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Groundwater potential assessment using 2-D resistivity method in Kluang, Johor (Malaysia)

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Abstract: Sources of clean water are decreasing due to rapid usage, contaminated surface waters, pollution and dry season. The dependence on the existing water source is not enough to fulfil the increasing demand of population in Malaysia. In order to overcome the problem, groundwater source is the most suitable alternative. 2-D resistivity method was carried out in a granitic area of Kluang, Johor to delineate and locate groundwater resource. 5 survey lines were conducted by using ABEM SAS4000 terrameter and electrode selector which were connected to 41 electrodes through lund cables. Pole-dipole array was chosen in this study for deeper penetration. Collected data were processed by using RES2DINV software to produce inversion model which was then exported to Surfer8 software for visualisation and interpretation. The result shows that most of the study area consist of granite with different level of fracturing. Unconfined aquifer was found at depths of 0 to 50 m. Confined aquifers can be seen at two different zones. They exhibit same properties at three parallel lines, R1-R3 and show continuity between them. It is predicted that the aquifers flow in the southwest to northeast direction. The hard rock aquifers are highly recommended to be drilled as they contain a large amount of fresh water for further usage.

Keywords: Groundwater, 2-D resistivity, granite, confined aquifer

INTRODUCTION

Water is an important element in life because it is used on a daily basis, including industries and agricultures who utilize water in large amount. A growing population has increased clean water demand. The existing clean water sources which mostly originates from surface water is decreasing due to unplanned waste system which has led to pollution of rivers, streams and lakes. During the dry seasons, the amount of rainfall is reduced, simultaneously reducing the amount of water accumulated. Hence, a need for a new water source arises.

Groundwater poses as an alternative in fulfilling the urgent water demands as it is safe from pollution and of high quality water (Anomohanran, 2015). Groundwater exploration in other developed countries are very common but less conventional in Malaysia due to high dependence on surface water. Groundwater in the subsurface is present in either unconfined or confined aquifers. Aquifers are saturated zones of water filling pore spaces, fractures and cracks in the subsurface.

Drilling wells into an unconfined aquifer creates problems due to over pumping of the aquifer where the withdrawing rate is faster than the rate of water recharging. This leads to declination of existing water table and groundwater quantity. Empty pore spaces due to absence of water may cause land subsidence to occur (Changming *et al*., 2001). Aquifers near the coastal areas are inclined towards seawater intrusion because of the hydraulic connection of ground and sea waters (Al-Naeem, 2014). This intrusion causes the water from the aquifer to be unsuitable for drinking purpose. Unconfined aquifer is also susceptible to pollution problems as it is connected to surface water. Contaminated water bodies that seep through the soils will carry impurities into the subsurface, subsequently polluting the groundwater. These problems must be overcome to improve water management in this country. Hence, confined aquifer is an imperative solution for clean water resource as the water is safe from pollution and is unconnected to potentially contaminated surface water (Smith *et al*., 2013). When a well is drilled into a confined aquifer, the water will automatically flow upward under influence of high pressure of the subsurface. Hence, no pump is needed thus saving expenses (Encyclopedia Britannica, 2015; Lutgens *et al*., 2015). The deep aquifer is also unaffected by seasonal changes, making it vital for clean water source of all time.

Groundwater specifically confined aquifer can be investigated by using common geophysical and geotechnical techniques such as resistivity, seismic refraction, vertical electrical sounding (VES), induced polarization (IP), GIS, remote sensing, self-potential, gravity, ground penetrating radar (GPR) and boring. The most qualified way in delineating groundwater potential is electrical resistivity method because it is economical and effective (Anomohanran, 2013). This technique is able to map resistivity distribution of the subsurface, estimate aquifer properties and classify resistivity of different lithologies effectively (Sirhan *et al*., 2011; Majumdar & Das, 2011; Ewusi *et al.,* 2009). The objective of this study is to predict groundwater potential in Kluang, specifically confined aquifer with correlation to the geology of the area and generate useful information that can be used for groundwater exploration in the future.

STUDY AREA

The study took place in Kluang, the central district of Johor, Malaysia. It is located at Utm coordinate of 2.076° N, 103.374° E, about 8 km from the nearest main town, Bandar Kluang (Figure 1). This study covered 200,000 m^2 area. Geomorphologically, this area is surrounded by palm oil plantations where some parts have been cleared. Industrial factories and main road can also be found nearby. The study area is elevated about 40 m to 70 m from sea level in the northwest towards southeast direction. The geology of Kluang consists of sedimentary rocks which come from the Semberong Ridge of Jurassic to Cretaceous age. The rocks are dominated by mudstone, siltstone, sandstone and partly tuffaceous (Said *et al*., 2003). The study area however is located within undifferentiated acid intrusive region close to the border of the sedimentary formation, as shown in Figure 2. This site was chosen for study of groundwater occurrence in a granite setting which is expected to take place through discrete fractures that act as a secondary porosity (Misstear *et al.*, 2017). The topsoil is dominated by clay and sand as observed in the vicinity.

METHODOLOGY

A total of five survey lines were successfully conducted in the study site. Three of the lines were designed parallel to each other in a northwest-southeast orientation with a gap of about 80 m between them while the other two lines cut across them perpendicularly to cover the area as much as possible within a considerable period. R1 – R3 were conducted by implementing the roll-along method (Dahlin, 2001). R1 survey line consists of 3 spreads of 400 m length, overlapped for every 200 m, making the total length 800 m and it is the same for R3. While R2 consists of 2 overlapped spreads. The lines were designed to observe any significant changes between them and predict the groundwater flows. The study was done by employing 41 electrodes that were planted firmly on the ground to ensure good quality data acquisition of the subsurface true resistivity (Soupios *et al*., 2007). The electrodes were connected to electrode selector and ABEM SAS4000 terrameter through lund cables in straight lines with a constant spacing of 5 m. Pole-dipole electrode arrangement was chosen in this survey because it can penetrate deeper compared to other arrays, which is useful for mapping subsurface at great depth for groundwater exploration (Loke, 1999). The collected data were processed using RES2DINV to produce true resistivity subsurface images. Then, the result was exported to Surfer8 software to produce contour maps for a better presentation and a clearer perspective of the subsurface. Table 1 provides a standard resistivity value of different types of soils and rocks for reference.

Figure 1: Location of study area showing electrical resistivity lines (Google Earth, 2017).

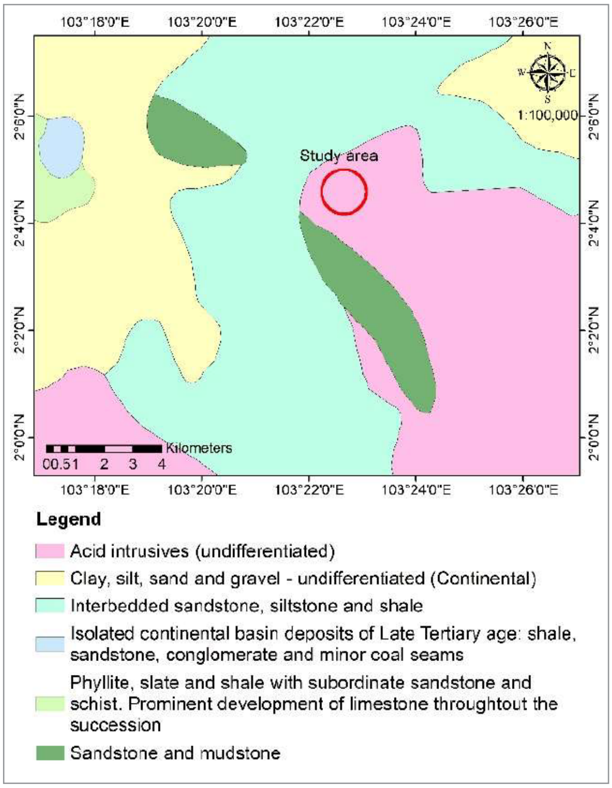

Figure 2: Regional geology map of Kluang (Mineral & Geoscience Department Malaysia, 1985).

Table 1: Resistivity values of common rocks and materials (Nicaise *et al.*, 2012).

Material	Resistivity (Ωm)
Dry sand	1000 – 10,000
Sand saturated with fresh water	50 – 500
Sand saturated with salt water	0.5 – 5
Clay	2 – 20
Silty sand	10 – 50
Sandstone	50 – 1000
Limestone	50 – 4000
Granite, basalt	1000 – 10,000

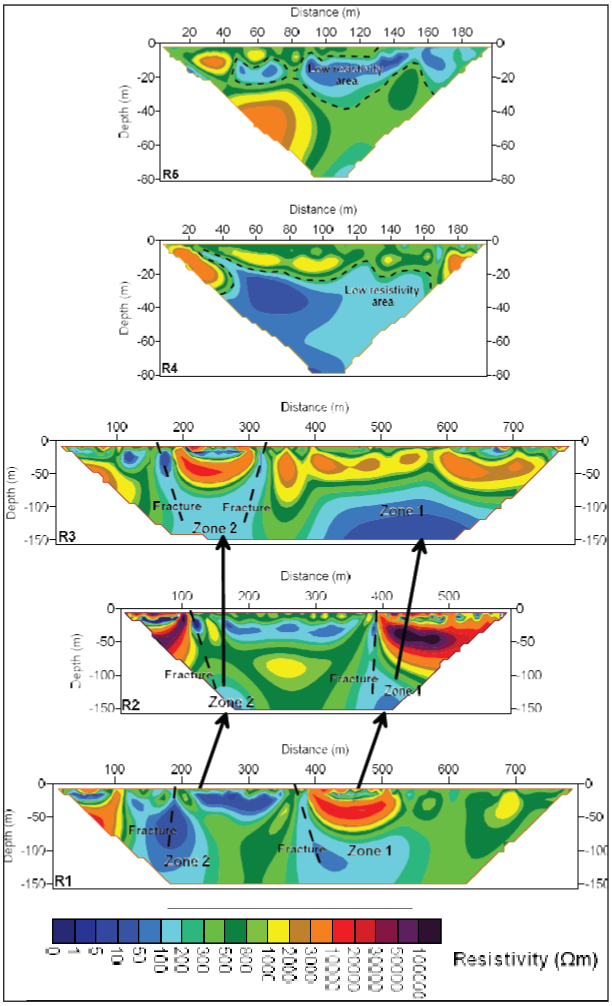

Figure 3: 2-D resistivity result of R1-R3 in Kluang.

RESULTS AND DISCUSSION

The interpretation of the results is the most crucial part to understand the subsurface. The processed data were correlated with some common rocks and minerals values to map the subsurface. However, these values might differ depending on the degree of subsurface disturbances or subsurface intermixture. For example, granitic rocks have a very high resistivity value which is above 5000 Ωm, but if many fractures are present in the rock and it is filled with water, the measured resistivity value will appear to be lower than the initial value (Loke, 1999).

Figure 3 shows the 2-D resistivity inversion of R1–R5. R1-R3 comprise of 400 m spreads, the maximum penetration depth obtained is about 160 m. The overall results show a large variation in resistivity values which indicate that the soils in the study area is not homogenous. Resistivity model of R1 shows that the subsurface is largely made up of granite. The top soil is made up of clay and alluvium materials. Granite with high resistivity values can be seen at distance 0 – 100 m and 400 – 530 m, both at depth of 0 – 100 m with resistivity value of 3000 – 20000 Ωm. A small and low resistivity area (0 – 100 Ωm) can be seen at 200 – 350 m with depth up to 50 m, most likely to be unconfined aquifer as it is shallow. The obtained values are in accordance with values reported by Nazaruddin *et al.* (2016). 'Blue zones' existed on this line at distance 100 – 250 m and 350 – 550 m respectively, indicated by resistivity value of 50 – 200 Ωm. These areas are distinguished as heavily fractured granite retaining waters that filled up the tiny gaps and joints inside the hard rock.

Resistivity profile R2 indicates that the topsoil composes of clay. The layer is underlain by hard rock granite with a large range of resistivity values (>3000 Ωm) near the starting point from 0 – 100 m and from 400 m towards the end of the line. The rock is dry, enabling it to retain its properties. At the center, low resistivity values can be seen at around distance of 150 – 370 m at 20 – 50 m depth, indicating the shallow aquifer. Below the aquifer is a zone dominated by weathered granite with resistivity value of 300 – 1000 Ωm. The lowest part of this line is suspected to be confined aquifer at two different distances which are 150 – 200 m and 350 – 450 m respectively. The areas are denoted by vertical and sub-vertical fractures which are favorable for groundwater movement (Sukhija *et al.*, 2006). Most parts of R3 is made up of alluvium and clay underlain by weathered granite except at the distance of 200 – 300 m of this line, where an oval-shaped hard rock granite exist. At the bottom, two zones of confined aquifer can be seen, consistent with R1 an R2 lines.

The resistivity profiles R5 and R4 compliments the first 3 lines. Due to some limitations and accessibility, both lines can only be conducted for 200 m and reached a limited depth of 80 m (Cassiani *et al.*, 2006). The 70 m distance of R5 crossed with 30 m distance of R2 showed a low resistivity zone. Similar subsurface features can be seen at the intersection between R5 at 140 m and R3 at 50 m. R4 model crossed R2 and R3 at 300 m, showing low resistivity zones at both lines and is consistent with the unconfined aquifer on R2. From the overall results, confined aquifer can be seen at 2 different zones which flows through lines R1 to R3. Gunung Lambak hills that is located 6 km from the study area in the southwest

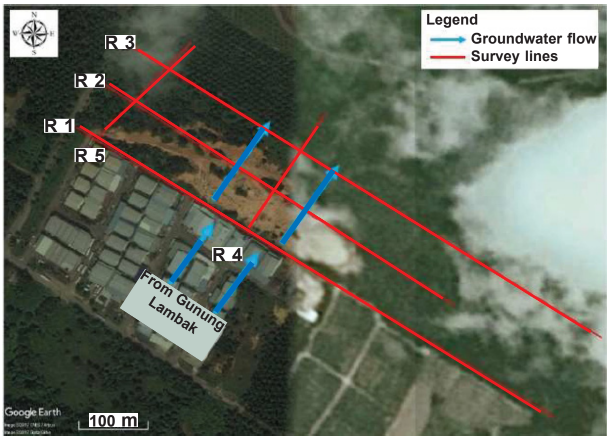

Figure 4: Predicted groundwater flow.

Table 2: Generalized resistivity values in Kluang study area.

Lithology	Resistivity (Ωm)
Granite	>3000
Weathered granite	300 – 1000
Saturated fractured granite	50 – 200
Unconfined aquifer	0 – 100

direction is suspected to be the recharge area for the confined aquifer. Hence, the water movement inside the aquifer is predicted to flow from R1 to R3 (Figure 4). The hard rock aquifer is highly recommended to be drilled because they contain a large amount of fresh water that can be extracted for further usage. The overall resistivity results are classified in Table 2.

CONCLUSION

The 2-D resistivity method carried out in this study was able to locate a few potential groundwater zones including confined and unconfined aquifers in a hard rock granitic area. Both aquifers have low resistivity values due to the presence of fresh water. From the inversion model, 2 potential zones of confined aquifer can be seen flowing in a southwest to northeast direction as a sustainable potential reservoir. This survey has successfully developed an initial network of information that is essential for future water exploration in this study area on a regional scale.

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