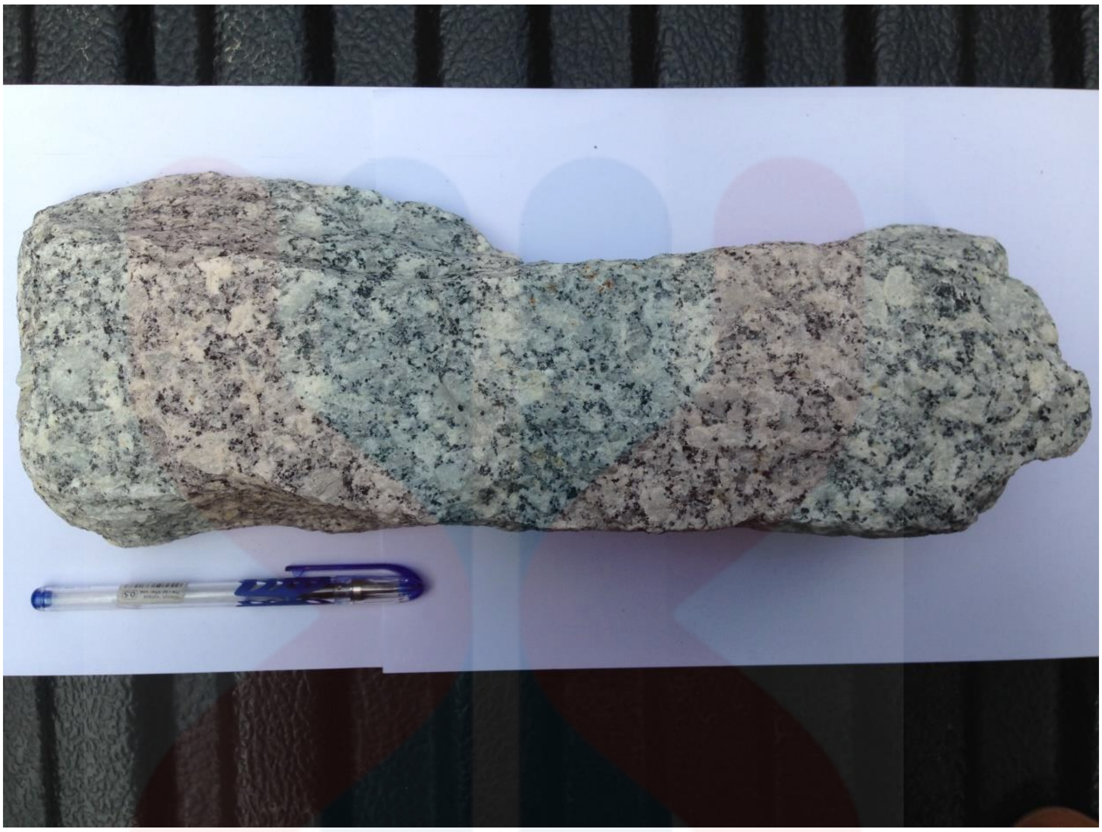


Figure 4.14: Hand specimen of Granite

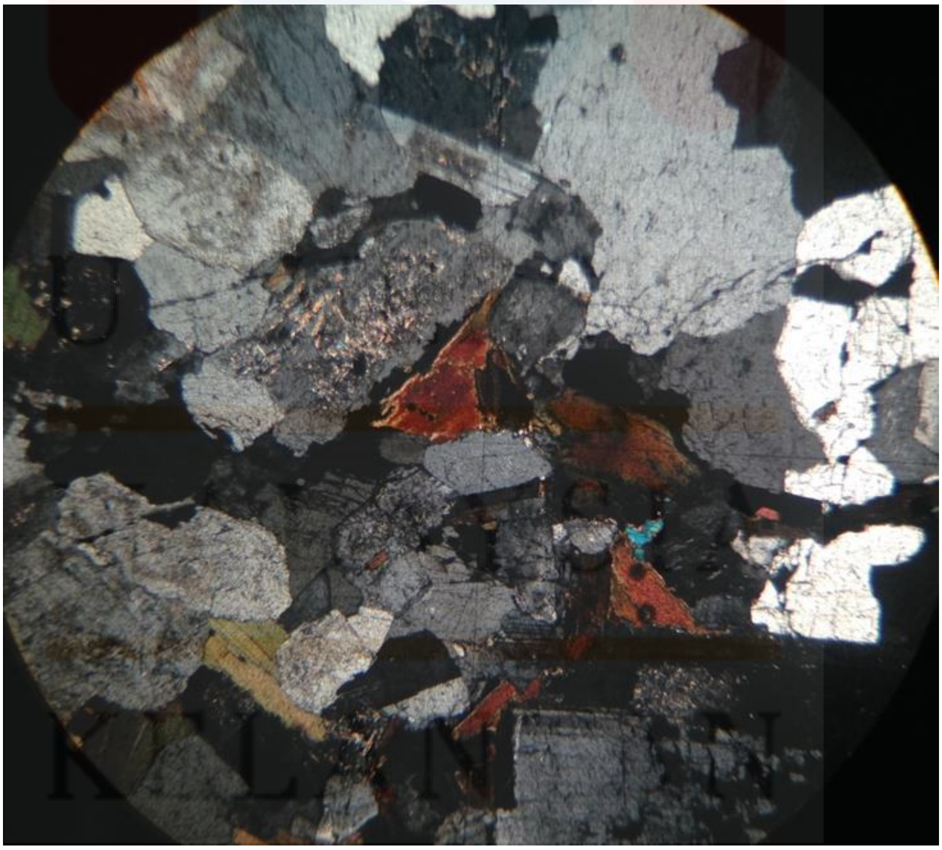


Figure 4.15: Microscopic of Granite

4.3.2 Sedimentary and Metasedimentary Rocks

The sedimentary rocks in the area have been classified by J.R. Paton (1967) into units of argillaceous and arenaceous sediments. The metasedimentary rocks in the study area included slate, phyllite and metaquartzite. 20% of the study area is covered by metasedimentsary rocks as figuring in Figure 4.16. The slate and phyllite are significantly a low grade metamorphic product of shale. The slate turn into the coarse grained phyllite through the increasing magnitude of metamorphism in which the schistosity become more clear that can be seen by naked eyes. The metasandstone in the study area are metamorphosed equivalent to sandstone. However it is difficult to determine the sharp line between these units as the range from argillaceous to arenaceous rocks passes through all degrees of interbedding. Bordering the granitic body in the north western of the study area, these regionally metamorphosed sediments are further metamorphosed by the intrusion of the igneous rocks adjacent to it, hence resulting in a formation of a narrow thermal aureole. Despite that the exact outline of this aurole could not be determines due to the intense weathering processes that have changed the morphology of the most rocks in the study area. Further away from the igneous body, no evidence of polymetamorphism were observed in the study area.

Figure 4.16: Metasedimentary outcrop.

Figure 4.17: Hand specimen of Slate

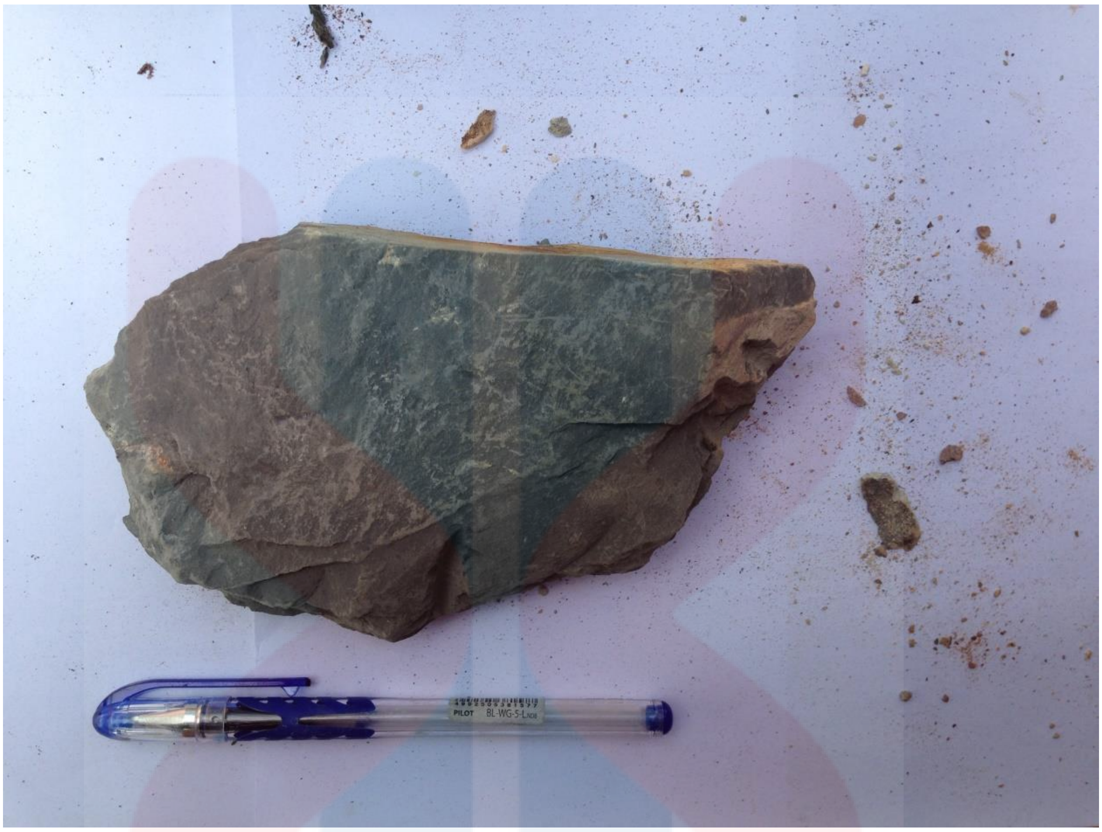


Figure 4.18: Hand Specimen of Phyllite

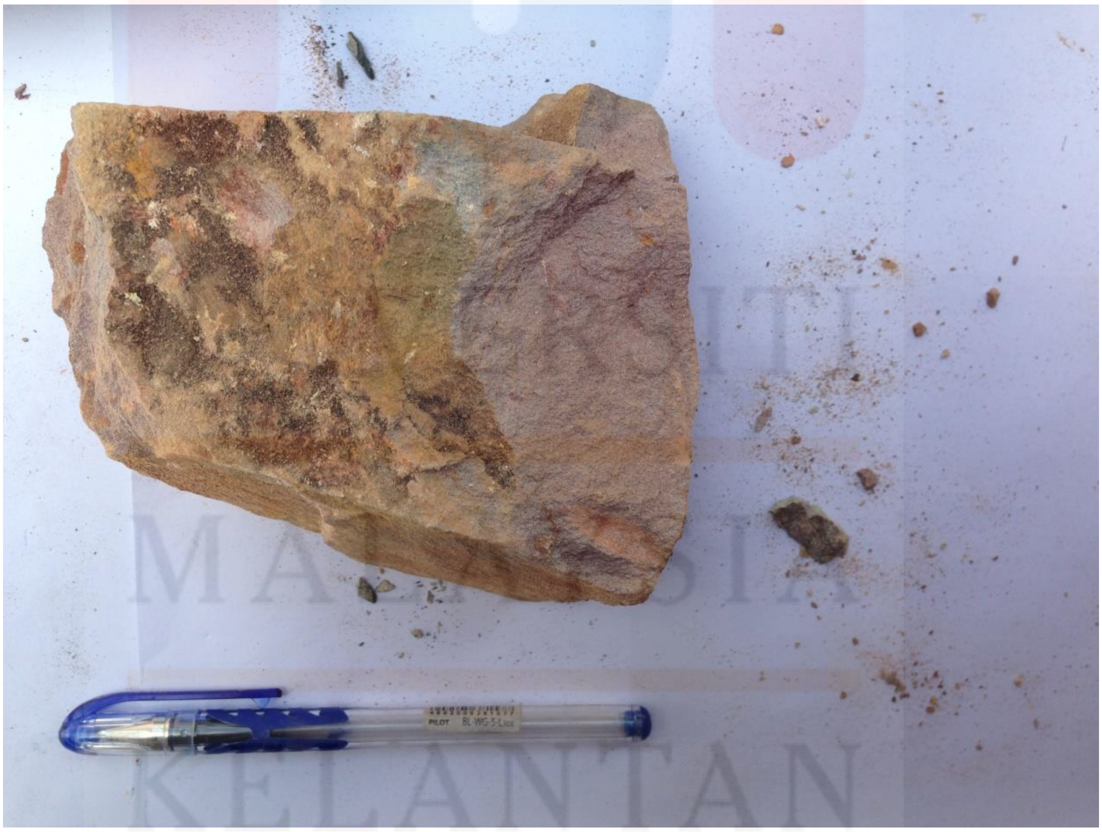


Figure 4.19: Hand specimen of Metasandstone.

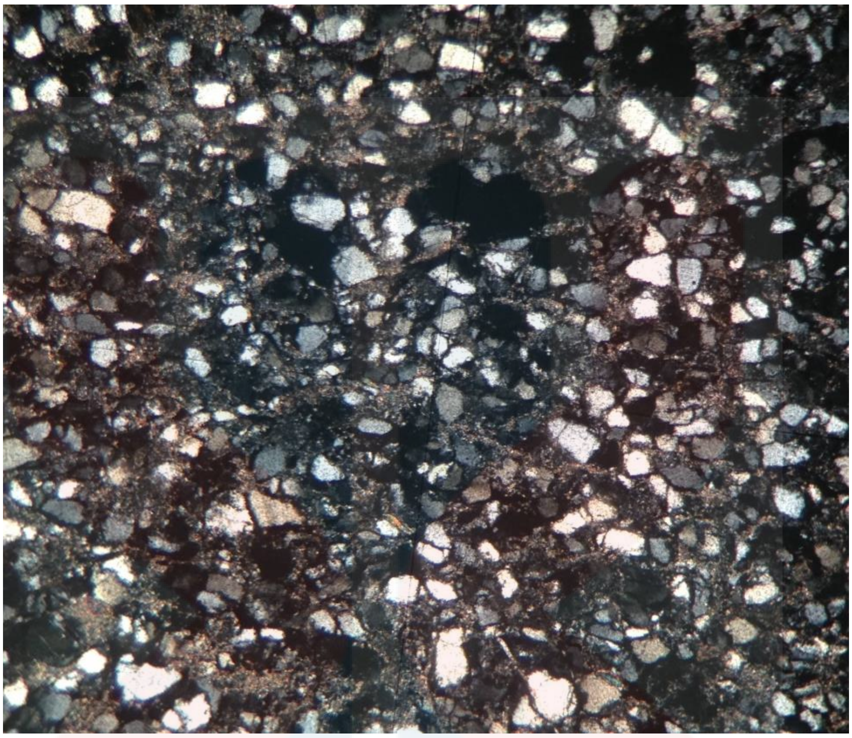


Figure 4.20: Microscopic of metasandstone

4.4 Structural Geology

The structural study could be observed from the field study and traversing the base map. The structures of the study area are basically low grade of metasediments. Various of structural element such as interbedding of phyllite, slate, metasandstone and quartzite are observed. Basically, phyllite and slate are characterized by well-developed cleavage. The quartzite beds usually more competent of thick bedded and all the joints, fracture and faults commonly shown.

4.4.1 Lineament

The lineament patterns can be interpreted through the aerial photograph map and marked on the topography map as shown in Figure 4.21. From the observation of aerial photograph of study area lineaments could be seen by river valley where the pattern observed are mainly restricted on the mountainous and ridges. The reading of lineament has been drawn in GeoRose diagram. Based on the Figure 4.22, the readings of lineament show the biggest force came from the north-east in one specific reading of bearing where probably fault or joints were occurred.

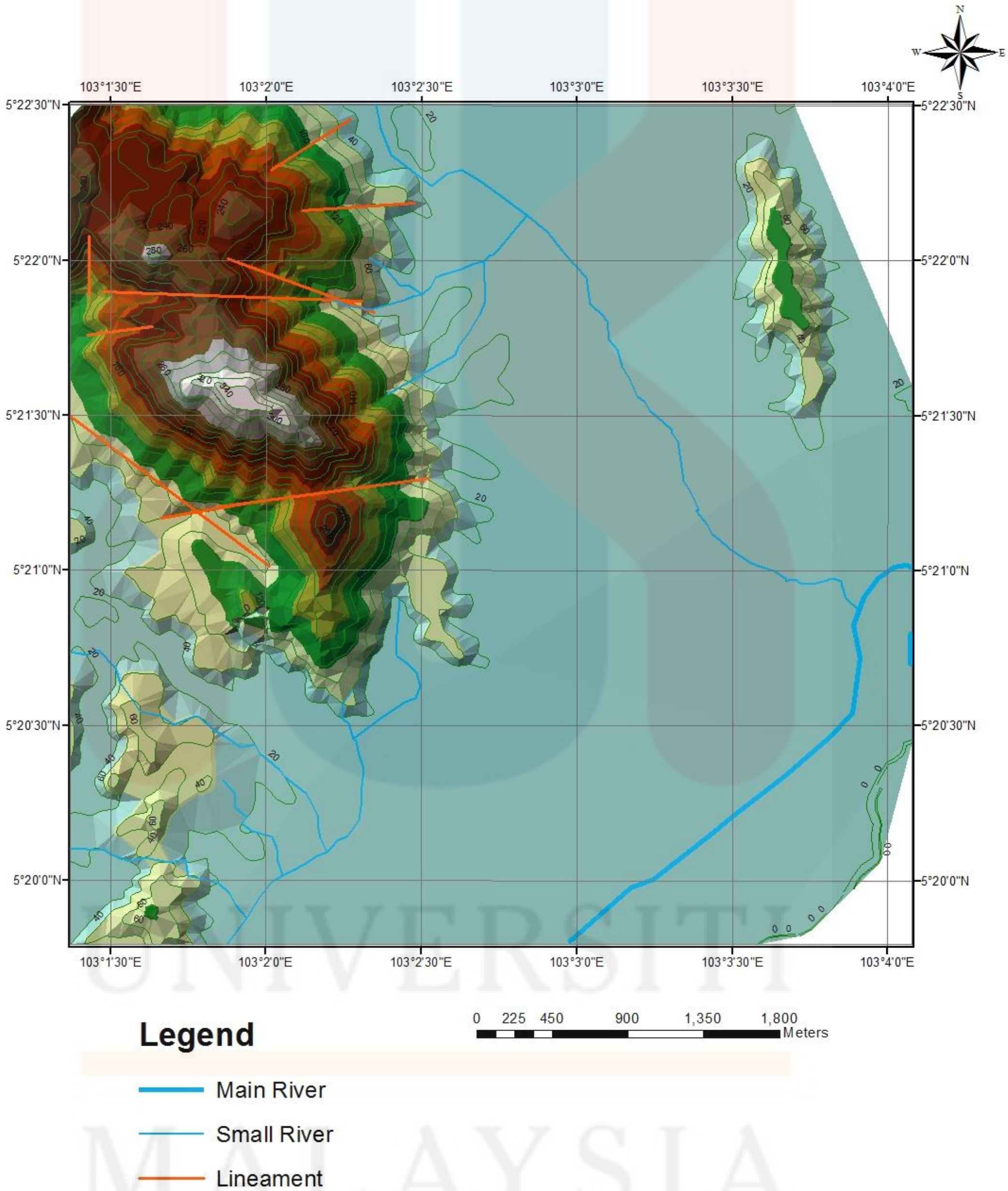


Figure 4.21: Lineament of study area.

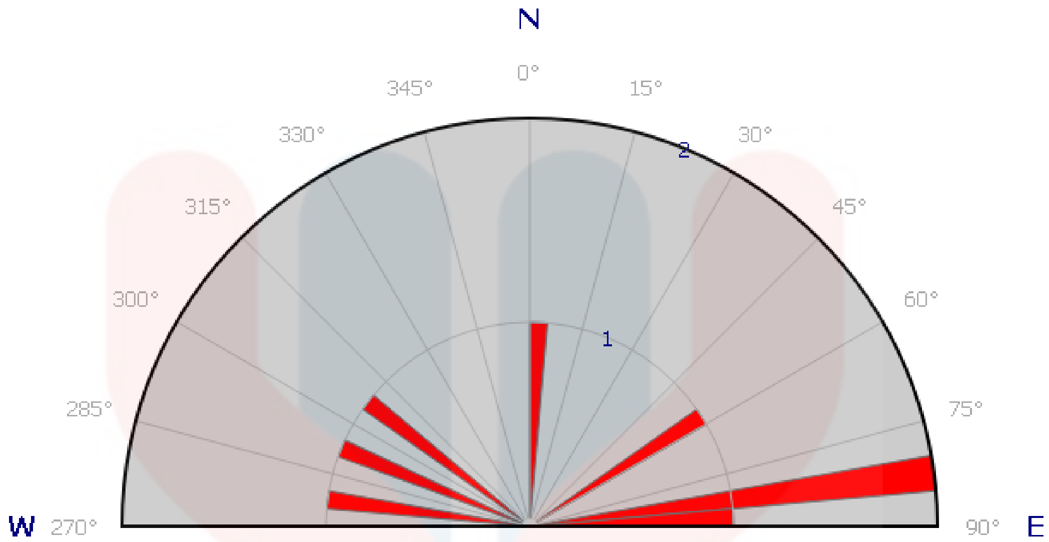


Figure 4.22: Rose diagram of lineament.

4.4.2 Bedding

Bedding is generally defined as a sedimentary layering thicker than one centimeter (Tucker, 1982). In the study area, the beds that almost vertical can be seen and averaging dipping between 40° to 60°. The metasandstone beds are slightly thick rather than slate and phyllite whereas relatively thinner. Bedding planes are commonly sharp. However, in Figure 4.23 showed the bedding planes in the study area cannot be seen clearly due to the excavating activities and might be washed through weathering.

Figure 4.23: Unclear bedding of metasediment

4.4.3 Cleavage

Cleavage is another prominent planar structure in fine grained metamorphic rocks such as slate and phyllite. In this context, cleavages are referred as parallel to subparallel plans that are secondary in origin and are formed by the combined effect of metamorphism and deformation. Rock cleavage includes shistosity which is a structure by rock that are fractured and cleaved into thin slices distinct from stratification. Varieties of cleavage have been observed in the study area which includes axial plane cleavage, slaty cleavage and crenulation cleavage.

As the cleavage nearly parallel to the axial plane of a fold in the hinge area it is known as axial plane cleavage as shown in Figure 4.24. Generally, most of the outcrop in the area show that the cleavage and bedding formed an acute angle or approximately parallel to each other.

According Winkler (1974), slaty cleavage can be defined as a structure in which new mineral grows in the rocks. This is probably due to the metamorphism and tectonic control and developed mostly parallel to axial plane or parallel to subparallel to the bedding. Slaty cleavage usually can be observed in most of the metargillite outcrops especially in slate and phyllite. However, as in the Figure 4.25 the slaty cleavage that found in the study area is unclear due to the excavating activities as well as the weathering process.

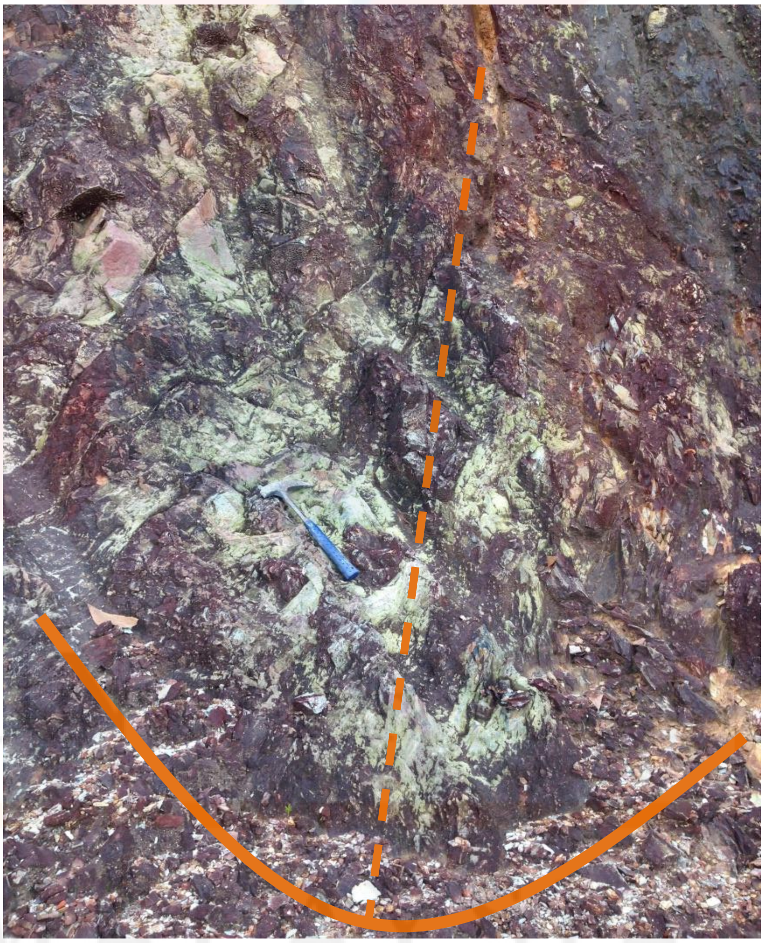


Figure 4.24: Axial plane cleavage

Figure 4.25: Unclear of slaty cleavage

4.4.4 Fault

Billing (1972) defined that fault are ruptures along which the opposite wall moved past each other. In the study area faults are mostly observed in the metasediments where they are easily recognized, characterized by the offset of the strata and displacement of beds yet it cannot be seen surely due to the excavating activities. Besides, the slickensided and shear zones associated with faulting in most of the granitic exposures that used to determined fault in the granite.

However, the major fault can only been observed and recognize through the contour map and only several minor faults found in the study area such as normal fault. A fault along which the hanging wall has moved down relatively to the footwall is defined as normal fault (Billing, 1972).

4.4.5 Joint

According Ramsay (1967), joints are structures resulting from brittle behavior of rocks in which blocks of rocks are not displaced relative to one another with nearly planar discontinuities. Joints are the most common structural feature that has been observed in the granitic rocks and metasediments of the study area.

In metasediments their occurrences are commonly in metasandstone or quartzite. Those joints in metasediments are confusedly recognized with the bedding. Some of the joints are filled with quartz as shown in Figure 4.26.

In the granitic rocks the extension joints are referred to as joints and sheet joints are rather common. Extension joints are those in which shear component is zero and related to lateral stretching. This extension may be developed and occurred into orthogonal joints when two or more sets of extension fractures occur together. These joints can be observed as in the Figure 4.27 which in the granitic outcrops especially at all quarries in the area.

Figure 4.28 is figuring the readings of joints in Rose diagram. From the diagram the forces can be proved has come from the north-west direction. Hence, all the joints occurred due to the forces and tensions present on the outcrop.

Figure 4.26: Joints filled with Quartz

Figure 4.27: Joints at granitic body

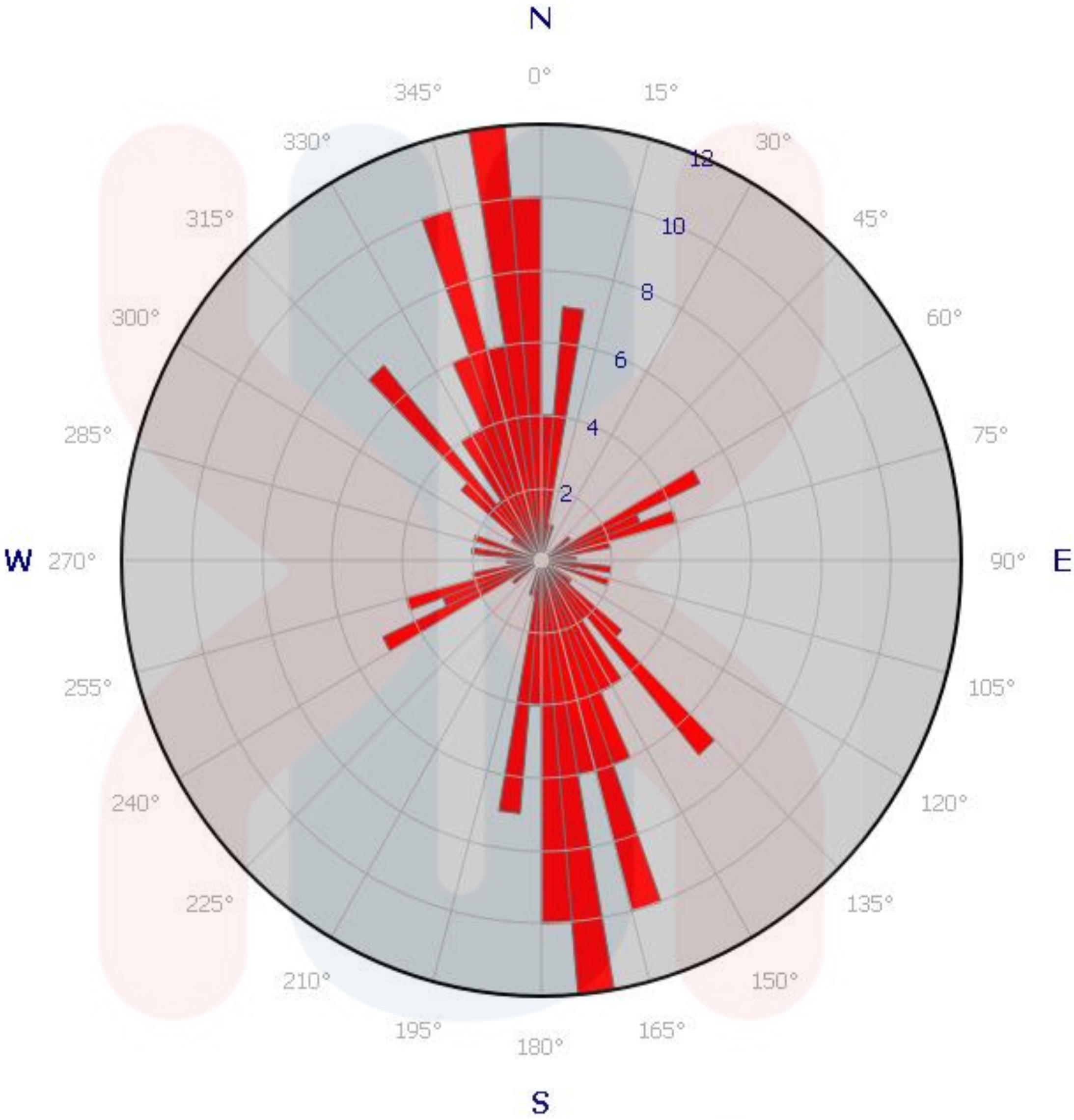


Figure 4.28: Rose diagram of joints

4.4.6 Fold

Folds are commonly formed of distortion features that have been observed in the intensely deformed metasediments in the study area. Fold can be defined as undulation or waves in the rocks of the crust (Billing, 1972). It is also described as a bend or flexure in a bed or a series of beds. Folds usually occur when the layers or stratification of rock are in a plastic stage and the forces are acting on it.

There are several type of folds have been observed in the study area such as asymmetrical fold and plunging fold. The folds observed in the study area are classified based on their appearance in profile, style, orientation of their axial surface and hinge lines as described by Hobbs (1979). However, the folds cannot be seen clearly as in Figure 4.29.

Figure 4.29: Asymmetrical fold at study area

4.5 Geological History

The area described in this project comprises of the most easterly regionally metamorphosed sediments of West Malaysia thought to be largely of Upper Paleozoic age. In the middle of the area lies the most easterly of the mainland granite masses outcrops in the north where Bukit Maras is the highest point. It passes under alluvium and reappears in the south where the highest point is Bukit Jong.

The oldest rock in the area is the Upper Carboniferous sediments underlying the eastern and western parts. Sedimentary rocks are regionally metamorphosed to varying but always mild degrees forming slate, phyllite and quartzite. The sediments are differentiated into units of arenaceous on the east and units of argillaceous on the west based on the lithology of the area. The eastern arenaceous sediments were deposited in a shallow marine environment with a shore line towards the northeast. This is indicated by both sedimentary and paleocurrent criteria. Mudflow and slumping activities were noticed at the lower part of the eastern arenaceous unit. These sediments were probably deposited on unstable slopes and were triggered by the periodic volcanic activitiy initiating mass flows and slumps. This slumping was probably initiated by uplift and faulting causing thick sequence of sediment to slide down the slope. The total thickness of this sequence is unknown because this sequence is not completely exposed. A rich biota of organism which includes brachiopods, trilobites, crinoids, bivalve and bryozoans existed at that time.

The sedimentation continued possibly till Late Carboniferous when orogenic activity commenced. The mountain building forces were approximately in the direction of east to west. The sediments suffered intense deformation during which they were tightly folded with their axes trending nearly in the north to south direction. The sediments were largely affected by a low grade regional metamorphism involving low temperature and low pressure forming slate, phyllite and quartzite.

The adamellite in the area when emplaced caused the metasediments to further be uplifted refolded and tilted to almost vertical position during Late Permian to Late Triassic. The adamellite was emplaced at a shallow depth of epizonal. This emplacement had thermally metamorphosed the metasediments forming politic hornfels as indicated by the presence of chiastolite slate. However, as a whole the effect of the thermal metamorphism appear to be localized. This is indicated by the presence regional metamorphic rock textures preserved in the rock close to the igneous contact. The force of intrusion and the force generated during volume decrease when magma cooled caused crustal disturbance in the overlying rock. This is indicated by further faulting in metasediments as well as in granitic mass of the area. Basaltic dykes intruded into granitic rocks possibly in Jurassic after which there was a long spell and apparently no sedimentary or igneous activity occurred.

CHAPTER 5

HYDROGEOCHEMISTRY OF GROUNDWATER AT TERENGGANU RIVER BASIN

From the result obtained, some of the location is tend to be contaminated. However, most of the parameters and major ions contained in the groundwater are still safe and allowable to be used for drinking when refer to "National Water Quality Standards for Malaysia". Groundwater is protected by the sediment layer compared to open surface water that probably received contaminant that flow by surface water. Besides, water that percolate into ground will occur attenuation as contaminant that may be filtered in vadose zone before reaching saturated zone. The details of data for the sediment layer and borehole log have been stated in the appendixes. Both Table 6.1 and Table 6.2 show all the chemical data and in-situ parameters data. The box that have been bold and filled by color are exceeded the limit of groundwater quality standard based on World Health Organization (WHO) standard, 2011.

Table 5.1: Physical parameters value of groundwater at Terengganu River Basin

Number of Well	Coordinate	Sampling Location	Depth (m)	Water Table	Temperature (°C)	pH	Salinity (ppt)	Turbidity (NTU)	TDS (mg/L)	TSS (g/L)	EC (µS/cm)
		Groundwater Quality Standard based on (WHO)	-	-	-	**6.5 - 8.5**	-	**< 5 NTU**	**1000 (mg/L)**	-	1400 (µS/cm)
1	5° 18' 39.9" N 103° 09' 26.1" E	SMA Atas Sultan Zainal Abidin	7.95	4.32	31	5.83	0.1	6.5	180.7	14.6	289.2
2	5° 19' 33.5" N 103° 07' 13.9" E	Surau Darul Islah, Pulau Ketam	8	1.67	32.1	7.09	0.4	0.42	799.5	130	65.2
3	5° 20' 43.9" N 103° 07' 04.2" S	Surau Kg Kebor	11	2.22	33	6.34	0.1	4.78	92.4	27.3	947
4	5° 17' 32.3" N 103° 01' 23.2" E	Surau Kg Kesom, Manir	8.28	3.62	32.8	6.04	0	17.6	40.14	12.7	150
5	5° 08' 27.9" N 102° 56' 55.8" E	Kg Kepah 1 (MW1)	10.3	3.31	27.9	6.23	0.1	0.43	68.1	23.5	167.4
6	5° 08' 27.9" N 102° 56' 55.8" E	Kg Kepah 2 (MW2)	11	3.70	30	6.3	0.1	6.13	72.35	73.6	109.7
7	5° 08' 36.1" N 102° 45' 29.3" E	SIG UMT Kenyir	6.48	1.04	31.2	5.37	0.1	4.38	103.5	15.4	116.8
8	5° 02' 03.4" N 102° 33' 54.6" E	Santuari Gajah	7.0	4.4	28.5	6.46	0	0.77	58.14	63.5	97.1
9	5° 06' 22.5" N 103° 00' 01.3" E	Kg Tajin	6.83	2.4	29.2	6.7	0.1	4	137.9	42.7	198.6
10	5° 16' 46.2" N 103° 04' 15.6" E	Padang Macang	6.7	3.18	29.3	6.72	0	4.52	37.23	48.7	60.3
11	5° 22' 25.4" N 103° 07' 09.1" E	Surau Mawaddah	13	4.5	29.6	6.75	0.1	0.91	109.5	35.9	219.2
12	5° 24' 25.6" N 103° 02' 07.4" E	SMK Tengku Mizan Zainal Abidin	8.3	5.63	30.7	6.02	0	0.13	22.92	49.9	37.3
13	5° 25' 31.6" N 103° 03' 25.8" E	SMK Kompleks Mengambang Telipot	9	2.8	31	5.85	0.1	35.7	135.9	46	185.1
14	5° 20' 14.1" N 103° 02' 08.9" E	Bukit Jong	12	3.1	32.4	6.89	0.2	46.9	241.8	141	378.4

Table 5.2: Chemical data of groundwater at Terengganu River Basin

Number of Well	Coordinate	Location of Sampling	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Fe (mg/L)	Mn (mg/L)	Cu (mg/L)	Zn (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	HCO3 (mg/L)
		Groundwater Quality Standard based on (WHO)	200 (mg/L)	150 (mg/L)	200 (mg/L)	50 (mg/L)	1 (mg/L)	1 (mg/L)	1 (mg/L)	15 (mg/L)	1 (mg/L)	300 (mg/L)	500 (mg/L)	500 (mg/L)
1	5° 18' 39.9" N 103° 09' 26.1" E	SMAZA	32	2.35	24	3.257	0.1	0.01	0.004	0.014	<0.1	24	19	100
2	5° 19' 33.5" N 103° 07' 13.9" E	SURAU DARUL ISLAH, PULAU KETAM	21	22.06	159	13.803	4.97	0.49	0.007	0.01	0.37	233	28	193
3	5° 20' 43.9" N 103° 07' 04.2" E	KG KEBOR AIR	2	1.3	30	4.581	0.08	0.03	0.008	0.014	<0.1	29	15	190
4	5° 17' 32.3" N 103° 01' 23.2" E	KG KESOM	2	1.1	4	1.51	8.4	0.12	0.097	0.02	<0.1	6	4	100
5	5° 08' 27.9" N 102° 56' 55.8" E	KG KEPAH 1	13	1.88	5	1.5	0.29	0.05	0.003	0.015	0.13	3	2	280
6	5° 08' 27.9" N 102° 56' 55.8" E	KG KEPAH 2	12	2.37	6	1.212	0.46	0.04	0.002	0.017	0.21	3	3	220
7	5° 08' 36.1" N 102° 45' 29.3" E	SIG UMT	2	0.73	3	1.187	37.83	1.86	0.002	0.013	<0.1	2	4	233
8	5° 02' 03.4" N 102° 33' 54.6" E	SANTUARI GAJAH	9	2.24	6	0.861	0.41	0.02	0.001	0.019	<0.1	2	4	220
9	5° 06' 22.5" N 103° 00' 01.3" E	KG TAJIN	36	1.17	5	0.696	0.35	0.6	0.002	0.02	0.1	7	6	207
10	5° 16' 46.2" N 103° 04' 15.6" E	PADANG MACHANG	2	0.89	7	2.083	1.34	0.08	0.008	0.03	<0.1	7	2	183
11	5° 22' 25.4" N 103° 07' 09.1" E	SURAU MAWADDAH	18	2.46	10	2.985	0.18	0.09	0.001	0.02	<0.1	13	17	213
12	5° 24' 25.6" N 103° 02' 07.4" E	STEMZA	1	0.28	4	2.94	0.05	0.01	0.04	0.03	<0.1	4	3	267
13	5° 25' 31.6" N 103° 03' 25.8" E	SMKKMT	28	2.03	10	2.555	1.46	0.08	0.006	0.019	<0.1	11	7	120
14	5° 20' 14.1" N 103° 02' 08.9" E	BUKIT JONG	4	4.2	80	3.475	13.15	0.06	0.691	0.035	1.3	15	4	240

5.1 Physical Parameters

According to the Table 5.1, physical characteristic of groundwater has been observed. Some of the samples show a tendency to be contaminated. Observation of pH for all well is approximately neutral. However, well 7 shows the lowest reading (5.73) that is more acidic than other well. This is probably the water from the well contained a big number of iron due to the area of the well is located near to Kenyir Lake where many human activities been done.

Basically, electrical conductivity of the water depends on the water temperature. When the temperature is high, the electrical conductivity would be high as well. As the electrical conductivity is a good indicator for a total value of salinity, it still not significantly provides any detail information about the ion composition in the groundwater. From the observation of physical parameters for groundwater, the highest value of electric conductivity is 378.4 μS/cm. The high value of electrical conductivity probably due the temperature of the water that been taken during sunny day as well as the high contained of ion in the water from the well 14. The solubility of substances and ionization causes a variation ratio for the relationship of electrical conductivity to TDS in water samples as not some of the substances are insoluble in the water, hence the substances in water samples will not affect TDS. Besides, not all compounds can ionize in solutions or water samples. Amount of groundwater salinity from all well is nearly identical that is in between 0 to 0.4 thus, all the samples are nearly pure. However, the presence of salinity probably caused by the ion or dissolved substances that contained in the groundwater samples. All the parameters are related to each other as well as the amount of ion and chemical elements contained in the samples.

5.1.1 Total Dissolve Solid (TDS)

A measure of all dissolved substances in water including organic and suspended particle is the meaning of Total Dissolve Solid (TDS). The primary components are generally sodium, calcium, magnesium, potassium and iron as cations while bicarbonate, carbonate, chloride, sulfate, and fluorite as anions. A conductivity probe that detects the presence of ions in water is one of the methods that commonly used to determine the value of TDS in water as the measurement of specific conductivity. According to Singh and Kalra (1975), conductivity measurements are converted into TDS values by means of a factor that varies with the type of water.

As the TDS is concerned, the range of the value is from 22.92 to 799.5 mg/L. From the distribution map in Figure 5.1, the high values of TDS can be observed only in north-eastern of study area. Meanwhile the low values of TDS have distributed at southern of study area and some patches at north-eastern. A significant point from the distribution map of TDS is to be concluded as the area has shown the increasing of TDS values from south towards north-east of the study area.

The highest concentration of TDS values is from well 2 that located at Surau Darul Islah, Pulau Ketam which contained of 799.5 mg/L. The value is way too high from the other wells due to the location that is very close to the river where the river is recharging the groundwater hence the TDS is probably from the river. Besides, the river is the main river of Kuala Terengganu that located at the middle of the town. The human activities and their social economics could affect the river. Therefore, the interaction between the surface water and groundwater shows the groundwater flow trend is from the river to the groundwater. The other reason for the high concentration of TDS at this locality is probably caused by the lower of water elevation.

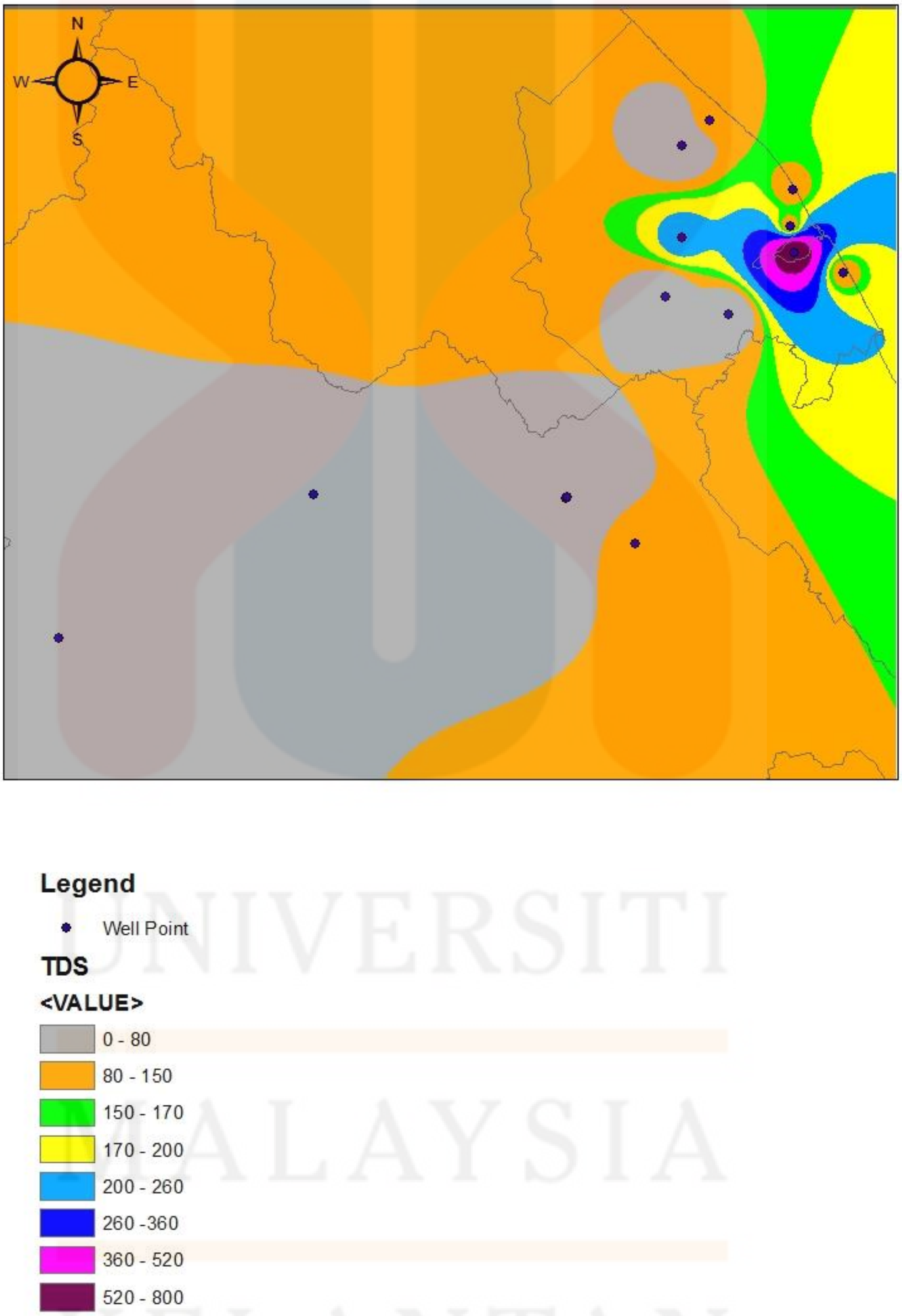


Figure 5.1: Distribution map of TDS

5.2 Major Components

The major dissolved components of groundwater are including the cations calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K) and the anions chloride (Cl^-), bicarbonate (HCO_3^-) and sulphate (SO_4^{2-}). The concentrations of these major components are usually present in the range of a few mg/L to several hundred mg/L.

Sodium and calcium are the major cations in these groundwater samples and chloride and Bicarbonate are the major anions. The concentration value for all the components of cations are obtained from Inductively Coupled Plasma Mass Spectrometry (ICP-MS) while some of the anions components such as Chloride and Sulphate are using Ion Chromatography despite the concentration of bicarbonate that use titration method.

5.2.1 Bicarbonate

Carbonates are formed in many different types of rock which is mostly in sedimentary rocks, some in igneous and some in metamorphic rocks. Yet, the chemical reaction of carbonate is relevant to the evolution of most groundwater.

Bicarbonate (HCO_3^-) is the highest value of concentration that present at the study area. Refer to the Figure 5.2, the distribution map of bicarbonate exhibit the range of the bicarbonate concentration in between 100 to 280 mg/L. Titration method has been used by titrating the samples with the hydrochloric acid (HCL). Particularly, bicarbonate and carbonate can be the primary indicator of dissolve carbon species to determine the alkalinity in most waters. The higher concentration of bicarbonate in groundwater is common. Somehow the concentration could be over than 1000 mg/L in waters which are low in calcium and magnesium relatively where the sulphate reduction is probably occur in groundwater due to the processes of releasing carbon dioxide.

Generally, bicarbonate concentration of waters is held within a moderate range by the effects of the carbonate equilibrium. At first, anions are formed by the reaction of carbon dioxide with water and followed by an equation that encourages the dissolution of calcite;

$CO_2(g) + H_2O = H + HCO_3^-$

$CaCO_3 + H = Ca^2 + HCO_3^-$

$CaCO_3 + CO_2(g) + H_2O = Ca^2 + 2HCO_3^-$

From the distribution map, it can be seen clearly that the high value of bicarbonate concentration has lies on the southern and slightly to the east. A small distribution of high bicarbonate concentration is located at north-eastern. 280 mg/L is the highest amount of the concentration where is from well 5. Well 5 is located at Kg. Kepah, Kuala Berang, Hulu Terengganu. The source of the bicarbonates is come from the industrial discharges where is 50 metres close to the well. Besides, Kg Kepah is believe made of calcareous environment thus, the circulation of water that rich in carbon dioxide is possible to produce solutions that are highly supersaturated when exposed to the air.

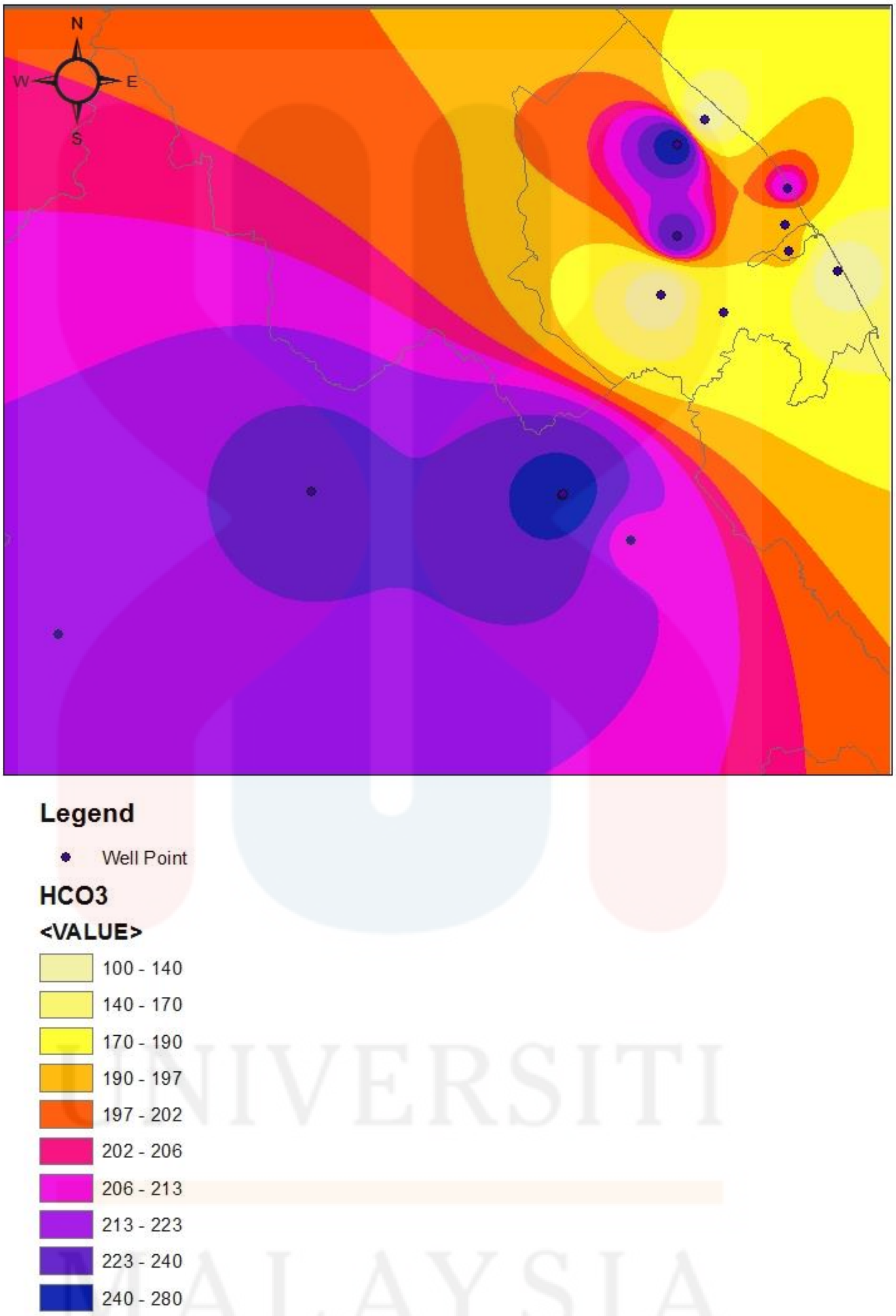


Figure 5.2: Distribution map of Bicarbonate (HCO_3^-)

5.2.2 Chloride

According Boyd (2000), the concentration of chloride (Cl^-) in groundwater is usually 100 mg/L yet can be as high as 19000 mg/L in seawater. The value that is exceeds 250mg/L will produce a salty taste. The concentration value of chloride in the study area has been observed in range between 2 to 230 mg/L. The value of chloride concentration is obtained by using Ion Chromatography.

The high value of chloride concentration has lies at north-eastern area. All the value are not more than 100 mg/L except for the well 2. The highest value is 233 mg/L that is obtained from well 2 which is located at Surau Darul Islah, Pulau Ketam. Similar to the concentration of Mg, Na and K, Chloride is also the highest range on the distribution map as shown in Figure 5.3 as well as the value of TDS. The value of chloride concentration from the well 2 is way too high and exceed the common value that stated by Boyd (2000).

Ottawa (1978) has stated that chloride in surface and groundwater from both natural and anthropogenic sources, such as run-off containing road de-icing salts, the use of inorganic fertilizers, landfill leachates, septic 2 tank effluents, animal feeds, industrial effluents, irrigation drainage, and seawater intrusion in coastal areas. Therefore, the extremely high value of chloride concentration from well 2 is upon on a number of factors. Well 2 is located near to the main river of Kuala Terengganu besides the location is in the middle of town. All the human activities are the main contribution of high concentration of chloride. Farming is one of the significant economic social for local at the area of Pulau Ketam yet, they use inorganic fertilizer such as potassium for their plants. The concentration value of chloride from well 2 is slightly dangerous to be consumed and need to be cured and prevent.

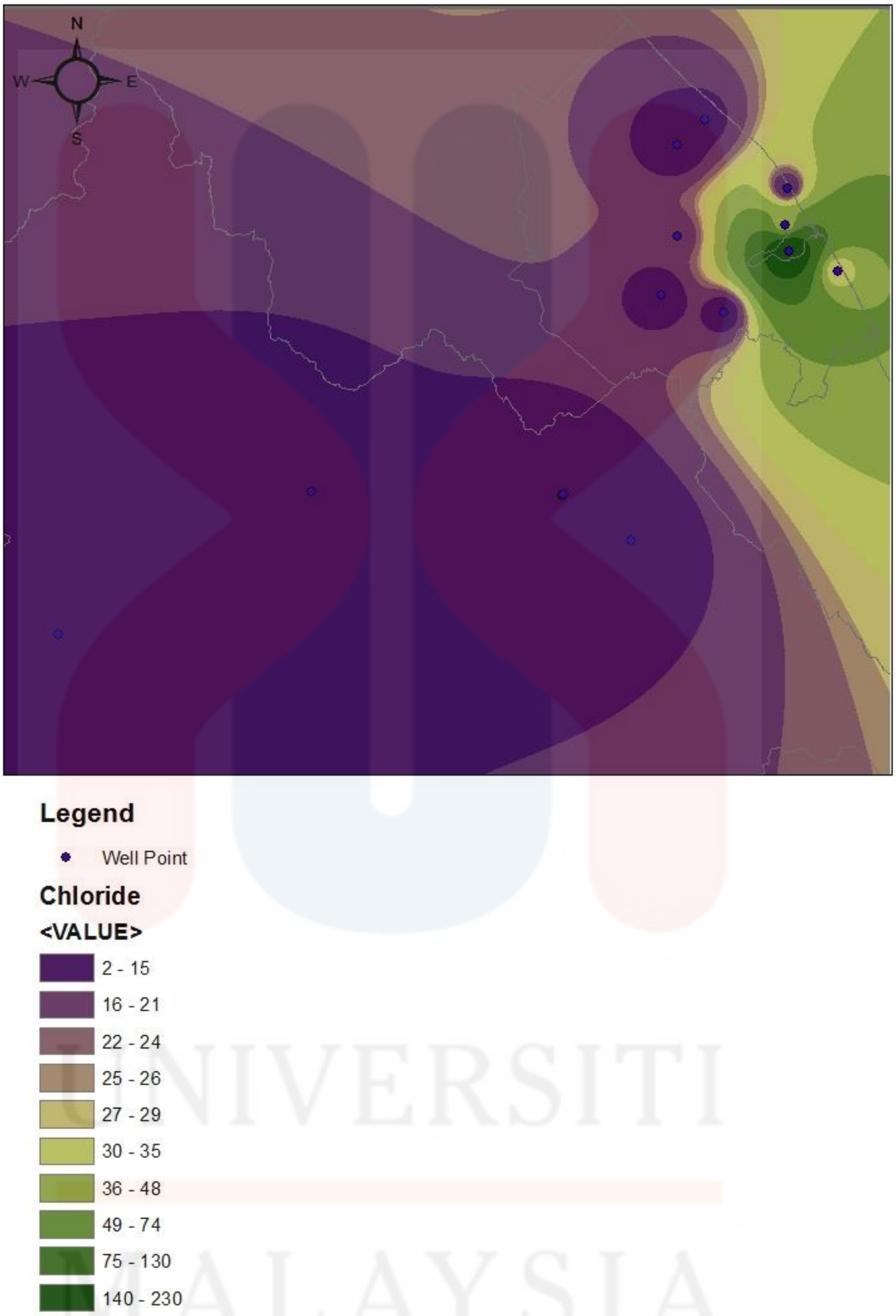


Figure 5.3: Distribution map of Chloride (Cl)

5.2.3 Sulphate

Sulphate (SO_4) is easily dissolved in water and respectively found with high concentration in either surface water or groundwater. Combustion of fossil fuels contribute a big number of sulphur. Sulfur in the atmosphere is oxidized to sulfate and eventually deposited with precipitation or through dry deposition. Because sulfate occurs as a dissolved ion, it is mobile in ground water. According Davis and DeWiest (1970), concentrations of fluoride in natural waters are generally range between 0.1 mg/L and 10 mg/L.

From the distribution map of sulphate distribution in Figure 5.4, the range of the sulphate concentration is in between 2 to 30 mg/L. 30 mg/L is slightly high than the general range of sulphate concentration. The high concentration has lies on the north-eastern of distribution map. Well 2 is contained the highest concentration of sulphate as well as chloride. The reason of the sulphate occurrence is related respectively to chloride. The well is nearly to the river that could be contributed the occurrence of sulphate since the TDS value from this well as high as 799.5 mg/L. The concentration of sulphate in groundwater is probably be influenced by the variety of geochemical processes, sources and time as well. One significant source is the dissolution or weathering of sulphur that contained minerals.

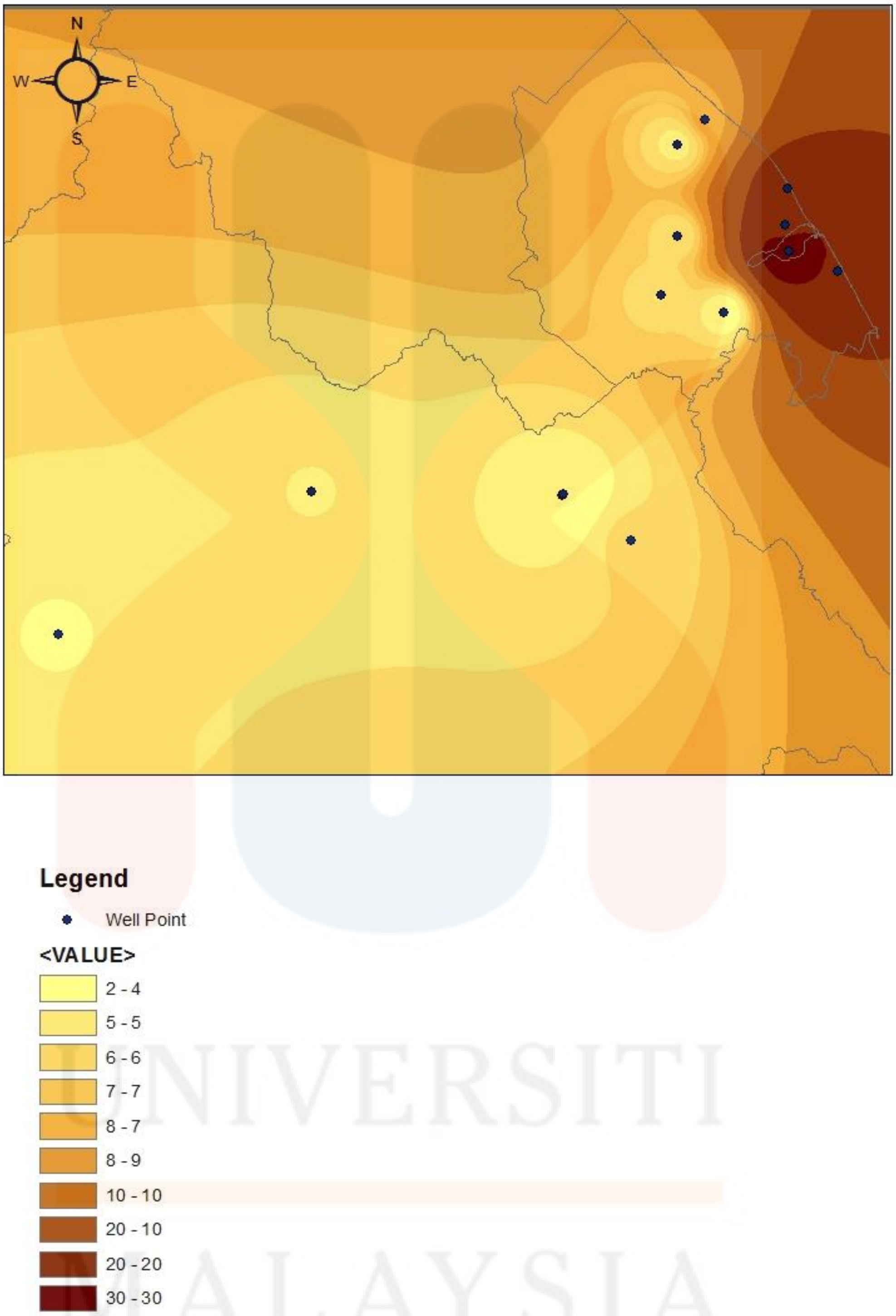


Figure 5.4: Distribution map of Sulphate (SO_4)

5.2.3 Calcium

Concentration value of calcium (Ca) is obtained from the Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The concentration of calcium is commonly 0 to 60 mg/L in groundwater is to be said soft in term of hardness. In the study area, the concentration value of calcium is clean and safe for consumption. However, there are some distributions of high value at the eastern of study area in the distribution map of calcium in Figure 5.5.

Well 9 shows the highest concentration value of calcium that is located at Kg. Tajin whereas familiar with the agricultural lime. Therefore, the reason of the high concentration of calcium at this well is due to the big amount of calcium consumed by the villagers for their agricultural lime. For the well 1 and 13 are both in the school area that also high concentration value of calcium is because of the well is located near to a small dumpsite area. The leachate is probably the source of calcium contained in that particular area.

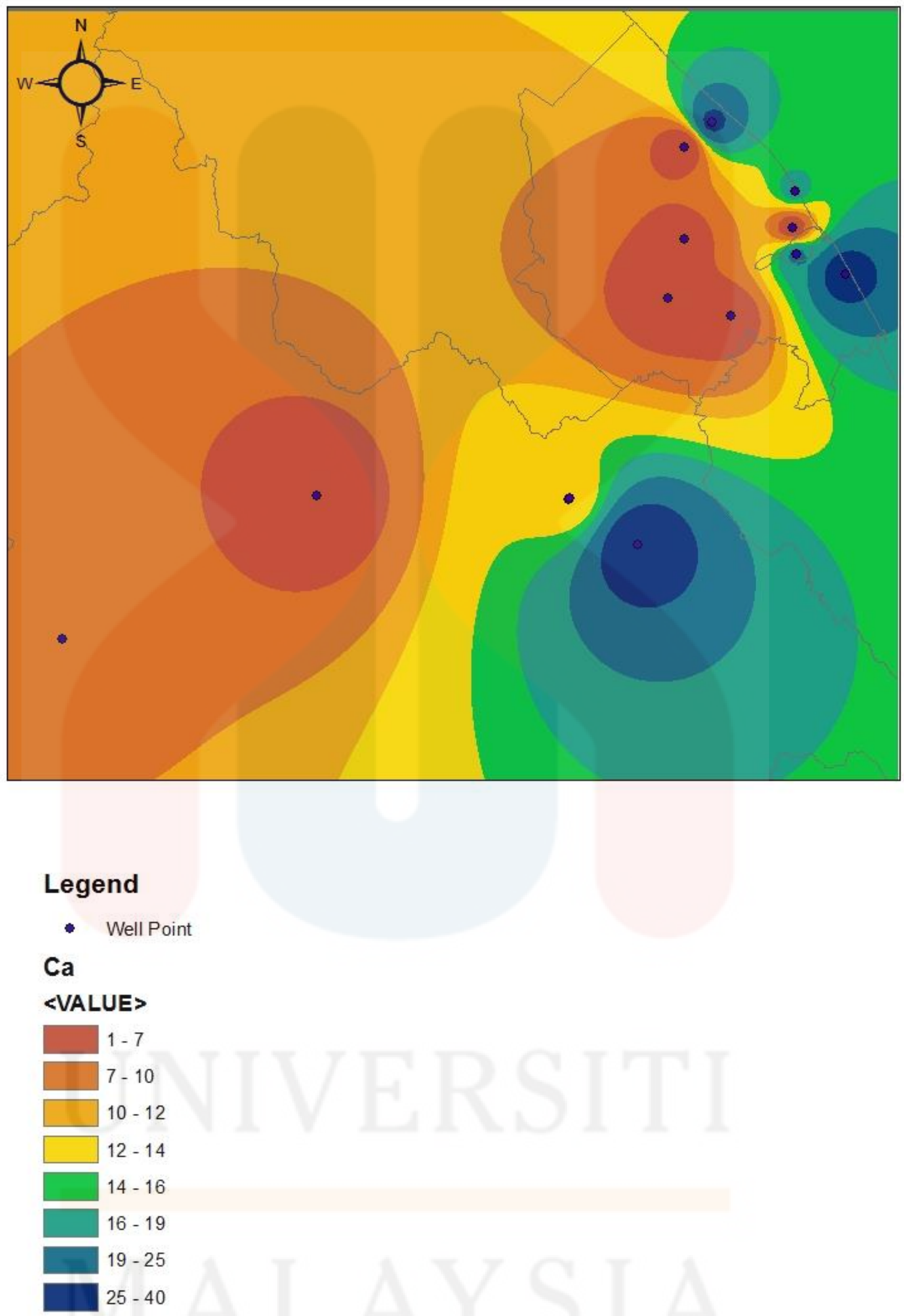


Figure 5.5: Distribution map of Calcium (Ca)

5.2.4 Magnesium

The magnesium (Mg) contained at the study area is in the range between 0.2 to 23 mg/L. The common concentration value for magnesium to be safe to consume is relatively same as the value of calcium (Ca). From this fact, the groundwater is safe to be consumed. Figure 5.6 shows the distribution map of magnesium. There is one point of well in the high range of the magnesium concentration at north-eastern area which is well 2 that contained 22.06mg/L.

According to the value obtained, the groundwater from well 2 is still safe to be consumed. However, the reason of the concentration value of magnesium high at this well point is due to the location of the well where is near to the main river of Kuala Terengganu. The river might be affected the groundwater because the river is recharging the groundwater. Furthermore, the river is located at middle of the town of Kuala Terengganu. Human activities and their social economics are the consequence of the river to be contaminated. Therefore the flow of the river into the groundwater affects the concentration value of magnesium of groundwater at well 2.

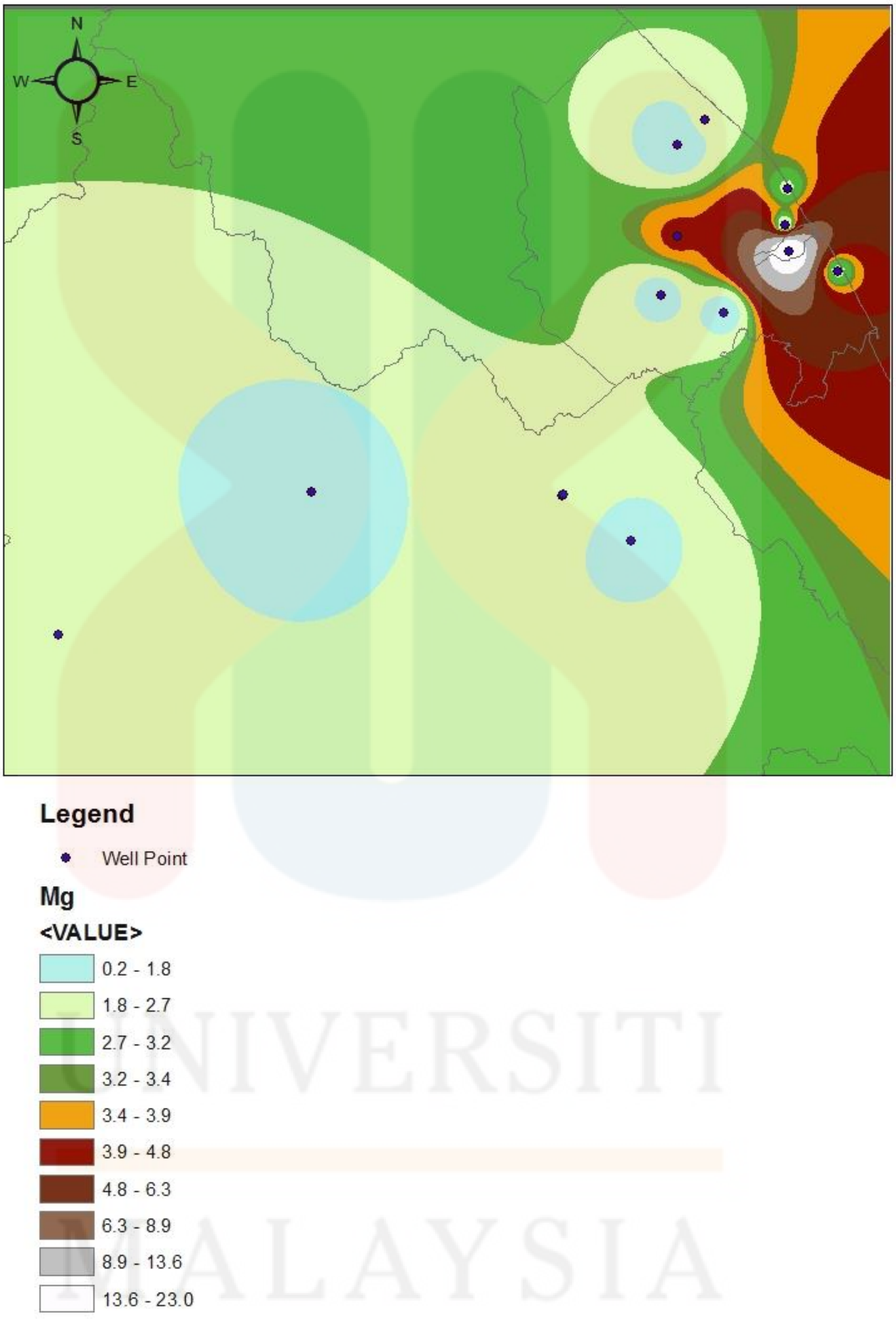


Figure 5.6: Distribution map of Magnesium

5.2.5 Sodium

Sodium concentration is obtained from the method that is using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The range of the concentration value for sodium is from 3 to 160 mg/L. The higher concentration value of sodium in the study area had lies on the area of north-eastern. The south-west area shows the low concentration. In Figure 5.7 shows the concentration value of sodium has increased due to the environment of the well point that is mostly located near to the residential area.

159 mg/L is the highest value of sodium concentration which is contained in the well 2. Well 2 is located at Surau Darul Islah, Pulau Ketam where is near to the main river of Kuala Terengganu. Along the river has developed by the residential area and buildings consequently to the town area. Therefore, the high concentration of sodium in the groundwater at this well is because to the environment at the middle of town where some of the nearby area become the landfill. Since the sodium is more able to move in the soil hence it is often to be the indicator of human impacts to the surface water as well as the shallow groundwater.

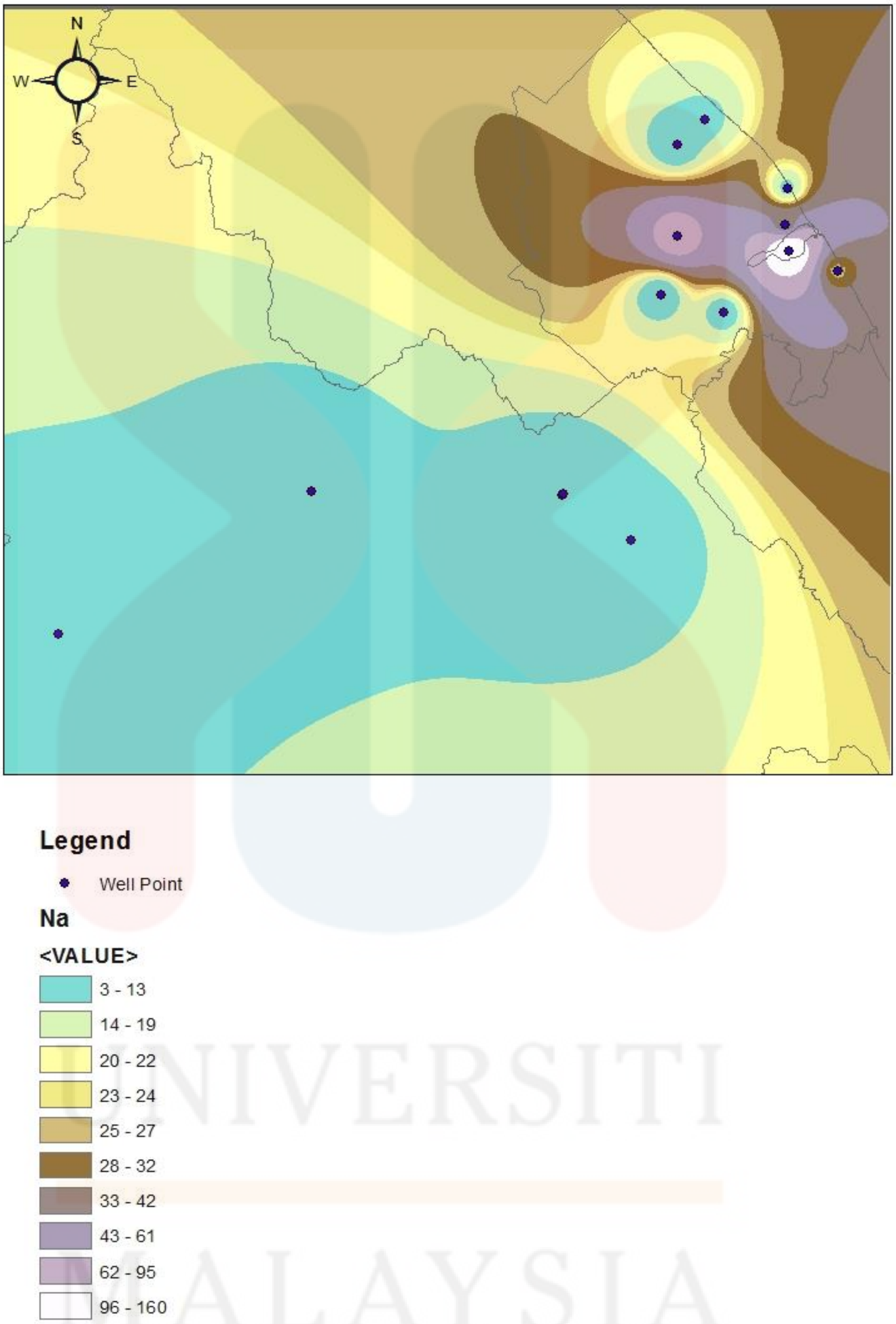


Figure 5.7: Distribution map of sodium.

5.2.6 Potassium

From the result obtained, the range of the concentration value for potassium is between 0.7 to 14 mg/L. The pattern of the distribution in the study area has increased equivalently to the pattern of sodium concentration which is contributing at north-eastern area as figuring in Figure 5.8.

The highest value of potassium concentration is 13.08 mg/L while the lowest concentration value of potassium is 0.69 mg/L. As the pattern of the distribution increased equivalent to the distribution of sodium, the highest concentration of potassium is obtained from the same well as the highest sodium concentration which is well 2 that located at Surau Darul Islah, Pulau Ketam. All the factors of the potassium concentration at the well is identical to the sodium concentration which is caused by the residential area that having abundant of human activities such as farming. Farming activity is commonly use potassium as fertilizer. Thus, the concentration value of potassium is high at this area. However, potassium concentration is not as high as the sodium concentration.

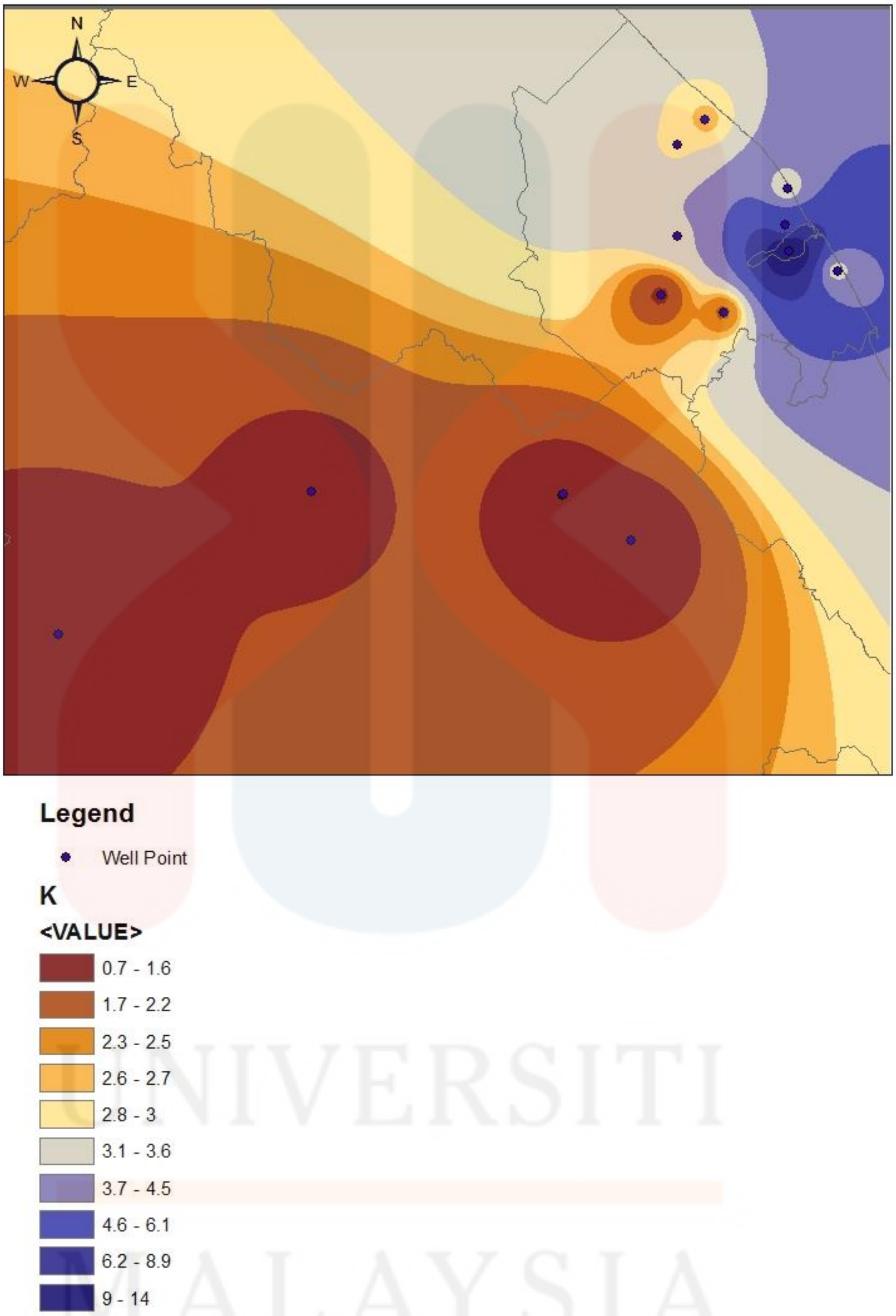


Figure 5.8: Distribution map of Potassium.

5.3 Trace Element

In these groundwater samples some of the elements in the periodic table are present at some concentration. Iron (Fe) is the most abundant of the trace elements in these groundwater samples, followed by Manganese (Mn), Copper (Cu) and Zinc (Zn). All of these trace elements are minor cations.

Fortunately, the concentrations of the trace elements in these samples are not as higher as the major elements that have been observed. All of these trace elements have been obtained through a method that called as Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

5.3.1 Iron

Inductively Coupled Plasma Mass Spectrometry (ICP-MS) has been used to calculate the concentration value of iron (Fe). The range of the iron concentration is between 0.07 to 38 mg/L. The high value of iron concentration is lies at the south-west area and patch at north-eastern. The distribution of iron is shown in Figure 5.9.

As the groundwater is tremendously used for daily routine in Terengganu the high concentration of iron can give impact the reddish stains on pipes installations and attire. The highest concentration value which is 37.83 mg/L that shown in the distribution of iron is located at Kenyir. The groundwater from well 7 has been used for Special Interest Group (SIG) of University Malaysia Terengganu (UMT) for their activity that related to the biodiversity at Kenyir Lake. According to the pH value obtained, the groundwater at well 7 is quite acidic as in many places that contained excessive amounts of iron. Fortunately, the groundwater is not use for daily routine and no residential area using this well.

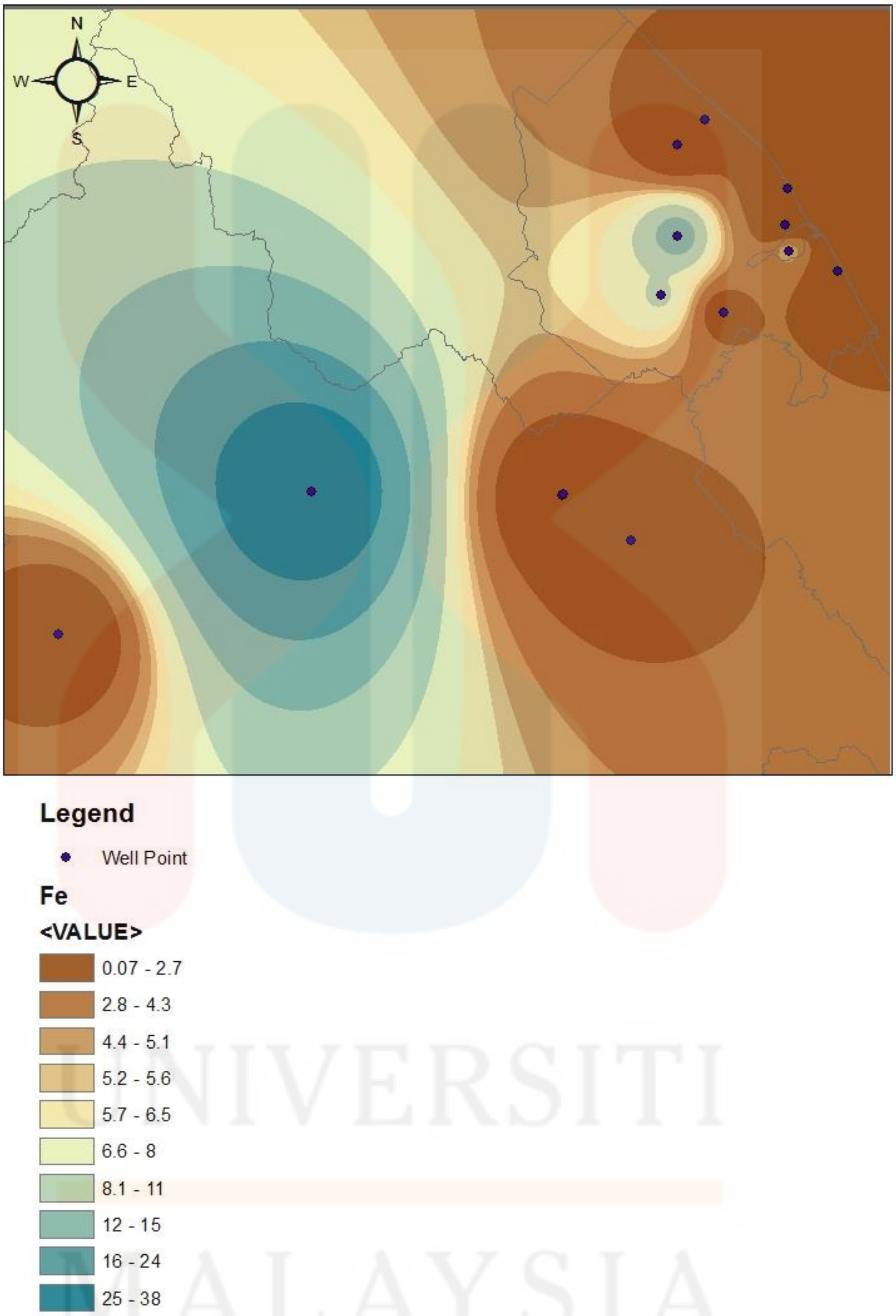


Figure 5.9: Distribution map of Iron (Fe)

5.3.2 Manganese

Manganese (Mn) is particularly occurred and inexhaustible component that is fundamental in organic frameworks. The synthetic bearing of manganese is overwhelmed by pH, reduction and oxidation reactions. As a naturally occurring element, manganese is also prevalent in the environment thus it found in sediments, soils, surface water and groundwater. Basically, the concentrations of manganese in groundwater are reliant upon various elements for example rainfall, geochemical environment, aquifer lithology and groundwater flow. According to Figure 5.10, the distribution map shows the range value of manganese concentration is between 0.02 to 1.9 mg/L. The common value of manganese concentration that is safe to be consumed is 0.05 mg/L.

The high concentration value in the study area is distributed at southern area. All the concentration value that above 0.05 mg/L is significantly can be affected the usefulness of the groundwater. The area that contained of high manganese concentration is probably due to the dissolution of manganese in minerals from the surrounding rocks as well as the strain of manganese in percolating through soils. The low pH value of groundwater which is acidic also the factor of the high manganese concentration obtained. The highest concentration value of manganese is located identically where the highest concentration of iron (Fe) that is well 7 at Kenyir.

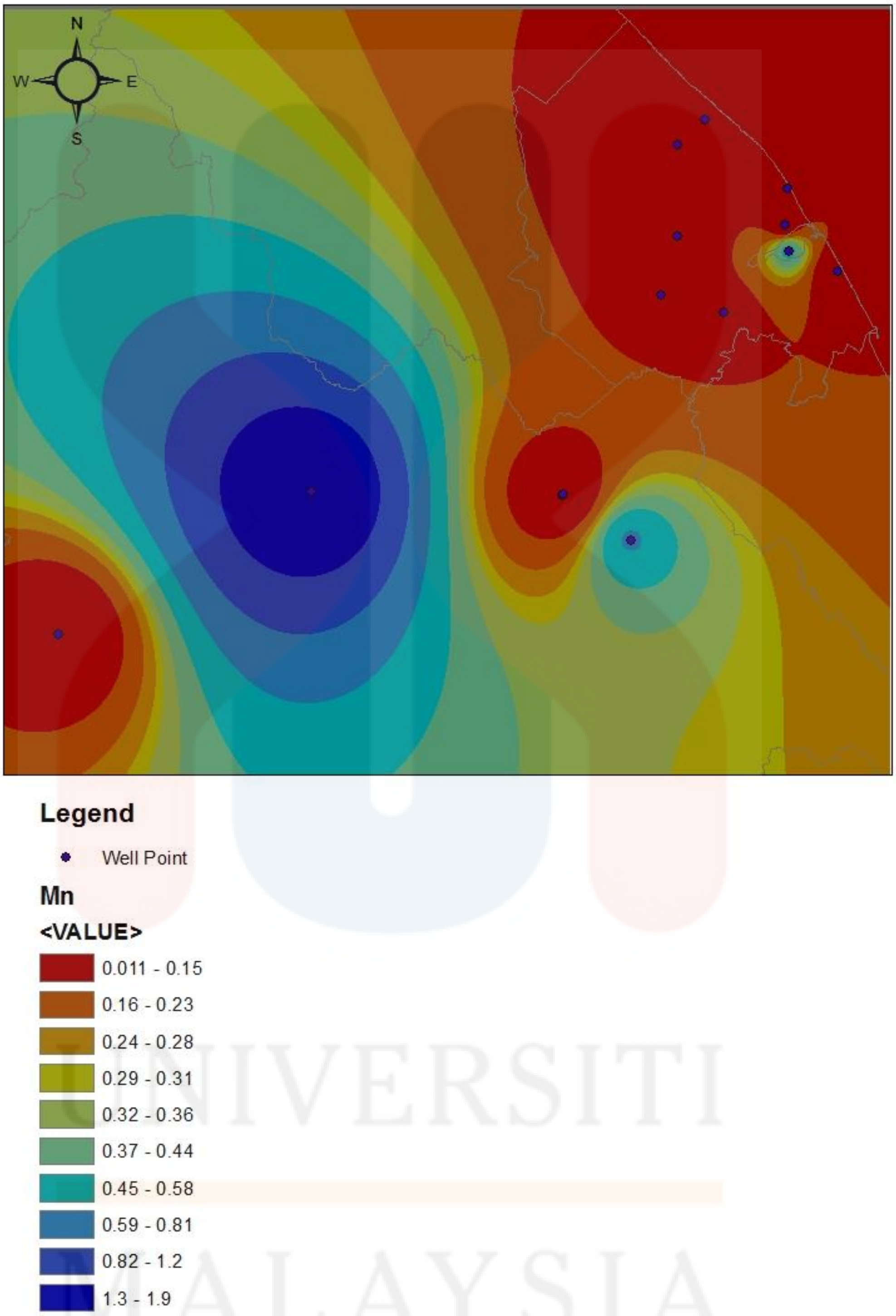


Figure 5.10: Distribution map of Manganese (Mn)

5.3.3 Copper

Generally, the concentration level of copper (Cu) in surface water or groundwater is very low. A precise and accurate amount of copper (Cu) in our diet is necessary for good health. Unfortunately, the excess amounts of copper (Cu) will cause health problems. Figure 5.11 shows the distribution of copper (Cu) in the study area that is ranging in between 0.001to 0.69 mg/L. All the concentration value is safe to be consumed since the safe range of copper concentration value is 0.001 to 0.17 mg/L (Pettersson & Rasmussen, 1999). The high concentration value of copper is distributed at the north-eastern area on the distribution map.

0.691 mg/L is the highest value of copper (Cu) concentration in the study area. It is located at Bukit Jong from well 14. Although the concentration value is still safe to be consumed the tendency of copper (Cu) concentration to be increase is possible. The occurrence of copper (Cu) at Bukit Jong area is due to the environment which is near to the quarry and excavating area. The mining activities and mineral leaching are the factors of the occurrence of copper (Cu). If these mining activities happen continuously the possibility of copper concentration increase is high.

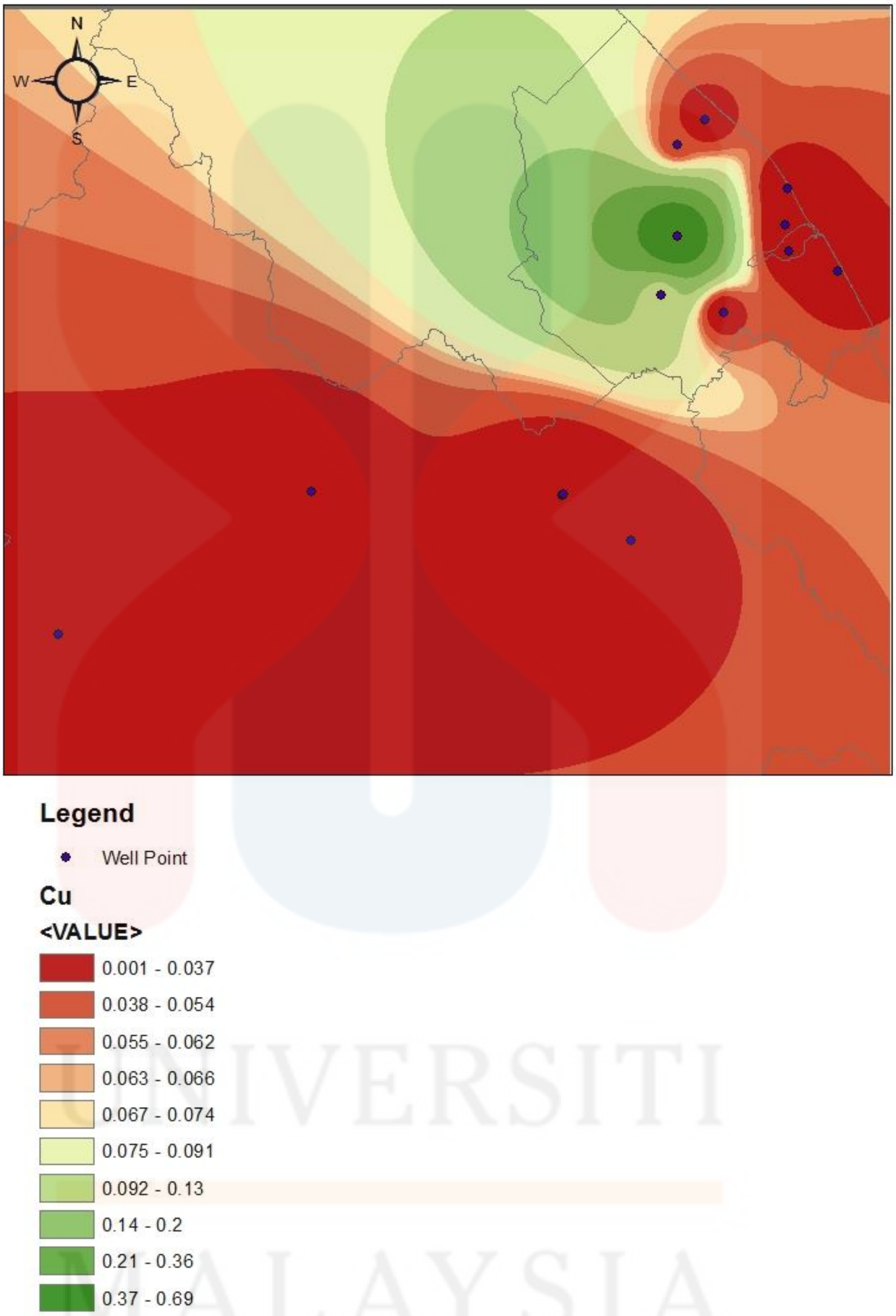


Figure 5.11: Distribution map of Copper (Cu)

5.3.4 Zinc

Zinc (Zn) is nearly identical to the copper (Cu) which is approximately distributed between aquifer. Ground water does not have all the earmarks of being contaminated by zinc (Zn) due the commonly low value occur. Based on the Figure 5.12 the range distribution of zinc (Zn) is in between 0.01 to 0.035. All the values are not even reach 0.1, thus the groundwater is safe from the contamination of zinc (Zn).

The area where is abundant of zinc is distributed at north-eastern similar to the distribution of coppor (Cu). The mining and excavating activities probably caused the well point of groundwater at Bukit Jong contained the highest concentration value of zinc (Zn) as well as copper (Cu) distribution.

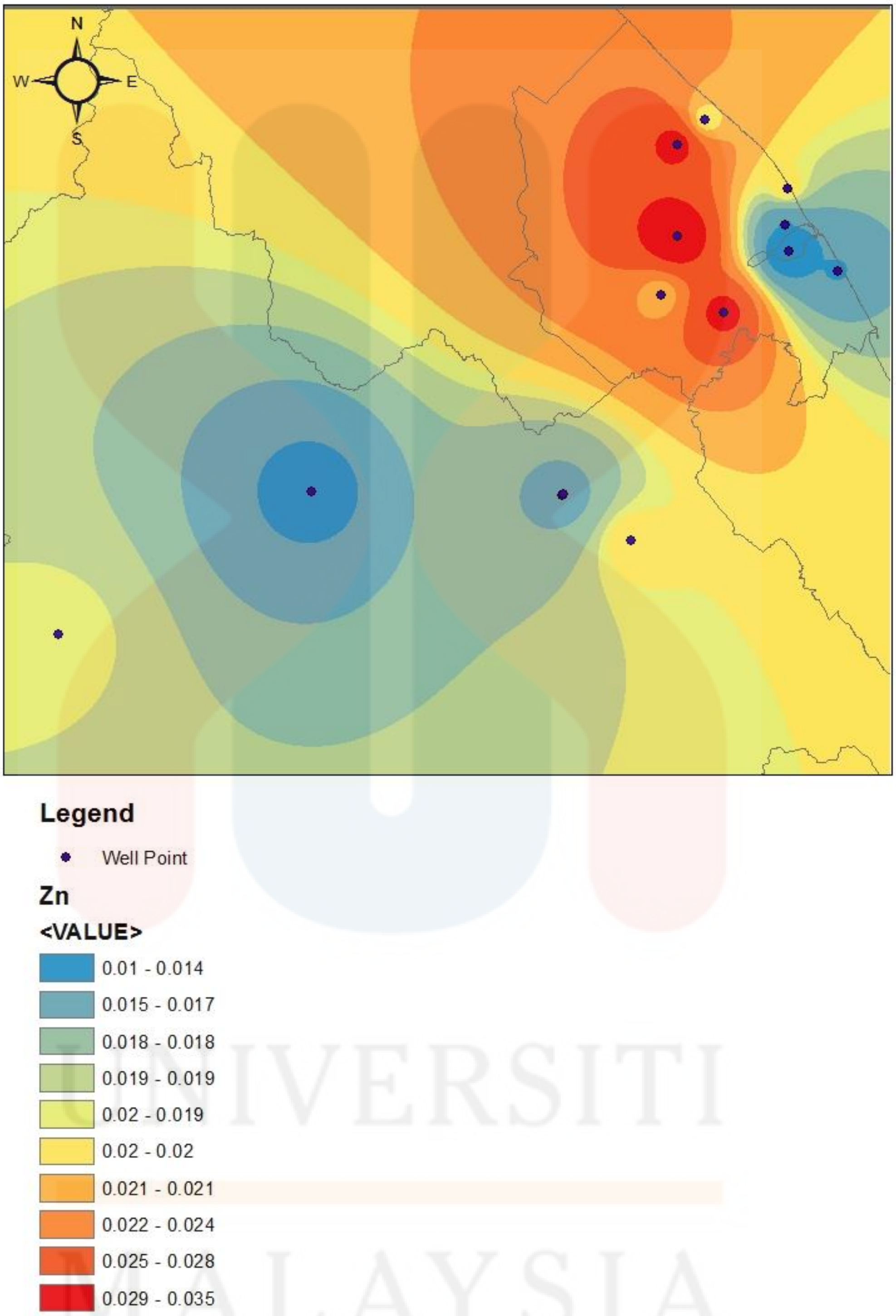


Figure 5.12: Distribution map of Zinc (Zn)

5.4 Hydrogeochemical Facies and Classification

Water types are commonly used in the characterization of waters as a diagnostic tool (Leybourne et al., 1998). The Piper trilinear diagram has contributed by (Piper, 1944). This diagram has been used for the purpose of characterizing the water types present in the study area. According to Freeze and Cherry (1979), the cation and anion compositions of many samples also enable to be represented on a single graph in which major groupings or trends in the data can be discerned visually through the piper diagram. Besides, it is can aided the hydrogeochemical facies.

Based on the Figure 5.13 below, a few conclusions can be concluded from the piper diagram of the collected samples. There is there is an equal distribution on cation diagram where magnesium an sodium/potassium group have similar number of groundwater samples and the rest of the well has plotted on no dominant type of group. For anion diagram there is a large percentages that is abou 90% of the samples fall on the group of bicarbonate and 1 sample has fall in the sulfate group. The data points in the both triangle of cations and anions have been predicted hence, the intersection point on the quadrilateral plot shows 3 types of water.

1. Alkali-HCO_3
2. Ca-Mg-HCO_3
3. Alkali-SO_4-Cl

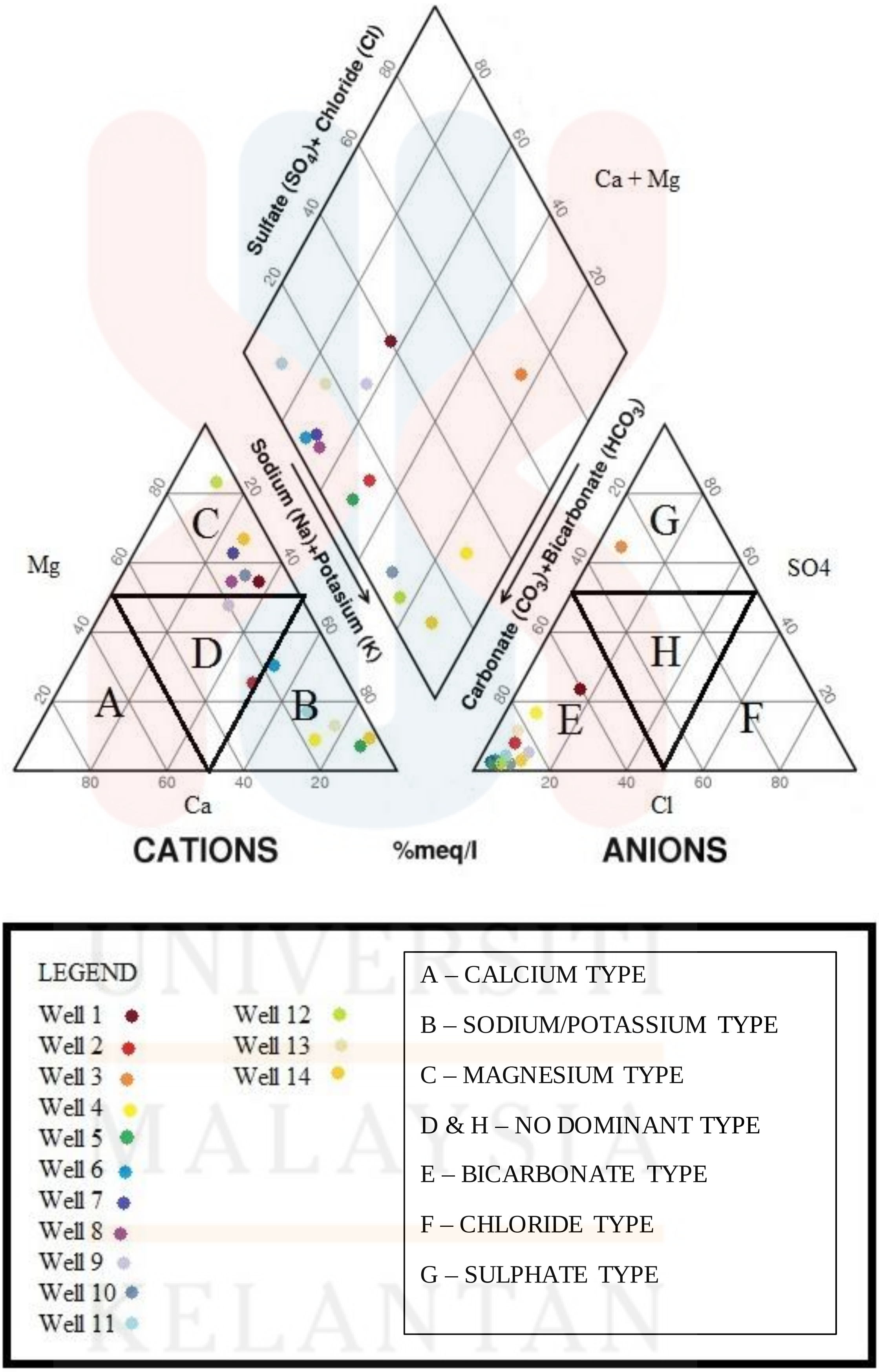


Figure 5.13: Piper Trilinear Diagram

5.5 Discussion

Groundwater resource can be managed by not only concern about the quantity of water in fact, the quality is the most important thing to be concerned. Degradation of groundwater quality may give an impact in serious conditions on its purposes of usage. The hydrogeochemical approaches apply in this study that shows a number of groundwater wells at certain specifically area have a tendency to be contaminated due to the high concentration of some major ions and trace element.

From the result obtained, both physical and chemical parameters shows in vary of value and concentration. All the sampling point is located way too far from each other and surrounded by different environment thus, shows a variety value of physical parameters and concentration of chemical parameters. The high value of both physical and chemical parameters might be generally affected by the sewage disposal systems that is poor their designed or maintained since most of the location of well is mostly nearby the river and residential area. As the well 3 that is located at Surau Darul Islah, Pulau Ketam where surrounded by the residential area and 50m near to the main river of Kuala Terengganu.

The value of TDS, TSS, pH and salinity from this well is the highest compared to the other wells in value 799 mg/L, 130 g/L, 2.09 pH and 0.4 ppt respectively. However the value of electrical conductivity is not as high as other parameters. The solubility of substances and ionization causes a variation ratio for the relationship of electrical conductivity to TDS in water samples as not some of the substances are insoluble in the water, hence the substances in water samples will not affect TDS. Besides, not all ion components can ionize in solutions or water samples. Only the component that can be ionized will affect the electrical conductivity. For chemical parameters this well obtained the highest value of Mg, Na, K as well as

Chloride and Sulphate. All the concentration respectively 22.06 mg/L, 159 mg/L, 13.803 mg/L, 233 mg/L, 28 mg/L. The social activities from the local that is nearby to the well 2 such as farming is one of the factor that contribute to the high concentration of chemical parameters due to the usage of fertilizer to their plants. Referring Boghici and Van Broekhoven (2001) the excess concentration value of calcium and magnesium is most probably supplied by the suspension of various minerals such as gypsum, dolomite and calcite or even weathering of silicate minerals such as plagioclase, pyroxene and amphibolites. The other chemical constituents were also found and observed as the highest concentration from the other well such as Cu and Zn which are both contained 0.691 mg/L and 0.035 mg/L in the groundwater samples of well 14. This is because the well 14 is close to the quarry area and the lithology of Bukit Jong area could be believed as the reason of the occurrence for those chemical constituents.

The total rainfall in the study area is slightly high. Besides, the weather during the water sampling is the early period of monsoon season, hence the infiltration of the local rainfall is recharging the aquifer that caused the concentration of ions diluted. A big number of rainfall is contributing the recharge as well as the low terrain that assist the recharge significantly by retaining runoff over long period in depression area.

Freeze and Cherry (1979) were pointed out that the quality of groundwater depends on the chemical composition of recharge water, the interaction between water and soil, the interaction between soil and gas, the types of rock with where it comes into contact in the unsaturated zone, the long period time of groundwater in the subsurface environment and the reactions that take place within the aquifer. An amount of other researchers proved that the hydrogeochemical characteristics of groundwater and groundwater quality in different aquifers over space and time are significant for parameters in solving the groundwater management issues (Panigrahy *et al.*, 1996).

Generally, geology and geochemical process are contributed to the chemical composition of groundwater which occurs within the groundwater system. According Karanth (1997), Bhatt and Salakani, (1996) the concentration of ions in groundwater is partially controlled by lithology, groundwater flow rate, natural geochemical reactions and human activities. Both bicarbonate and carbonate are generated in fresh groundwater that predominantly from the atmosphere. However, dissolution of sulfates or calcites minerals also contributed to the concentration of carbonate and bicarbonate ions. Refer to the concentration value of bicarbonates in the study area could be relatively due the reasons as stated above.

The evolution of hydrogeochemistry for groundwater may be conducted by natural processes for example dissolution of mineral components through water and rock interaction. However, introduction of anthropogenic pollutants can also play a very significant role.

CHAPTER 6

CONCLUSION

For the general geology study of Bukit Jong, Terengganu, a geological map was produced and updated. A few types of rocks have been recognized that existed in the study area such as Metasandstone, Phyllite, Slate, Quartzite and Granite. The study of geological mapping is significantly needed in order to observe and recognize the distribution of rocks, geomorphology, tectonic setting, geological structural and lithology especially in Kuala Terengganu where is lack of the geological mapping study rather than Kelantan. All the geological knowledge is strictly important to learn and know in order to produce and update the geological map of the study area.

Most of the groundwater study is discussed about quality and quantity in fact they supposed to be discussed about how does the hydrogeochemical acts in reservoir in order to get the detail and complete data of their groundwater study either it safe or dangerous to be consumed. Another study was conducted to characterize the hydrogeochemistry of groundwater with particular prominence on distribution and attenuation of major ions and the trace elements. The physical and chemical characteristic has been identified in order to achieve the objective of this study. From both identification of physical characteristic, the value the physical parameters such as pH, TDS, salinity, TSS, and electrical conductivity were obtained and indicated indirectly for the groundwater quality.

Moreover, the identification of chemical characteristic leads to the determination of hydrogeochemical process as stated in the objective of this study.

Hydrogeochemical process could assist a lot in order to get the precise value of concentration of major constituents and trace elements. Besides, the type of groundwater also could be determined from this study. Generally, all the major constituents and trace elements are still low of the concentration and safe for the groundwater to be consumed.

6.1 RECOMMENDATION

As the groundwater is the significant source of water for either agriculture or daily purpose, a regular monitoring should be done in order to maintain the quality of the groundwater. Hydrogeochemical study is more significant to observe the physical and chemical characteristic. A proper design of landfill as the geological analysis should be concern to prevent the leachate that escapes from the landfill and probably can contaminate the groundwater system. A proper recharge for agriculture and industrial activities is also a significant recommendation to prevent the contamination of groundwater as well as surface water.

Natural attenuation landfill could preserve the groundwater by develop a landfill above the water table by capping the landfill with three feet of compacted clay soil. The borehole log data or lithology data for each well of Terengganu River Basin must be recorded precisely during the well construction in order to study the relationship between the rock composition and aquifer. Therefore, it would be beneficial for any consequences in future.

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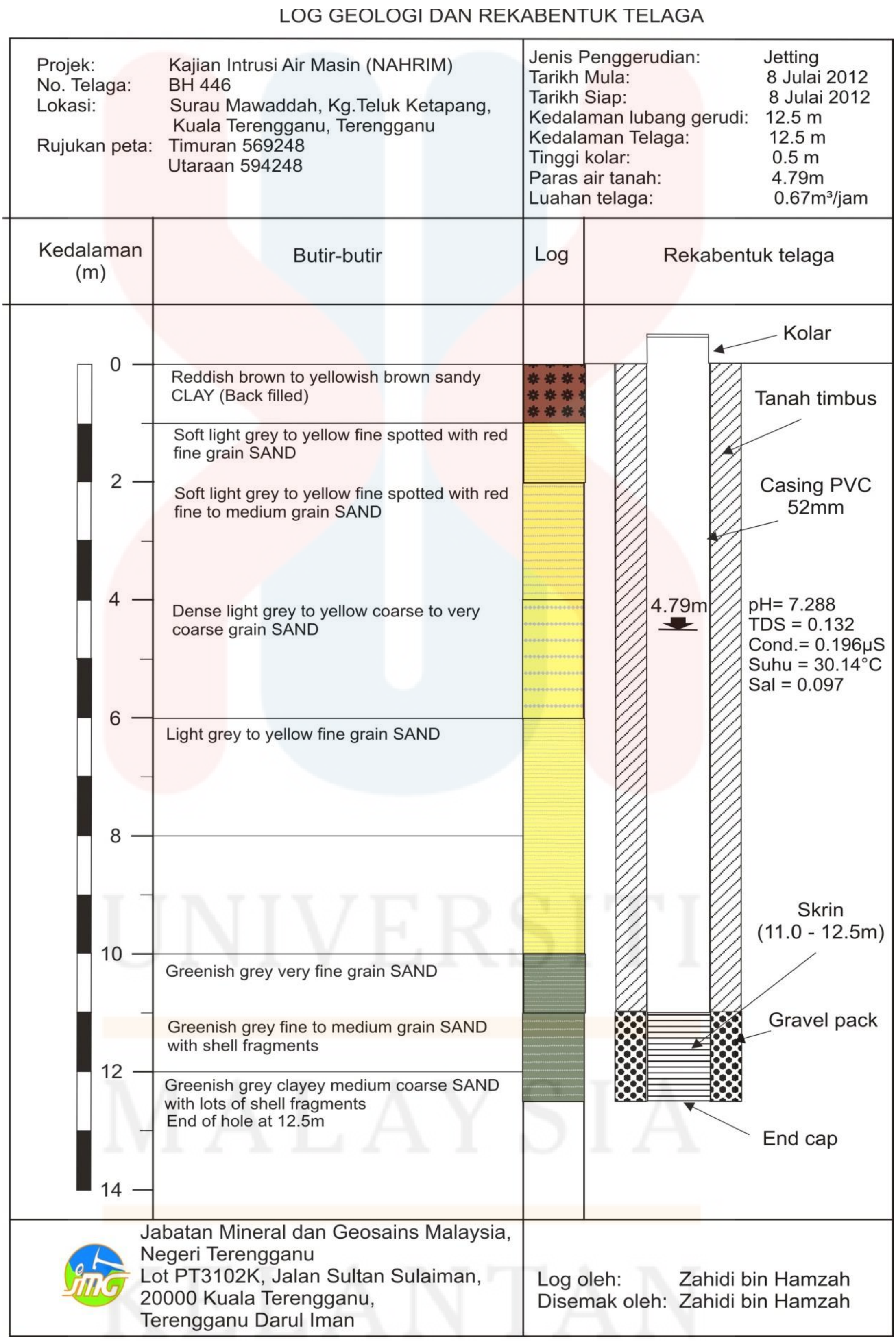
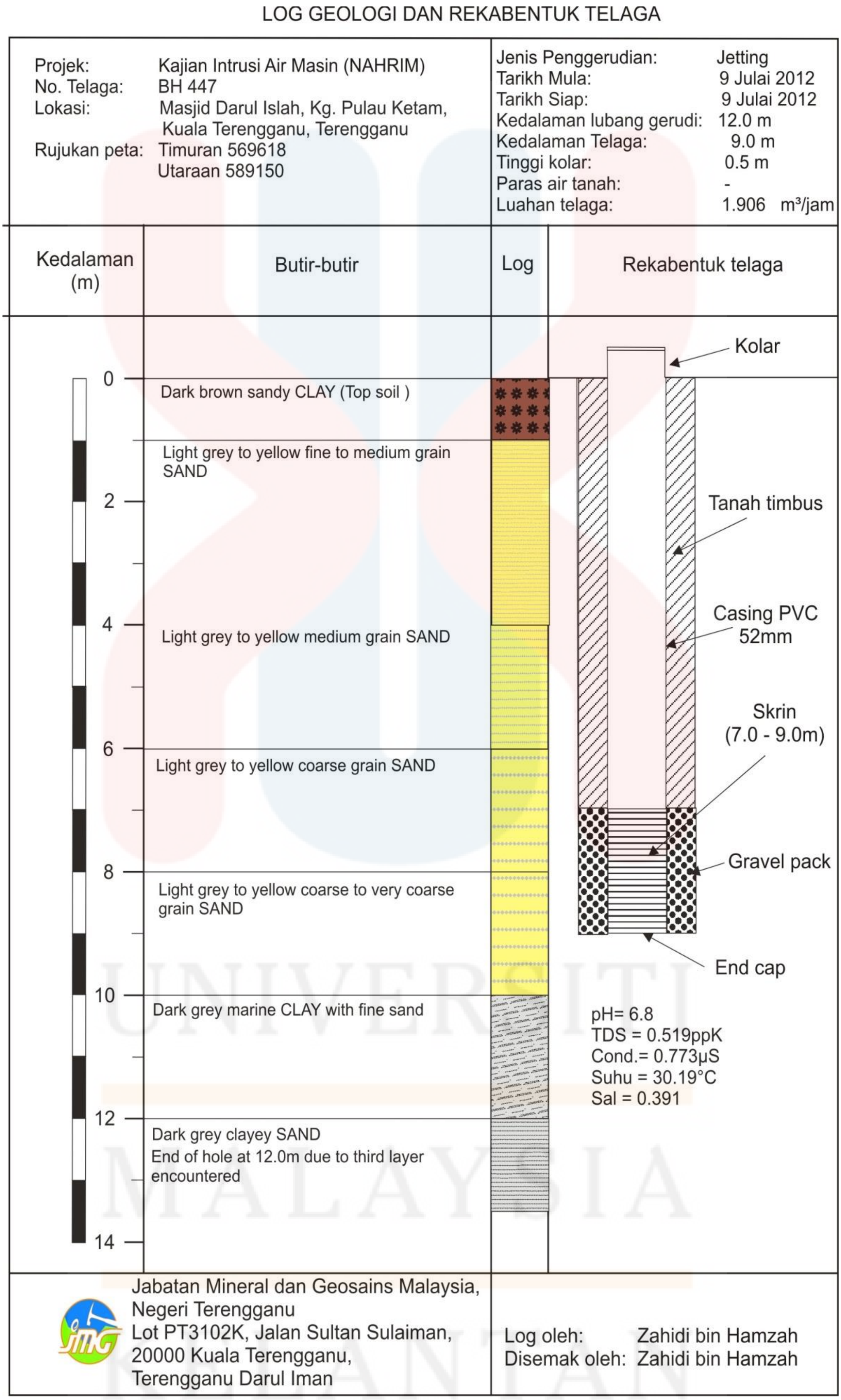
APPENDIX



Appendix A: Borehole Log 446

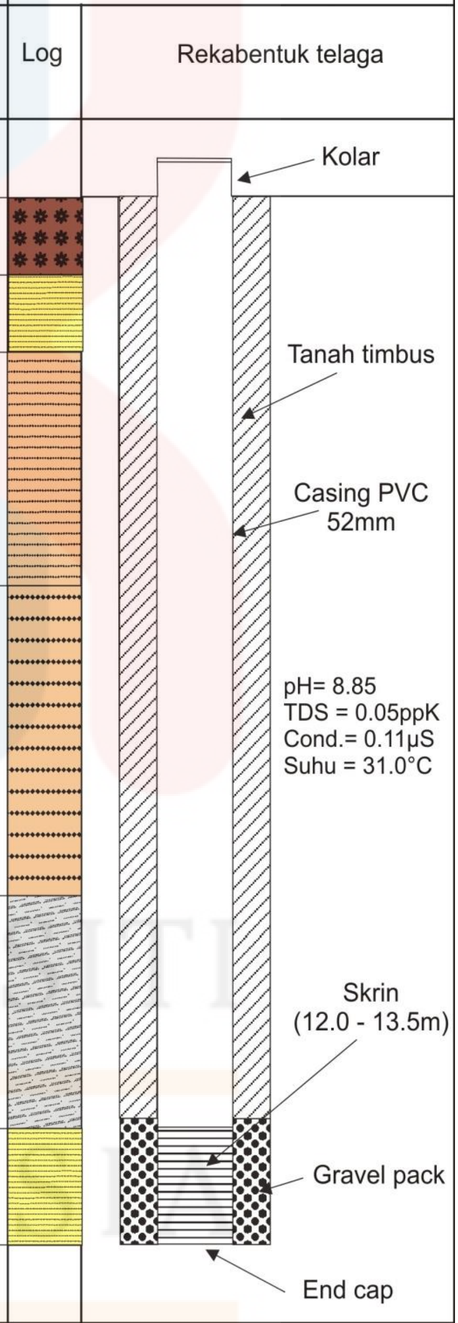


Appendix B: Borehole Log 447

LOG GEOLOGI DAN REKABENTUK TELAGA

Projek: Kajian Intrusi Air Masin (NAHRIM)	Jenis Penggerudian: Jetting
No. Telaga: BH 448	Tarikh Mula: 11 Julai 2012
Lokasi: Surau Sek. Men. Agama Atas Sultan Zainal Abidin, Kuala Terengganu, Terengganu	Tarikh Siap: 11 Julai 2012
Rujukan peta: Timuran 573637 Utaraan 587307	Kedalaman lubang gerudi: 13.5 m
	Kedalaman Telaga: 13.5 m
	Tinggi kolar: 0.5 m
	Paras air tanah: -
	Luahan telaga: 0 m³/jam

Kedalaman (m)	Butir-butir
0	Brown to dark brown silty SAND with organic materials (Top soil)
1	Loose light grey to light yellow fine grain SAND
2	Loose brown to dark brown fine grain SAND
5	Brown to dark brown fine to medium grain SAND
9	Soft light grey sandy CLAY
12	Light brown to light yellow fine grain SAND
13.5	End of hole at 13.5m due to bedrock encountered

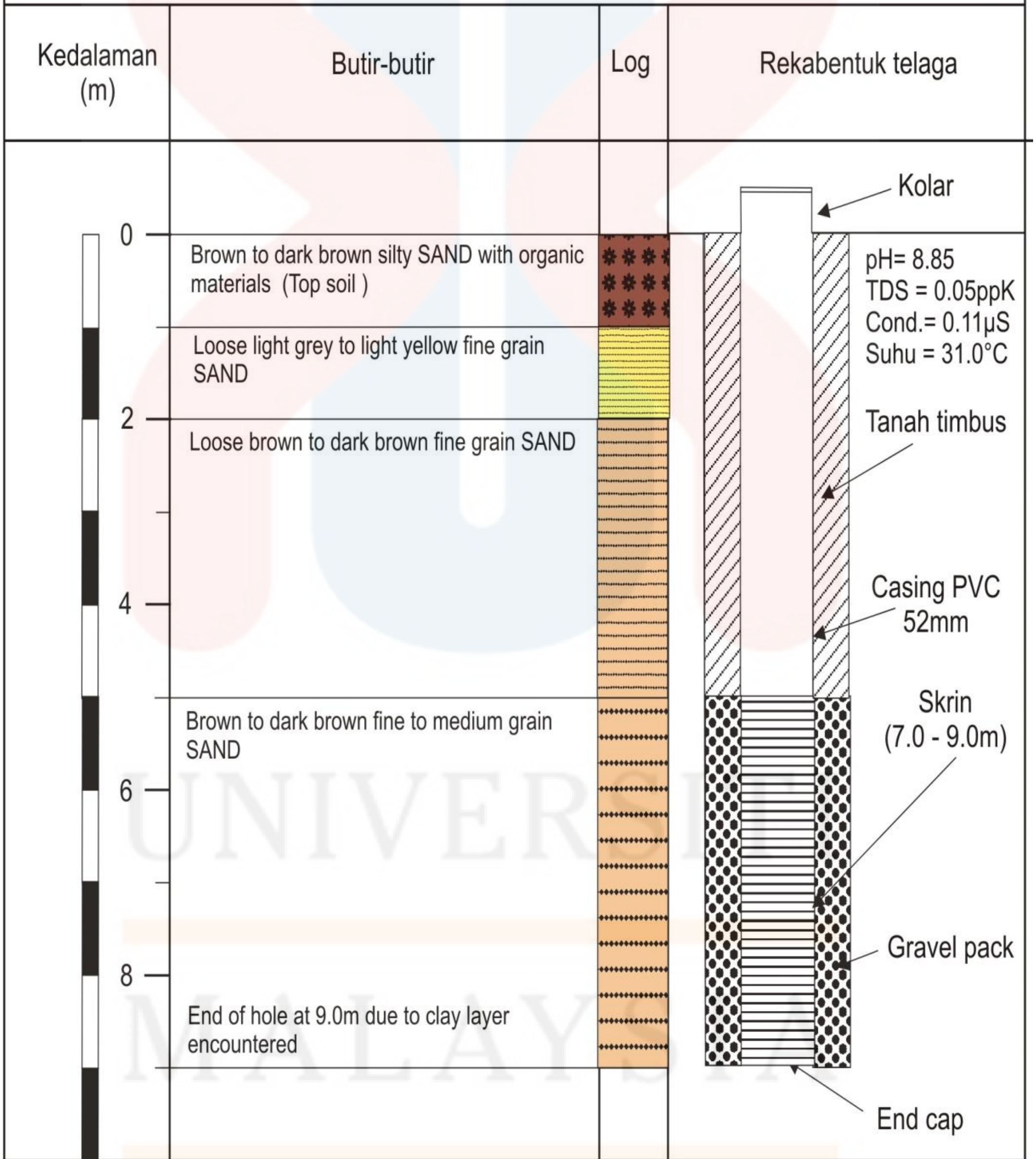


Jabatan Mineral dan Geosains Malaysia, Negeri Terengganu, Lot PT3102K, Jalan Sultan Sulaiman, 20000 Kuala Terengganu, Terengganu Darul Iman	Log oleh: Zahidi bin Hamzah Disemak oleh: Zahidi bin Hamzah

Appendix C: Borehole Log 448

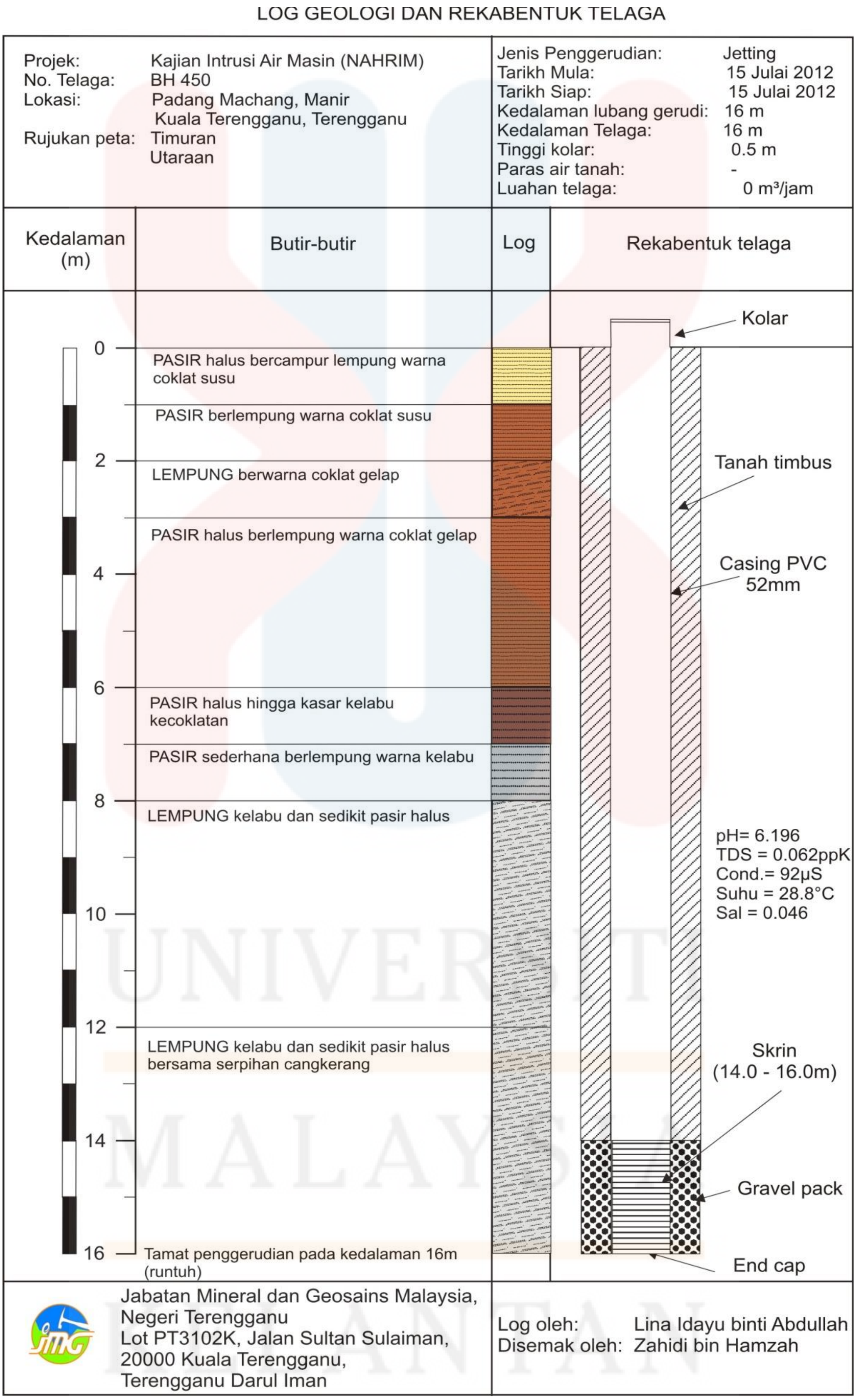
LOG GEOLOGI DAN REKABENTUK TELAGA

Projek:	Kajian Intrusi Air Masin (NAHRIM)	Jenis Penggerudian:	Jetting
No. Telaga:	BH 449	Tarikh Mula:	11 Julai 2012
Lokasi:	Surau Sek. Men. Agama Atas Sultan Zainal Abidin, Kuala Terengganu, Terengganu	Tarikh Siap:	11 Julai 2012
		Kedalaman lubang gerudi:	9.0 m
		Kedalaman Telaga:	9.0 m
Rujukan peta:	Timuran 573637	Tinggi kolar:	0.5 m
	Utaraan 587307	Paras air tanah:	-
		Luahan telaga:	1.705 m³/jam

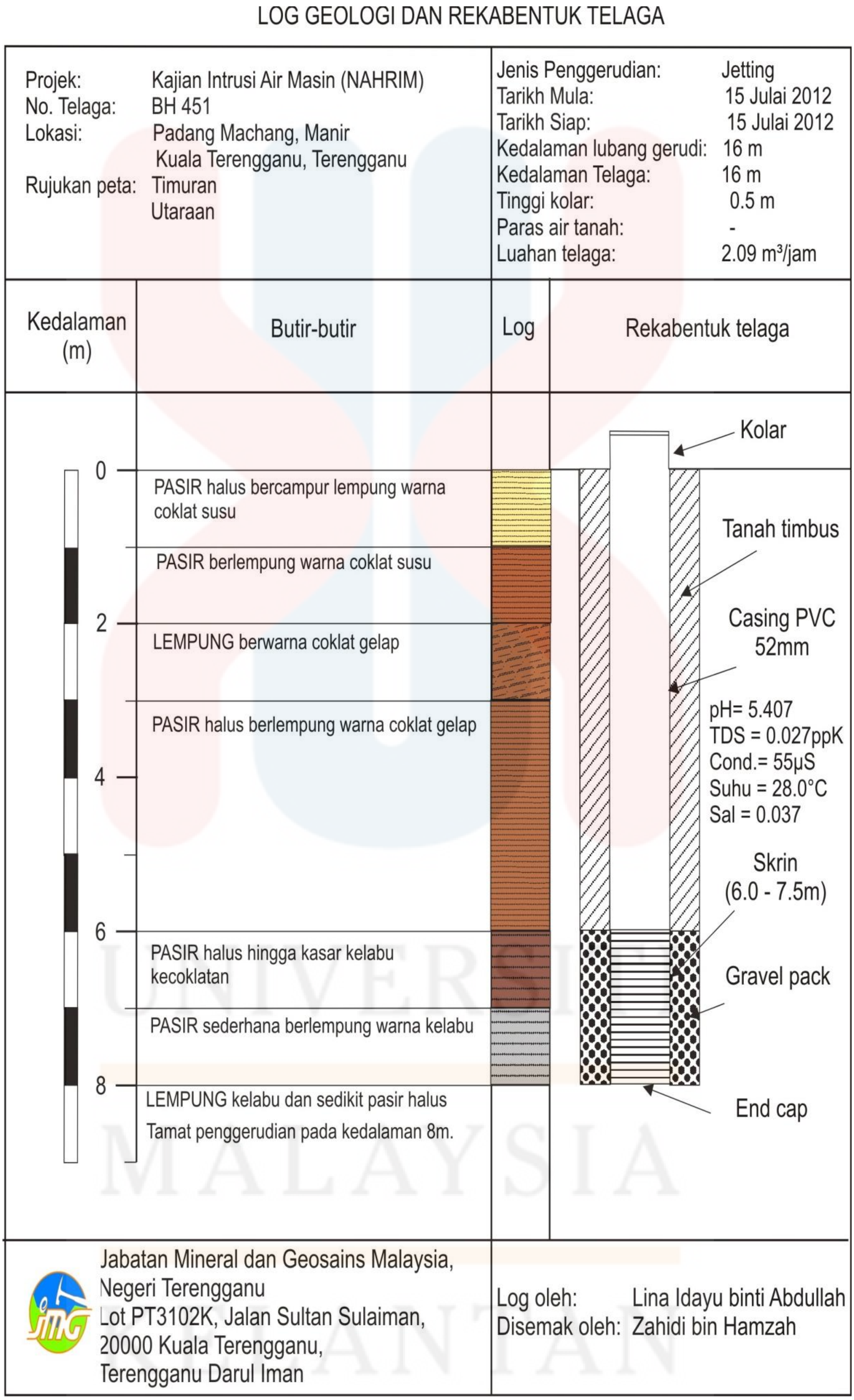


Jabatan Mineral dan Geosains Malaysia, Negeri Terengganu Lot PT3102K, Jalan Sultan Sulaiman, 20000 Kuala Terengganu, Terengganu Darul Iman	Log oleh: Zahidi bin Hamzah Disemak oleh: Zahidi bin Hamzah

Appendix D: Borehole Log 449

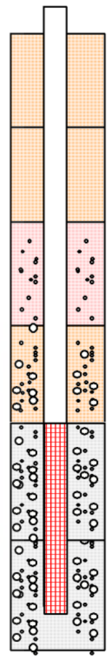


Appendix E: Borehole Log 450



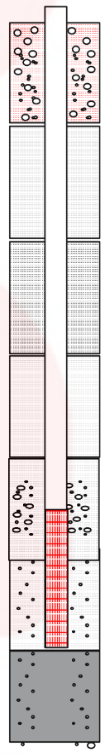
Appendix F: Borehole Log 451

NO TELAGA:	PT000475 MASA:	LUAHAN:	1500l/j
NO RUJUKAN GPS:	RV 563 451 588 176	KONDUKTIVITI:	
LOKASI:	Surau Kg. Kebor Air	SUHU:	
LOG OLEH:	Sagnal	PH:	
JENIS PERALATAN:	Jetting	KOLA:	0.86m
KEDALAMAN:	12.0m PARAS AIR: 0.7m	TARIKH:	14 Nov 2014

KEDALAMAN	LOG GEOLOGI DAN KETERANGAN	GAMBARAJAH
0.0m - 2.0m	Tanah liat bercampur sedikit pasir halus dan sedikit sederhana berwarna kuning bata.	
2.0m - 4.0m	Pasir sederhana bercampur pasir halus berwarna kuning bata.	
4.0m - 6.0m	Pasir sederhana bercampur pasir kasar dan sedikit pasir halus berwarna kuning bata.	
6.0m - 8.0m	Pasir kasar bergravel bercampur pasir sederhana berwarna kelabu kekuningan.	
8.0m - 10.0m	Pasir kasar bergravel dan sedikit pasir sederhana berwarna kelabu cerah.	
10.0m - 12.0m	Pasir sederhana bercampur pasir halus dan sedikit gravel berwarna kelabu cerah.	
12.0m	Batu hampar.	
	Screen pada 9.0m hingga 11.0m	

Appendix G: Borehole Log 475

NO TELAGA:	PT 000478 MASA:	LUAHAN:	23000l/j
NO RUJUKAN GPS:	Rv 558 985 585 237	KONDUKTIVITI:	
LOKASI:	SMK Komplek Mengabang Telipot	SUHU:	
LOG OLEH:	Sagnal	PH:	
JENIS PERALATAN:	Jetting	KOLA:	0.8m
KEDALAMAN:	10.0m PARAS AIR: 0.25m	TARIKH:	10 Mac 2015

KEDALAMAN	LOG GEOLOGI DAN KETERANGAN	GAMBARAJAH
0.0m - 1.0m	Tanah liat kuning bata berbatu (berpabel). Tanah timbus.	
1.0m - 2.0m	Pasir halus berwarna kelabu cerah.	
2.0m - 3.0m	Pasir halus berwarna hitam.	
3.0m - 4.0m	Pasir halus bercampur pasir sederhana berwarna kelabu cerah.	
4.0m - 6.0m	Pasir sederhana bercampur pasir halus berwarna kelabu.	
6.0m - 8.0m	Pasir sederhana bercampur pasir kasar berwarna kelabu cerah.	
8.0m - 9.0m	Pasir sederhana bercampur pasir halus berwarna kelabu cerah.	
9.0m - 10.0m	Pasir pasir halus bercampur sedikit batu kecil berwarna kelabu gelap. Batu hampar.	
	Screen pada 6.0m hingga 8.0m.	

Appendix H: Borehole Log 478