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DEVELOPMENT OF 3D MODEL VIEW OF POTENTIAL GROUNDWATER AQUIFER FOR IRRIGATION USING GEOPHYSICAL TECHNIQUE

Fathin Ayuni Azizan[a*], Mohamed Azwan Mohamed Zawawi[b], Ahmad Fikri Abdullah[b]

[a]School of Bioprocess Engineering, Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia
[b]Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

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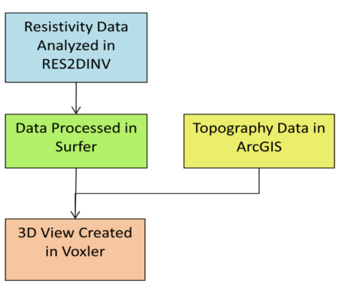
*Corresponding author
fathin.azizan@gmail.com

Graphical abstract



Abstract

A 2D surface electrical resistivity is one of non-destructive methods to investigate groundwater. In this study, 2D resistivity method was used to produce subsurface imaging profiles which are known as ERT (Electrical Resistivity Tomography) at Block C, Sawah Sempadan, Tanjung Karang, Selangor. These ERT profiles were then used to create 3D model view of potential aquifer at the study area. Overall, there were 3 ERT profiles of 1600m for major survey lines and 6 ERT profiles of 400m for minor lines. ERT profiles were then compared to lithology log from nearby tube wells of same geological formation in order to locate potential aquifer location in these profiles. Results show that there were 7 locations of identified potential aquifer in this study area. Later, the resistivity data were added with longitude and latitude data before imported into Voxler to achieve the objective of the study. The 3D model view of skeleton shape was productively built in Voxler as it visibly illustrates the whole subsurface profiles of study area. Locations of potential aquifers were identified in this 3D model view to show the exact location and depth of each potential aquifer.

Keywords: 2D resistivity, 3D model view, Electrical Tomography Results (ERT), groundwater, irrigation

1.0 INTRODUCTION

Surface water is a major resource in Malaysia including for irrigation purpose. This resource is now facing huge problems such as drought and pollution. Hence surface water becomes limited in quantity [1]. Therefore many researchers have urged to utilize groundwater as an alternative resource to solve this problem [2]. Due to an increase of cropped area and population, the need of alternative water resources is increasingly crucial [3, 4].

In China and many other countries, farmers have already exploited this water resource to offset droughts and shortfalls in surface water irrigation supplies [5]. Therefore, the exploitation of groundwater for irrigation has been successfully proven.

Groundwater in Malaysia is an important resource that is yet to be exploited on a bigger scale to meet the increasing demand for various uses and solve the water shortage problem [6, 7]. However, the use of groundwater as source of irrigation has not been widely practised in Malaysia.

Water shortage problem in Selangor Malaysia is becoming more common either for daily uses or for agricultural purpose. The Sawah Sempadan rice area also faces limitation in surface water supply although the irrigation supply system is well developed. The efficiency of water distribution system for this area is only 67% [8]. Many canals built in this area have encountered some damage and leakage, with sedimentation also formed at the bottom of the canals.

Other than the problem stated above, the quantity of the water in main canal also varies from time to time depending on the seasons. This is obviously affected by the amount of water flowing onto the last receiver, the paddy plots. The water depth in paddy plots in this study area [9] shows that the actual water depth in the paddy plot did not reach the recommended required water level [10].

In addition, the results revealed that, a high level of water in the paddy plot yield a high amount of rice harvested in that research season. Researchers have found that low yield of rice produced is due to the water stress which means less of water supply during planting [11].

In order to solve this problem, the study of groundwater as an alternative source for irrigation purpose is urgently needed. With the aim of managing the water resource, a 3D model that captures the whole of the study area should be developed in order to locate potential groundwater. A 3D model was chosen as it presents a real site of subsurface view.

The main objective of this study was to create a 3D model view of potential aquifer at Block C, Sawah Sempadan. The 3D model view would be built by using 2D ERT (Electrical Resistivity Tomography) profiles as geophysical technique of 2D surface electrical resistivity was applied throughout the study.

2.0 EXPERIMENTAL DESIGN

Block C, Sawah Sempadan, Tanjung Karang was chosen as the study area as in Figure 1. The area is marked by the red circle and located at longitudes 101° 05" E and latitude 3° 35" N.

Figure 1 Map of Tanjung Karang, Kuala Selangor

The irrigation scheme controlled by the Integrated Agricultural Development Area Barat Laut Selangor has eight compartments. One of it is Sawah Sempadan Irrigation scheme.

This scheme has 24 blocks namely block A to X. The survey was carried out at Block C. Figure 2 shows the location of Block C in Sawah Sempadan Irrigation Scheme. Block C contains 118 paddy plots with each plot's dimension of 200 m length with 60 m width.

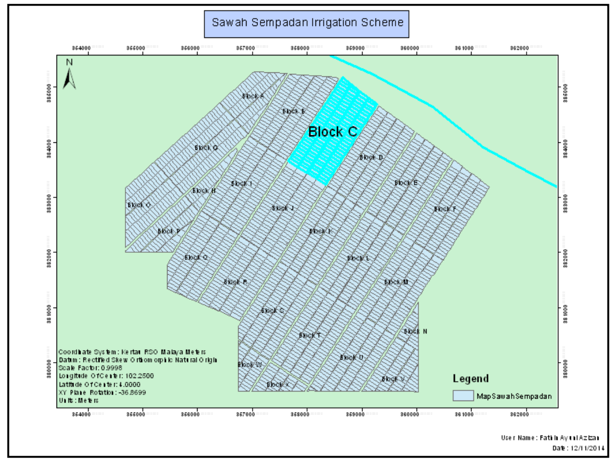


Figure 2 Location of Block C at Sawah Sempadan Irrigation Scheme

As marked in the Hydrogeological Map of Selangor and Kuala Lumpur Federal Territory (2008), the potential aquifer in the study area is categorised as a freshwater type and it is being rated as medium generalised aquifer potential [12].

While based on Geological Map of Peninsular Malaysia, 8th Edition, 1985 this study area is an unconsolidated deposit which composes of four elements [13]. The elements are clay, silt, sand and peat with minor gravel of marine type.

2.1 Resistivity Survey

A 2D surface electrical resistivity was carried out throughout the study area. The array configuration of Wenner-Schlumberger with 5m electrode spacing was selected to apply as it is moderately sensitive to horizontal and vertical layer. A set of ABEM Terrameter SAS 4000 were used as shown in Figure 3.

Figure 3 Equipment used in 2D resistivity survey

The survey plan came up by proposing major and minor survey lines since the study area covers a total of 145 ha of paddy field. There were 3 major lines and 6 minor lines.

Each major and minor survey lines have length of approximately 1600 m and 400 m respectively. The major lines were named alphabetically; Major Line A, B and C while minor lines were named numerically; Minor Line 1, 2,3,4,5 and 6.

The red lines indicate major lines A to C while blue lines are minor lines 1 to 6 as projected in Figure 4.

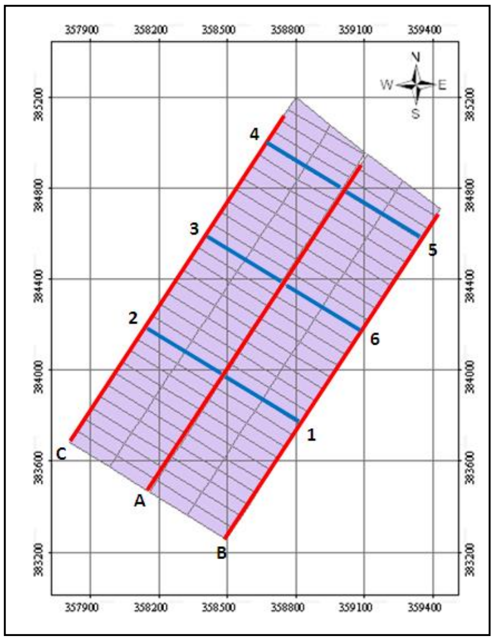


Figure 4 Major (red lines) and minor (blue lines) survey lines at Block C

All field data were collected and stored automatically in ABEM Terrameter SAS 4000. Then resistivity survey line data was analysed in RES2DINV software to result an electrical resistivity tomography (ERT). Each ERT result gave the deepest depth of more or less 80 metres from the ground surface.

2.2 Geological Log

Two resistivity surveys were conducted at two existing borehole logging locations. The tube well locations are at Block B and Block F, Sawah Sempadan Irrigation Scheme. These tube wells are located in the same or identical geological formation with the study area. Both tube wells log are owned by Sime Darby Sdn Bhd.

Comparisons between ERT profiles at these tube wells to their lithology were made. This practice was done to come up with resistivity value reading for existing soil type at the study area in verifying the potential aquifer.

2.3 3D Model View

In creating 3D model view, the raw data of resistivity were first analyzed in RES2DINV software before being processed in SURFER. The supportive data of topography were also collected by using Trimble RTK GPS set. The topography data were plotted in ArcGIS to interpolate the latitude and longitude data of specific x-location of 2D ERT profiles.

Next, both resistivity and topography data were combined before creating a 3D model view of potential aquifer in VOXLER software. This step was taken to ensure that each resistivity data was attached to its precise easting and northing value. Figure 5 shows the stage process as described.

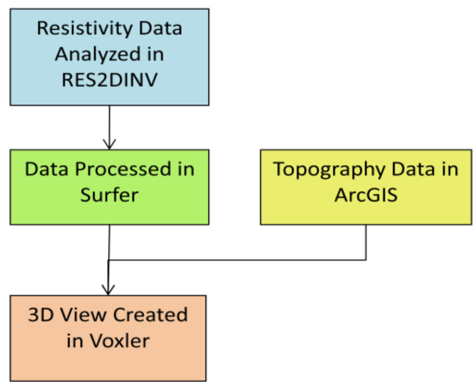


Figure 5 Stage process of creating 3D model view

A 3D model view data in skeleton shape was preferred because geological data are hardly guesstimated by any forecast or projection.

3.0 RESULTS AND DISCUSSION

3.1 Resistivity Results

In order to uniformly represent all ERT profile of major and minor lines, specific resistivity contour scale was set. Figure 6 and 7 show 2D ERT result profiles for major and minor survey lines respectively.

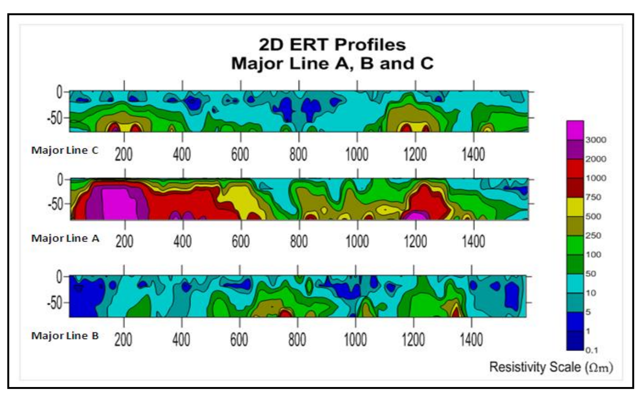


Figure 6 2D ERT profiles of major lines

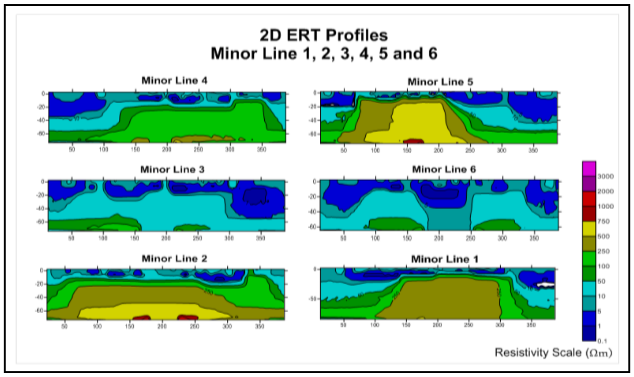


Figure 7 2D ERT profiles of minor lines

From ERT profiles of major lines, the subsurface profiles were seen to be divided into three main layers. The first top layer is a blue region layer with resistivity from 0.1 Ωm to 50 Ωm. Second layer, green region layer, has a resistivity range between 50 Ωm to 250 Ωm. The bottom layer is a hard material layer from 250 Ωm which can exceed up to around 3000 Ωm.

As for minor lines, most profiles were composed of two main layers too; blue and green region layers. The hard material layer was obviously existed in Minor Lines 1, 2 and 5.

Later comparisons of geological log to the ERT profiles at exact well locations were made to be able to interpret these layers and verify the potential aquifer layer.

3.2 Comparison of Geological Log to ERT Result

Based on the details from well log lithology, the soil type was classified and compared to ERT profiles. Table 1 shows tube well lithology compared to resistivity value.

Table 1 Tube well lithology versus resistivity value of ERT profile survey

No	Lithology	Soil Type	Resistivi-ty Value (Ωm)*	Combin-ed Resistivi-ty Value (Ωm)	Resisti-vity value of ERT profile survey
1	Clay	CLAY	37-88	20-88	10-50
2	Clayey Silt		20-69		
3	Silty Sand	SAND	29-57	29-257	50-250
4	Sand		81-257		
5	Silty Sand		29-57		
6	Sand		81-257		
7	Gravel	GRA-VEL	not related	not related	not related
8	Quartz-Mica Schist	SCHIST	not related	not related	not related

*[14]

From the table, the resistivity values for each specific soil were taken from research journal [14]. Combined resistivity values were made to compare with resistivity value of ERT profile survey.

The resistivity values of both clay and sand in ERT profile were found to be within the range concluded in combined resistivity values column.

Therefore it can be concluded that, clay and sand are the main continuous subsurface layer for Sawah Sempadan area including the study area of Block C. Clay is the upper layer of both lithology of tube wells that creates a thickness to around 30 m depth from ground surface. Whereas, sand layer is the second subsurface layer, that can be found from depth 30m downwards from ground surface.

The marked 'not related' filled in the column as gravel and schist were present from 80 m depth downwards while resistivity profiles are only up to a maximum of 80 m depth.

As this study area is an alluvium deposit area, alluvial aquifers that contain groundwater potential might be present. Alluvial aquifers are generally shallow sand and gravels deposit. In this study, sand deposit layer was found as an alluvial aquifer.

Therefore, medium that store groundwater is an alluvial aquifer that has two criteria to be met. First, the particular sand layer must have the resistivity value ranging from 50 Ωm to 250 Ωm. A second criterion is the potential aquifer should be positioned 30m below ground surface. Furthermore, it is easier to extract groundwater in sand soil layer rather than clay soil because of its high porosity.

Table 2 shows the location, depth, area, resistivity value and potential of each potential aquifer verified to extract groundwater for irrigation purposes. From the table, four PA where identified to have high potential ability to extract groundwater while two were classified as medium and one more as low. This was based on depth and area characteristics of each PA.

Table 2 Location, depth, area, resistivity value and potential to extract groundwater for irrigation purposes for each PA

PA*	Location	Depth** (m)	Area (m)	Resistivity Value (Ωm)	Potential
1	Major Line A	30-60	1300 – 1500	50 – 250	High
2	Major Line B	30-80	500 – 600	50 – 250	Medium
3	Major Line B	45-70	750 – 900	50 – 250	Medium
4	Major Line B	30-80	1150 – 1300	50 – 250	High
5	Major Line C	30-60	1400 – 1600	50 – 250	High
6	Minor Line 2	20-60	275 – 400	50 – 250	Low
7	Minor Line 4	20-60	125 – 300	50 – 250	High

*PA= Potential Aquifer
**below ground surface

3.3 3D Model View of Potential Aquifer

In creating 3D model view in Voxler software, an equal contour scale of resistivity value and colour was fixed to avoid confusion. By considering these criteria, the green region layer was identified to be as potential aquifer layer at Block C, Sawah Sempadan. That colour region confined a resistivity between 50-250 Ωm.

The location of this region layer that form below 30 m depth was next labelled as 'PA' which stands for potential aquifer. There were 5 potential aquifer locations spotted in major survey lines and 2 more locations in minor lines.

In addition to create 3D model view of resistivity, x-location of each 2D ERT profile which start with 0m were replaced with precise northing and easting value from topography data collected. Data were imported with 5 variables. X-axis represents easting; y-axis represents northing; and z-axis represents depth. The other two variables were; resistivity and ID.

In Voxler, some computational and graphic output functions were run to give a better view of the model created. Figures 8 and 9 show 3D skeleton model of major and minor survey lines respectively.

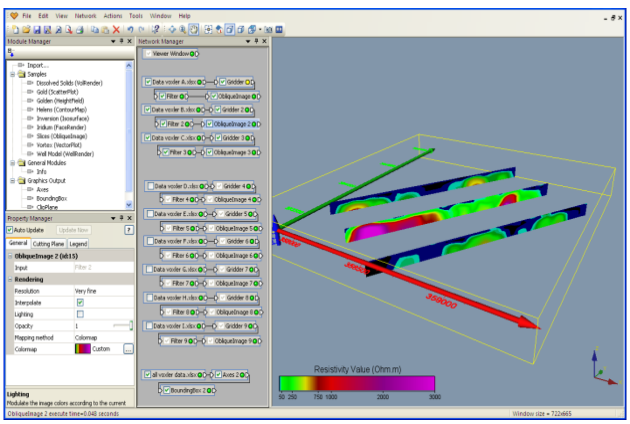


Figure 8 3D skeleton model for major lines

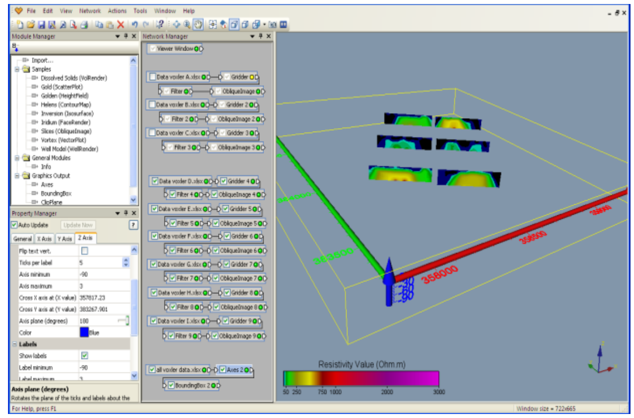


Figure 9 3D skeleton model for minor lines

After both ERT profiles of major and minor survey lines were inserted in Voxler, the ERT profiles were combined to outcome a full result of combination of both survey lines. Figure 10 shows a combination of major and minor survey lines from the view.

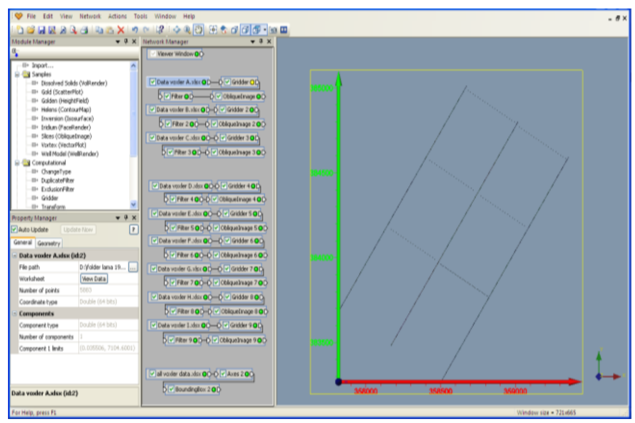
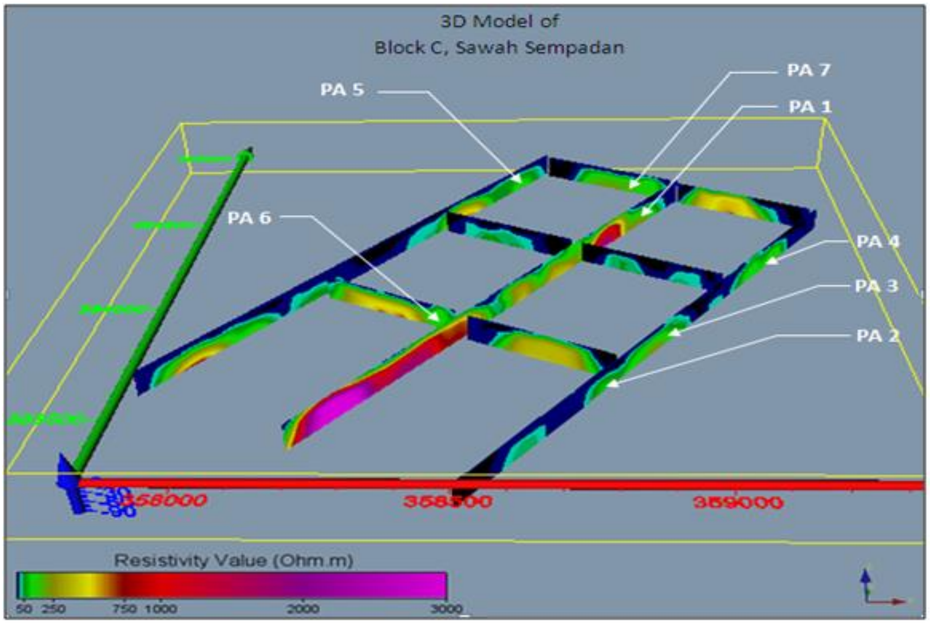


Figure 10 3D skeleton model from top view

From that view, it is clearly seen that, the pattern, shape and position of this model was similar to the purposed survey lines as discussed in the experimental section.

Figure 11 below shows the final result of 3D model view of Block C, Sawah Sempadan area. The model was marked with seven locations of potential aquifer where 'PA' in the figure stands for potential aquifer.



*PA: Potential Aquifer

Figure 11 2D ERT profiles of Line A, B and C

4.0 CONCLUSION

The objective of this study was achieved. The 3D model view of the groundwater potential model for the study area was productively created using 2D ERT profiles of major and minor survey lines in Voxler. Therefore, a better view of subsurface layer and location of potential aquifer are visibly captured. Seven locations were identified to be potential aquifer that stores groundwater in this study area.

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