Identification groundwater aquifer by using geoelectrical method: case study Pondok Pesantren Darussallam, Kradenan, Grobogan

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Abstract. Geoelectrical is one of the geophysical methods that used to characteristic of rocks for early stage exploration. Geoelectrical using Wenner-Schlumberger configuration has been used to estimate the aquifer at Pondok Pesantren Darussallam. Based on the geological map of Grobogan, Kradenan is consist of Alluvium. There are three lines acquisition which length 500 meters and the space of electrode is 25 meters. The data processed using Res2Dinv and the 2D inversion show that the maximum depth is 78.2 meters. The result of this research show that there is an aquifer at depth 30 - 50 meters. Based on the values of resistivity, 1 - 10 ohm.m identified as clay, then resistivity 10 - 100 ohm.m is sandstone indicated as aquifer, and resistivity 100 - 1338,9 ohm.m is limestone.

1. Introduction

Water is the most important thing for human life in every day. For plant, the nutrition is carried by water from soil to the plant. And for human, 60% of human bodies consist of water. Some of this water is in human’s cell, but there is about 34% of water that moving in the body and carrying substances that it is important for sustaining human life [1]. The source of water on the earth is about $1.36 \times 10^{12}$ M ha-m, where the 97.2% is salt water in the ocean and only 2.8% is fresh water. From its 2.8%, the 2.6% is found on surface, whereas 0.2% is groundwater [2].

The geoelectrical method is one of the most suitable geophysical survey methods that used to identify the groundwater aquifers. Because the geoelectrical method can describe the type of lithology, spreads, thickness, and the depth of rock layers under the surface, include the aqueous rock or aquifers [3]. The depth that can be achieved by this method is also suitable to identified aquifer, both shallow aquifer and deep aquifer.

The data acquisition is done around Pondok Pesantren Darussalam its located at Kradenan, Grobogan, Central Java. From the geological structure, Kradenan is a region that composed of alluvium deposits, i.e. clay, silt, sand, and gravel which its deposited along the flood plains of the Lusi river, Madiun river, Wulung river, and Bengawan Solo river [4]. However, that area, especially Kradenan, there is a mud volcano. Mud volcanoes causes the groundwater in the area become salty. Therefore, in that area is difficult to get the freshwater.

Pondok Pesantren will be developed and it will make the number of Santri in that Pesantren will be increase. The large number of Santri will make Pondok Pesantren need more water, both for consumption, and for the needs of cleanliness. And according to the owner of Pondok Pesantren, the
amount of water available is not enough for that. The location of the research is shown in Figure 1, and the geological map for Kradenan is shown in Figure 2.

Based on that background, the purpose of this research is to find out the distribution of groundwater aquifers which will be used for the development of Pondok Pesantren Darussalam.

![Figure 1. The location of data acquisition](image1)

![Figure 2. Geological map of Kradenan Sub-district, Grobogan District](image2)
2. Methods

The acquisition of the research is using geoelectrical method with Wenner-Schlumberger array and the number of line in this research is three. Then, the data will be processed using software res2Dinv to find out the real resistivity of subsurface.

Geoelectrical method is one of the geophysical survey methods who’s the principle is using the electrical properties of rocks in subsurface [5]. This method drains the current from the surface to the subsurface, and the result is potential which the values is influenced by the type of rocks in it [6].

The values of apparent resistivity for geoelectrical method is influenced by geometry factor (k). And the equation is:

\[ \rho = \frac{\Delta V}{I} k \]  

For Wenner-Schlumberger array, the values of geometry factor (k) = \( \pi n(n + 1)a \), so the apparent resistivity for the Wenner-Schlumberger array is:

\[ \rho = \frac{\Delta V}{I} \pi n(n + 1)a \]  

Wenner-Schlumberger array is a configuration fusion of Wenner array with Schlumberger array (Figure 3). So it can be said that this configuration is a Schlumberger array with the sounding points can be moved.

![Figure 3. Wenner-Schlumberger array](image)

3. Result and discussion

The research is located in around of Pondok Pesantren Darussalam area, Kradenan Sub-district, Grobogan District, Central Java with three points data measurement and each span length is 500 m, then the spacing of each electrode as far as 25 m. From that length and that spacing, resulted the penetration depth is 72.8 m. The line 1 is located in coordinate 517284 m E – 517383 m E and 9211267 m S – 9211749 m S. And the line 2 is located in coordinate 517125 m E – 517634 m E and 9211489 m S – 9211398 m S. And the the line 3 is located in coordinate 517516 m E – 517582 m E and 9211109 m S – 9211600 m S.
Based on geological map of Ngawi Sheet and Salatiga sheet, the Grobogan District, especially Kradenan sub-district is composed of alluvium (clay, silt, sand, and gravel), as shown in Appendix 2. The area is a mud volcano area that carries salt compounds, so the groundwater in there is mixed by the salt compound and consequently found the salt water around the area. There are two reasons that make the groundwater become salty. The first is connate water trapped in the aquifer, where that trapped water is usually highly mineralized. And the second is the intrusion of sea water into the groundwater [8].

From the Figure 4, Pondok Pesantren Darussalam is passed by line 1 and line 2. And then, after the data is processed using res2Dinv software, the result is shown in Figure 5, Figure 6, and Figure 7.
The geoelectric sections show the variations of resistivity and thickness values of the subsurface layers within the study area [9]. From the three lines above, the resistivity is varied, ranging from 0.0202 – 13389.9 ohm.m. According to the Table 1 and the geological map of Kradenan (Figure 2), resistivity <1 ohm.m is identified as rocks aquifer that contain salty water. Then, for the resistivity ranging from 1 – 10 ohm.m is identified as clay. And then, for resistivity ranging from 10 – 100 ohm.m is identified as sandstone that act as groundwater aquifers [10]. And the last, the high resistivity that ranging from 100 – 1338.9 ohm.m is identified as a limestone (Table 1). And from the results above, the aquifers is located 30 – 50 m in depth. The dissolution of evaporitic rocks may be a significant cause of groundwater salinization, especially when the ground contains large volume of evaporitic rocks [11].

| Rocks          | Resistivity value (Ohm.m) |
|----------------|---------------------------|
| Clay           | 1-100                     |
| Silt           | 10 - 200                  |
| Marls          | 3 – 70                    |
| Sandstone      | 50 – 500                  |
| Limestone      | 100 – 500                 |
| Lava           | $10^2 – 5 \times 10^4$    |
| Groundwater    | 0.5 – 300                 |
| Salty water    | 0.2                       |
| Breccias       | 75 – 200                  |
| Andesite       | 100 – 200                 |
| Vulcanic tuff  | 20 – 100                  |
| Conglomerate   | $2 \times 10^3 – 10^4$    |
| Quartz         | $10 – 2 \times 10^8$      |

4. Conclusion
Based the acquisition data at 3 line and then it’s processed using res2Dinv software, resistivity <1 ohm.m is identified as rocks aquifer that contain salty water. Then, for the resistivity ranging from 1 – 10 ohm.m is identified as clay. And then, for resistivity ranging from 10 – 100 ohm.m is identified as sandstone that act as groundwater aquifers. And the last, the high resistivity that ranging from 100 – 1338.9 ohm.m is identified as a limestone. And from the results above, the aquifers is located 30 – 50 m in depth. So, the drilling must do on the surface below which has the resistivity 10 – 100 ohm.m.
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References
[1] Davie T 2008 *Fundamentals of Hydrology: Second Edition* (New York: Taylor and Francis)
[2] Raghunath H M 2006 *Hydrology: Principles, Analysis, Design* (New Delhi: New Age International Ltd.)
[3] Arafia S A, Adel M E, Mohamed, Fernando M and Santos 2017 *Egypt. J. Petroleum* 26 457
[4] Datun M, Sukandarrumidi, Hermanto B and Suwana N 1996 Peta Geologi Lembar Ngawi, Jawa: second edition. Pusat Penelitian dan Pengembangan Geologi Bandung
[5] Kazakis N, Pavlou A, Vargempezis G, Voudouris K S, Soulios G, Pliakas F and Tsokas G 2016 *Sci. Total Environ.* 543 373
[6] Gebremedhin B, Mogos A, Tesfamichael G and Kristine W 2017 *J. Afr. Earth Sci.* 129 82
[7] Hussein H M and Tawfik M Z 2015 *J. Afr. Earth Sci.* 104 6
[8] Noorain M I and Aris A Z 2016 *Procedia Environ. Sci.* 30 291
[9] Kayode J S, Adelusi A O, Nawawi M N M, Bawallah M and Olowolafe T S 2016 *J. Afr. Earth Sci.* 119 289
[10] Ochuko A, Merrious O O and Friedrick O O 2017 *J. Afr. Earth Sci.* 129 108
[11] Abdelkader M, Ferid D, Mouez G, Lahmadi M and Soussi M 2015 *J. Afr. Earth Sci.* 112 83
[12] Telford W M, Gledart L P and Sheriff R E 1990 *Applied Geophysics* (Cambridge: Cambrigde University Press)