Determination of Groundwater Potential in Pulutan Wetan Village Wuryantoro District Wonogiri Using Vertical Electrical Sounding Method

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Abstract. The Pulutan Village is in the karst area consisting mostly of limestone so that during the dry season will cause drought. Drought caused by water is located below the surface so it is difficult to take and known location, it is necessary to investigate the presence of aquifer. The study aims to find out the structures beneath the surface, the depth of the aquifer, and to get cross-section results in 3-dimensional form. The method used in this research is the method of geoelectric resistivity with Schlumberger configuration using the 3 points sounding. The results of the study were obtained that aquifer is located on a coating of tuff sandstone with a resistivity between 2.40 Ωm to 4.15 Ωm. The second Sounding point, it is known that there is a large prospect of groundwater visible from the thickness of the aquifer layer.

1. Introduction
Water is the natural wealth that all creatures on earth need. Water falling due to the rain moving into the soil will be stored on the ground layer below the ground surface as groundwater with a period of storage is very long depending on the geological condition of an area. Water is a natural resource that is needed by human beings for daily life, hence the exploitation of groundwater needs to be done to meet the current needs. Therefore groundwater availability will decrease [1].
Figure 1. Geological Map of Wuryantoro Distric [2]

Wuryantoro district is located at 7°50′37″ – 7°57′07″ S and 110°48′25″ – 110°53′34″ E with an area of 7.260.77 hectares located in Wonogiri Regency, Central Java [2]. Geologist, Pulutan Wetan village included in Wonosari-Punung formation [3]. It is located in a karst area consisting of mountains and limestone hills. Karst is defined as areas with easy-to-dissolve rocks with high secondary porosity [4]. The karst area is known for its unique geomorphology due to its characteristic reliefs and drainage. This region is usually considered dry, arid, and water shortage. But there is the considerable potential of carbonate rocks.

Groundwater in the karst area is very abundant, but with the geological condition of limestone that can pass the rain on the surface through the cracks of rocks causing the groundwater to be difficult. The aquifer is a layer that is located beneath the surface like a water storage area. The aquifer is also able to store and drain adequate amounts of water [5]. So that if there is aquifer able to use to fulfill water needs. The aquifer in the Karst region has three properties that are diffuse and fissure. Limestone which has many gaps and easily soluble in water causes the drainage system below the surface to dominate. The location of the aquifer that is located below the surface resulted in the dry season, there will be drought. This drought is caused by water that is located far below the ground level so it is difficult to reach and not known the exact location [6].

The geoelectric method is a method of geophysical learning the nature of electricity in the earth[7]. The electric current flows into the earth through two current electrodes, then two potential electrodes are used to measure the value of the potential difference. Thus it can be known the magnitude of resistivity and the type of coating beneath the earth's surface[8]. The longer the range between electrodes, the deeper the information is obtained [7]. The Geoelectric resistivity method is generally regarded as a suitable and optimal method for groundwater exploration among other geoelectric methods based on the difference in its resistance value, mathematically can be written in the equation:

$$\rho = k \frac{\Delta V}{I}$$

(1)

With $\rho$ is apparent resistivity ($\Omega\text{m}$), $k$ is a geometry factor, $\Delta V$ is a different potential (volt), and $I$ is a current (ampere).
Vertical Electrical Sounding (VES) is a geoelectric method through the measurement of Sounding to obtain information on the layer below the ground surface using the Schlumberger configuration. Equation Factor geometry Schlumberger is:

\[ k = \pi \left( \frac{L^2 - \ell^2}{2\ell} \right) \]  

Where \( \ell \) point sounding spacing with the potential electrode and \( L \) point sounding spacing with the current electrode [8]. The Schlumberger arrangement is most widely used in the search for structures below the ground surface [9]. Sounding is done by changing the distance between the electrode starting from the smallest distance to the largest distance. The greater the distance between the electrodes used will affect the depth of the layer you want to know [10]. This method is suitable for searching for the earth's subsurface structure. The research aims to determine the subterranean structure of the soil, the depth of the aquifer, and see the subsections of the land surface in 3 dimensions.

2. Methods

The research was conducted in October 2019 in the village of Pulutan Wetan, Wuryantoro District, Wonogiri Regency using 3 points sounding as in figure 2.

![Figure 2. Geoelectric Data Acquisitions Location Map (Google Earth) ![Figure 2. Geoelectric Data Acquisitions Location Map (Google Earth)](image)

| Number | Location | Longitude | Latitude | Elevation (m) |
|--------|----------|-----------|----------|---------------|
| 1. W01 | 7°51’45.78"S | 110°50’16.52"T | 240 |
| 2. W02 | 7°51’57.71"S | 110°50’08.12"T | 251 |
| 3. W03 | 7°51’56.21"S | 110°50’16.71"T | 219 |

Data acquisition carried out using the resistivity meter tool of OYO model 2119C McOHM-EL to measure potential difference and current, 4 pieces of the electrode to inject current and potential into the ground, the accumulator as a source of current, meter to measure the length of the track, hammer to plug the electrode into the ground, connecting cable to connect between components, handy talky (HT) for communication tools, and global positioning system (GPS) to determine the position of the measurement point. Required supporting tools such as multimeter to have the electrode condition checked, calculator to calculate the measurement results, and data table sheets to record the measurement results. The acquisition process uses the Vertical Electrical Sounding method with Schlumberger configuration. Data retrieval is carried out by injecting the electrical current through 2
electrodes and the voltage will be measured at 2 potential electrodes. The research data obtained is the distance between the current electrode and the sounding (MN/2), Current (I), Potential (V), geometry factor (k), and apparent resistivity (ρa).

In the process of data processing using the software Progress Version 3.0 by entering the value of AB/2 and ρa. Processed Data will produce the type of coating, depth of each layer, and also the actual resistivity value. Rockwork Software is used to view cross-section results in 3-dimensional.

3. Result and Discussion
The Schlumberger configuration geoelectric method is used to obtain information on the geological structure under the vertical surface of each measuring point. Information obtained to obtain a geological overview as well as potential aquifers under the surface. Research conducted with 3 points sounding using stretch along 200 m to 325 m. The data acquisition process is done by flowing the current to the ground surface through the current electrode, which will be obtained by the value of potential difference through a potential electrode. The result of potential difference measurement and currents at each distance is used to determine the apparent resistivity. The Apparent resistivity data then processed using Progress software so obtained result as in figure 3 and figure 4. The result of data processing using the Progress software, which is resistant curve resistivity and resistivity log, is the resistivity value of each layer, thickness, and depth of each layer.

In figure 3 yellow point image is observation data, the Blue line is a model of resistivity parameters and the red line is the calculation result of the Progress software. The curve line is obtained from the matching curve. The processing of this data is done until the RMS value is as small. Figure 4 resistivity shows the thickness of the rock layer obtained as well as its resistance value. Resistivity values of each layer are used to determine the type of rocks in the research area. The type of composer layer can be viewed based on the resistivity value of each type of rock. The estimate of the rocks of
Each layer is based on the geological map and the research area of Pulutan Wetan village, including the Wonosari-Punung formation with its constituent rocks: limestone, marl-tuffaceous limestone, conglomeratic limestone, tuffaceous sandstone, and siltstone.

The first sounding point is known to have 8 lithological layers with a depth of 128.13 m as in Table 2. At this point, it is known that the aquifer is at the seven layers with the rock-building of the tuff sandstone in the depths of 78.07 m. This layer is suspected to be an inner layer of the aquifer with great potential.

### Table 2. Data Processing Results Sounding Point 1

| Layer | Resistivity (Ω) | Thickness (m) | Depth (m) | Constituent Rocks  |
|-------|----------------|---------------|-----------|--------------------|
| 1     | 7.91           | 0.36          | 0-0.36    | Limestone          |
| 2     | 29.82          | 1.82          | 0.36-2.18 | Limestone          |
| 3     | 19.47          | 5.36          | 2.18-7.54 | Tuff Marlstone     |
| 4     | 26.50          | 12.13         | 7.54-19.67| Limestone          |
| 5     | 15.05          | 19.48         | 19.67-39.15| Tuff               |
| 6     | 21.07          | 38.92         | 39.15-78.07| Limestone          |
| 7     | 4.15           | 50.06         | 78.07-128.13| Tuff Sandstone    |
| 8     | 15.15          | >128.13       |           |                    |

The processing result at the second Sounding point shown in Table 3 there is 8 lithological layers with a depth of 176.16 m. The aquifer in the knowledge lies in the layer of tuff sandstone with a depth of 44.92 m. The data shows that the potential of groundwater in the soil is quite large because its thickness is more than 100 m.

### Table 3. Data Processing Results Sounding Point 2

| Layer | Resistivity (Ω) | Thickness (m) | Depth (m) | Constituent Rocks  |
|-------|----------------|---------------|-----------|--------------------|
| 1     | 13.17          | 2.89          | 0-2.89    | Limestone          |
| 2     | 1.07           | 0.89          | 2.89-3.78 | Sandstone          |
| 3     | 120.85         | 13.72         | 3.78-17.50| Limestone          |
| 4     | 37.43          | 13.28         | 17.50-30.78| Limestone         |
| 5     | 17.23          | 14.14         | 30.78-44.92| Tuff Marlstone    |
| 6     | 3.97           | 106.28        | 44.92-151.20| Tuff Sandstone   |
| 7     | 12.69          | 24.96         | 151.20-176.16| Tuff            |
| 8     | 9.99           | >176.16       |           |                    |

The third sounding point indicates that there are 7 lithological layers as seen in Table 4. The result of the treatment was found that aquifer was at a depth of 14.13 m with its constituent rocks being tuff sandstone. Based on the depth of aquifer indicates at this point it has a shallow groundwater face with small potential.

### Table 4. Data Processing Results Sounding Point 3

| Layer | Resistivity (Ω) | Thickness (m) | Depth (m) | Constituent Rocks  |
|-------|----------------|---------------|-----------|--------------------|
| 1     | 80.47          | 0.81          | 0-0.81    | Limestone          |
| 2     | 24.92          | 1.82          | 0.81-7.77 | Tuff               |
| 3     | 64.62          | 5.36          | 7.77-14.13| Limestone          |
| 4     | 2.80           | 12.13         | 14.13-26.44| Tuff Sandstone   |
| 5     | 13.17          | 19.48         | 26.44-58.70| Tuff Marlstone   |
| 6     | 20.74          | 38.92         | 58.70-107.37| Tuff            |
| 7     | 31.00          | >107.37       |           |                    |
Figure 5. Section 3 Dimensional Rock Layer Based on Resistivity Value

Based on the processing using Progress, the next 3 points sounding are connected to the 3-dimensional forms using Rockwork software. Figure 5 shows each of the lithologies of limestone, tuff marlstone, sandstone, tuff sandstone, and tuff. The results of the study showed that aquifer is found in tuff sandstone or visible on a green cross-section of 3-dimensional. It can be seen that most of the research area is composed of limestone (blue), it is proven based on the geological map of the area that is in the limestone mountains of the southern side of Java Island. The limestone nature of the secondary porosity will pass the rainwater towards the bottom of the surface through a rock gap, which results in the dry season as the drought will occur, but the potential of groundwater in the research area is quite large. The results of this research can be used to know the location and depth of the aquifer, making it easier in the process of groundwater search.

4. Conclusion
Based on the results of the study of research conducted using the geoelectric method of Schlumberger configuration can be concluded that the aquifer is located on a layer of tuff sandstone that is at a depth of 78.07 m or the first sounding point, depth of 44.92 m for the second sounding point, and the third sounding point at a depth of 14.13 m. Modeling of 3-dimensional form is used to facilitate the analysis of lithology obtained from the research results.

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