J E M T
Journal of Earth and Marine Technology
homepage URL: ejurnal.itats.ac.id/jemt

Application of Vertical Electrical Sounding (VES) Resistivity Method to determine a well recommendation point at deep-groundwater exploitation

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DOI: j.jemt.2021.v2i1.1481

Article info
Received:
January 29, 2021
Revised:
February 10, 2021
Accepted:
February 15, 2021
Published:
March 31, 2021

Keywords:
VES Method, deep-groundwater, well-recommendation

Abstract
The demand of fresh water to develop of life community is very important, where almost all construction activities is required a water such as irrigating rice fields, building infrastructure, and to daily consumption. To obtain a good quality of groundwater, several parameter must be specified such as the depth of groundwater, thickness of the source, and resistivity value of rock. In this case, we try to applied Vertical Electrical Sounding (VES) resistivity method with Schlumberger configuration on one of Pamsimas Project to answer that parameter. VES Resistivity method is one of the active methods in geophysical study based on electrical properties of the subsurface rock by injecting electric current (I) into the earth and record the potential difference (ΔV) produced to the surface. From the results of current and potential difference measurements for each electrode spacing (AB/2) different then be lowered resistivity variations in the value of each layer below the measuring point (sounding points). After the acquisition on 3 points at Pandansari Village (PS-01, PS-02, PS-03), we get the result on PS-01, the water layer is indicated on the depth 60-80 meters with resistivity values equal than 36.7-50 Ωm. On PS-02, the water layer is indicated on the depth 50-100 meters with resistivity values equal than 18.7-40 Ωm. On PS-03, the water layer is indicated on the depth 30-60 meters with resistivity values equal than 52.8-70 Ωm. Afterthat, we run 2D-pseudosection to know the distribution of groundwater layer in subsurface and get the thickness of groundwater is 20-50 meter with depth 40-80 meter. Based on this result, the PS-01 is the best point to make a well-exploitation on South Pandansari Pamsimas Project.

1. Introduction

The demand of fresh water to develop of life community is very important, where almost all construction activities is required a water such as irrigating rice fields, building infrastructure, and to daily consumption. To meet those needs, several water resources can be found at the mountain, river, and subsurface [7]. In this research, we want to find deep-groundwater (Artesis) [7] source to help a Pamsimas Project. It's the Government Program to build infrastructure facility based on community to search water resources, building storage facilities, and distribution for the villager. With target of the source are have minimum depth >30 meters and thickness >2 meter, we used Vertical Electrical Sounding (VES) from Resistivity Method with Schlumberger configuration to answer that challenges [2].

2. Methodology

Resistivity method is one of the active methods in geophysical study the electrical properties of the subsurface rock by injecting electric current (I) into the earth and record the potential difference (ΔV) produced to the surface [6]. From the results of current and potential difference measurements for each electrode spacing (AB/2) different then be lowered resistivity variations in the value of each layer below the measuring point (sounding points) [6]. Resistivity values is what we will use to determine the depth and thickness of subsurface layer (see **Figure 1**). For the penetration depth and thickness, we use Schlumberger configuration for measurement technique in this study.

Schlumberger configuration ideally the distance of MN is made as small as possible, so that the distance of MN completely fails. However, due to the sensitivity of the measuring instrument, compilation of AB distance is relatively large, so the distance of the MN allows it to be changed. The change in distance of MN is greater than 1/5 of the distance AB. The advantage of this Schlumberger configuration is the ability to prove the non-homogeneity of surface layers on the surface, by comparing the compilation apparent resistivity values of MN/2 electrodes. So that the voltage readings on MN electrodes can be questioned, relatively large AB distance compilation requires distance MN electrodes are also enlarged. Schlumberger configuration is usually used for sounding, which is data collection that is focused vertically. The advantage of this configuration is that it can detect the non-homogeneity of rock layers on the surface by comparing the values of apparent resistivity when shifting. While the drawback is the reading on the small MN electrode when AB is very far away, almost an eccentricity limit [1].

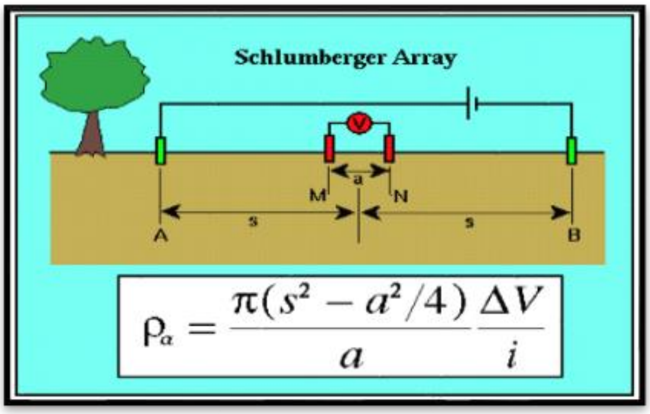

Figure 1. The schematic electrode on Schlumberger Configuration [1].

3. Results

3.1. Station PS-01

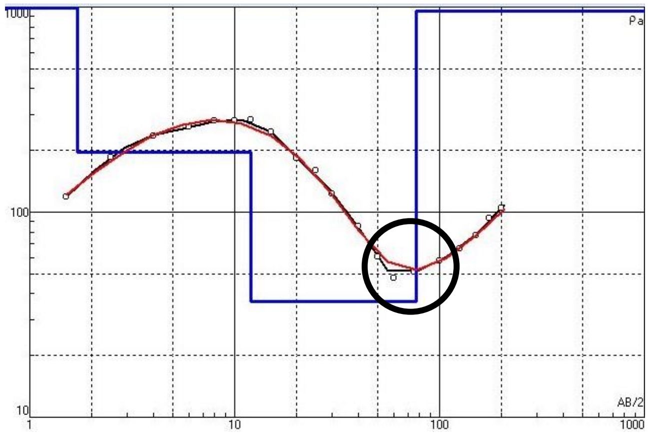

Figure 2. 1D VES Resistivity Modelling on Station PS-01, black hole is indicated by low resistivity

3.2. Station PS-02

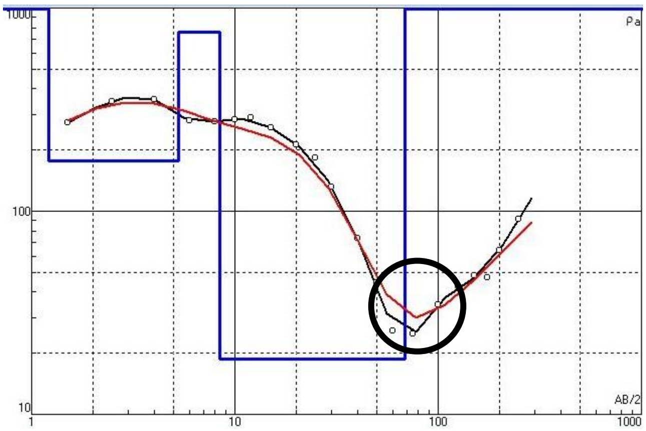

Figure 3. 1D VES Resistivity Modelling on Station PS-02, black hole is indicated by low resistivity

3.3. Station PS-03

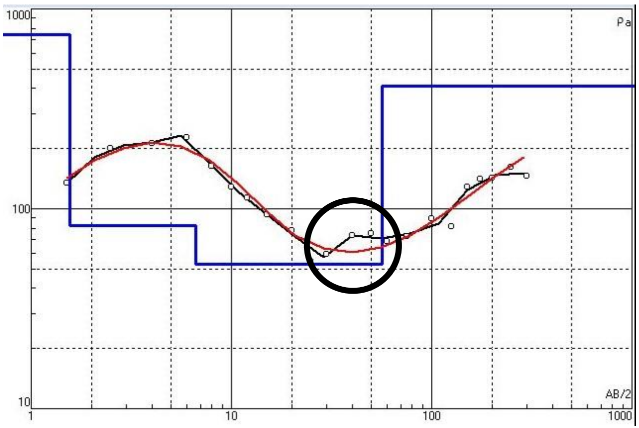

Figure 3. 1D VES Resistivity Modelling on Station PS-03, black hole is indicated by low resistivity

4. Discussion

In this research, we run vertical electrical sounding (VES) method on 3 sounding point (station PS-01, PS-02, and PS-03) at South Pandansari Village with distance per point is 500 meter. Based on geological map [3], research area is dominated by Lampung Formation (QTl) such as pumiceous tuff, rhyolitic tuff, welded tuffit, tuffaceous sandstone, and tuffaceous claystone.

From the result of acquisitions, we calculated a value of electric current (I) and the value of potential difference (ΔV) to obtain the Apparent Resistivity (Rho) [5]. The Apparent Resistivity (Rho) data will process into 1-dimensional (1D) graph to obtain depth and the thickness of subsurface layer. Then, from the reference, the Resistivity value table [6], we can analysis subsurface lithology [3] and estimated depth and thickness of water resources.

On the Station PS-01 (see **Figure 2**), a graph show a vertical lithology based on resistivity (with error 3.95%), on PS-01 have 5 (five) layers. The first layer, in the depth 0-0.69 meter with resistivity values equal than 62.7 Ωm is indicated a wet top soil. The second layer, in the depth 0.69-1.71 meter with resistivity values equal than 62.7-1278 Ωm is indicated a wet top soil until dry-tuffaceous. Third Layer, in the depth 1.71-12 meter with resistivity values equal than 196-1278 Ωm is indicated a dry-tuffaceous until wet-tuffaceous sandstone. Four Layer, in the depth 12-76.9 meter with resistivity values equal than 36.7-196 Ωm is indicated a water-saturated sandstone until wet-tuffaceous sandstone. And last, in the depth 76.9-150 meter with resistivity values equal than 36.7-955 Ωm is indicated a water-saturated sandstone until dry-tuffaceous.

Table 1. Subsurface Layer Result of PS-01

N	Top Layer	Depth Layer	Thickness	Rho (ρ)
1	0.00 m	0.69 m	0.69 m	62.7 Ωm
2	0.69 m	1.71 m	1.02 m	1278.0 Ωm
3	1.71 m	12.00 m	10.30 m	196.0 Ωm
4	12.00 m	76.90 m	64.90 m	36.7 Ωm
5	76.90 m	150.00 m	74.10 m	955.0 Ωm
				Error 3.95%

On the Station PS-02 (see **Figure 3**), a graph show a vertical lithology based on resistivity (with error 11.3%), on PS-02 have 5 (five) layers. The first layer, in the depth 0-0.56 meter with resistivity values equal than 150 Ωm is indicated a dry top soil. The second layer, in the depth 0.56-1.21 meter with resistivity values equal than 150-1114 Ωm is indicated a dry top soil until dry-tuffaceous. Third Layer, in the depth 1.21-8.43 meter with resistivity values equal than 177-1114 Ωm is indicated a dry-tuffaceous until wet-tuffaceous sandstone. Four Layer, in the depth 8.43-60.7 meter with resistivity values equal than 10.7-177 Ωm is indicated a water-saturated sand until wet-tuffaceous sandstone. And last, in the depth 60.7-150 meter with resistivity values equal than 10.7-2110 Ωm is indicated a water-saturated sand until pumiceous tuff.

Table 2. Subsurface Layer Result of PS-02

n	Top Layer	Depth Layer	Thickness	Rho (ρ)
1	0.00 m	0.56 m	0.56 m	150.0 Ωm
2	0.56 m	1.21 m	0.65 m	1114.0 Ωm
3	1.21 m	8.43 m	7.22 m	177.0 Ωm
4	8.43 m	60.70 m	52.27 m	10.7 Ωm
5	60.70 m	150.00 m	89.30 m	2110.0 Ωm
				Error 11.30%

On the Station PS-03 (see **Figure 4**), a graph show a vertical lithology based on resistivity (with error 8.94%), on PS-03 have 5 (five) layers. The first layer, in the depth 0-0.55 meter with resistivity values equal than 67.4 Ωm is indicated a wet top soil. The second layer, in the depth 0.55-1.56 meter with resistivity values equal than 67.4-740 Ωm is indicated a wet top soil until wet-tuffaceous. Third Layer, in the depth 1.56-6.63 meter with resistivity values equal than 82.4-740 Ωm is indicated a wet-tuffaceous until wet-sandstone. Four Layer, in the depth 6.63-52 meter with resistivity values equal than 52.8-82.4 Ωm is indicated a water-saturated sandstone until wet-sandstone. And last, in the depth 52-150 meter with resistivity values equal than 52.8-411 Ωm is indicated a water-saturated sandstone until wet-tuffaceous sandstone.

Table 3. Subsurface Layer Result of PS-03

n	Top Layer	Depth Layer	Thickness	Rho (ρ)
1	0.00 m	0.55 m	0.55 m	67.4 Ωm
2	0.55 m	1.56 m	1.01 m	740.0 Ωm
3	1.56 m	6.63 m	5.07 m	82.4 Ωm
4	6.63 m	52.00 m	45.37 m	52.8 Ωm
5	52.00 m	150.00 m	98.00 m	411.0 Ωm
				Error 8.94%

Resistivity data from station PS-01, PS-02, and PS-03 will be carried out pseudo-section on 2D layout to know the distribution of fresh-water zone below the surface (provided that the distance between measurement stations is not more than 150 meters). Based on the results of 2D-pseudosection (see **Figure 4**), groundwater zone is indicated on the depth 50-140 meters with resistivity values is equal than 25-55 Ωm. Based on the distribution of groundwater from 1D-graph and 2D-pseudosection, the best area for drilling a groundwater zone is station PS-01 (It's because from the thickness of the fresh-water and the composition or lithology (see **Figure 5**) above the target zone which is easy to drill).

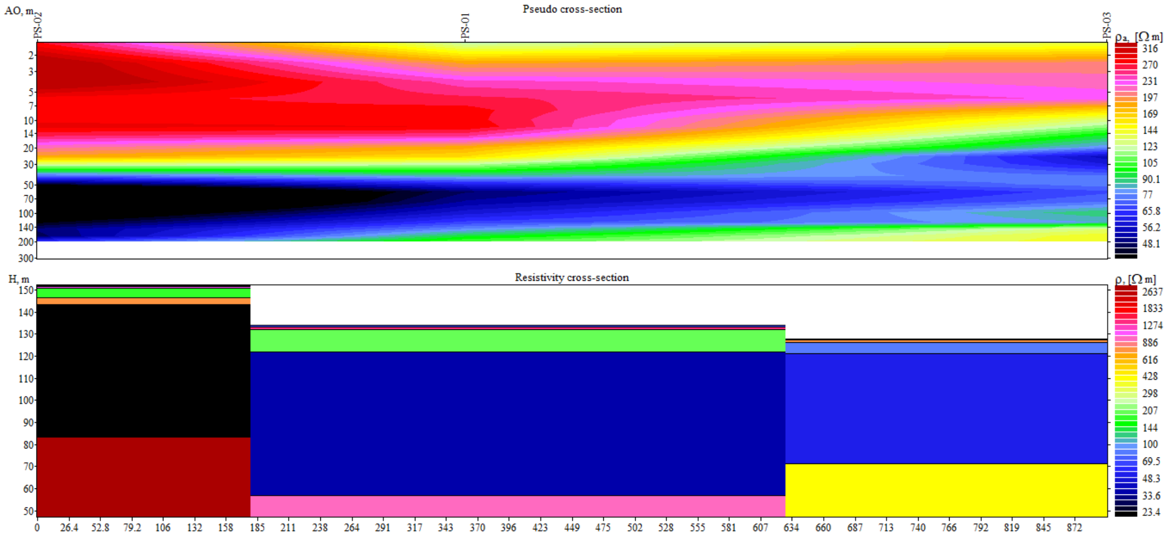

Figure 4. 2D Pseudo-section from station PS-01, PS-02, PS-03, it show groundwater zone is indicated by low resistivity in 50-140 m under surface

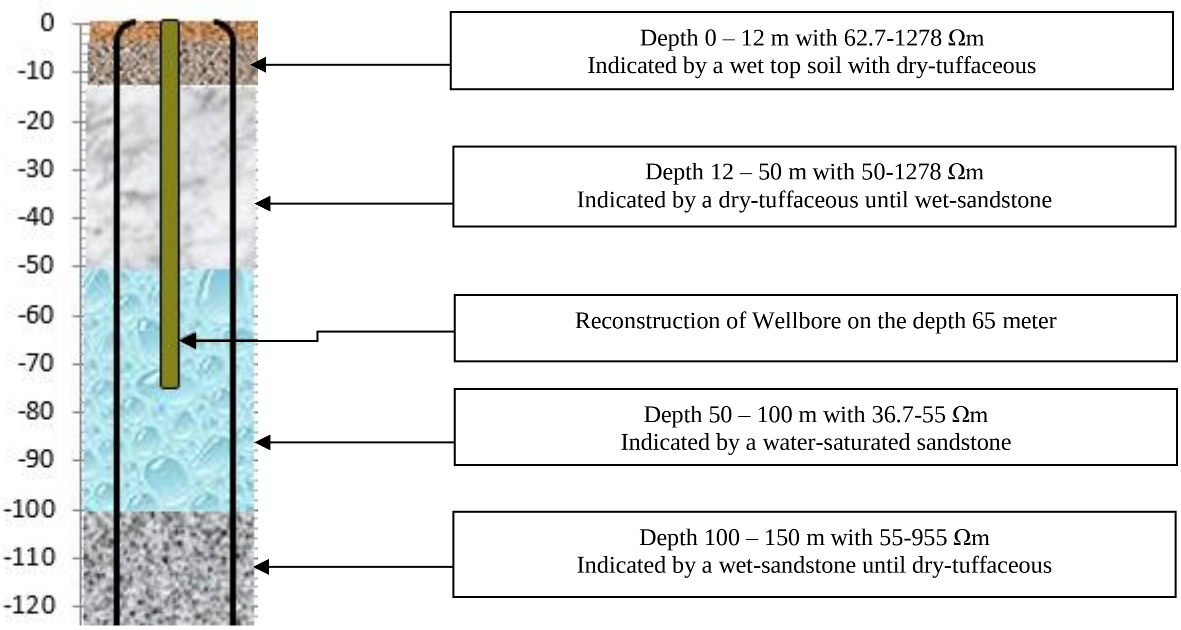

Figure 5. Well Modelling from data 1D VES Resistivity on Station PS-01 with depth 0-150 m from surface elevation

5. Conclusion

The conclusion of this paper are:

1. Based on 1D-resistivity graph and Lithology Model on Station PS-01 until PS-03, we can obtained the deep-groundwater zone indicated with low resistivity which is equal to 10.7-52.8 Ωm and in the depth 50-100 meters from the ground surface.
2. Based on resistivity values, we interpreted the research area on PS-01, PS-02, and PS-03 is dominated by top soil, tuffaceous, and tuffaceous sandstone.
3. Based on 2D-pseudosection model, we can conclude station PS-01is the best point to drill a groundwater well with the depth of well is 60 to 70 meter.

6. Acknowledgement

We would thanks to Innovation & New Ventures (INV) Pertamina who permit us create this paper and would thanks to Lampung Geoscience Survei (LGS) who give us the data acquisition.

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