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Application of Geophysical Technique in Investigation of Groundwater Quality at Melaka Tengah, Malacca

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Abstract - *A study on 2D geo-electrical resistivity imaging at Melaka Tengah, Malacca was conducted to determine the potential groundwater zone. This investigation is needed to identify the quality of the groundwater, since the site is located in the coastal areas where groundwater influence tends to diminish due to intrusion of seawater. Two resistivity lines were proposed with length of 400m each by using Terrameter SAS 4000 and ES1064. Geo-electrical of electrical resistivity and induced polarization method with the Wenner-Schlumberger configuration were carried out. The Res2Dinv software would then render the 2D resistivity image through inversion method which provided detailed information of both the laterally and vertically geological structures based on their part. The electrical resistivity measured the resistance of the subsurface to the flow of electric current in units of ohm-meters and value of chargeability during the transient decay of the applied voltage in ms for induced polarization. Well data provided was very useful in direct determination of subsurface soil lithology. The result obtained showed an 84.7-meter subsurface depth for both areas which then reflected that the subsurface consisted of two different layers namely overburden (laterite, clay, and/or peat soil) with ranged 1 ohm.m – 10 ohm.m and 50 ohm.m – 500 ohm.m for schist formation. However, this area was considered to be brackish water area because of the low chargeability value of 0ms – 1ms especially in top soil layer and 5ms – 20ms for schist formation. Thus, this area was deemed not suitable for groundwater exploration due to the intrusion of salt water.* ***Copyright © 2016 Penerbit Akademia Baru - All rights reserved.***

Keyword: geo-electrical, electrical resistivity, induced polarization, brackish water

1.0 INTRODUCTION

Groundwater is the alternative source of drinking water and has become important especially for developing countries due to the increased in population and industrialization [1]. Demand for clean water has increased and available surface water is becoming inadequate and highly polluted [2]. However, in some places such as Mukim Keeling, Cheng, Ayer Molek and Cage, the groundwater is salty and brackish as a result of seawater intrusion. Thus, an investigation is needed to understand the present groundwater potential and quality to meet the demand [3]. The water sources in coastal areas are basically result in sea water intrusion [4]

Among all the geophysical methods, electrical technique is the most popular in groundwater exploration [5] and is widely used to identify zones of salt water contamination. Electrical resistivity can also be applied to determine the subsurface resistivity distribution and generate a range of resistivity values [6]. However, it is difficult to distinguish between formations of similar resistivity as it is difficult to discriminate between salt and freshwater. Combination of electrical resistivity and induced polarization methods can give a good result in mapping saline water intrusion because they act differently based on their part [7]. Difference of lithology composition and groundwater salinity can be distinguished by using induced polarization. Thus, by using two or more types of geophysical methods and with many assemblages of geophysical data available data interpretation can be enhanced. The main objective of this project is to determine the groundwater quality at Melaka Tengah, Malacca.

2.0 STUDY AREA

Malacca is on the Malay Peninsula's southwest coast with a surface area of 1650km^2 and is the third smallest state in Malaysia. Melaka has 81 sub-districts and three districts, namely Alor Gajah, Melaka Tengah and Jasin [8]. Temperature ranges between 30-35 °C during daytime and between 27-29 °C during night time. Figure below show the study area (Fig. 1).

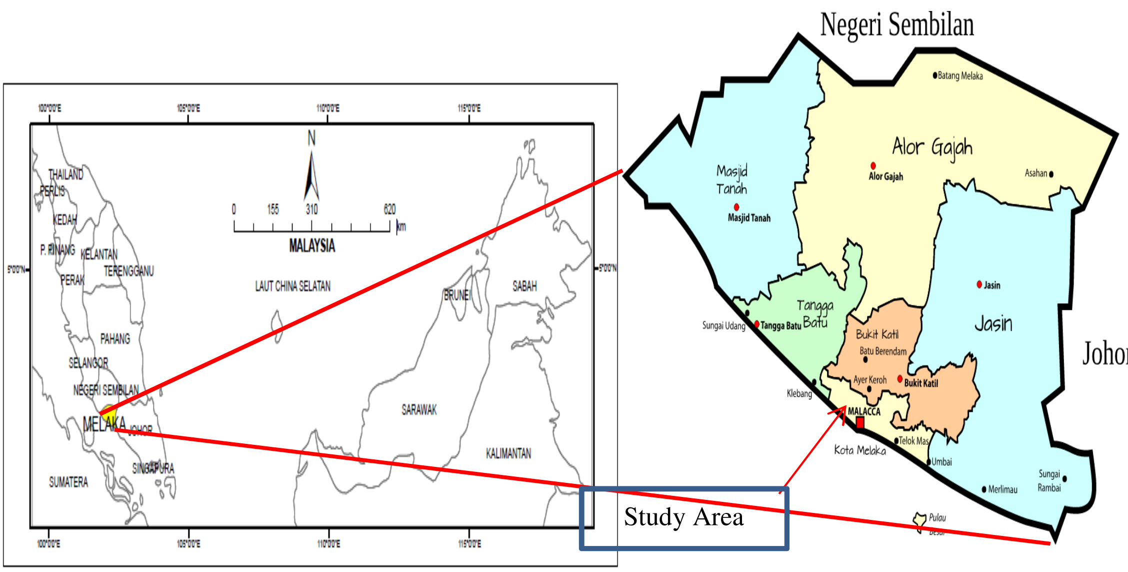

Figure 1: Location of the study area [9]

2.1 Geology of the Study Area

Malacca soil lithology can be divided into four groups (Fig. 2). Phyllite, schist and slate are found in the northern parts and in coastal areas. Shale, mudstone, phyllite, slate and hornfels are found in the central parts, in coastal areas and in smaller areas in the north. The north areas and smaller areas in the centre of the state contain sandstone and metasandstone. Most of

Malacca is dominated by phylitte, schist and slate. Second major consist of igneous acidic rock and granitoid. Schist is found in the central and southern parts of the state [8].

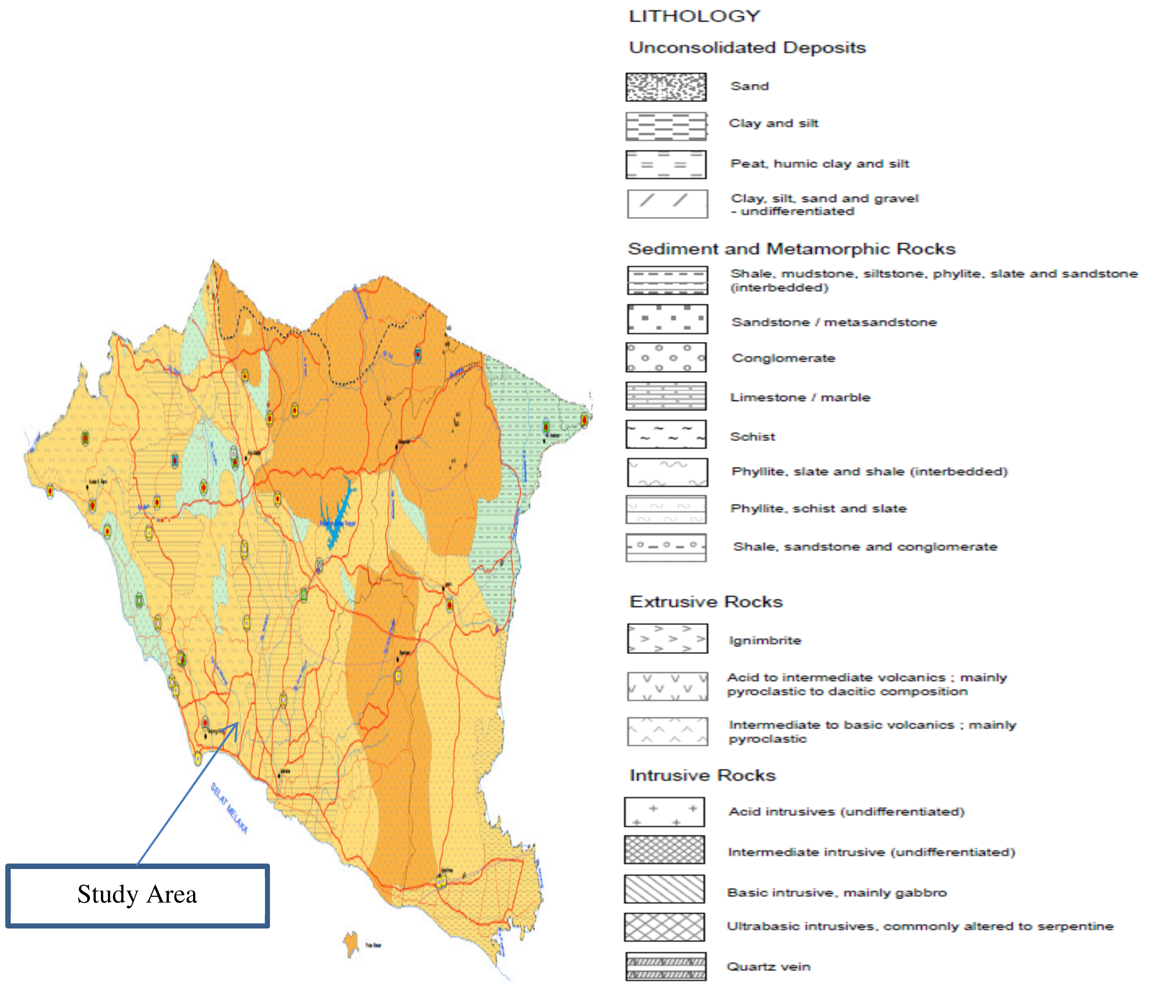

Figure 2: Hydrogeology of Malacca [10]

3.0 ELECTRICAL RESISTIVITY

The purpose of electrical surveying is to determine the subsurface resistivity distribution of lateral and vertical subsurface structures [11]. The measurement of electric potential difference can be obtained by introducing direct current into the ground by a pair of electric current electrodes [12]. Resistance can be determined from the measured of voltage (V) and current (I) [13]. The subsurface apparent resistivity will be plotted at one depth point for each potential electrode point in two dimensional images called pseudosections [14]. It is important to differentiate between apparent and true resistivity [15]. True resistivity is almost impossible to obtain because it can only be measured in ideal condition. Res2Dinv software helps to calculate numerous amounts of data by minimizing the difference between true and apparent resistivity by subdividing the subsurface into small rectangular cells. Thus, the closest resistivity value to the true resistivity will be obtained. The reference of electrical resistivity value for different geological materials and different types of water are shown in Table 1, Table 2 and Fig. 3.

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Table 1: Resistivity and conductivity value of selected rocks, soil and water [16, 17]

Material	Resistivity (Ω.m)
Igneous and Metamorphic Rocks	
Granite	$5x10^2 – 10^6$
Basalt	$10^3 – 10^6$
Schist	50-10,000
Slate	$6x10^2$ - $4x10^7$
Marble	10^2 - $2.5x10^8$
Quartzite	10^2 - $2x10^8$
Sedimentary Rocks	
Sandstone	8 - $4x10^3$
Shale	20 - $2x10^3$
Limestone	50 - $4x10^2$
Soils and Water	
Clay	1 – 100
Alluvium	10 – 800
Groundwater	10 – 100
Sea water	0.2
Chemicals	
Iron	$9.074x10^{-8}$
0.01 M Potassium chloride	0.708
0.01 M Sodium chloride	0.843
0.01 M acetic acid	6.13
Xylene	$6.998x10^{16}$

Table 2: Resistivity values of some types of waters [17]

Type of water	Resistivity (Ωm)
Precipitation	30 – 1000
Surface water, in areas of igneous rock	30 – 500
Surface water, in areas of sedimentary rock	10 – 100
Groundwater, in areas of igneous rock	30 – 150
Groundwater, in areas of sedimentary rock	> 1
Sea water	≈ 2
Drinking water (max salt content 0.25%)	> 1.8
Water for irrigation and stock watering (max salt content 0.25%)	> 0.65

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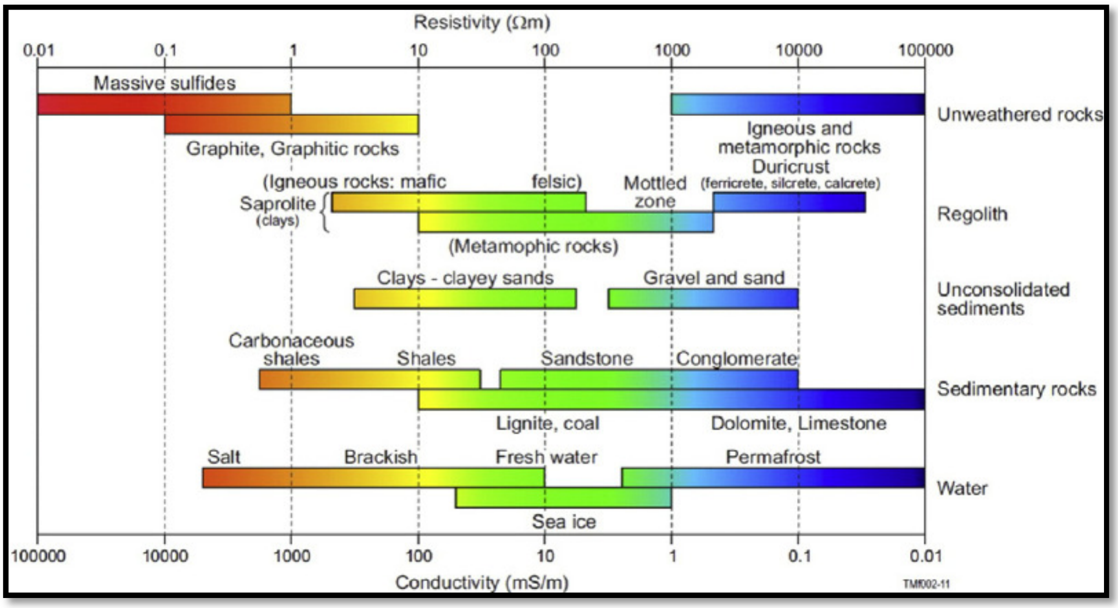

Figure 3: Typical range of resistivity for different earth materials [18]

4.0 INDUCED POLARIZATION

Induced polarization (IP) or chargeability is measured using a standard 4-electrode of electrical resistivity survey. The current is injected into the ground through the two current electrodes, while the voltage is measured between the two potential electrodes (Fig. 4).

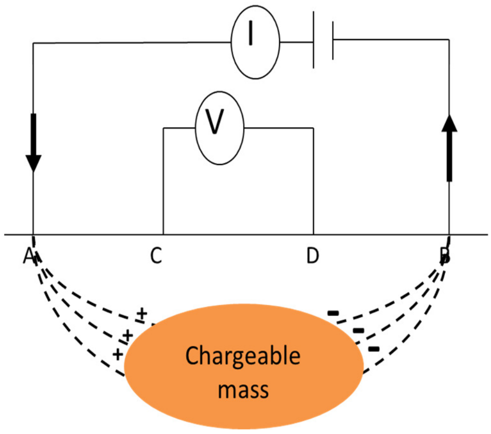

Figure 4: Induced polarization measurement [19]

Induced polarization (IP) imaging is a complementary technique to electrical resistivity imaging and is able to store electric charge (capacitance), analogous to a leaky capacitor of the subsurface. IP imaging measures how much energy is stored. The electric current that passes through subsurface causes the material to become polarized. Then, when current is turned off, the accumulated charges discharge, eventually returning to their original state. By measuring the rate of this decay it is possible to calculate the chargeability of the subsurface. Two materials that possess the same resistivity might possess contrasting chargeability. IP imaging can provide additional discrimination of subsurface materials. The rate of decay depends on

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the lithology of the rock, its pore geometry and hydrogeological properties favors. The induced polarization technique is primarily caused by electrode polarization and membrane polarization [20]. IP usage is increasingly used in detecting the contaminant in the ground. The chargeability of minerals, rocks and various materials is given below in Table 3 and Table 4.

Table 3: Chargeability of Minerals and Rocks [21]

Material	Chargeability (msec)
20% sulfide	2000 – 3000
8 – 20% sulfide	1000 – 2000
2 – 8% sulfide	500 – 1000
Volcanic tuffs	300 – 800
Sandstone, siltstone	100 – 500
Dense volcanic rocks	100 – 500
Shale	50 – 100
Granite, grandodiorite	10 – 50
Limestone, dolomite	10 – 20

Table 4: Chargeability of Various Materials [21]

Material	Chargeability (msec)
Groundwater	0
Alluvium	1 – 4
Gravels	3 – 9
Precambrian volcanics	8 – 20
Precambrian gneisses	6 – 30
Schists	5 – 20
Sandstones	3 – 12
Argillites	3 – 10
Quartzites	5 – 12

5.0 METHODOLOGY

5.1 Field Measurement

Electrical Resistivity Imaging method and Induced Polarization method with Wenner-Schlumberger configuration have been conducted in the field by using ABEM Terrameter SAS 4000. Switcher units were used to control the induction of current and potential readings from electrodes connected by multicore-cable along the survey line. Two surveys line 400 meter in length with inner and outer electrodes spacing of 5 meter and 10 meter were set up. In this system, 41 electrode numbers and jumpers were connected. Then, the data was interpreted and analyzed by using software Res2Dinv which can produce continuous images of the variation in the properties of the subsurface. The inversion model obtained using Res2Dinv software is then correlated with the borehole record which acts as geological reference. This will help in the making the interpretation of the inversion resistivity models obtained more reliable and effective. Refer Fig. 5 for the arrangement of electrodes for a resistivity of 4 cables imaging and the sequence of measurements used to build up a pseudosection for Wenner-Schlumberger array.

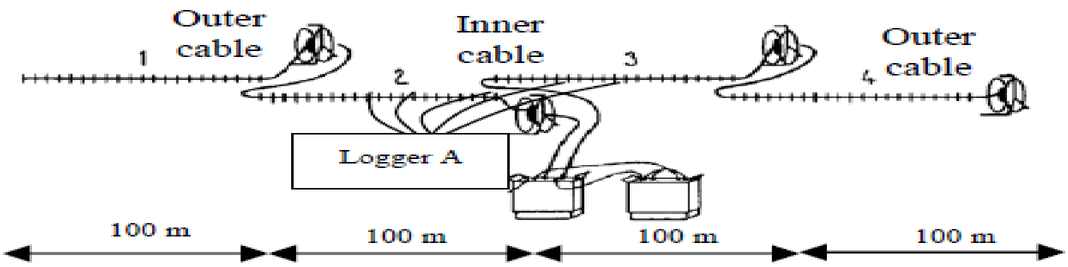

Figure 5: Measuring procedure in the field using 4 cables in a spread [22]

5.2 Wenner Schlumberger Array

Wenner-Schlumberger is a new generation technique which was created by integrating Wenner and Schlumberger arrays for resistivity imaging. The Schlumberger has two outer electrodes that are current electrodes, while inner two electrodes which serve as a receiver. The arrangement of this array is the same as Wenner array, C1, P1, P2 and C2 as shown in Fig. 6.

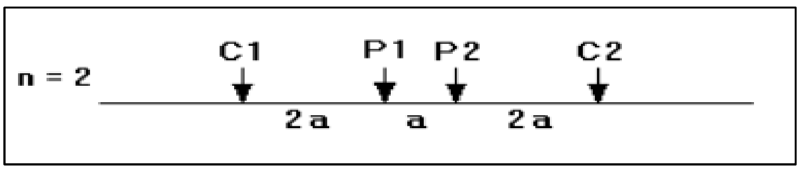

Figure 6: The arrangement of the array used in this project. **C** is current electrode and **P** is potential electrode and **a** is electrode spacing [23]

6.0 RESULTS AND DISCUSSION

Electrical resistivity is more focusing on the contrast of the resistivity values which is reflected by the geological structures. The data was process using Res2Dinv software, 2D profile from the reflection of the formations beneath the surface is shown below. From the 2D profile result, the maximum depth that can be achieved is 84.7 meters beneath ground surface and resistivity values obtained ranged from 1 to 500 Ωm. The result of the resistivity profile from this survey is shown in Fig. 7 and Fig. 8.

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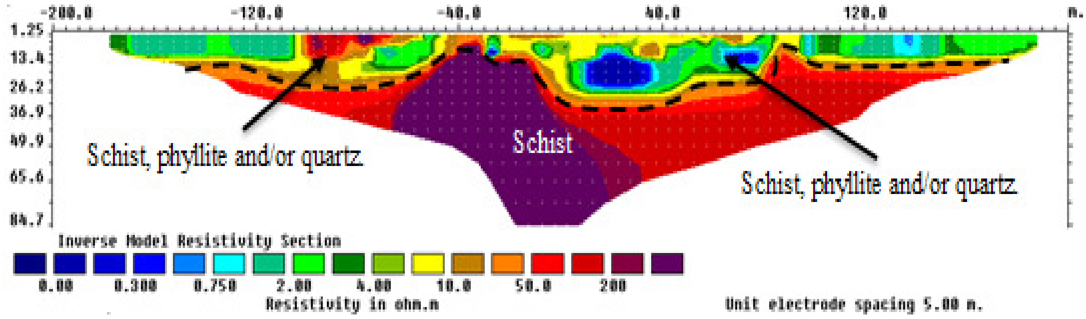

Figure 7: Resistivity Imaging Profile (Line 1)

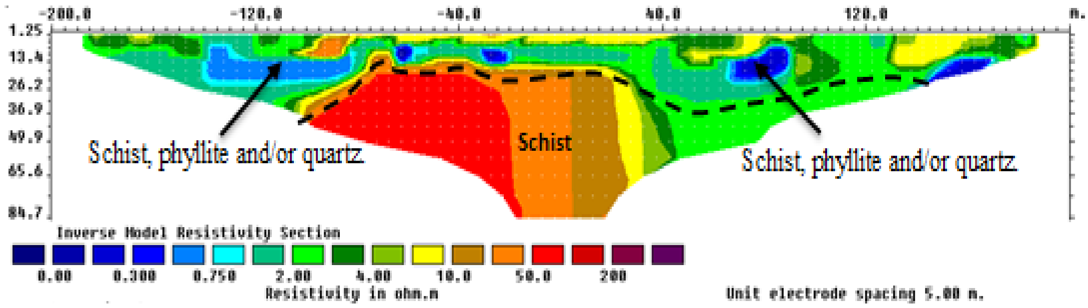

Figure 8: Resistivity Imaging Profile for (Line 2)

The study area can be determined to have two main soil layers which are overburdened at the top layer covered by meta-sediments such as schist, phyllite and/or quartz with ranged between 1 ohm.m – 10 ohm.m. Resistivity values for second soil layer were between 50 ohm.m – 500 ohm.m which is considered as schist formation. This was proven through the analysis of the hydrogeology characteristics and through the deep aquifer lithology analysis at Malacca [3]. The illustration of the deep aquifer geology is shown in Fig. 9 below. From the results, there was no presence of impermeable layer between the top and second layer. Therefore, the aquifer is determined to be unconfined aquifer.

It was found that both top soil layers for Fig. 10 and Fig. 11 may contain brackish water because it has low resistivity values that are overlapping with low chargeability value. The value of brackish water can be estimated between 0.1ohm.m – 4ohm.m for resistivity and chargeability between 0ms – 1ms for top soil. Since the aquifer is unconfined aquifer, there is probability that second soil layer may also contain brackish water. This can be proven with low chargeability of 5ms – 20ms within the schist formation. The groundwater quality within Cheng area was found to be salty and brackish as a result of seawater influence and hydro-geochemical processes [3]. The brackish water is illustrated with circle line as shown below.

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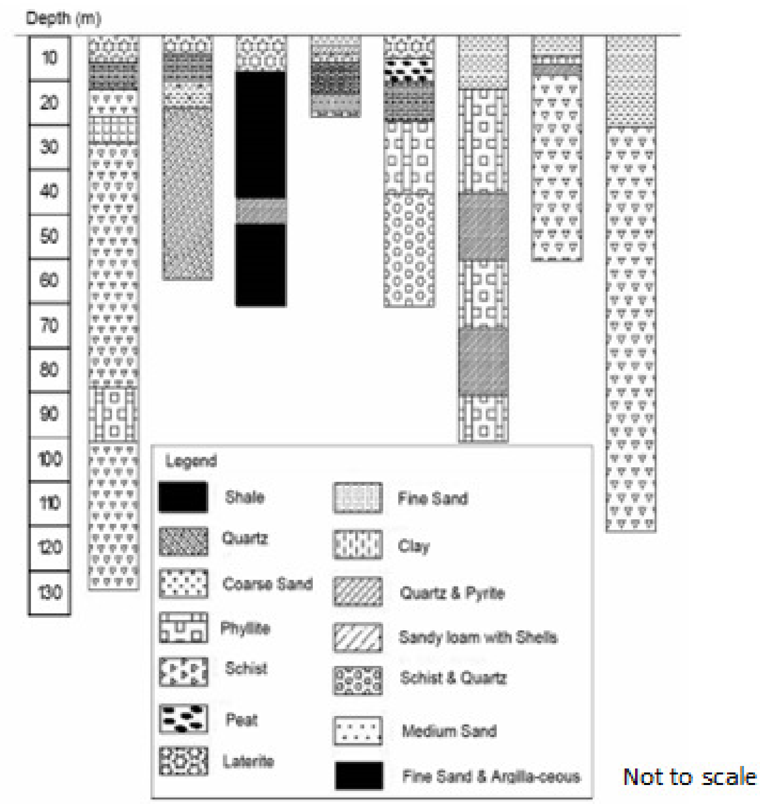

Figure 9: Typically, deep aquifer lithology at Malacca [3]

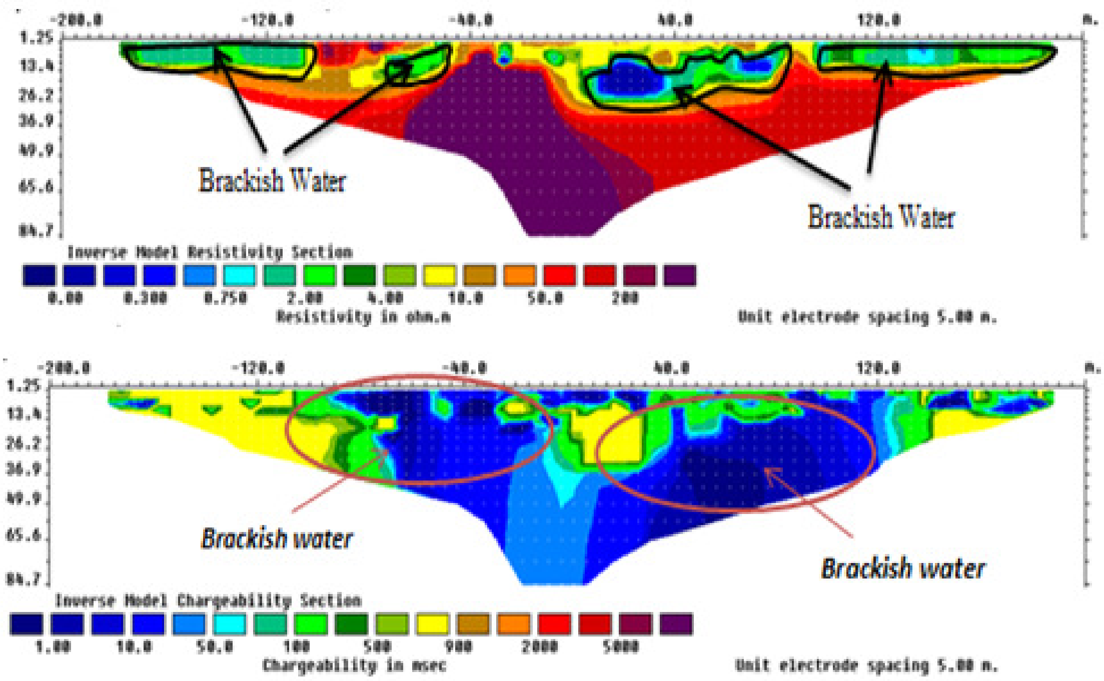

Figure 10: The illustration of brackish water zone in the study area (Line 1)

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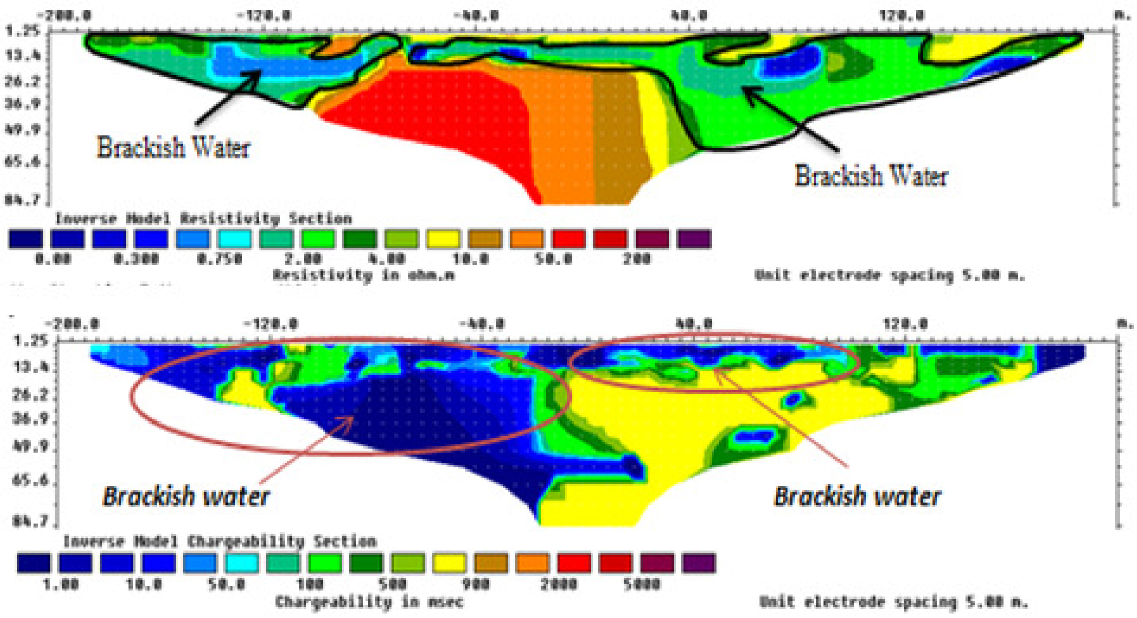

Figure 11: The illustration of brackish water zone in the study area (Line 2)

7.0 CONCLUSION

Field electrical resistivity and induced method have successfully been used to identify the groundwater quality of the study area. It was concluded that the study area consisted of two different layers namely overburdened and schist formation. However, the overburdened soil layer may contain brackish water. There is high probability that the second layer may contain brackish water since the aquifer is unconfined aquifer. Low resistivity value that is overlapping with low chargeability value of the subsurface is influence to be brackish water.

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