GEOLOGICAL MAPPING IN KUALA BETIS AREA, GUA MUSANG AND SEAWATER INTRUSION STUDIES IN PENGKALAN CHEPA USING GEOPHYSICAL AND GEOCHEMICAL METHODS

by

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

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2020

DECLARATION

I declare that this thesis entitled **"GEOLOGICAL MAPPING IN KUALA BETIS AREA, GUA MUSANG AND SEAWATER INTRUSION STUDIES IN PENGKALAN CHEPA USING GEOPHYSICAL AND GEOCHEMICAL METHODS"** is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : ______________________________

Name : ANIS SYAHIRA BINTI MOHD MOZLI

Date : ______________________________

APPROVAL

"I hereby declare that I have read this thesis entitled **"GEOLOGICAL MAPPING IN KUALA BETIS AREA, GUA MUSANG AND SEAWATER INTRUSION STUDIES IN PENGKALAN CHEPA USING GEOPHYSICAL AND GEOCHEMICAL METHODS"** and in my view, this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Applied Science (Geoscience) with Honours"

Signature : ____________________________

Name of Supervisor : DR. MOHAMMAD MUQTADA ALI KHAN

Date : ____________________________

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Geological Mapping in Kuala Betis Area, Gua Musang and Seawater Intrusion Studies in Pengkalan Chepa Using Geophysical and Geochemical Method

ABSTRACT

Generally seawater intrusion is a natural process but this process can be exacerbated by human activities. Human activities such as over-exploitation of groundwater can be one of the reason of sea water intrusion. Seawater intrusion can affect the quality and quantity of fresh groundwater in shallow aquifers as seawater is one of contamination source for groundwater. Therefore, this research is important to identify the extent of seawater intrusion in Pengkalan Chepa using Electrical Resistivity Imaging (ERI) and analyse the quality of coastal groundwater in Pengkalan Chepa using in-situ physical parameter. Electrical Resistivity Imaging (ERI) method used by using ABEM Terrameter LS instrument to produce a 2D pseudosection imaging of the subsurface to distinguish the seawater-freshwater interface with configurations used such as Wenner-Schlumberger and Pole-dipole array. The result display the extension of seawater intrusion from the shoreline. Integrated together with in-situ multiparameter, the parameters such as pH, temperature, salinity, turbidity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and Electrical Conductivity were assessed. Using collected water samples, it is analysed using Atomic Absorption Spectroscopy (AAS) to measure the concentration of trace elements such as copper (Cu), manganese (Mn), potassium (K), sodium (Na) and Iron (Fe). The results then correlated with the National Guideline of Groundwater Quality Standards by Department of Environment. Latest geological map of Kuala Betis area, Gua Musang was produced by using ArcGIS software based on geological data during geological mapping.

Pemetaan Geologi di Kawasan Kuala Betis, Kajian Intrusion Gua Musang dan Pencerahan Laut di Pengkalan Chepa menggunakan Kaedah Geofizik dan Geokimia

ABSTRAK

Umumnya pencerobohan air laut adalah proses semulajadi tetapi proses ini dapat diperburuk oleh kegiatan manusia. Aktiviti manusia seperti eksploitasi terlalu banyak air bawah tanah boleh menjadi salah satu sebab pencerobohan air laut. Pencerobohan air laut boleh menjejaskan kualiti dan kuantiti air bawah tanah segar di akuifer cetek sebagai air laut adalah salah satu sumber pencemaran air bawah tanah. Oleh itu, kajian ini adalah penting untuk mengenal pasti tahap pencerobohan air laut di Pengkalan Chepa dengan menggunakan Pengimejan Pengawalan Elektrik (ERI) dan menganalisis kualiti air bawah tanah pantai di Pengkalan Chepa menggunakan parameter fizikal dalam-situ. Kaedah Pemantauan Ketahanan Elektrik (ERI) yang digunakan dengan menggunakan instrumen ABEM Terrameter LS untuk menghasilkan pengimejan pseudosection 2D dari bawah permukaan untuk membezakan antara muka air laut dengan konfigurasi yang digunakan seperti array Wenner-Schlumberger dan Pole-dipole. Hasilnya memaparkan perpanjangan pencerobohan air laut dari garis pantai. Bersepadu bersama dengan multiparameter in-situ, parameter seperti pH, suhu, saliniti, kekeruhan, Total Solved Solids (TDS), Total Suspended Solids (TSS), dan Konduktiviti Elektrik dinilai. Menggunakan sampel air yang dikumpul, ia dianalisis dengan menggunakan Spektroskopi Penyerapan Atom (AAS) untuk mengukur kepekatan unsur surih seperti tembaga (Cu), mangan (Mn), kalium (K), natrium (Na) dan Besi (Fe). Hasilnya kemudian dikaitkan dengan Garis Panduan Kebangsaan Standard Kualiti Air Tanah oleh Jabatan Alam Sekitar. Peta geologi terkini kawasan Kuala Betis, Gua Musang dihasilkan dengan menggunakan perisian ArcGIS berdasarkan data geologi semasa pemetaan geologi.

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LIST OF ABBREVIATIONS

2D	2-Dimensional
AAS	Atomic Absorption Spectroscopy
bcm	billion cubic metres
EC	Electrical Conductivity
ERI	Electrical Resistivity Imaging
FYP	Final Year Project
GIS	Geographic Information System
GPS	Global Positioning System
HCl	Hydrogen chloride
JAKOA	Jabatan Kemajuan Orang Asli
km	kilometres
m	metres
mm	millimetre
m^3/hr/well	cubic metre per hour per well
Ma	Million ago
mg/L	milligram per Litre
TDS	Total Dissolve Solids
TSS	Total Suspended Solids
µS/cm	micro Siemens per centimetre
VES	Vertical Electrical Sounding

LIST OF SYMBOLS

%	percentage
°	degree
°C	degree Celcius
′	minute (in coordinate system)
″	second (in coordinate system)
Na^{+}	Sodium
K^{+}	Potassium
Ca^{2+}	Calcium
Mg^{2+}	Magnesium
Fe^{+}	Iron
HCO_3^{-}	Bicarbonate
Cl^{-}	Chloride

CHAPTER 1

INTRODUCTION

1.1 General Background

Geology is the study of the earth that concerned with the origin, elements and structures of the earth. Meanwhile, hydrogeology combines the study of geology and the relationship of it with the processes and properties of water including groundwater.

The study of all aspect of groundwater is very important. Groundwater is the next most significant source after ocean and polar ice. However, groundwater is considered low quality if it is disturbed by contamination into the aquifer. Nowadays, most surface waters especially those are use as water supply are protected over contamination through various way. Compared to that, groundwater reservoirs are not protected effectively over contamination.

With an average annual rainfall which is 2420 mm, Malaysia is estimated to have approximately 63 billion cubic metres (bcm) of groundwater storage. Groundwater in Malaysia accounts for over 90 % of the country's water resources. Currently, groundwater is a major source of water supply in several state in Malaysia such as Kelantan and Selangor. According to A. R. Samsudin, Haryono, Hamzah, and

Rafek (2008), in Kelantan especially at north part, water supply from groundwater become main source.

Generally, water especially groundwater is used for domestic use, agriculture activities and industrial activities around the world (Arslan, 2013). Kota Bharu district is coastal area which particularly known as the area that undergoes changes over the century with increasing industrialisation, urbanisation and population growth. Rapid population growth, extensive industrialisation and agriculture can cause the increase demand of water and contamination to the aquifer (Jeevanandam, Kannan, Srinivasalu, & Rammohan, 2007).

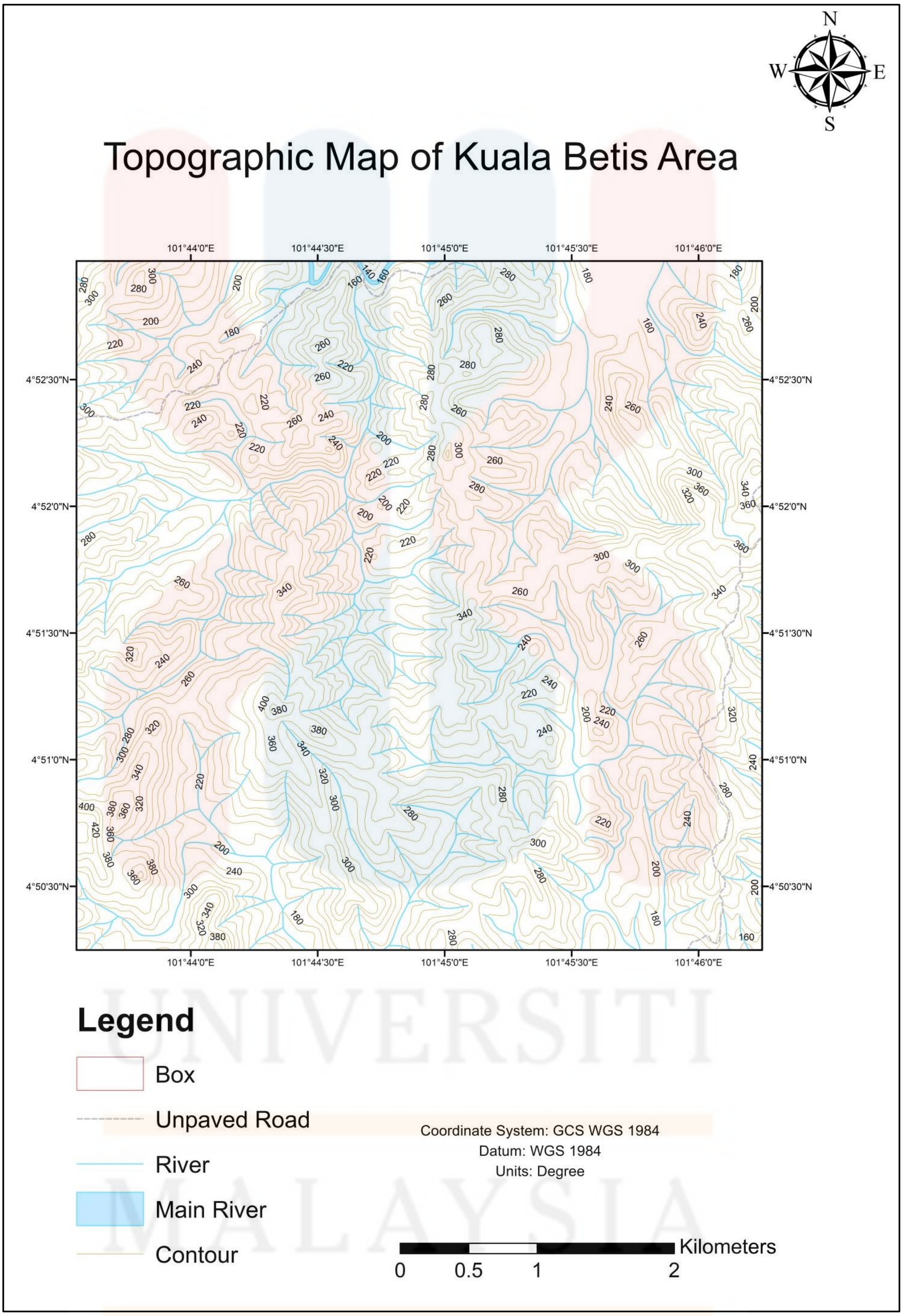
This research will evaluate the potential of seawater intrusion towards groundwater. The methods used are electrical resistivity imaging (ERI) and multiparameter. Geophysical method is to study the subsurface of aquifer and obtain data of structural geology, subsurface porosity and volume of water at subsurface. Geophysical is a reliable and ideal method to study the aquifer subsurface since it gives precise data with minimum damage or the least side effect to the ground. This method also simple and save cost but it requires expertise to run the geophysical equipment and certain software to interpret the geophysical data.

ERI is an active method that employs measurements of electrical potential associated with the subsurface electrical current flow generated by a direct current. The current injected into the subsurface to measure the difference in electrical potential. Among the usages of ERI is to measure the depth of bedrock and water table, detect sinkholes and hidden voids and also profiles landslip geometry. This method was chosen since it can give all the data required to study the slope subsurface characteristics.

Geochemical method used is in-situ hydrochemical analysis parameter which analyse the pH value, turbidity, temperature, Total Dissolve Solids (TDS), Total Suspended Solids (TDS), salinity, chloride and Electrical Conductivity (EC) from selected analysis.

1.2 Study area

The study area for geological mapping is Kuala Betis area, Gua Musang whereas the study area for research specification is Pengkalan Chepa, Kota Bharu.


N
W
E
S
Topographic Map of Kuala Betis Area
101°44'0"E
101°44'30"E
101°45'0"E
101°45'30"E
101°46'0"E
4°52'30"N
4°52'0"N
4°51'30"N
4°51'0"N
4°50'30"N
Legend
Box
Unpaved Road
River
Main River
Contour
Coordinate System: GCS WGS 1984
Datum: WGS 1984
Units: Degree
Kilometers
0
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1
2

1.2.1 Location

The study area is located in the district of Gua Musang, which is southern part of Kelantan, Malaysia. It is the largest district in Kelantan. Gua Musang is administered by the Gua Musang District Council. Gua Musang is bordered by the state of Pahang to the south, Terengganu to the east, Perak to the west and the other districts of Kelantan to the north which is Kuala Krai and Jeli.

Kuala Betis is a sub-district of Gua Musang and it is located about 20 kilometres from the town of Gua Musang. The earliest human settlements in Gua Cha can be found there since there is Mesolithic period which lies in this area. Kuala Betis is also familiar with the largest settlement of Orang Asli Temiar in the state of Kelantan.

1.2.2 Road connection/Accessibility

The road connection within the study area is connected by the main road from Gua Musang town and Cameron Highlands it takes about 30 minutes to reach the Kuala Betis area from Gua Musang by driving whereas from Cameron Highlands needs 2 hours. The paved road within the study area was not fully organized, which means the road is only about 5 m width and some parts of the road is only one way direction for vehicles. The road may be muddy, slippery and not accessible during heavy rain

1.2.3 Demography

Based on data of statistics Department of Statistics Malaysia (2010), the total population in Kuala Betis are 14,000. Major ethnic in Kuala Betis is Malay which is about 97.0 % from the total people distribution. Minority ethnics include other bumiputera, Chinese, Indian and others. Non-Malaysian citizens make about less than a thousand people in Kuala Betis.

1.2.4 Landuse

Despite the settlement, the land also covered by agriculture plantation such as rubber trees and palm oil trees. Other than that, there are also some logging areas which conducts deforestation activity on a significance area. Most villagers believed that it is one of the factors that lead to contamination and responsible for the changing of the characteristics of the main river, Betis River. The other parts of study area covered by thick forest with different morphology and lithology.

1.2.5 Social Economic

The community involve mainly in agriculture like rubber tree and palm oil plantation. Also, there are mining and logging activities organized by some company. These activities used heavy transportation that cause damage on the road surface at the study area. Some villagers also work with government agencies such as in school, clinic and Jabatan Kemajuan Orang Asli (JAKOA).

There is only one primary school known as Sekolah Kebangsaan Kuala Betis which accommodate education to children of native community in study area. There is no secondary school and any tertiary education at Kuala Betis. The children in need for education need to go outside the village to further their studies. However some of them decide to stay at the village due to money problems or without the intention to further study to make a better life.

1.3 Problem statement

Kelantan is one of the state with highest consumption of groundwater compare to other state. Generally seawater intrusion is a natural process but this process can be exacerbated by human activities. Human activities such as over-exploitation of groundwater can be one of the reason of sea water intrusion. Seawater intrusion can affect the quality and quantity of fresh groundwater in shallow aquifers as seawater is one of contamination source for groundwater. At study area, most of local residents use water supply that come from groundwater for irrigation, domestic use and industrial activity. Deterioration of groundwater in terms of quality and quantity due to intrusion sea water in shallow aquifer, consequently, will give effect to agriculture activity as well as human health.

1.4 Objective

This research is proposed to achieve the following objectives:

1. To produce a geological map of Kuala Betis area on the scale of 1:25,000.

2. To identify the extent of seawater intrusion in Kota Bharu using ERI

3. To analyse the quality of coastal groundwater in Pengkalan Chepa using in-situ hydrochemical parameter.

1.5 Scope of Study

The scope of study includes geological mapping the regional geology mapping will be done in study area. In geological mapping, geological data such as geomorphology, lithology, stratigraphy and structural geology will be required. Geological mapping is a method to interpret all the geological characteristics of an area which is significant to study various fields such as tectonic setting, historical geology,

This research also includes the geophysical and geochemical studies of study area. Resistivity investigation will be done in study area for subsurface investigation to obtain the data of structural geology, depth of bedrock, seepage presence and the porosity of soil. These data will be used to study the subsurface of the aquifer to identify the extent of seawater intrusion at Pengkalan Chepa.

1.6 Significance of study

As the demand for the fresh groundwater increase continuously, it is very importance to check the status of the groundwater in the aquifers from time to time to ensure the groundwater is safe, no contamination for the domestic use and irrigation. The evaluation of seawater intrusion should be done especially in shallow aquifers along the coastline as seawater is the most common source of contamination in the groundwater. This evaluation is an important step, so that enforcement party can prepare the methods for controlling the seawater intrusion. Early remedial action for this phenomenon can save cost of the remediation and time. Plus, this study also useful for the planner/driller to drill the suitable wells in suitable locations.

At the end, this research can give knowledge of society on the importance of groundwater. Plus, they can to manage the fresh groundwater of the coastal region for their own benefits. Groundwater is one of the valuable resources for us, therefore the conservation of this resources is our responsibility in order to protect the sustainability for the future generation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Chapter 2 contains literature review that is essential in any researches. This chapter contains various information relate with the research topic. It includes searching, reading and understanding various literature materials related to the highlight of research. The literature review includes regional geology and tectonic setting and hydrogeology were also included in this chapter.

Literature review related with topic study also included in chapter 2. Introduction to saline water intrusion was explained in this chapter so that a better understanding of the research achieved. Previous studies on saline water intrusion in Malaysia were collected during preliminary research to relate and compare with the evaluation of saline water intrusion in coastal aquifer in study area which is in Pengkalan Chepa, Kota Bharu.

2.2 Regional Geology and Tectonic Setting

The geological formation of Kelantan ranges from Lower Paleozoic until Quaternary and can be divided into three main chronologies which are Paleozoic, Mesozoic and Cenozoic. Upper Paleozoic rocks which formed Gua Musang Formation and Aring Formation can be found in south Kelantan while Taku Schist in east Kelantan.

Permian-Triassic age of Paleozoic formation include Gua Musang formation. Gua Musang formation is made up of crystalline limestone. It is interbedded with thin layers of shale, tuff, chert nodules and subordinate sandstone and volcanic. Limestone interbedded with shale is a part of Middle Permian age. Meanwhile, Upper Carbonifereous to Lower Triassic Aring formation is dominated by pyroclastic rock with minor lava, dolomite marble and argillaceous rock. Dolomite marble underlain tuff and calcareous argillite and argillo-tuffaceous limestone lies on top of Aring formation.

In Mesozoic age, Lower Triassic limestone is deficient in Gua Musang Formation. Argillaceous rocks are conformable on basal conglomerate mapped along the western margin of Gua Musang basin.

Cenozoic formation covered north Kelantan. Pengkalan Chepa which is a part of Northern Kelantan is covered by alluvium deposits of Quaternary age. The quaternary deposits of Kelantan can be divided into Pleistocene and Holocene deposit. Simpang formation is a part of Pleistocene age. Gula Formation and Beruas Formation that are underlain by granite bedrock is a part of Holocene age. Its deposits are mainly consisting of unconsolidated to semi-consolidated boulders, gravel, sand, silt and clay that underlie the coastal and inland plain. The Kelantan plain is covered with Quaternary sediments and the sediments overlying granite bedrock.

2.3 Stratigraphy

The stratigraphy of Kelantan consist of several formation which are Aring Formation, Taku Schist, Gua Musang Formation, Telong Formation, Gunung Rabong Formation, Koh Formation and Badong Conglomerate. Taku Schist and Aring Formation are formed at the age of Paleozoic era while the others formation are formed during Mesozoic era (C.S. & Tan, 2009). But for this research, only Gua Musang Formation will be discuss and the area of the study is related to Gua Musang – Semantan Formation within East of Bentong – Raub suture.

The stratigraphy of Gua Musang Formation can be describes as far from complete and its development during Permian- Triassic transition remains a matter of debate (C.S. & Tan, 2009). Based on western margin of the Gua Musang basin, argillaceous rocks are conformable on basal conglomerate which form in continental basement.

While in the central part, the volcanic activities maybe created topographic highs allowing for the deposition of the limestone bodies on top of them. The research area is located at lower boundary of Semantan Formation within the Bentong- Raub Suture. Redbeds is a part of the melange belt of Bentong- Raub Suture. The age of redbeds is unknown but the absence of granite clasts as the evidence their age to be pre- Triassic.

Moreover, their conglomerate beds consist clasts of chert and Early Permian is the youngest age for chert clasts in melange belt (Metcalfe, 2000). But it is uncertain whether the redbeds is continuation of the Gunung Ayam Conglomerate on the north.

2.4 Structural Geology

In Gua Musang area, a sequence of well-bedded tuffaceous siltstone, sandstone, carbonaceous shale and minor limestone lenses, belonging to the Permian to Middle Triassic Gua Musang Formation is exposed at Gua Musang – Pulai junction. A refolded fold is exposed associated with two well-developed cleavages. The slate characteristically contains a bedding parallel or sub-parallel slaty cleavage that has been folded together with bedding into tight to isoclinal folds with gentle southerly plunges, which associated with a well-developed crenulation cleavage.

The pre-Middle Triassic strata of Central Belt have undergone many deformations. The deformation of strata is explained. First, folding formed tight to isoclinal and recumbent folds associated with both easterly and westerly-lying thrusts and oblique reverse faults. Seconds, the strata refolded because of movement, then the strata were cut by strike-slip faults.

As pre-Middle Triassic, Upper Permian to middle Triassic metasediments and limestones have undergone many deformations. This involving refolding of boundinage and isoclinal folded layers. The middle to upper Triassic rocks unconformable overlies the Upper Palaeozoic rocks, implying that the Semantan and Telong Formation are unconformable over the Raub Group and Gua Musang and Aring Formations.

2.5 Historical Geology

Historical geology is one of the factors which discovers about the past, because it is the largest clue to the present. For example, process and events of river valley formed over past million years are mostly similar to the processes that operate today. Peng, Leman, Hassan, Nasib, and Karim (2004) suggests that Gua Musang Formation is form in age Mesozoic era which about 248 to 65 million years ago. While the upper part of Gua Musang Formation is interfingering with Semantan Formation, Telong Formation, and Gunung Rabong Formation.

The oldest rock formed in tectonic contact along the western margins of East Peninsula Malaysia is pelagic schists and chert-argillite sequence of the Bentong-Raub-Kuala Pilah zone and this formation were recognized as Raub Group of Carbo-Permian age. The Raub Group is underlain by limestone, calcareous shale, and acid pyroclastic rocks. Mapping deeper into north of Kelantan, Raub Group is known as Gua Musang Formation. It is mainly formed of argillaceous with commonly interbedded limestone and volcanic pyroclastic rocks. The limestone forms prominent reefal karstic hill. At Gua Musang and its localities, Lower Triassic ammonoids were found at Gua Musang and Middle Permian to Early Triassic fossils was found. The Gua Musang Formation become more rapidly metamorphosed towards the Stong and Taku Schist metamorphic complex (Hutchison, 2007).

According to Mohamed, Joeharry, Leman, and Ali (2016), from sedimentological appraisal, made through analysis on type section and previous study, it can be concluded that Gua Musang is made up of argillaceous, carbonate and volcanic. The argillaceous facies which consist of shale, siltstone, mudstone, slate and phyllite is the dominant facies of Gua Musang and Telong Formation. In Aring Formation and Nilam Marble, the facies occur in form of interbedded or lenses. Carbonate is the dominant facies in Nilam Marble, and as extensive facies in Gua Musang Formation, and in Telong and Aring Formation it form beds and lenses. At northern part, limestone facies had been metamorphosed to marble while facies at south still preserved and showed distinction between allochems and micrites which consist of shallow marine benthic fauna such as Brachiopods, Bivalves, algae and crinoid. The volcanic facies is dominant in Aring Formation and interlayered with carbonate and argillite in other formation studied. Volcanic or pyroclastic facies exist in the form of agglomerates, tuff, lapilli and volcanic breccia which are interlaminated, interfingered or interbedded with limestone, black carbonaceous shale or tuffaceous shale.

2.6 Specification

The research specification will be highlighted about current and previous issue at study area.

2.6.1 Hydrogeology

The main river in Kelantan is known as Sungai Kelantan. In northern Kelantan, the groundwater resources occurred in coastal alluvial aquifer that covered by basement rocks (Abdul Rahim Samsudin, Haryono, Hamzah, & Rafek, 1997). The groundwater aquifers exist in the alluvial deposits of Quaternary age. The aquifers consist of layers of coarse gravels to silt or a mixture of these two materials. The groundwater in North Kelantan is naturally rich in iron which exceeds the raw water quality limits (Suratman, 1997). Contamination by nitrate and ammonium is quite apparent, resulting from various human activities in the urban and agriculturally active areas. Semipermeable strata of silty clay separated these aquifers among each other. Abdul Rahim Samsudin et al. (1997) stated those groundwater have no direct hydraulic connection with river water or the South China Sea.

2.6.2 Seawater intrusion

Sea water intrusion generally occurs when fresh groundwater are pumped out from the aquifers especially coastal aquifers, then results in declining groundwater levels and facilitating lateral and/or vertical migration of sea water into the aquifers. This will causing a great changes towards groundwater quality (Kumar, Priju, & Prasad, 2015). Ghyben-Herzberg principle can explain the relation between fresh groundwater and sea water in this phenomenon.

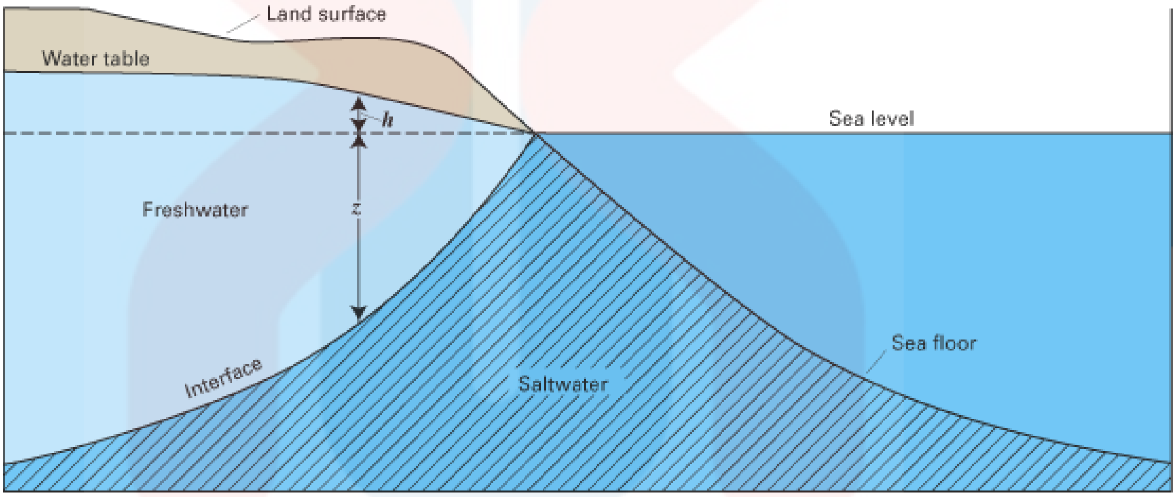


Figure 2.1: Idealized sketch of fresh and sea water groundwater in unconfined coastal aquifer.

(Saltwater intrusion, n.d.)

The equation Ghyben-Herzberg principle:

$$Z = \rho f \rho s - \rho f h$$

where,

ρf = Fresh water density

ρs= Sea water density

h = Elevation of the water table above sea level

Z = Depth to the fresh – sea water interface below sea level 20

Based on Ghyben-Herzberg principle, if water table in aquifers lowered by one metre, the sea water interface will rise by 40 metres. Regarding freshwater-sea water equilibrium, the water table must lie above sea level and it slope downwards to the sea. Without this two condition, when withdraw of groundwater reduce the water table of freshwater, the intrusion of sea water will occur (Hiscock & Bense, 2014).

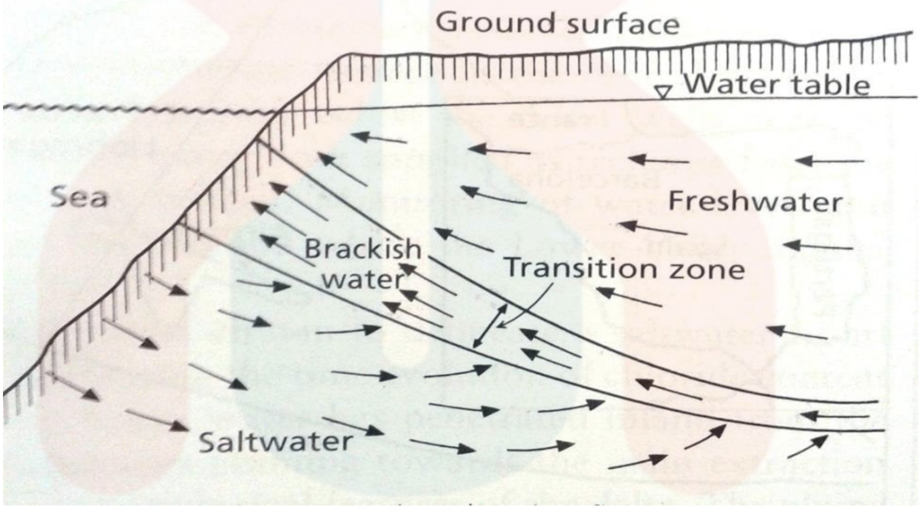


Figure 2.2: Flow pattern of fresh water and saltwater in aquifer (Hiscock & Bense, 2014)

Based on Figure 2, the interface between fresh water and sea water seem sharp but in reality, there is a brackish transition zone of finite thickness that separates freshwater and sea water as shown in the Figure 4. This zone formed from dispersion due to the flow of freshwater with the present of unsteady movement of the interface. Unsteady movement of the interface caused by external factors such as tides, groundwater recharge and pumping wells (Hiscock & Bense, 2014).

(Kamal, Hashim, & Zin, 2015) and (Baharuddin, Taib, Hashim, Abidin, & Rahman, 2013) are the previous researchers that conducted the study of sea water intrusion in Malaysia. Research area for both study are in Kota Bharu, Kelantan and Carey Island, Selangor.

2.6.3 Resistivity survey

According to (Piegari et al., 2009), ERI method is sensitive to the layer which content of water, so it is suitable to be used in landslide investigation (M. McCann & Forster, 1990). Electrical Resistivity Imaging (ERI) are focused to identify geometry, internal structure, failure surface, water content, physical properties of landslide material and landslide mass movement. There are three types of electrode arrays in electrical resistivity imaging survey such as dipole-dipole, Wenner-Schlumberger and pole-pole.

2.6.4 Hydrogeology

Groundwater is defined as water beneath the earth surface which the water fill all the pores and fractures of soil and rocks. Generally, groundwater can be stored in two types of aquifers which are alluvial aquifers and hard rock aquifers (A. R. Samsudin et al., 2008). According to (Kura et al., 2015) and C. L. Heng (2004), the alluvial aquifers with the 30-50 m3/h of hydraulic conductivity, are the most productive aquifers compared to the hard rock aquifers. These alluvial aquifers can be found along the coastline of the east-coast states in Peninsular Malaysia which are Kelantan, Terengganu and Pahang (C. L. Heng, 2004). In Kelantan, the alluvial aquifers can be found in the northern region of Kelantan.

According to C. L. Heng (2004), hard rock aquifers are comprised of three types of aquifers based on the rock types which are limestone aquifers, sedimentary and volcanic aquifers and lastly is fractured crystalline igneous rocks aquifers. For limestone aquifers, the yield of the well is up to 30 m3/h/well. The groundwater quality is good but total dissolved solid is at the moderate to high level due to the soluble bicarbonates from the dissolution process of limestone itself. Mostly, this type of aquifers can be found in the Kedah, Perlis and Perak (C. L. Heng, 2004).

Sedimentary and volcanic rocks aquifers generally represented by fractured sandstone, quartzite, conglomerate and all volcanic rocks. Well from sedimentary and volcanic rocks can yield approximately from 5 m3/hr/well until 20 m3/hr/well. This type of aquifer distributed in Kedah, Selangor, Johor, Sarawak and Sabah and the quality of water is at medium to good level (C. L. Heng, 2004).

Lastly, fractured crystalline igneous rocks aquifers can be found in Kedah, Selangor, Johor, Melaka and Negeri Sembilan. Among all type of aquifers, the wells from fractured crystalline igneous rocks aquifers have least water yield, only up to 10 m3/hr/well. The water quality of this aquifers is good to excellent with the present of low total dissolved solids (C. L. Heng, 2004).

In terms of system, groundwater can be divided into shallow groundwater and deep groundwater. Previous study from T. E. Heng and Singh (1989) stated that shallow aquifers or known as 1st aquifers made up from sand and gravel that extends from the ground level or from the base of the surface clay down to the next major clay bed. Generally, the shallow aquifers lies between 5 to 15 metres of depth below ground surface. It can be unconfined and confined by the surface clay or aquitard. Most places exploited shallow groundwater as it contained with fresh groundwater but iron concentration can be in the range of 0.85 mg/L to 10.95 mg/L depends on the areas.

The shallow groundwater is the most exploited source in the Kelantan groundwater basin (T. E. Heng & Singh, 1989).

Deep groundwater is an aquifers that situated beneath the shallow groundwater. There are three main aquifer intervals have been found and recognised as the 2nd, 3rd and 4th aquifers respectively. The water in the 2nd aquifer is brackish while the 3rd aquifer which lies between 45 to 130 metres depth contains the better quality water and thus has been developed at Tanjong Mas. At the 4th aquifers, the water has been found to be saline (T. E. Heng & Singh, 1989).

CHAPTER 3

MATERIALS AND METHOD

3.1 Introduction

Chapter 3 focuses on the methodology and materials will be needed to achieve the following objectives. The flowchart given in Figure 3.1 whereas the materials listed in Table 3.1. Some of the materials are in the laboratory while some of the materials will require permission from another laboratory

3.2 Material/Equipment

All the materials/equipment which will be needed to conduct several methods in completing the study are in the following Table 3.1.

RESEARCH FLOWCHART

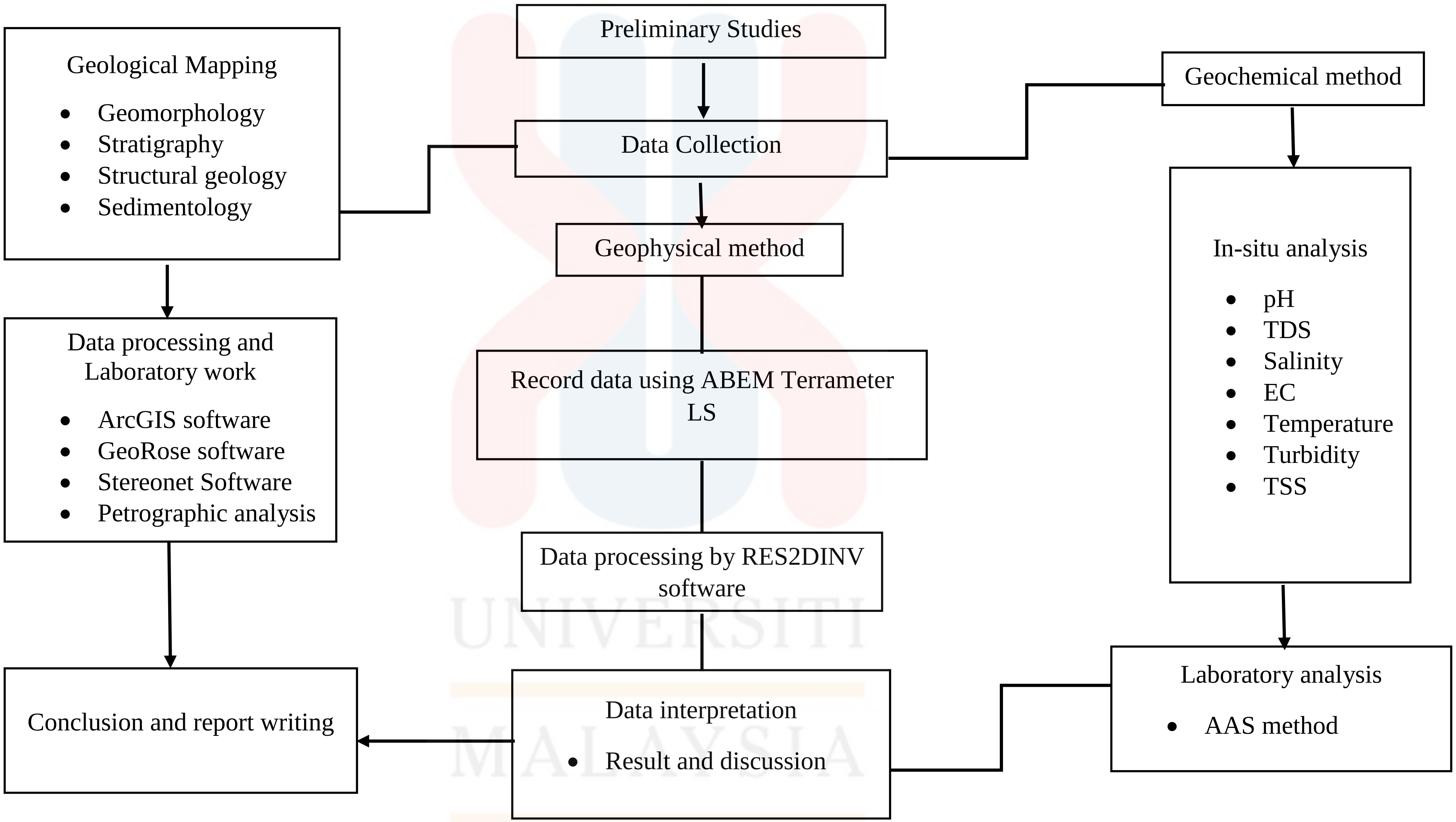


Table 3.1: List of materials/equipment with functions

No.	Material	Function	Picture
1	Compass	Measure the strike and dip of beds or plunge and trend of joints.	
2	Global Positioning System (GPS)	Provide accurate coordinate system of an area, record traversing and measure the azimuth of a direction	
3	Rock hammer	Used for splitting and breaking rocks to obtain a fresh surface of rock. Sometimes use as a scale in a photograph.	
4	Hand lens	Identify small mineral crystals and structures in rocks.	
5	ABEM Terrameter LS	To analyse resistivity	

7	Polarizing Microscope	To analyse the thin section samples properties	
8	Hydrochloric acid	To determine the presence of carbonate minerals in a rock. To distinguish limestone and dolostone	

3.3 Methodology

In this section, the steps to conduct research were discussed. Generally, preliminary studies was done followed by field studies, laboratory work, data processing, data interpretation and analysis and report writing.

3.3.1 Preliminary studies

Preliminary study was conducted once the title and study area were confirmed. In this phase, the research was started by studying the literature review related to the general background of study. Previous research of study area, groundwater and seawater intrusion, geophysical and geochemical methods were recorded and reviewed as references before, when and after conducting this research. Data acquired from journal article, websites and books are the sources in studying literature review. Literature review can reveal the history that related to our research so that we can improve and conduct a better research methodology in order to complete this research with the expected outcomes.

Preliminary study also helps in conducting initial investigation where the study of remote sensing is made, such as satellite imagery and aerial photograph as a preparation for field study. From this preliminary study, this research can obtain data of study area such as geomorphology, lineament analysis and demography that related to this research. The data obtained can be used in Geographic Information System (GIS) to make a base map of study area.

3.3.2 Field studies

The field studies were divided into three stages; geological mapping, geophysical test and geochemical test. In this research, geological mapping was done at Kuala Betis area, Gua Musang whereas geophysical and geochemical tests were done at Kota Bharu to analyse the seawater intrusion and to identify the quality of coastal groundwater.

a) Geological Mapping

Geological mapping are method used to study the geology of study area including geomorphology, lithology, stratigraphy and structural geology of study area. These study are important for a geologist as it can explain the tectonic activity, historical geology and stratigraphy of study area.

In geological mapping, the equipment used are compass, GPS, hammer, hand lens, HCL and measuring tape. These equipment are the common equipment in geological mapping as it can help in determine the coordinate, record orientation and also taking rock sample.

The data collected at study area are lithology (i.e. rock description), geological structure (i.e. faults, joints, fractures, folding), geomorphology (i.e. drainage pattern, landform, slope), petrography (i.e. hand specimen description, outcrop description), sedimentology and stratigraphy (i.e. sedimentary structure, deposition pattern, facies model). For sampling, samples of rocks were obtained from different outcrops. The samples must be fresh and carefully hammered when taken.

Every feature at study area such as outcrop, sample, and structures were pictured as an evidence for report writing. Each observation station was marked using GPS and the reading measurement for strike and dip of bedding and trend and plunge of joint were measured using a compass. The highest point or elevation of location was used for geomorphological study.

b) Geophysical survey

In specification, geophysical method was used to analyse the seawater intrusion using resistivity method. This method was chosen because it is cheap, fast and can obtain all the data require for coastal aquifer in subsurface. Data such as porosity, structural geology and volume of water at subsurface can be obtain through ERI to analyse the properties of aquifer at study area. In geophysical method, the equipment used are ABEM Terrameter LS, measuring tape, electrode and also power source. These 22 equipment are used to run ERI method and obtain raw 2D data for further analysis. This test can be done with maximum length coverage of 200 m depend on number of electrode available and the dimension of aquifer.

The resistivity method was conducted using the ABEM Terrameter LS. The ABEM Terrameter LS was connected to two ABEM LUND cables. 41 electrodes are arranged on a straight line connected to a multicore cable in a low-laying areas and the location should be free from building structures and obstacles. The electrode spacing for each traverse is constant spacing about 5 m. At the centre of line, ABEM LUND cable and battery were located, in order to record the measurements. For each measurements, the electrode selector system was used to automatically select the active electrodes.

c) In-situ analysis

In specification, geochemical method was used to identify the quality of coastal groundwater using in-situ hydrochemical multiparameter. For Atomic Absorption Spectroscopy (AAS) method, the water samples will be taken from kampung wells and place in a sample bottle. The total number of sampling to be analysed will be 15 samples for 5 different elements which are Sodium (Na), Potassium (K), Copper (Cu), Manganese (Mn) and Iron (Fe) into the AAS instrument. The in-situ hydrochemical multiparameter will analyses the parameters of pH value, EC, TDS, temperature, turbidity, TSS and salinity of sample by using handheld analysing kits (Kumar et al., 2009). All the data were recorded in the fieldwork note book.

3.3.3 Laboratory work

Rock samples collected will further process into thin section samples. Thin section was conducted to identify the constituent minerals and textures using polarizing microscope to determine and justify the name of the rocks. There are procedures regarding thin section is conducted;

1. Rock samples collected at field. Make sure samples are fresh and weathered samples are rejected.

2. Sample of rock is cut using cut-off saw. If the sample is unconsolidated, the thickness must be thick up to 10 mm. The size of sample must occupied the size of glass slide. A line marked on the surface of sample for make sure the cutting process undergo easily.

3. The grinder and abrasive corundum powder were used to eliminate scratches on the sample and to dilute the sample. Mirror glass used along fine corundum for sublimate the surface of sample and after that cleans the sample with water.

4. Slab and glass slide placed on a tripod and preheated using Bunsen burner. Canada balsam placed on the surface of glass slide. The slab placed on glass slide when the Canada balsam is completely cooked. Make sure there is no any air bubble. Wait until the slab cooled.

5. The slab on the glass slide kneaded until it become terribly thin. After that, glass slide was washed using water.

6. The slab was grinded and polished by using minor glass along the fine corundum until the slab has uniform adhesive thickness.

7. To find out the slab is thick or thin, when quartz still coloured, meaning the slab is still thick. So the slab should be kneaded back until quartz is colourless.

8. The slide was covered up with glass carbo and make sure there is no air bubbles

9. The slab placed under the microscope to observe the constituent of mineral and its texture.

Laboratory analysis are done to analyse the data obtain during field survey. In this method, more detailed result can get by interpreting raw data from field such as structural analysis, petrographic study and ERI inversion data.

3.3.4 Data processing

In this analysis, geological data such as geomorphology, sedimentology, stratigraphy, and structural geology are used to make a geological map of study area using ArcMap 10.2 software.

The electrical resistivity measurement data that recorded by ABEM Terrameter LS was converted to resistivity images in form of pseudosection by using 2D inversion software RES2DINV. From pseudosection images, groundwater potential was interpreted based on resistivity value.

3.3.5 Data analysis and interpretation

All the field data and GPS data will be transferred to ArcGIS software to complete the geological map. Strike and dip data will be interpreted according to orientation and forces that act upon the outcrops using Rose Diagram. Depositional environment will be determined using the lithology and sedimentology data.

Stratigraphy of the study area can be determined by indicate of fossils. The sample of rocks will be used for petrographic study. Petrographic study is a detailed explanation of mineral texture and structure under thin section using petrographic microscope. This analysis can explain the origin of rocks.

The result obtained as contoured in form of pseudosection. This result gave an appropriate visual of subsurface activity at under area of study. Each of colours represent the different resistivity value. The electrical resistivity depth section was produced by plotting true resistivity values versus depth. RES2DINV used for inversion of field data by least square inversion procedure in order to get true resistivity and depth of groundwater.

3.4 Report writing

Report writing is a fundamental step in every research project. There are six chapters in this report writing. Chapter one is the introduction which include early information regarding the research. Introduction includes general background, problem statements, research objectives, scope of study and research important. Information regarding study area also included in the introduction.

Chapter two contained literature review that specifies on the research title. Literature reviews were gathered during preliminary study which is the early stage of this research. Literature review content focused on geological review and information related to this research such as hydrogeology and saline water intrusion. Chapter three contained information regarding materials and methodology used in this research.

Chapter four which is contained general geology information is included in report writing of this research. Geological information gathered during mapping part is shown in chapter four. Chapter five in this report writing covered results and discussion of this research. Results gather during field work and laboratory investigations are presented in this chapter. Meanwhile, conclusion and suggestion regarding this research were presented in last chapter which is chapter six.

Report writing is important during research processes because it visually presented the outcome of the researches. Readers' understanding and judgements about this research is based on how we write the research report.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

The chapter of general geology will cover the geological mapping of the area including geomorphology, petrography, stratigraphy, and structural geology. The field observation and mapping are the main factors for this chapter.

The study area is located at Kuala Betis, Gua Musang. The area is located in the west of Kelantan and this area has little amount of people who lived in it while the majority of the area has been used for agricultural purpose.

4.2 Geomorphology

Based on Hugget (2007), geomorphology is the study of Earth's physical land-surface features, in other words, landforms formed on the Earth surface such as rivers, hills, plains, beaches, sand dunes, and myriad others. From here, we understood the origin and evolution

4.2.1 Topography

The contour of the study area, which is Kuala Betis, Gua Musang showed elevation ranged from 140 meters to 420 meters.

Gua Musang is one of the districts that situated at high elevation area. Based on Table 4.1, the topographic unit of the study area was hilly and mountains.

Table 4.1: Topographic Unit versus Mean Elevation Standard of the Study Area. (Hutchinson & Tan, 2009)

Topographic Unit	Mean Elevation above sea level (m)	Category of Study Area
Low Lying	<15	
Rolling	16-30	
Undulating	31-75	
Hilly	76-300	Study Area
Mountains	>301	Study Area

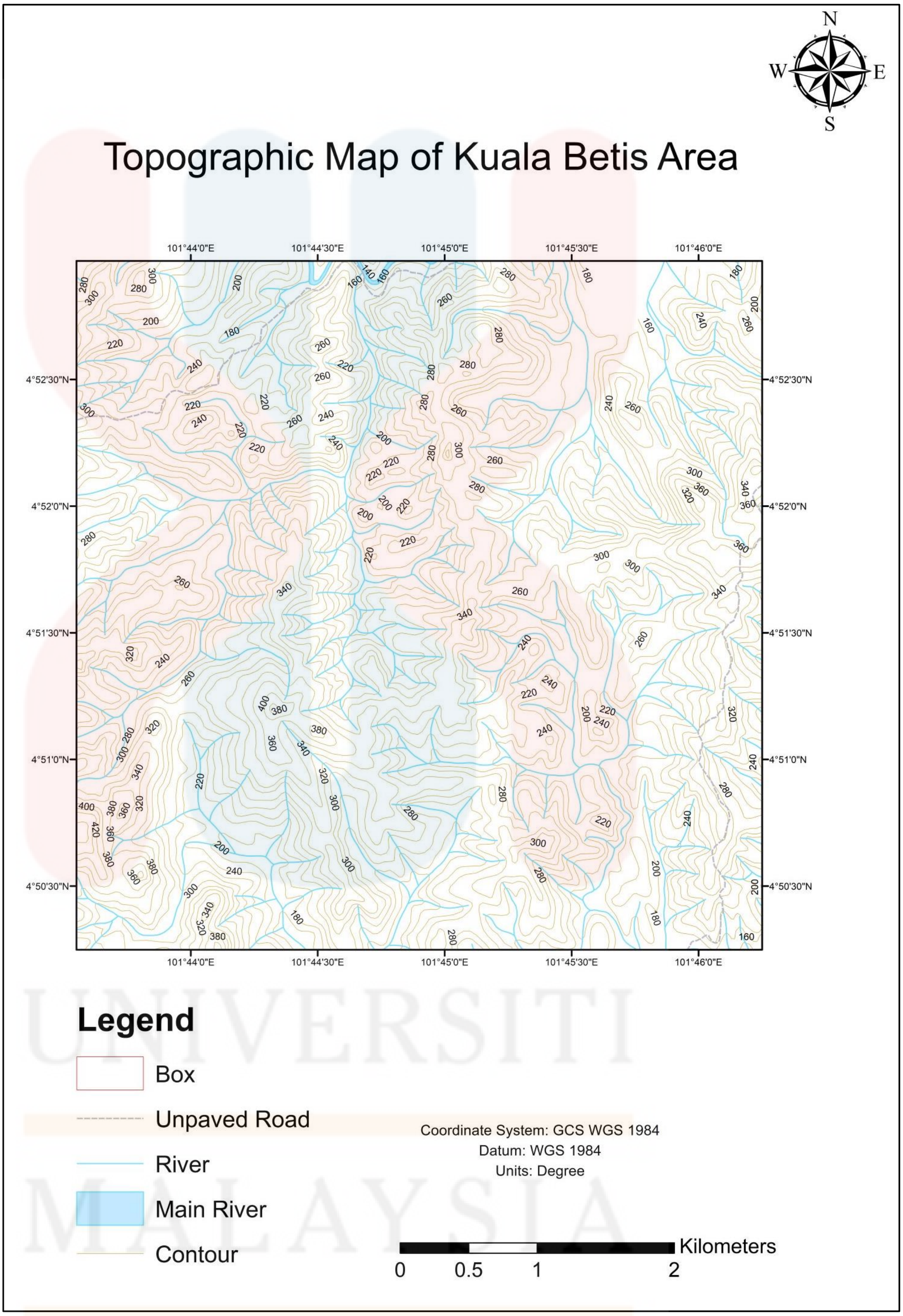


Figure 4.1: Topographic map of the study area

4.2.2 Drainage pattern

Drainage basin is the area that provide water and sediments to the channel of the river. The other term can be used are watershed and catchment. Generally, drainage is bounded by a drainage divide or catchment boundary. The boundary is something that is clearly visible as a ridge in mountainous and hilly areas but can be rather difficult to see in areas of more subdued topography. Drainage basin can form a mosaic across the land surface and varies in size from a few hectares to millions of square kilometres.

Figure 4.2 shows the watershed map of the study area. Based on figure 4.2, the watershed zones were divided based on the position of the Nenggiri River. The Nenggiri River is divided into two major rivers which are Betis River and Berok River which divided further into watershed zones A and B. In watershed A zone, the main river which is Betis River forms the connection with the small rivers in the study area whereas, in watershed B, the main river which is Berok River forms the connection with the small rivers in the study area.

Watershed zone A consists of dendritic drainage pattern whereas watershed zone B consists of rectangular drainage pattern

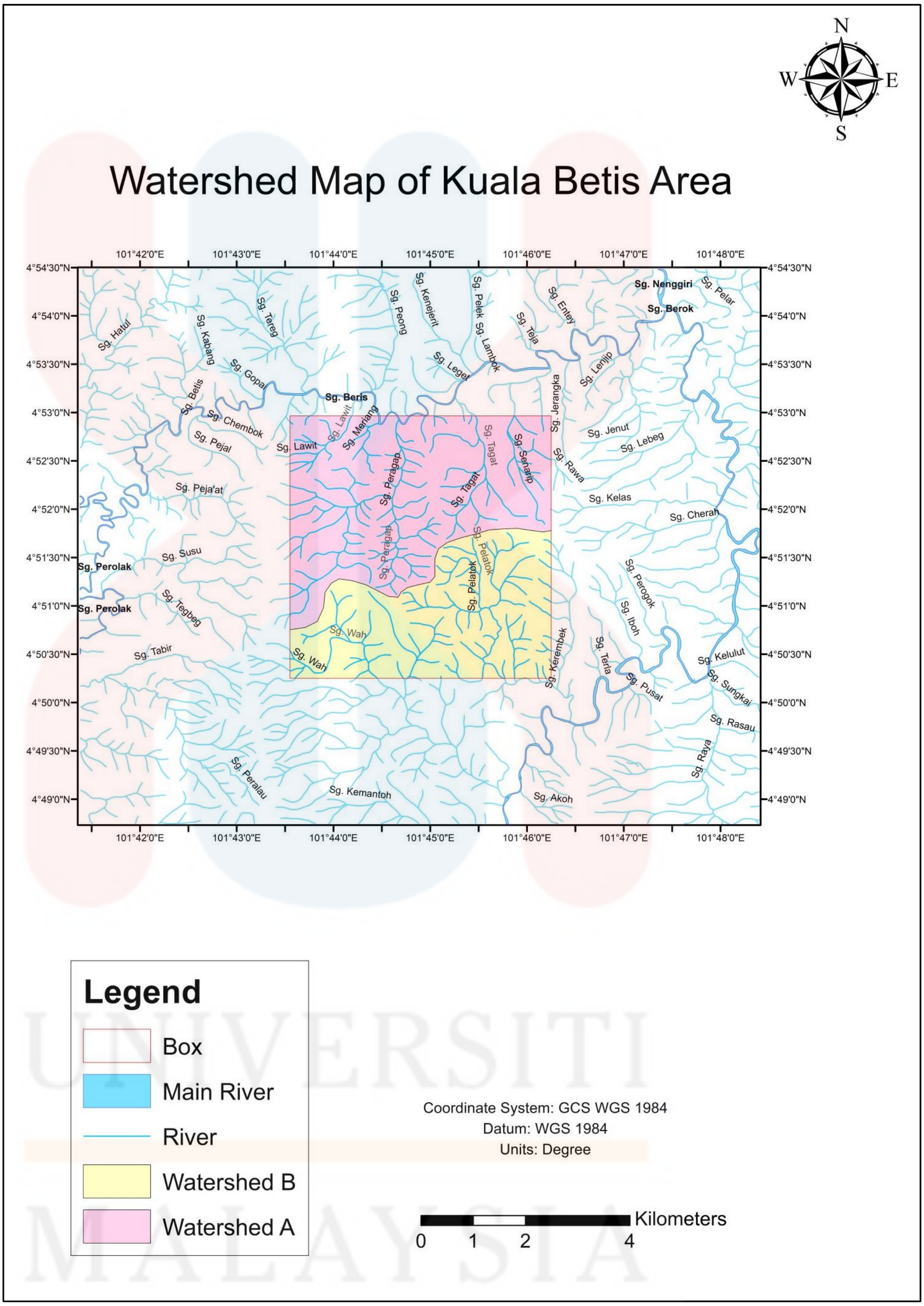


Figure 4.2: Watershed map of the study area

4.3 Stratigraphy

Stratigraphy as a term to study the stratified rocks based on time and space. This part split into two sections which are lithostratigraphy and stratigraphy column. For this study, lithostratigraphy is important to investigate the strata or rock layers especially the type of rock which involves each layer or bedding.

Meanwhile for the stratigraphic column was produced based on a table which consists of several factors such as formation, age, lithology unit and description shown in Table 4.2. All these factors are the main contribution to produce stratigraphic column and can be done by field mapping observation.

The stratigraphy column of the study area is produced based on Gua Musang formation. This formation is related to determining the age of rock formation in the study area. The arrangements of the lithology unit in the stratigraphic column are from the oldest which are quartzite unit from quartzite, slate, phyllite, and schist whereas, for oldest lithology unit are mudstone unit from mudstone, sandstone, and limestone

Both oldest and youngest lithology units are lies into different ages as for oldest lithology was lies into Permian age whereas for youngest was lies into Triassic age. All these lithology were from the same era at the Paleozoic era.

Table 4.2: Stratigraphic column of the study area.

Formation	Age	Stratigraphy	Lithology unit	Description
Gua Musang Formation	Triassic		Mudstone unit	Mudstone Limestone Sandstone
	Permian		Quartzite unit	Quartzite Slate Phyllite Schist

4.3.1 Lithostratigraphy

Lithostratigraphy is a sub-order of stratigraphy that is concerned about the description of rock units in terms of their geological features and connected with the identification of rock layers or strata. This section also includes the identification of rock based on the petrography method by using thin-section which is due to the study of rock minerals and textures. The thin section is observed under a polarizing microscope and view based on two types of lighting conditions which are plain polarized and cross-polarized light.

Therefore both field observation and thin section helped to investigate and classify the types of rock of study area and can be described as lithostratigraphy unit.

a) Clastic Sedimentary Rock Unit

Clastic sedimentary rock is a part of a sedimentary rock unit formed by an accumulation of weathering fragments of other rock that have hardened with a matrix material. When existing rock goes through weathering by flowing water or ice formation, the weathered fragments are transported to a separate location where they can form a new rock. This process has breakdown the rock into pebble, sand, or clay particles.

The clastic sedimentary rock is commonly classified based on the grain size of the sediment particles such as below:

I. Conglomerate – 64mm to 256mm, coarse and rounded grains

II. Breccia – 2mm to 64mm, course and angular grains

III. Sandstone – 2mm to 1/16mm

IV. Shale – 1/16mm and less

The types of clastic sedimentary rocks that can be found in the study area are mudstone, sandstone, and shale which at the same locality and interbedded to each other.

The distribution of clastic sedimentary rock to study area is about 15% and all this rock is from Permian age. This unit was done to represent the bedding of the sedimentary rock of the study area. The ranges of beds are between thick beds to the thin-bed where the conglomerate is dominated as the thickest. Mostly the outcrop was highly weathered so that the structure is hard to be observed as shown in Figure 4.3.

Figure 4.3: The outcrop of clastic sedimentary rock.

The second type of clastic sedimentary rock that can be found in the study area is mudstone. It is very fine-grained which consists of a mixture of both clay and silt-sized particles. Based on sample taken, mudstone is whitish-grey in color and it is only 3% distribution from this locality which also interbedded with sandstone.

Figure 4.4: The mudstone on the outcrop

Figure 4.5: Hand specimen of mudstone

From this locality, sandstone can be found interbedded with other clastic sedimentary rocks made up of sand size weathering debris. It also contains cementing material that binds the sand grains together and might contain a matrix of silt or clay-sized particles that take spaces between the sand grains. Based on the hand specimen, the color of the sandstone is yellowish-grey with medium grain.

Figure 4.6: Sandstone on the outcrop

Figure 4.7: Hand specimen sandstone

The last type of clastic sedimentary rock found in this locality is shale. The formation of shale is from the compaction of silt and clay-sized mineral particles. Shale also can be categorized in mudstone but it is distinguished based on its fissile and laminated behavior. Based on the hand specimen, the shale is dark grey in color and its very fine grain. Figure 4.8 and Figure 4.9 shows the shale on outcrop and hand specimen.

Figure 4.8: The shale on the outcrop

Figure 4.9: Hand specimen of shale

From figure 4.10, the polarized microscope shows that the mineral composition of shale can be identified under plane-polarized which are clay minerals and some very tiny fragments like quartz and calcite.

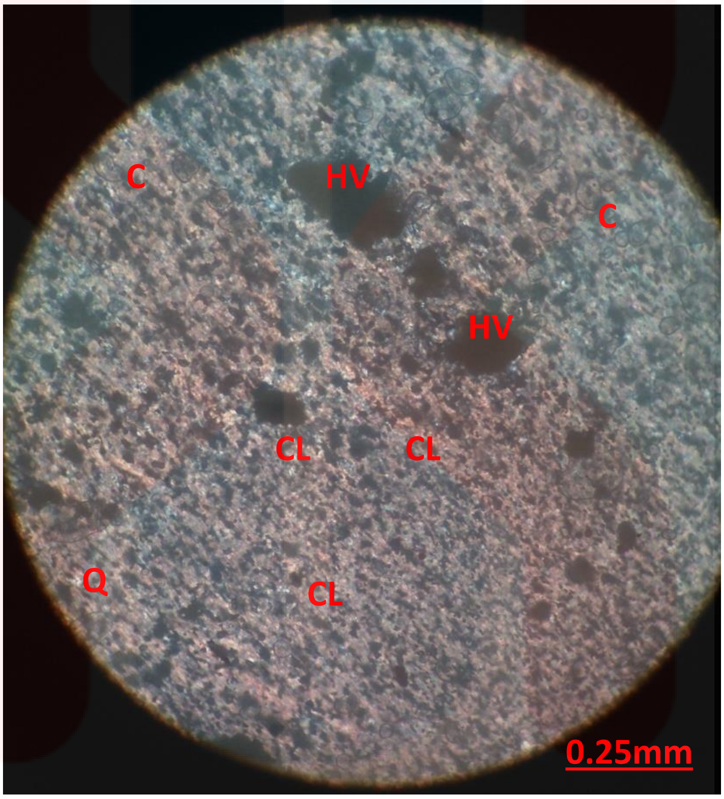


Figure 4.10: Plane Polarized of shale

Q: Quartz- 20%

CL: Clay Minerals- 45%

C: Calcite22%

HV: Heavy Metals-13%

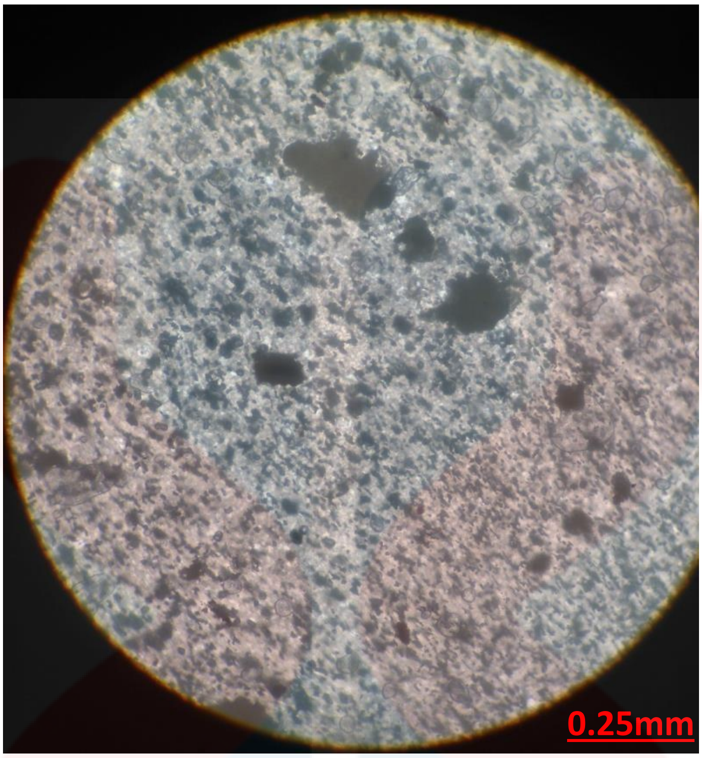


Figure 4.11: Cross Polarized of shale

b) Lapilli tuff

This type of rock as a new discovery from this study because based on past research, there is not a type of igneous rock in this area. Lapilli can be defined as the material that falls out of the air during a volcanic eruption and has pyroclastic material less than 2mm in diameter referred to as volcanic ash.

Hence it is formed like tuff which a type of rock made from volcanic ash and the ash is compacted into solid rock in the consolidation process. The age of this rock is Upper Carboniferous. Figure 4.12 shows the hand specimen of lapilli tuff and Figure 4.13 and Figure 4.14 shows the plane-polarized and cross-polarized of lapilli tuff thin section.

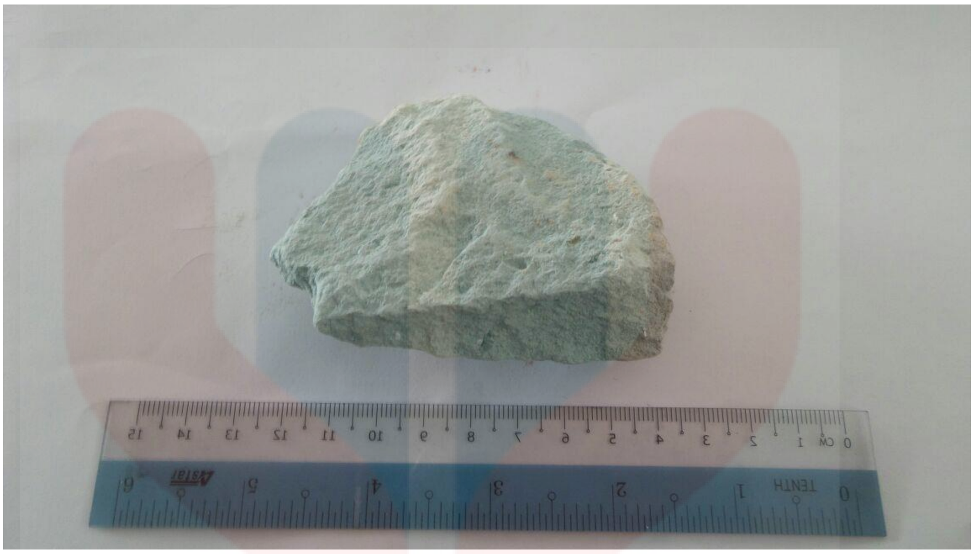


Figure 4.12: Hand specimen of la

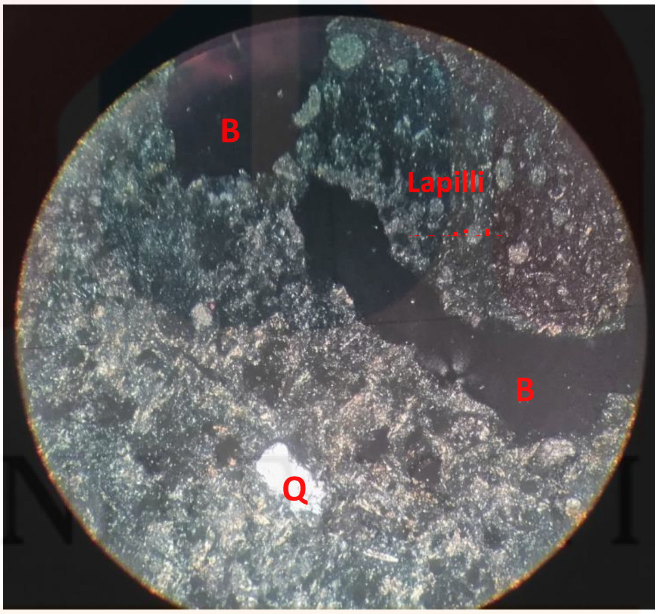


Figure 4.13: Plane polarized of lapilli tuff

B: Biotite- 25%

Q: Quartz- 20%

Lapilli particle- 55%

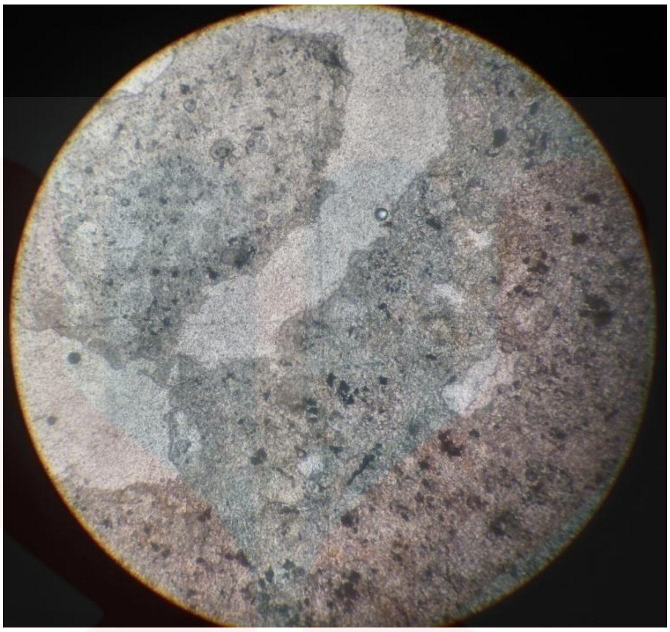


Figure 4.14: Cross Polarized of lapilli tuff

c) Metamorphic rock unit

Metamorphic rock is a type of rock that has been modified by heat, chemical process and pressure usually occur while buried deep under the earth's surface. This condition has altered the mineralogy, texture and chemical composition of the rock. It is also known as a result of transformation pre-existing rock when the physical and chemical of original rock change because of high heat and pressure.

There are two basic types of metamorphic rock which are foliated and not foliated. Both can be differ based on a layered or banded appearance on foliated metamorphic rock produced by exposure to heat and pressure while non-foliated type does not have layered or banded appearance.

From my study area, there are three types of metamorphic rock that can be found which are phyllite and schist from foliated metamorphic rock then quartzite from non-foliated metamorphic rock. All these rock are formed Permian age.

Phyllite as one of foliated metamorphic rock that made up of very fine grain mica. Usually, the surface of phyllite is lustrous and sometimes wrinkled. The grade of phyllite is intermediate between slate and schist. Based on the specimen, the colour of this rock is dark grey and very fine grain. The location of phyllite on study area at coordinate

While for schist is a well-developed foliation of metamorphic rock that contains a significant amount of mica that causes the rock split into thin pieces. The metamorphic grade of schist is between phyllite and gneiss. Refer to the hand specimen, the color of schist is whitish dark grey and sheet-like grains orientation. The rock is exposed at the coordinate

Figure 4.15: Foliation on phyllite outcrop

Figure 4.16: Hand specimen of phyllite

In the petrography of phyllite, the mineral compositions of this rock that can be observed are quartz, mica, and biotite. Phyllite also one of foliated metamorphic in which the parallel or wavy layering can be seen on cross-polarized and it is in fine grain. Figure 4.17 and 4.18 shows the plane and cross polarized of phyllite in thin section

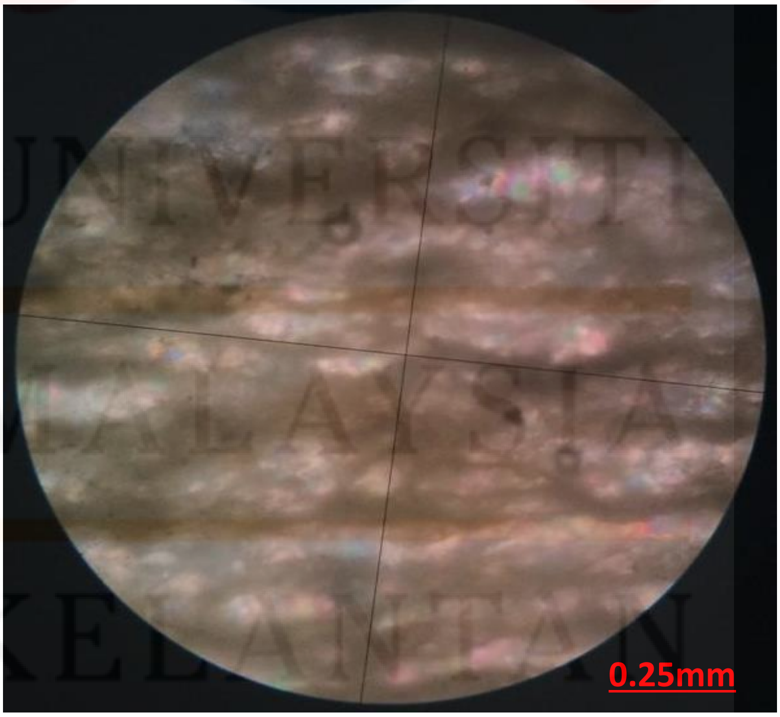


Figure 4.17: Plane polarized of phyllite

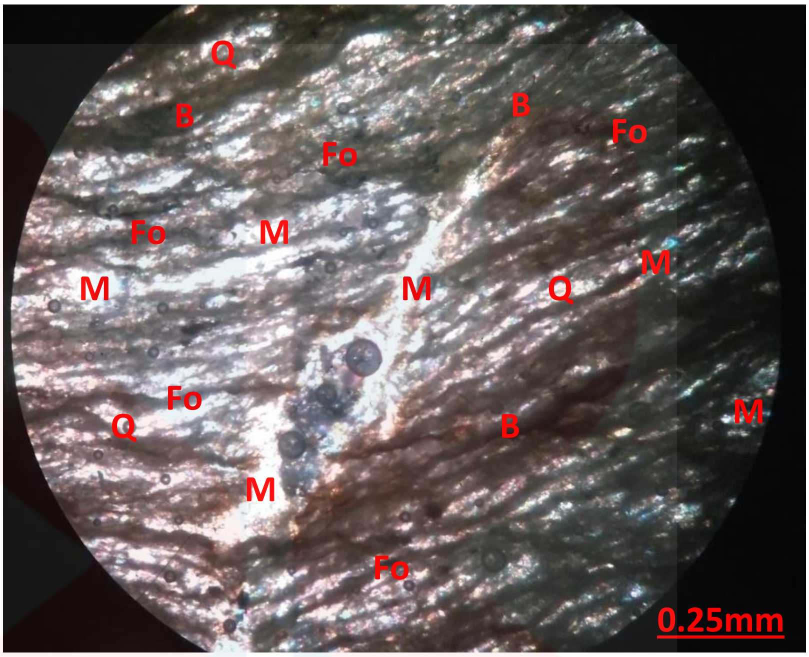


Figure 4.18: Cross polarized of phyllite

Q: Quartz 35%

B: Biotite 20%

M: Mica- 45%

Fo: Foliation

Figure 4.19: Schist outcrop

Figure 4.20: Hand specimen of schist

Characteristics of schist in the thin section can be observed based on the cross-polarized which are the size is a fine grain, rich in mica and quartz minerals and has a thin laminae or parallel layering which less than one centimeter of foliation thickness. Biotite also abundant and produced a weak planar foliation. All these characteristics are shown in Figure 4.41 under cross-polarized of schist.

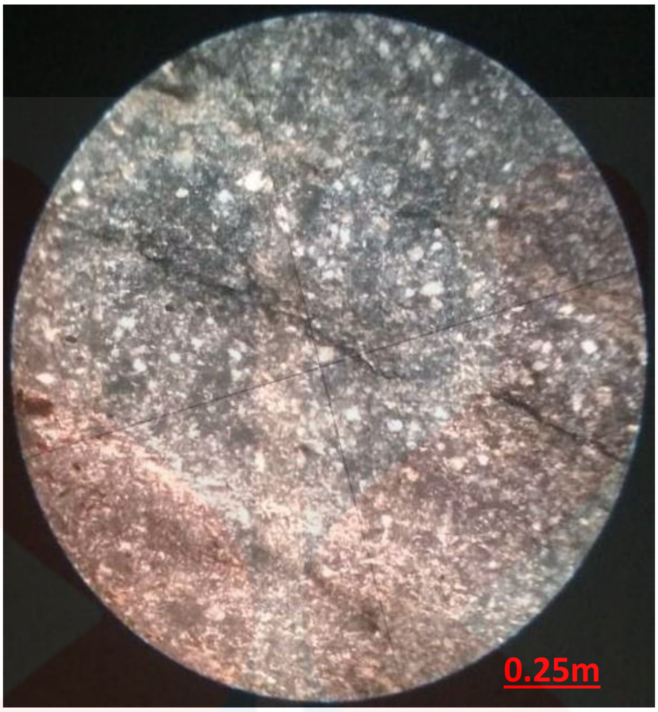


Figure 4.21: Plane polarized of schist

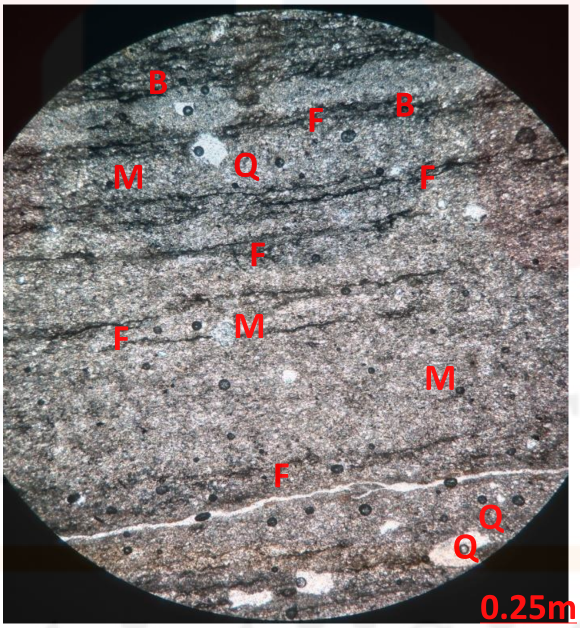


Figure 4.22: Cross Polarized

Q: Quartz- 30%

B: Biotite- 32%

M: Mica- 38%

Fo: Foliation

Generally, quartzite comprises greater than 90 percent quartz and also containing up to 99 percent of quartz as the largest and purest concentration of silica in the Earth's crust. This rock has a sugary appearance and glassy luster.

The physical characteristic for this rock can be observed during field mapping such as the grain size is generally medium grain and interlocking quartz crystals can be seen. The texture is granular and it is gritty to touch.

Figure 4.23: Hand specimen of quartzite in the study area

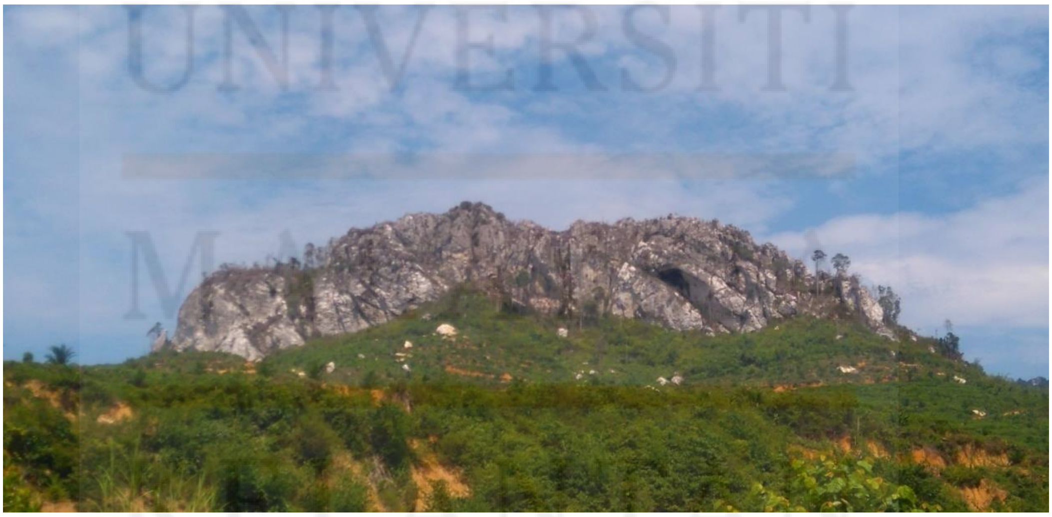
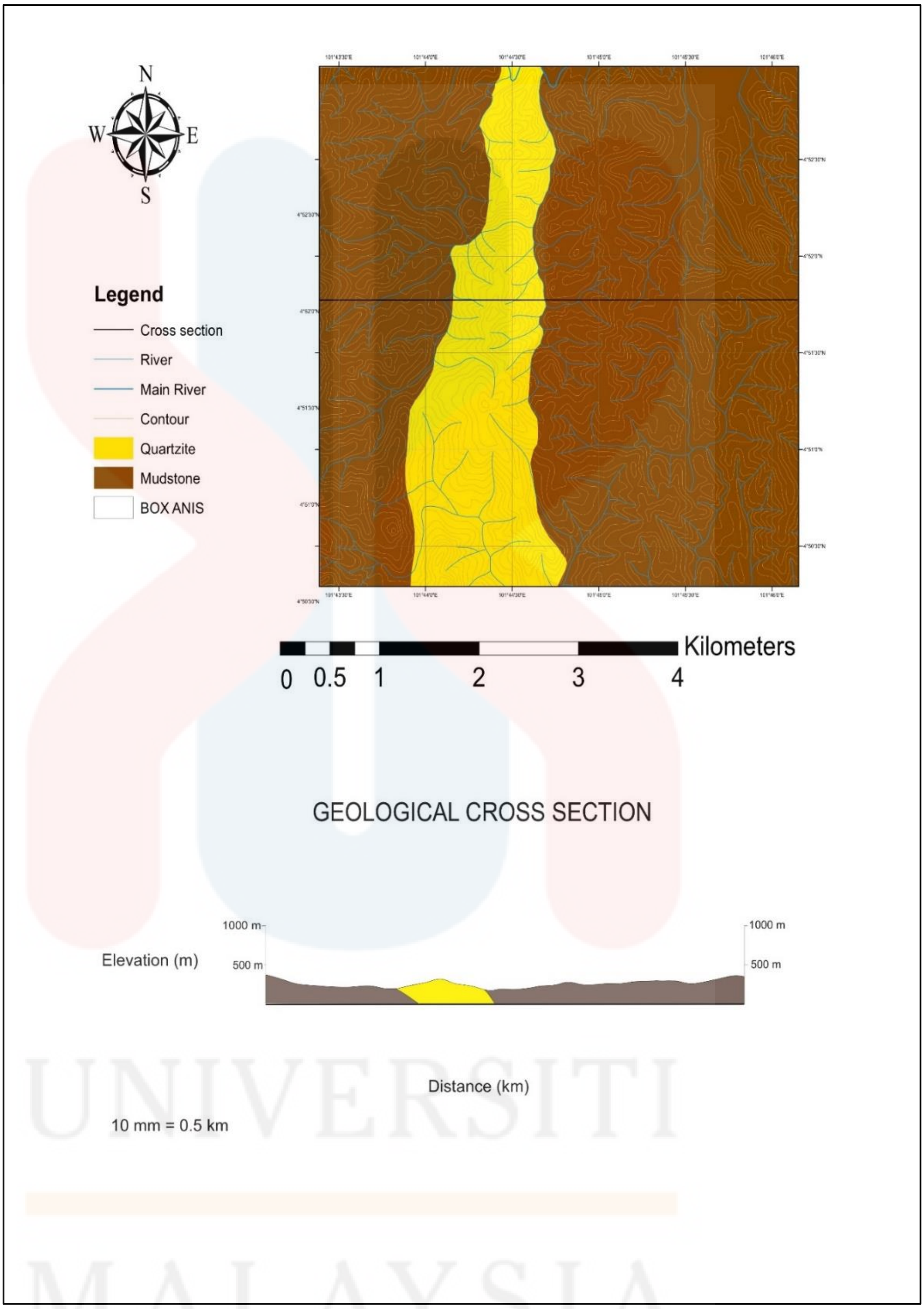


Figure 4.24: Quartzite hill in the study area.

The quartzite hill was found in the area of study with a high 60m and width 150m. Quartzite from this area is one of metamorphic rock which formed when quartz-rich sandstone has been exposed to high temperature and pressure. This type of rock implies not only a high degree of indurations but also the content of high quartz which more than 90 percent. So when the quartz mineral is major exposed, by the time transform to quartzite and form a hill.



N
W
E
S
Legend
Cross section
River
Main River
Contour
Quartzite
Mudstone
BOX ANIS
Kilometers
0
0.5
1
2
3
4
GEOLOGICAL CROSS SECTION
1000 m
500 m
Elevation (m)
Distance (km)
10 mm = 0.5 km

Figure

4.4 Structural analysis

Structural analysis is the analysis done to further analyze and discuss any deformation or changes brought about due to forces acting on continental blocks. Structural analyses that are usually observed and analysed include faults, folds, beddings, joints and fractures, foliations as well as lineament analysis (Christopher et al., 1981). In this study, structural analysis is confined to lineament, fracture, bedding analysis and joint analysis only due to the absence of other observable structures in the study area.

4.4.1 Joint

Joint is also known as crack. It is also can be defined as natural origin fracture in a rock along the body of rock that lacks any visible or parallel movement to the surface of fracture. A family of parallel is a joint set that often occurs in two sets of cracks intersecting between 45 to 90 degrees that dividing the rocks into rectangular blocks.

A joint can be identified through mapping and analysis of the orientations, spacing, and physical properties on the field. The rose diagram is used for joint analysis and the direction of applied forces if from the South East (SE) to North West (NW). In the study area, there is one location with the same type of rock which is chert had been observed for joint analysis.

Location 1

Coordinate: N 04º 44” 50.5‟ E 101º 44” 57.7‟

Elevation: 196m

Figure: Location 1

σ_1= N340ºW
Maximum stress force

σ_3= N70ºE

Minimum stress force

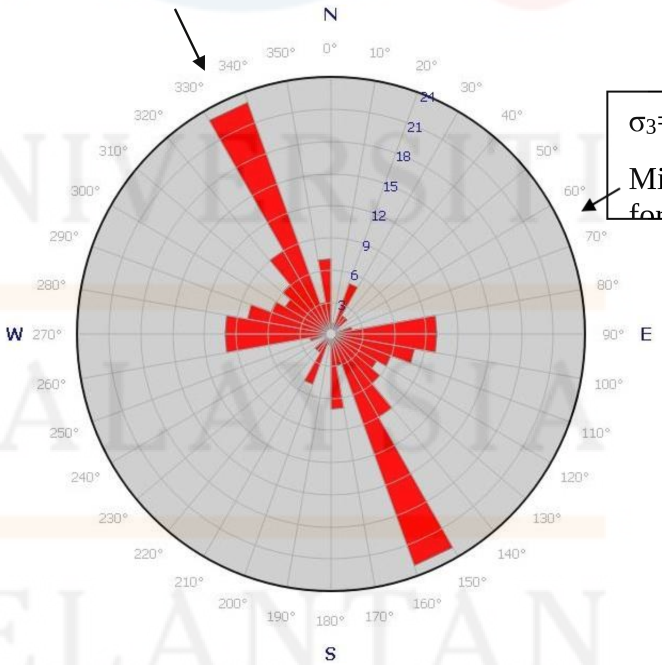


Figure: Joint analysis for location 1

4.4.2 Fault

The fault is known as a fracture in a rocking body caused by brittle failure or as a zone of fracture between two blocks of rock. This is because relative displacement has occurred between the adjacent blocks and allow the blocks to move relative to each other. The movement of a block may occur quickly or slowly because of an earthquake or in the form of creep.

There are three types of fault normally used as references in the field which are normal fault, reverse fault, and strike-slip fault. All these types differ based on the types of stress and movement caused by it. From my study area, there is a reverse fault occurred that can be found in the field.

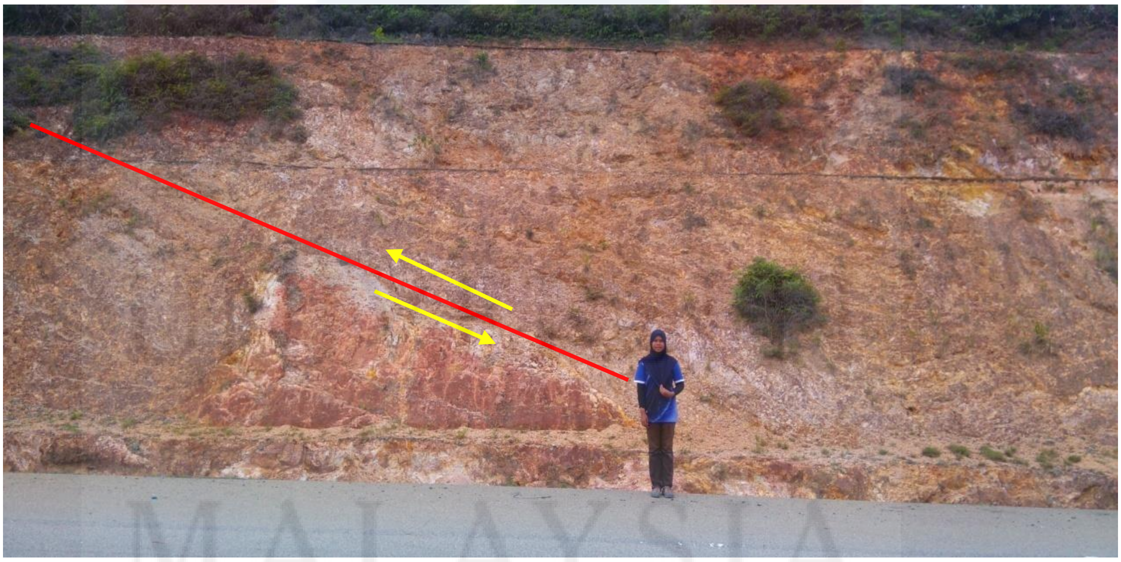


Figure 4.52: Reverse fault

4.4.3 Fold

Fold known as a bend in rock strata or in any planar feature that forms because of some conditions such as stress, hydrostatic pressure, pore pressure, and temperature gradient. It will take over very long periods of time to be formed as a fold until the pressure is finally enough to change the shape of rock strata. Their presence can be as evidence in soft sediments, the spectrum of metamorphic rocks, and as primary flow structure in some igneous rocks. Fold mainly consists of two curves which are anticline and syncline.

There are several types of fold differ based on their sizes and various scales which are anticline, syncline, monocline, chevron fold, recumbent fold, and isoclinals fold. From my study area, there are a few physical characteristics of fold that can be identified which are minor recumbent fold and two anticline fold at a different coordinate.

The recumbent fold is a fold that has a horizontal axial plane that folds axial plane oriented at a low angle caused the strata is overturned in one limb of the fold. Throughout the study area, part of recumbent fold had been found and weathering factor caused the disturbance for the rest original structure of this fold. It has occurred on chert outcrop as shown in the figure. The location of this fold is at coordinate N04º44‟50.6‟ E101º44‟57.9‟. To determine a direction force for this fold, the strike and dip readings were used to plot the stereonet.

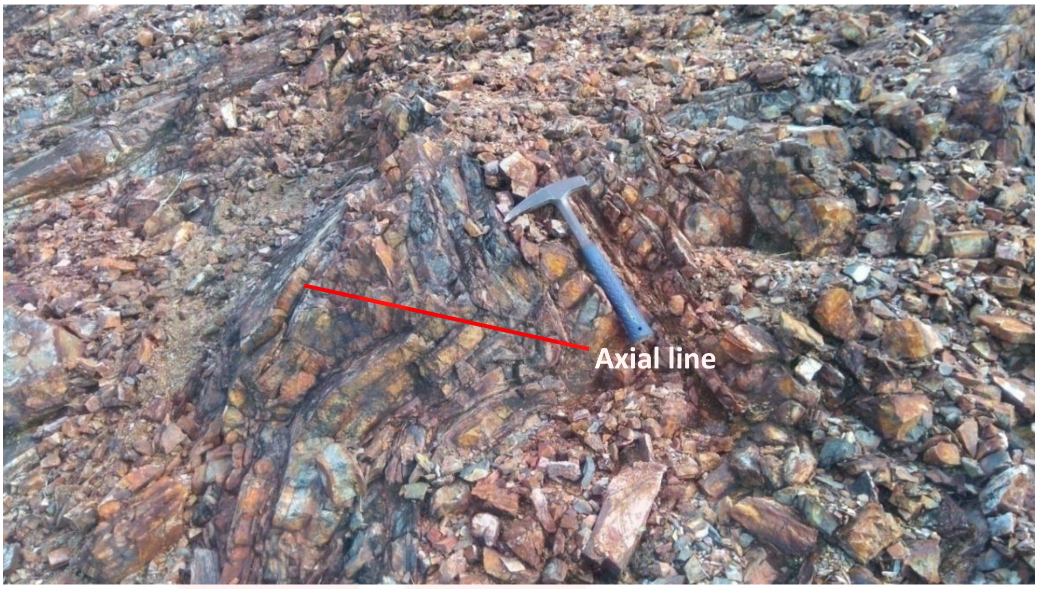
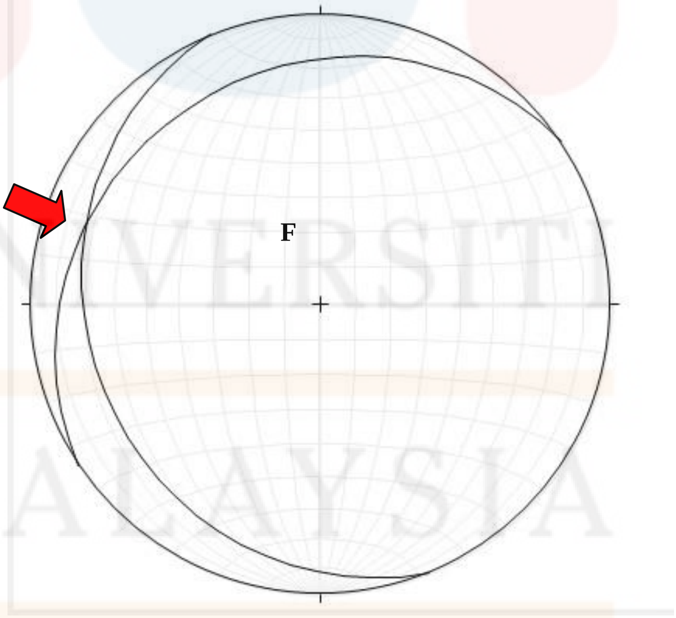


Figure 4.: Minor recumbent fold on chert outcrop at the study area.

Strike and dip readings	1. 236/20	
	2. 158/21	



igure 4.4: Fold analysis for recumbent

For anticline fold, it has the oldest beds at its core and convex up. In other term is a fold that curves up for both sides of the rock is pushed inward. From the study area, this type of fold can be found on two locations which at coordinate N04°45‟07.7‟ E101°45‟06.02‟ and N04°44‟34.8‟ E101°44‟37.5‟. The strike and dip readings of this both fold also used to determine the direction force of fold as shown in Figure and Figure. The direction force is important to see the direction of fold formation and to ensure the strike and dip readings that take from the site is also right.

Both these fold are from horizontal bedding, fold at the location first is bedding that has a lithology of chert interbedded with sandstone while for the second location is bedding that from chert interbedded with shale as their lithology.

Figure 4.: Anticline fold on interbedded chert and sandstone in the study area.

Strike and dip readings	1. 50/28
	2. 10/28

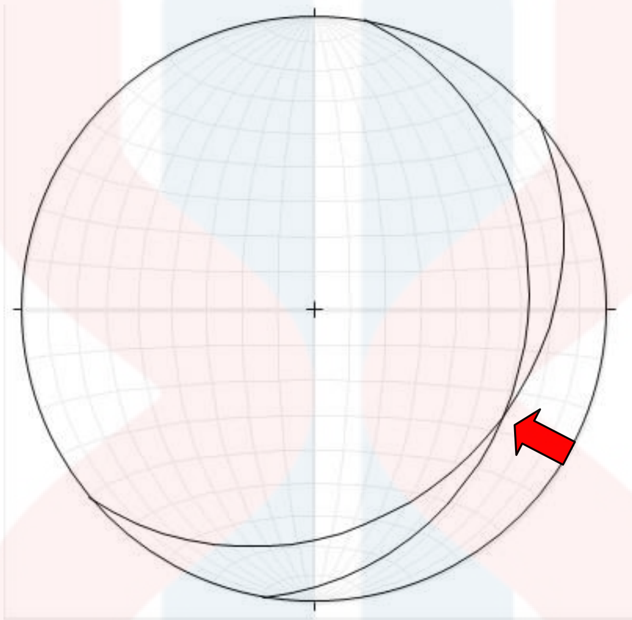


Figure 4.56: Fold analysis for anticline location first

Figure 4.: Anticline fold of chert interbedded with shale at the study area

Strike and dip readings	1. 8/19
	2. 24/12

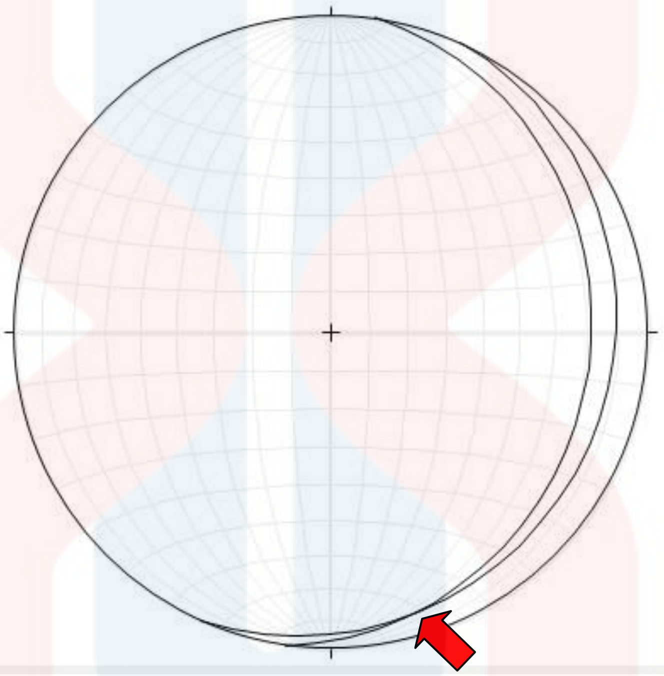


Figure 4.58: Fold analysis for anticline

4.5 Historical Geology

The study area in Kuala Betis consists of two age which is Permian and Triassic. Table 4.7 shows the stratigraphic column of the study area. The eldest lithology unit by order of stratigraphy is Quartzite unit followed by the younger unit which is the Mudstone unit. There are two lithology units which are mudstone unit; mudstone, limestone and sandstone and quartzite unit; quartzite, slate, phyllite, and schist.

Table 4.1: Stratigraphic column of Kuala Betis area, Gua Musang

Formation	Age	Stratigraphy	Lithology unit	Description
Gua Musang Formation	Triassic		Mudstone unit	Mudstone Limestone Sandstone
	Permian		Quartzite unit	Quartzite Slate Phyllite Schist

CHAPTER 5

SEAWATER INTRUSION STUDIES IN PENGKALAN CHEPA USING GEOPHYSICAL AND GEOCHEMICAL METHODS

5.1 Introduction

The Electrical Resistivity Imaging (ERI) survey and in-situ parameters of water sample were done at Pengkalan Chepa. ERI survey is used to identify the extent of seawater intrusion in the study area whereas the in-situ parameter instrument is used to analyse the quality of coastal groundwater samples in the study area. The data collected by in-situ and chemical parameters function to support the results obtained by the ERI survey.

5.2 Geochemical Analysis

The in-situ parameters and Atomic Absorption Spectroscopy (AAS) technique were used to analyse the quality of coastal groundwater samples in the study area. The result of water samples were tabulated and discussed. Approximately, the results display various values and concentrations for each location and the factors that contribute these disparity were addressed. The findings were then aligned with the Ministry of Health of Malaysia (MOH)'s National Guidelines of Raw Water Quality Standard to assess the quality status of coastal aquifer around study area. Table 5.1 shows the recommended raw water quality criteria by MOH.

Table 5.1: Recommended Raw Water Quality Criteria by Ministry of Health, Malaysia

Constituents	Permissible limit in Ministry of Health, Malaysia (MOH) in mg/L unless otherwise stated
pH	5.5 – 9.0
Total Dissolved Solids (TDS)	1500
Salinity	1.0 ppt
Electrical Conductivity (EC)	1000 µS/cm
Turbidity	9 NTU
Total Suspended Solids (TSS)	50
Sodium	200
Manganese	0.2
Potassium	30
Iron	1.0
Copper	1.0
Chloride	250

5.2.1 In-situ Parameters

Table 5.2: Water sampling location

Date	Sample	Time	Owner/Location	Latitude (N)	Longitude (E)	Elevation (m)	Distance from shoreline (km)
1/8	AS 01	5.00 p.m.	Kg. Tok Kaya	06° 12′ 28.7″	102° 15′ 26.1″	2	0.63
2/8	AS 02	10.40 a.m.	Pn. Pisah/Kg. Semut Api	06° 11′ 42.0″	102° 16′ 22.8″	2	0.51
2/8	AS 03	5.11 p.m.	Mosque/Kg. Chicha	06° 12′ 29.3″	102° 14′ 03.9″	5	2.56
2/8	AS 04	5.22 p.m.	Pn Halimah/Kg. Chicha	06° 09′ 25.0″	102° 14′ 49.1″	9	3.25
2/8	AS 05	6.45 p.m.	Kg Cina	06° 09′ 10.8″	102° 14′ 16.8″	14	6.60
3/8	AS 06	12.14 p.m.	En. Ishak @ Yamin/Kg. Tapai	06° 10′ 30.0″	102° 15′ 18.0″	6	3.48
5/8	AS 07	10.41 p.m.	Pn. Ainun @ Sabariah/Kg. Cabang 4	06° 11′ 59.8″	102° 15′ 21.6″	12	4.98
5/8	AS 08	11.26 p.m.	Pn. Ku Sharifah/Kg. Jambu	06° 10′ 53.0″	102° 17′ 20.0″	2	0.87
5/8	AS 09	11.55 p.m.	Pn. Rakiah/Kg. Kubang	06° 09′ 25.9″	102° 16′ 15.3″	10	3.70
5/8	AS 10	12.44 p.m.	Pn. Lijah/Kg Tukang Dollah	06° 12′ 57.2″	102° 14′ 31.2″	5	2.57

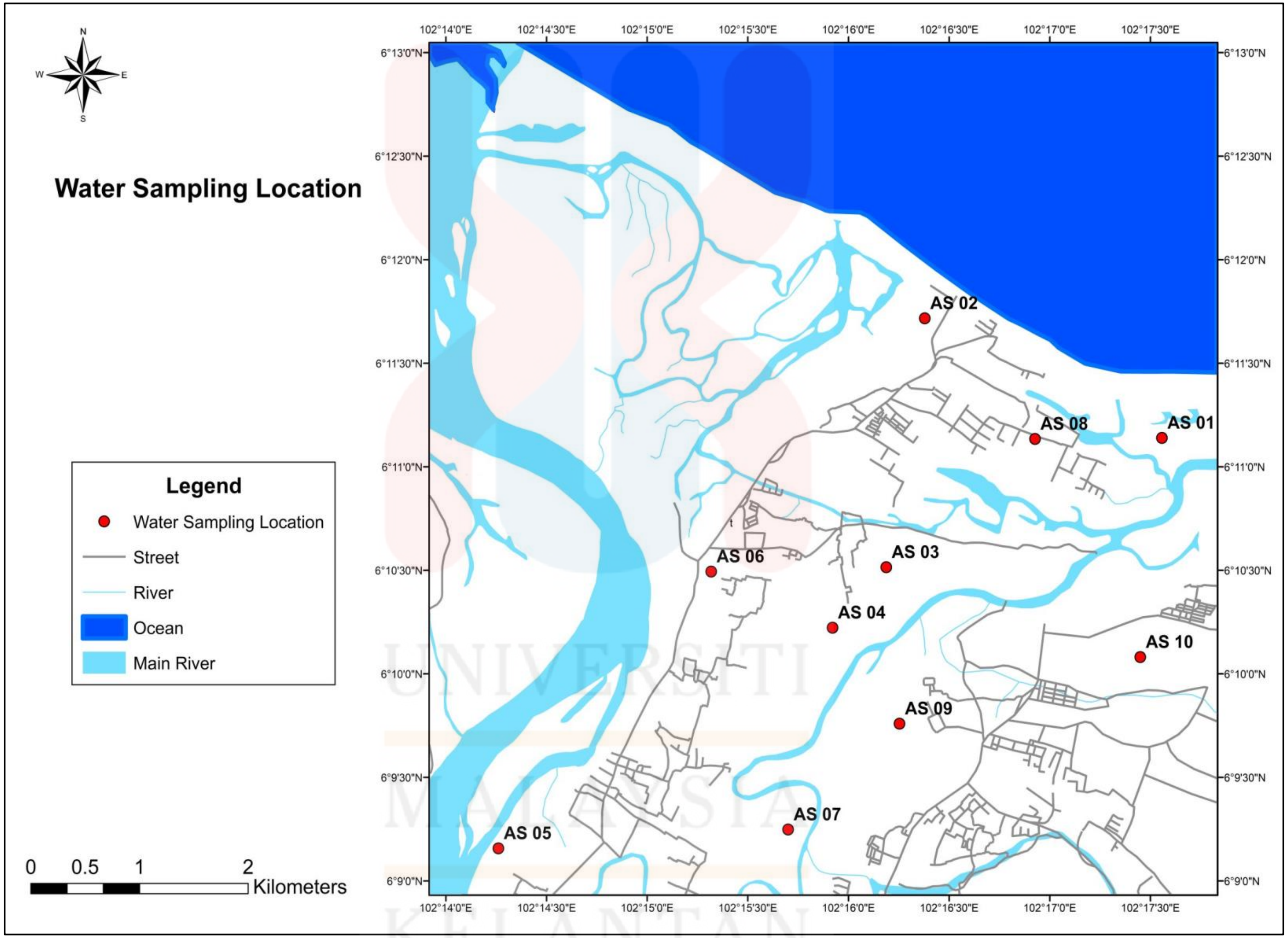


Figure 5.1: Water sampling location of study area

Table 5.3: In-situ parameters of groundwater sample in the study area

Sample	Date	Location	pH	TDS mg/L	Salinity ppt	EC µS/cm	Temperature °C	Turbidity NTU	TSS mg/L
AS 01	1/8	Kg	6.59	263.4	8.3	409.9	29.5	2.93	156
AS 02	2/8	Kg Semut Api	7.23	302.6	6.2	656.5	30.9	0.50	246
AS 03	2/8	Kg Chicha	6.21	298.2	6.3	356.9	29.9	5.34	190
AS 04	2/8	Kg Chicha	7.11	376.9	6.5	528.7	28.6	4.98	165
AS 05	2/8	Kg Cina	5.96	172.7	0.1	291.9	30.2	0.15	99
AS 06	3/8	Kg Tapai	6.79	581.0	4.1	989.9	30.6	9.99	267
AS 07	5/8	Kg Cherang	6.68	409.8	4.6	764.2	31.3	2.76	120
AS 08	5/8	Kg Jambu	6.74	367.4	2.2	406.5	30.0	2.55	126
AS 09	5/8	Kg Kubang	6.31	234.0	0.1	159.1	29.1	1.41	167
AS 10	5/8	Kg Tukang Dollah	5.81	185.5	5.0	228.3	30.6	0.39	214

a) pH

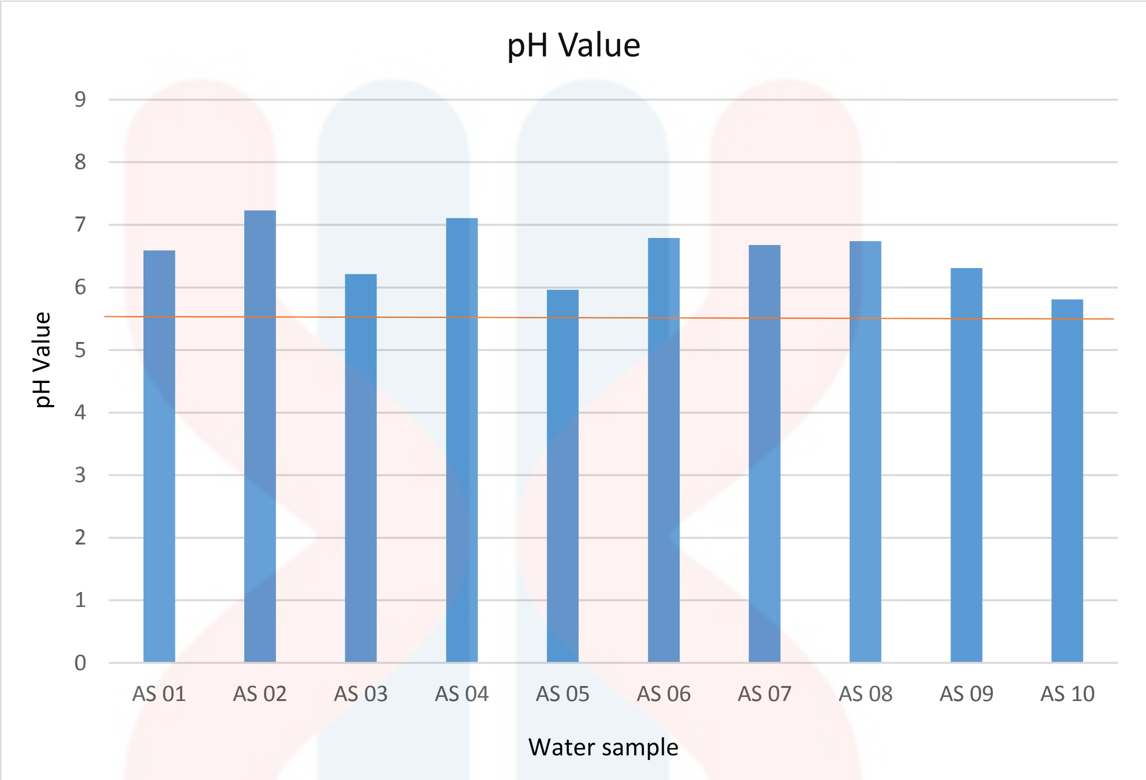


Figure 5.2: pH values of water sample around study area

The values for pH ranged from 5.81 to 7.23. The AS 02 recorded the highest pH value whereas AS 10 recorded the lowest pH value. The range of pH value from 5.81 to 7.23 passed the minimum permissible limit of pH value of 5.5 according to National Guidelines of Raw Water Quality Standard from MOH as shown in Figure 5.2.

b) Total Dissolved Solids (TDS)

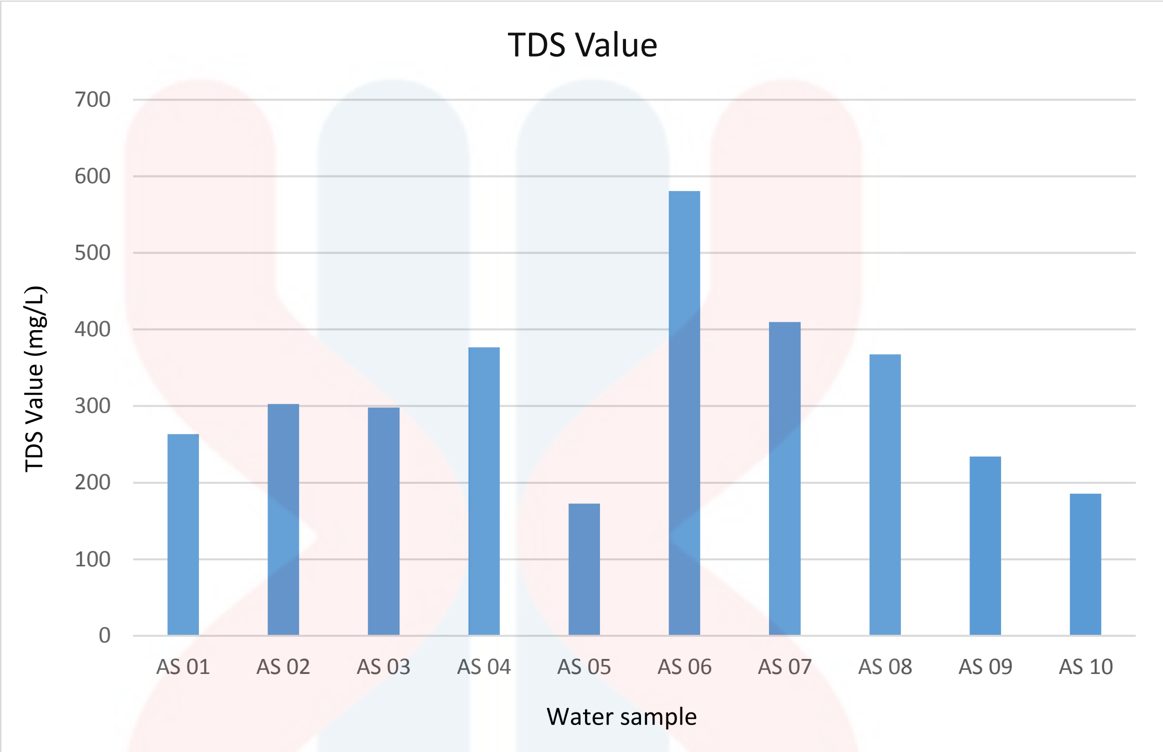


Figure 5.3: TDS values of water sample around study area

The range of TDS values of water samples recorded was 172.7 mg/L to 581.0 mg/L. AS 06 recorded the highest TDS value whereas AS 05 recorded the lowest TDS value. All the water samples passed the permissible limit of TDS value less than 1500 mg/L according to the National Guidelines of Raw Water Quality Standard from MOH as shown in Figure 5.3.

c) **Salinity**

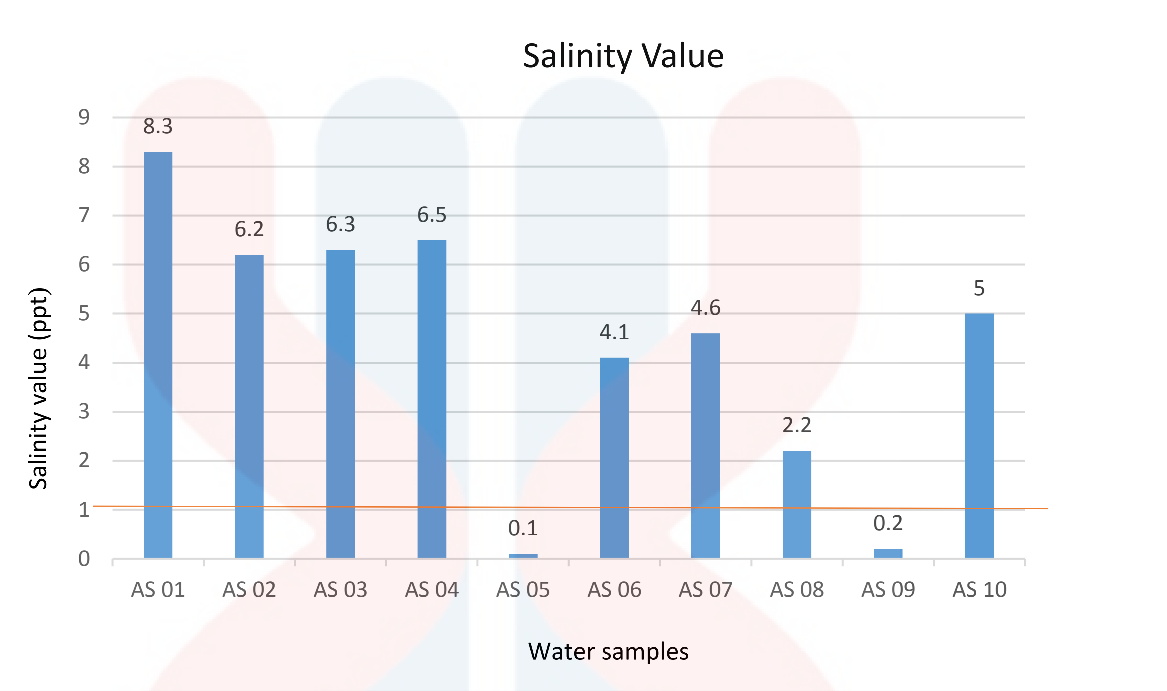


Figure 5.4: Salinity values of water sample around study area

The range of TDS values of water samples recorded was 0.1 ppt to 8.3 ppt. AS 01 recorded the highest salinity value whereas AS 05 recorded the lowest salinity value. All the water samples failed the permissible limit of salinity value less than 1.0 ppt except AS 05 and AS 09 according to the National Guidelines of Raw Water Quality Standard from MOH as shown in Figure 5.4.

d) **Electrical Conductivity (EC)**

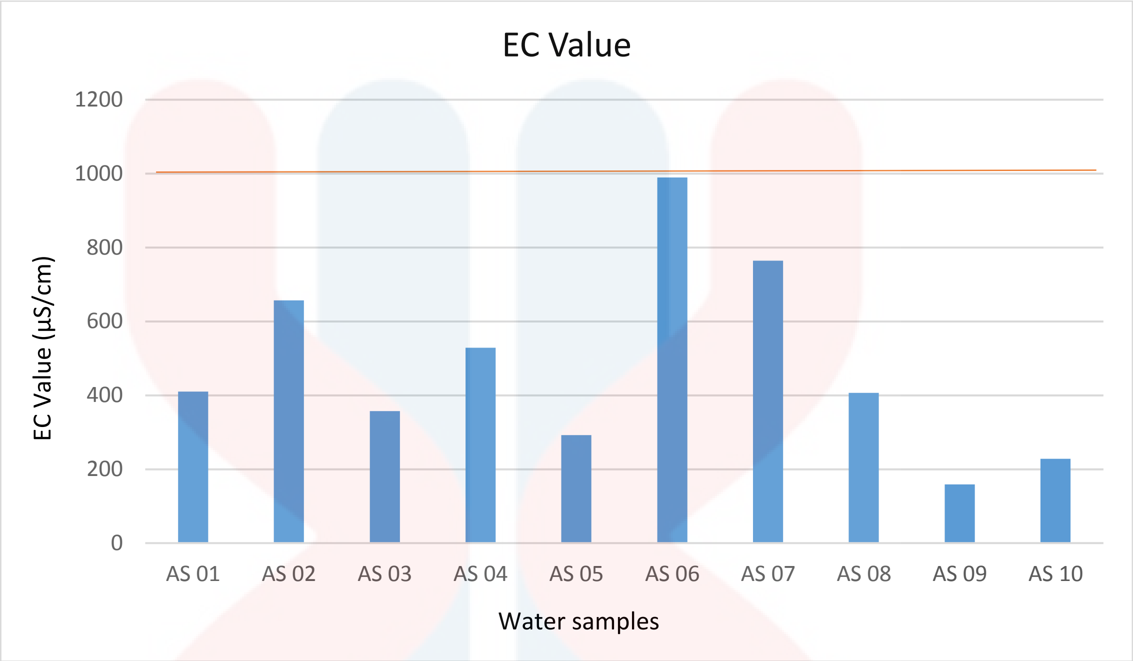


Figure 5.5: EC values of water sample around study area

The range of EC values of water samples recorded were 159.1 µS/cm to 989.9 µS/cm. AS 06 recorded the highest EC value whereas AS 09 recorded the lowest EC value. All the water samples passed the permissible limit of EC value less than 1000 µS/cm according to the National Guidelines of Raw Water Quality Standard from MOH as shown in Figure 5.5.

e) Turbidity

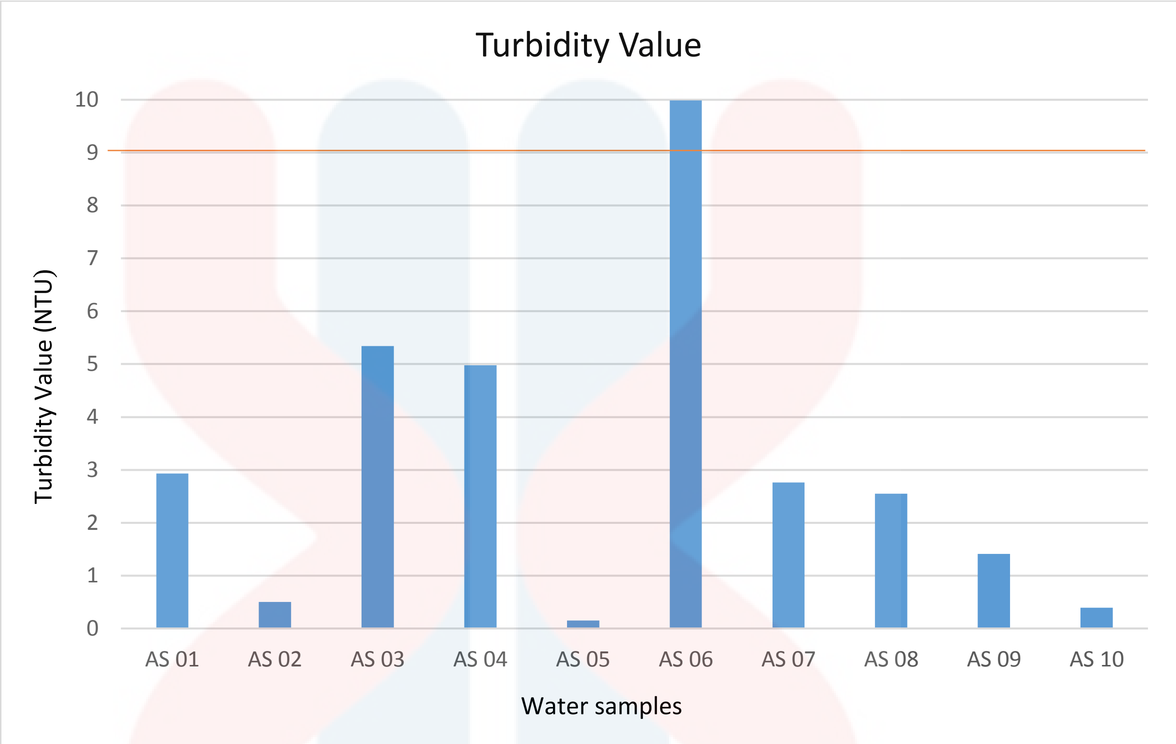


Figure 5.6: Turbidity values of water sample around study area

The values for turbidity ranged from 15 NTU to 9.99 NTU. AS 06 recorded the highest turbidity value whereas AS 05 recorded the lowest turbidity value. All the water samples passed the permissible limit of turbidity value less than 9 NTU except AS 06 according to the National Guidelines of Raw Water Quality Standard from MOH as shown in Figure 5.6.

f) Total Suspended Solids (TSS)

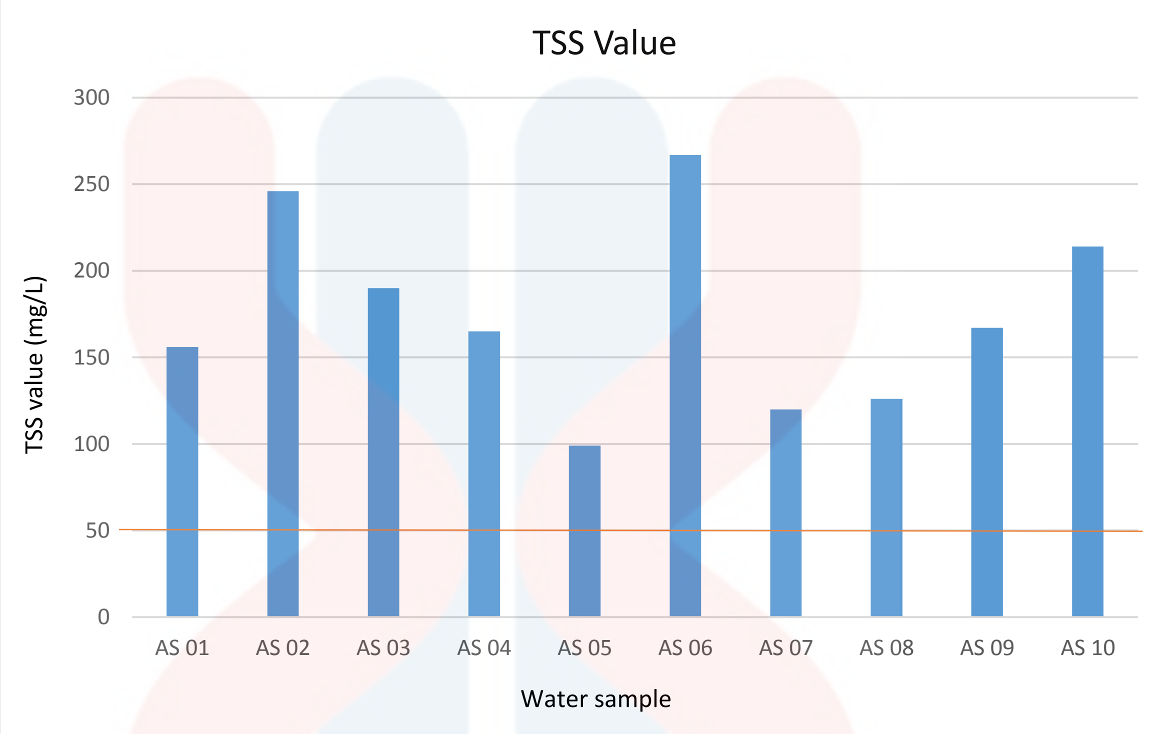


Figure 5.7: TSS values of water sample around study area

The values for TSS ranged from 99 mg/L to 267 mg/L. AS 06 recorded the highest TSS value whereas AS 05 recorded the lowest TSS value. All the water samples failed the permissible limit of TSS value less than mg/L according to the National Guidelines of Raw Water Quality Standard from MOH as shown in Figure 5.7.

5.2.2 Chemical Parameters

Table 5.4 below shows the results obtained from the Atomic Absorption Spectroscopy (AAS) analysis of five samples collected around the study area.

Table 5.4: Chemical parameters of water samples around study area analysed using AAS

Sample	Na^{+} (mg/L)	Mn^{2+} (mg/L)	K^{+} (mg/L)	Fe^{2+} (mg/L)	Cu^{2+} (mg/L)
AS 08	8.900	0.361	5.400	0.168	0.026
AS 07	14.09	0.061	10.59	0.319	0.016
AS 10	18.93	0.446	6.993	0.120	0.047
AS 04	6.173	0.315	2.776	0.944	0.039
AS 02	30.08	0.018	8.708	0.079	0.032

a) **Sodium, Na^{+}**

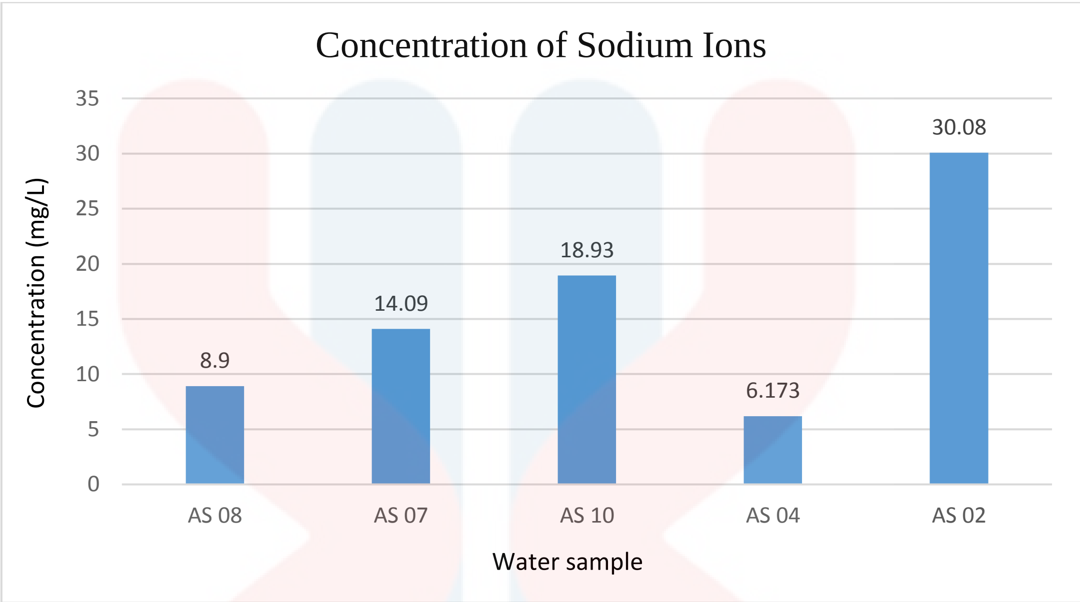


Figure 5.8: Sodium ion concentration of water sample around study area

The sodium ions concentrations in study area ranged from 6.173 mg/L to 30.08 mg/L. All the water samples passed the permissible limit of sodium concentration value less than 200 mg/L according to the National Guidelines of Raw Water Quality Standard from MOH as shown in Figure 5.8. Thus, all water samples are safe for domestic usage.

b) Manganese, Mn^{2+}

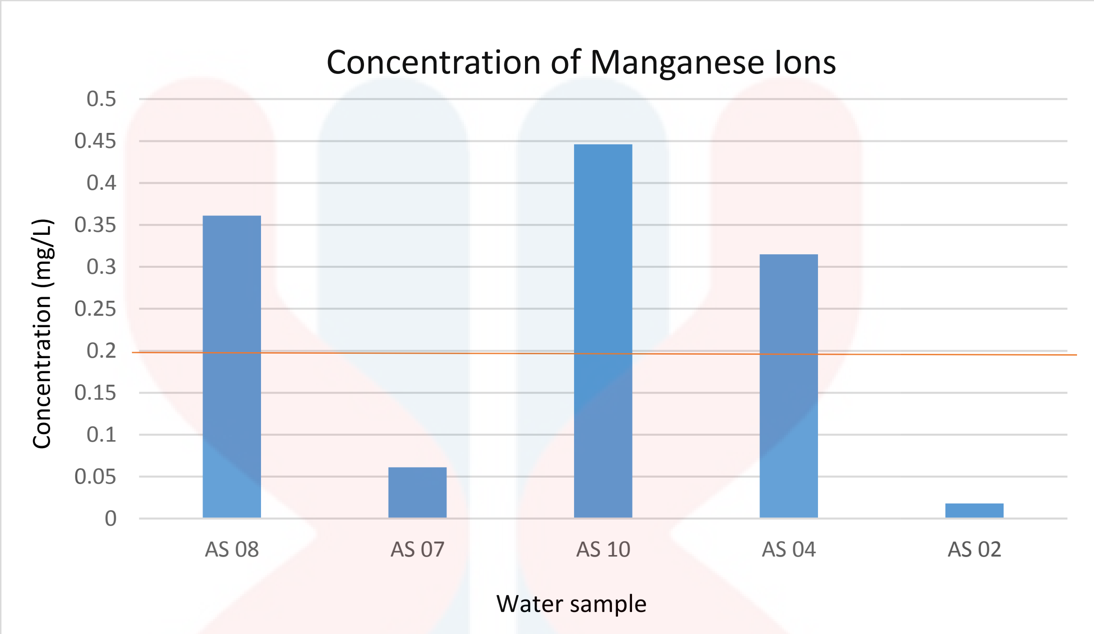


Figure 5.9: Manganese ion concentrations of water samples

The manganese ions concentrations in study area ranged from 0.018 mg/L to 0.446 mg/L. Samples AS 08, AS 10 and AS 04 display high manganese ion concentration which exceed the permissible limit of manganese ion value less than 0.2 mg/L except AS 07 and AS 02 according to the National Guidelines of Raw Water Quality Standard from MOH as shown in Figure 5.9. Thus, samples AS 08, AS 10 and AS 04 are not safe for domestic usage whereas samples AS 07 and AS 02 are safe for domestic usage.

c) Potassium, K^+

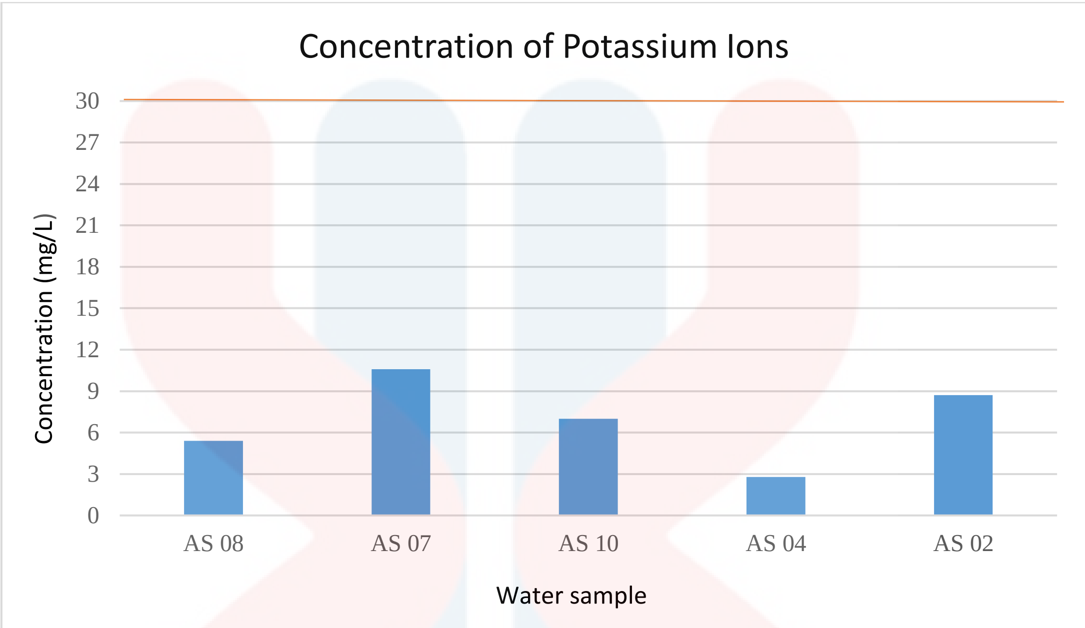


Figure 5.10: Potassium ion concentrations of water sample around study area

The potassium ions concentrations in study area ranged from 2.776 mg/L to 10.59 mg/L. AS 07 recorded the highest potassium ions concentration value whereas AS 04 recorded the lowest potassium ions concentration value. All the water samples passed the permissible limit of potassium concentration value less than 30 mg/L according to the National Guidelines of Raw Water Quality Standard from MOH as shown in Figure 5.10. Thus, all water samples are safe for domestic purposes.

d) Iron, Fe^{+}

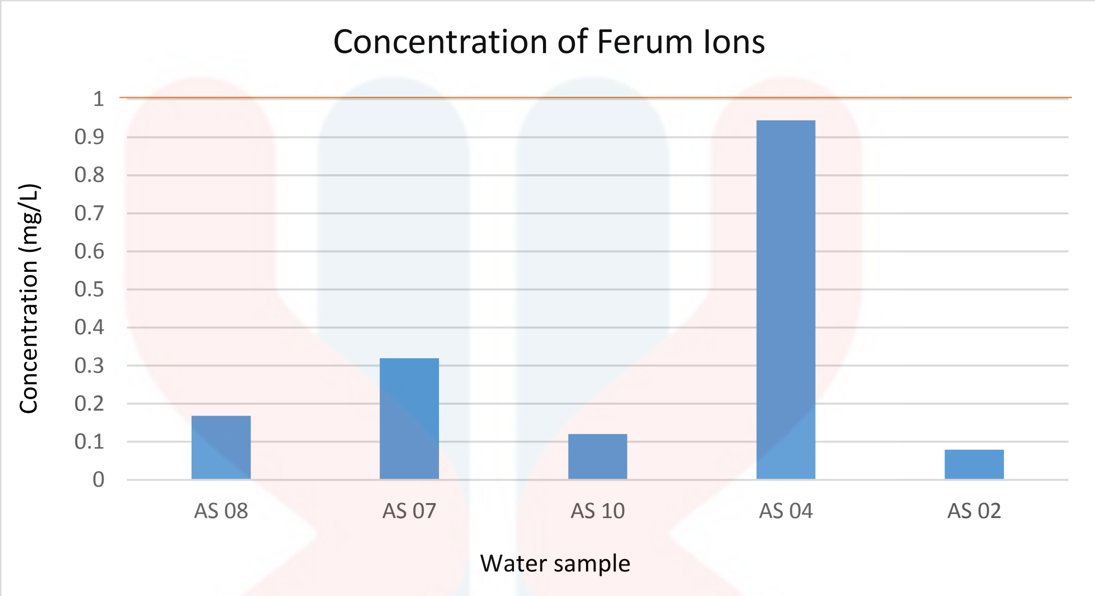


Figure 5.11: Ferum ion concentrations of water sample around study area

The ferum ions concentrations in study area ranged from 0.12 mg/L to 0.944 mg/L. AS 04 recorded the highest ferum ions concentration value whereas AS 02 recorded the lowest ferum ions concentration value. All the water samples passed the permissible limit of ferum concentration value less than 1.0 mg/L according to the National Guidelines of Raw Water Quality Standard from MOH as shown in Figure 5.11. Thus, all water samples are safe for domestic purposes.

e) **Copper, Cu^{2+}**

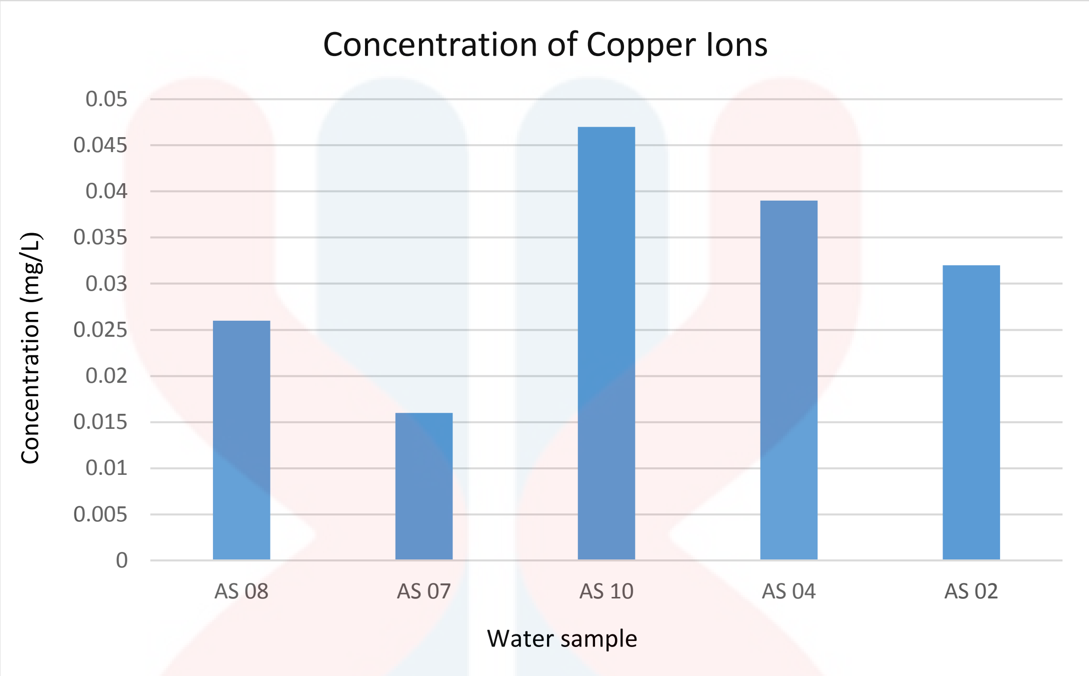


Figure 5.12: Copper ion concentration around study area

The copper ions concentrations in study area ranged from 0.016 mg/L to 0.047 mg/L. AS 10 recorded the highest copper ions concentration value whereas AS 07 recorded the lowest copper ions concentration value. All the water samples passed the permissible limit of copper concentration value less than 1.0 mg/L according to the National Guidelines of Raw Water Quality Standard from MOH as shown in Figure 5.12. Thus, all water samples are safe for domestic purposes.

f) Chloride, Cl^-

Table 5.4: Chloride ion concentration from water sample in study area

Sample	Location	mg/L
AS 08	Kg. Jambu	42.60
AS 07	Kg. Cabang 4	68.16
AS 10	Kg. Tukang Dollah	79.52
AS 04	Kg. Chicha	34.08
AS 02	Kg. Semut Api	79.52

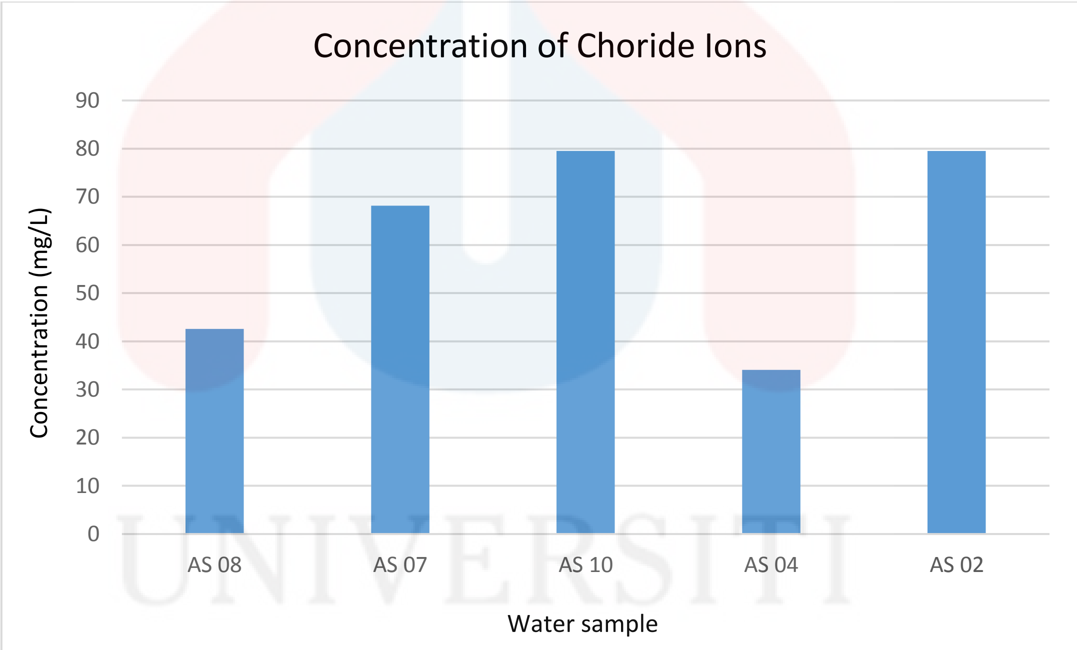


Figure 5.13: Concentration of chloride ions in study area

Presence of chloride ions are the one of the best indicators to detect seawater intrusion as the main component of salt water is $NaCl$. All the water samples passed the permissible limit of chloride concentration value less than 250 mg/L according to the National Guidelines of Raw Water Quality Standard from MOH as shown in Figure 5.13. Thus, all water samples are safe for domestic purposes.

5.3 Geophysical Analysis

The ERI method was used to identify the extent of seawater intrusion in the study area. A total of five survey lines were conducted but only 3 lines were successfully processed and the other two lines were corrupted. Thus, the lines conducted in the study area were Line 1, Line 2 and Line 3. Figure 5.12 shows the location of survey lines in the study area.

5.3.1 Location

The survey lines were chosen from nearest to the shoreline to furthest from the shoreline to identify the boundaries in where the saline water interface with groundwater. These lines were chosen appropriately according to the vastness of the area, its accessibility and the line must be perpendicular to the shoreline.

Table 5.5 shows the ERI survey line details which consists of the date, time, coordinate, and type of configuration, location and the survey distance from shore. Figure 5.14 shows the location of survey lines in study area.

Table 5.5: The ERI survey line

Date & time	Survey	Coordinate	Location	Distance from shore	Type of configuration
2/8/19 10:40 a.m.	Line 1	N 06° 11' 42.0" E 102° 16' 22.8"	Kg. Semut Api	0.51 km	Schlumberger array
2/8/19 7:00 p.m.	Line 2	N 06° 10' 30.0" E 102° 15' 18.0"	Kg. Tapai	3.48 km	Pole-dipole array
3/8/19 10:20 a.m.	Line 3	N 06° 09' 10.8" E 102° 14' 16.8"	Kg. Cina	6.60 km	Pole-dipole array

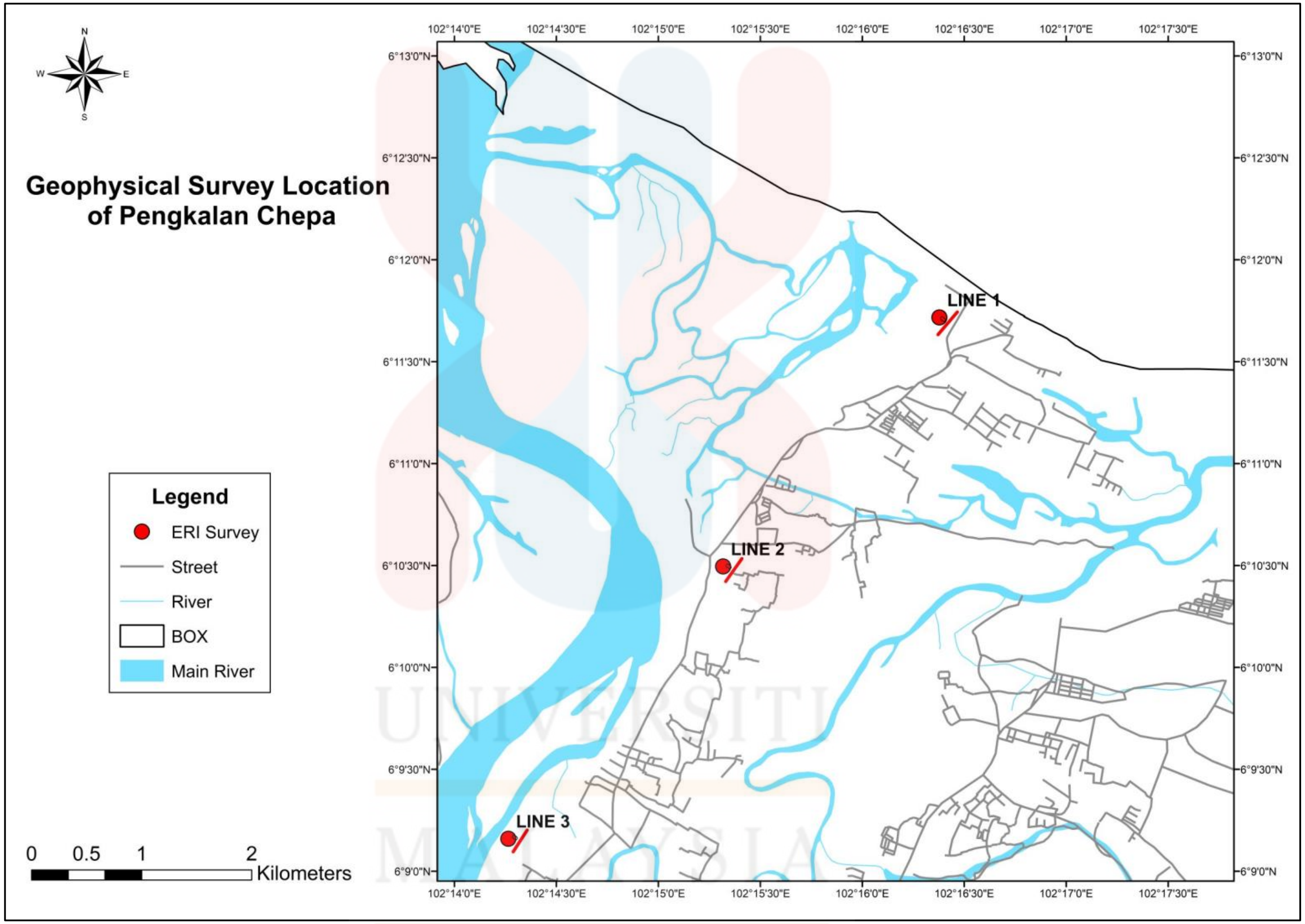


Figure 5.14: Location of survey lines in the study area

5.3.2 Survey line 1

Line 1 is located at Kg. Semut Api with coordinate of N 06° 11' 42.0", E 102° 16' 22.8" and elevation of 2 meters above sea level with a length of 200 metres. Line 1 is located about 0.51 km from the shoreline which is very near to shore. The selected configuration was Schlumberger array as the intrusion was predicted to enter freshwater aquifer at a shallow depth. The survey was conducted in the morning around 10:40 a.m. The soil condition was very dry and the weather was very hot. Figure 5.15 shows the setup survey of line 1.

Figure 5.15: Setup survey of line 1

Based on Figure 5.16, the range of values of line 1 shows from 9.82 to 12014 Ωm. Based on the standard resistivity value by Telford (1976), line 1 is showing seawater intrusion with 9.82 Ωm which is below than 20 Ωm.

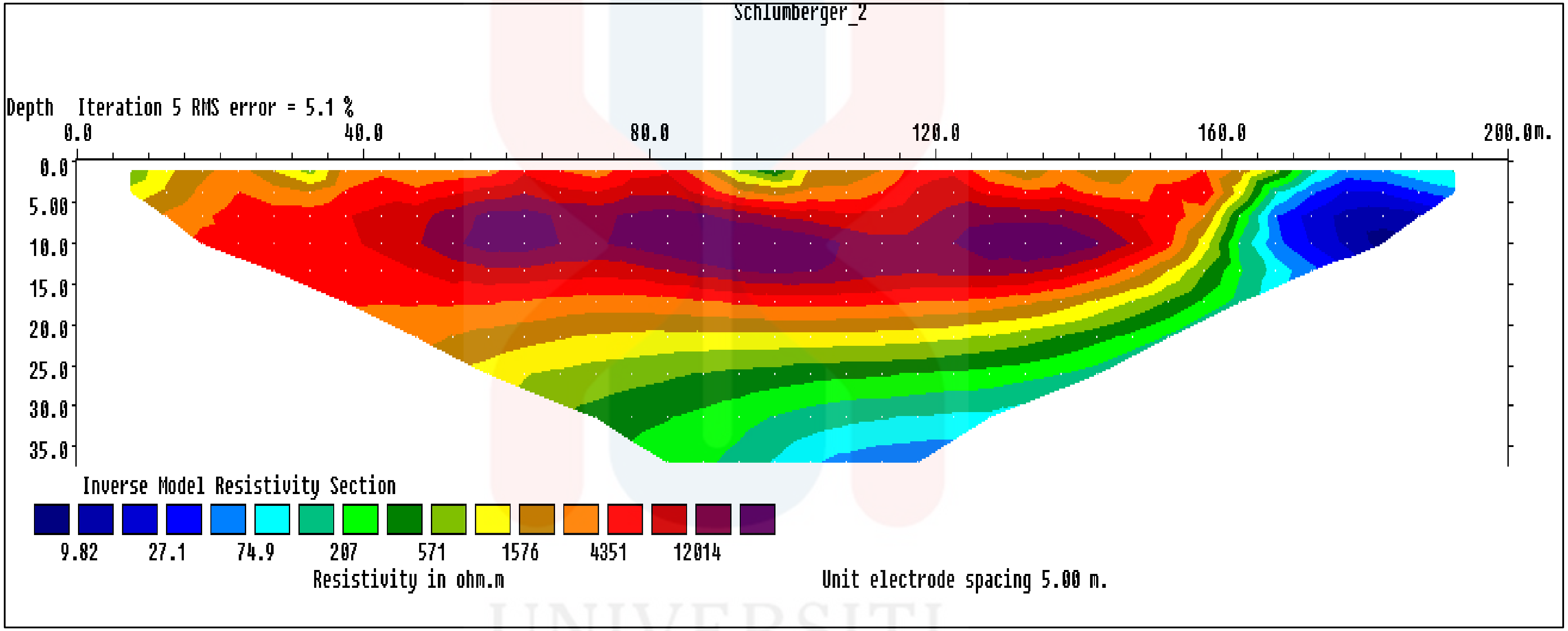


Figure 5.16: Inverse model resistivity section of line 1

5.3.2 Survey line 2

Line 2 is located at Kg. Tapai with coordinate of N 06° 10' 30.0" E 102° 15' 18.0" and elevation of 6 meters above sea level with a length of 200 metres. Line 1 is located about 3.48 km from the shoreline. The selected configuration was Pole-dipole array for more depth. The survey was conducted in the evening around 7:00 a.m. The soil condition was damp and the weather was cool. Figure 5.15 shows the setup survey of line 2.

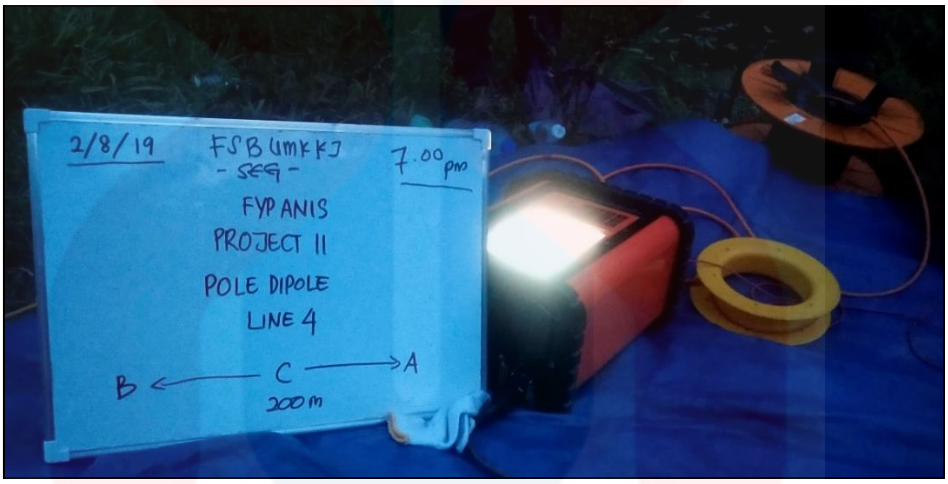


Figure 5.17: Setup survey of line 2

Based on the Figure 5.17, the total percentage of RMS error is 35.6% for resistivity although many bad datum have been eliminated. Minimum resistivity value for this survey line is 1.40 Ωm and the highest value is 3705 Ωm with the depth of 50 m. Based on Telford (1976), the resistivity value of this survey line indicates there is a presence of seawater intrusion in aquifers as the resistivity value for seawater is below 20 Ωm. Line 2 is situated 3.48 km from shore and the presence of saline water in this area shows that the groundwater aquifer already start to saline at the depth of 30 m.

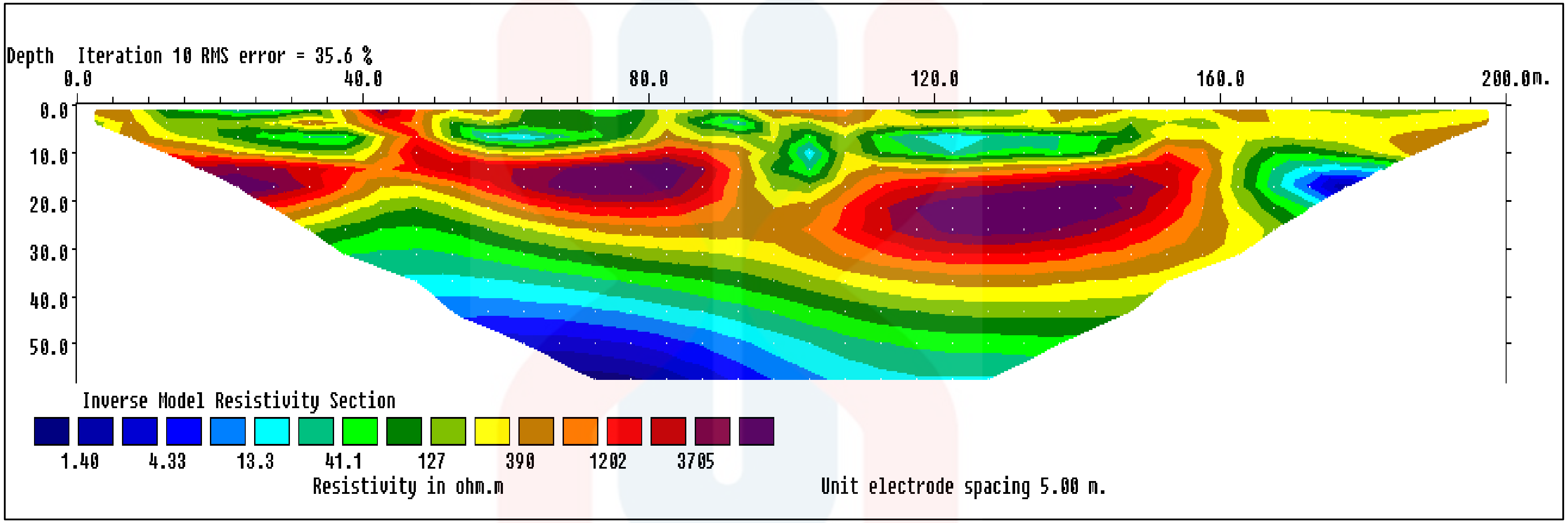


Figure 5.18: Inverse model resistivity section of line 2

.3.3 Survey line 3

Line 3 is located at Kg. Cina with coordinate of N 06° 09' 10.8" E 102° 14' 16.8" and elevation of 6 meters above sea level with a length of 200 metres. Line 3 is located about 6.60 km from the shoreline. The selected configuration was Pole-dipole array for more depth. The survey was conducted in the morning around 10:40 a.m. The soil condition was damp and the weather was cool. Figure 5.19 shows the setup survey of line 3.

Figure 5.19: Setup survey of line 3

Minimum resistivity value for this survey line is 0.114 Ωm and the highest value is 98.0 Ωm with the depth of 70 m. Based on Telford (1976), the resistivity value of this survey line indicates there is a presence of saline water as the resistivity value for saline water is below 20 Ωm. Line 3 is situated 6.60 km from shore and the presence of saline water in this area shows that the groundwater aquifer already start to saline at the depth of 10 to 20 m.

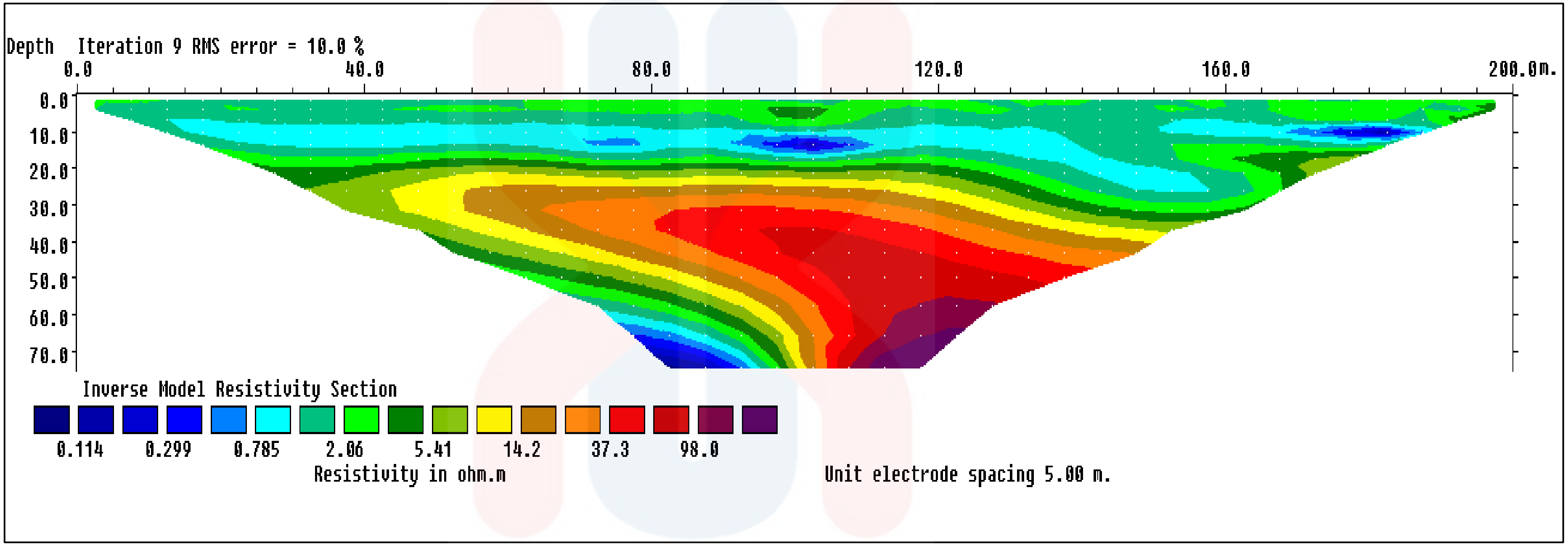


Figure 5.20: Inverse model resistivity section of line 3

CHAPTER 6

CONCLUSION & RECOMMENDATION

6.1 Conclusion

As conclusion, lithology in area of Gua Musang, Kelantan comprised of very highly weathered sedimentary and meta-sediment rocks such as mudstone, sandstone and quartzite with different phase of metamorphism as lamination and foliation structure were found on exposed outcrop. Meanwhile, a few groundwater samples are not safe and suitable for usage of all purposes in daily life as the data collected was compared to the Guidelines of Raw Water Quality Standard from the Ministry of Health of Malaysia. Based on the result obtained from Electrical Resistivity Imaging (ERI) survey, there is quite the distinct border in which the seawater and freshwater interface occurred at 2 to 3 kilometres from the shoreline

In conclusion, based on all the indicators, there was seawater that intrudes fresh groundwater aquifer within a few kilometres distance from the shoreline. This statement can be justified by the resistivity profile shown in Survey Line 2 and resistivity survey line 3 show a small amount salinity presence inside its shallow aquifer which can be supported by data collected from nearest groundwater well.

6.2 Recommendation

For groundwater well users that contained high concentrations of manganese ions and sodium, chloride and other related ions from saline water that intrudes groundwater aquifer that is above the allowable level, it is recommended that the water be treated before use whether it can affect health for domestic or drinking purposes as excess ions can be deteriorating for one's body.

Future research must be carried out again as this phenomenon are dynamic and must be regularly monitored. Groundwater demands will increase and groundwater over pumping will interrupt the coastal line balance between seawater and freshwater interface and contribute to the intrusion of seawater into aquifers. It is advisable for local authorities to control the abstraction of groundwater well to prevent from formation of cone of depression that may lead to seawater intrusion and subsidence due to over extraction done by consumers.

Based on the second indicator which the geochemical analysis is done on site and in laboratory, it is best to say that some of the location that extract groundwater aquifers especially near the shorelines must be monitored regularly by consumer and local governments in order to avoid over pumping or over extraction due to excessive groundwater usage that can cause the formation of depression cone. This will disrupt the freshwater – seawater interface beneath the water table that may contaminate the groundwater resources with hazardous trace elements that will pollute freshwater resources.

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