Groundwater potential zones identification in Purwobinangun, Pakem, Sleman, D.I. Yogyakarta using vertical electrical sounding (VES)

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Abstract. Water is crucial in tourism development. However, not all locations have good and accessible groundwater resources. Ngepring Vineyard in Purwobinangun Village, Pakem District, Sleman, Yogyakarta face this problem. Ngepring vineyard is a developing tourism area at southern mountainside of Merapi which is one of geotourism destination in Indonesia. In its development, there were obstacles to fulfill the water supply for tourism and locals’ daily use. This research aims to determine groundwater potential zone and recommend a drilling point for a new well. Geoelectric resistivity survey conducted to evaluate subsurface condition by measuring and interpreting rock resistivity properties. Schlumberger Vertical Electrical Soundings (VES) configuration used with a maximum spacing from the center point as far as 250 meters with three VES were measured in study area along two N-S profiles perpendicular to one E-W profile. As the results, there is a sand layer at approximately 80m depth interpreted as aquifer. This result can be used as a preliminary study used to determine potential location for a new water resource in Ngepring vineyard.

1. Introduction

Water has vital role in human activities as well as for tourism development. In dried area where there is lack of water, water consumption supported by using ground water production [1]. In groundwater exploration, geophysical assessment usually conducted to evaluate and predict possibility position of aquifer in subsurface. Geoelectric resistivity is one of common geophysical assessment in groundwater exploration. Geoelectric survey measures rock resistivity properties by flowing electric current in specific value to determine the rock by its properties [1].

Ngepring Vineyard, Purwobinangun Village, Pakem District (as shown in figure 1), is a developing tourism area in Yogyakarta Province. This location situated at southern mountainside of Merapi. Ngepring vineyard does not have enough water resources since it is located above Merapi’s spring belt. As the result of this condition, Ngepring vineyard is experiencing drought during dry season because most of the groundwater layers are deep aquifers (>40 meter). This condition makes difficulties for people in surroundings area to utilize water for tourism and daily use. Based on that condition, Ngepring
vineyard needs a new water resources to fulfill water needs. This survey aims to determine a new well location based on interpretation from geoelectric assessment.

**Figure 1.** Location of the study area with area of interest marked with red square.

2. Geological Settings

Study area located in Geologic Map of Yogyakarta Quadrangle [2]. Yogyakarta quadrangle geologic map composed by 24 formations. Of these 24 formations in Yogyakarta Quadrangle, only one formation represented in study area namely Young Volcanic Deposit of Merapi Volcano. This formation consists of tuffs, ash, breccia, and agglomerates [2]. Based on Yogyakarta Quadrangle Map, there is not any geological structure found in study area [2].

3. Hydrogeological

Research area is located on the Yogyakarta – Sleman groundwater basin. Yogyakarta – Sleman groundwater basin divided into 2 main formation, Old Merapi and Young Merapi Volcanic Deposits [3,5]. Young Merapi volcanic deposit consists of Yogyakarta Formation and Sleman Formation [3,4]. Sleman Formation extends from the upper slope of Merapi Volcano to the southern of Bantul Regency and features mostly sands, gravels with interspersed boulders and derivations from volcanic ejecta with a varying thickness of 38 to 120 m [4]. Yogyakarta Formation covers most of Yogyakarta – Sleman groundwater basin. This formation formed by sand, gravel, silts, clays up to 45 m thickness and lying unconformably upon the Sleman Formation [4]. Both volcanic formations form aquifer system known as Merapi Aquifer System.

These aquifers in Yogyakarta – Sleman groundwater basin can be classified into three aquifers: upper, lower, base aquifer [3,6]. Upper aquifer formed by Yogyakarta Formation which is consist by andesite lava, breccia, and sand. This aquifer lied in northern side of Yogyakarta – Sleman groundwater system. Lower aquifer dominated by Sleman Formation which is consists of coarse sand, coarse gravel, and lenses andesite lava [6]. Base aquifer located in north part of Yogyakarta – Sleman groundwater. This aquifer formed by volcanic breccia and andesite lava from Old Merapi Volcanic Deposits [3,6]. Study area is situated as shown as figure 2.
Figure 2. South-North cross section of hydrogeological concept of aquifer in the Yogyakarta - Sleman groundwater basin. The approximate location of the study area is marked with the red square [3].

4. Methods
Geophysical investigation was carried out to locate groundwater potential area. Geoelectrical resistivity as one of geophysical method used in this study because considered as a promising and most suitable method for groundwater exploration [5]. Vertical electrical resistivity (VES) applied in this geoelectric survey. Schlumberger electrode configuration was used, with four electrodes that are moved sequentially as shown in figure 3.

Figure 3. Installation of electrodes at point GL-02, using four electrodes in a E – W direction.

Three VES were measured in study area, two N – S profiles perpendicular to one E – W profile. Resistivity data for research area is taken from three measurement points as shown in figure 4 with the coordinates of each measurement point shown in table 1.
Figure 4. Research location map. Points GL-01, GL-02, and GL-03 (in red points) are located in the Ngepring Vineyard area, Purwobinangun Village, Pakem District.

Table 1. VES points coordinate.

| Point   | Coordinate           | Azimuth |
|---------|----------------------|---------|
| GL-01   | 7°36'16.4" S/ 110°24'54.2" E | N 22° E |
| GL-02   | 7°36'13.1" S/ 110°24'56.4" E | N 82° E |
| GL-03   | 7°36'14.2" S/ 110°24'59.5" E | N 186° E |

Measurement points not selected based on geological and geomorphological condition, because in study area only consists of one formation and no geological structure found. The distribution of measurement points determined by the availability of land for further construction of drilling well. The measurement points are not influenced by external factors such as irrigation pipes, due to the lack of infrastructure being built around the vineyard. Measured vertical electrical soundings (VES) calculated to get true resistivity (ρ). True resistivity value then interpreted to get subsurface overview which includes type, depth and thickness, distribution of aquifers both vertically and laterally. All the available data about the geologic and geophysical settings were used in this research to initiate the geoelectrical model. Acquired geophysical data processed by using PROGRESS software. Data processing results (layer resistivity and thickness) analyzed to determine groundwater potential zone in area of study.

5. Results
Based on the resistivity data acquisition, the measurement results from the three VES points are as follows:

a. VES point GL-01
Point GL-01 is located west of the gazebo, on the downhill bike trail, in the middle of the vineyard. The direction of the electrode stretches relatively North - South with the outer electrode distance of 250 m each from the center point. The measurement results can be seen in figure 5.
Figure 5. The results of the VES point GL-01.

b. VES point GL-02
Point GL-02 is located on the northern edge of the vineyard. The direction of the electrode stretches relatively West - East with the outer electrode distance of 250 m each from the center point. The measurement results can be seen in figure 6.

Figure 6. The results of the VES point GL-02.
c. VES point GL-03

Point GL-03 is located at the northeast of the vineyard, to the east of the newly constructed reservoir. The direction of the electrode stretch is relatively North - South with the outer electrode distance of 250 m each from the center point. The measurement results can be seen in figure 7.

![Curve of Apparent Resistivity vs Electrode Spacing](image)

**Figure 7.** The results of the VES point GL-03.

From interpreted VES data, there is a sand layer at approximately 80 meters depth. This sand layer interpreted as an aquifer at all measurement points. Thus, drilling can be carried out at all locations. Considering the possibility of aquifer presence and proximity to the constructed reservoir, it is recommended to drill wells around point GL-02 at a depth of approximately 80 meters. The results of the geoelectric interpretation correlation of the measurements at the GL-01, GL-02, GL-03 points are as shown in figure 8.
Figure 8. Perspective illustration of VES point correlation GL-01, GL-02, and GL-03.

6. Discussion
Based on three available profiles, there is a difference between GL-01 profile and GL-02 & GL-03. At GL-01 profile, there is a layer of sand between andesite. This condition is possible because deposition time gap between sand layer and andesite at point GL-01. The first andesite layer deposited, then the sand layer covered, before the andesite layer reappears. It achieved by andesite occurrence in research area present as sill and can reappears at any time in stratigraphy. The existence of this sand layer is probably the result of deposition from fluvial environment which flank the study area, namely Boyong River (east side) and Gendol River (west side).

However, the presence of aquifer layer does not necessarily mean this area is potential to fulfill their water need. We need to consider whether existing recharge supply will always be available in the aquifer. Groundwater recharge in this location is characterized by high magnitude supply up to 4270 mm/year with average rainfall 2801.5 mm/year based on the geomorphological model and calculations using the Water Table Fluctuation method [7]. It is known that the water supply at the research location is quite good, which resistant to changing seasons in Indonesia [7]. Based on recharge supply data, we can predict how much water we can utilize. It suggested maximum 40% of recharge supply can be extracted based on Regulation of The Minister of Energy and Mineral Resources the Republic of Indonesia [8]. So, that it can be used sustainably to fulfill the water supply for tourism and locals' daily use.

7. Conclusions
Based on the results and discussion above, the following conclusions can be drawn:

1. The research area is located on the southern slopes of Mount Merapi and above the Merapi spring belt.
2. Geologically, the research area is composed of layers of andesite breccias, andesite lava, and sand which is a product of Young Merapi volcanic deposit.
3. There is a layer of sand at approximately 80 meters below the surface that interpreted as aquifer in the research area.
4. Andesite layer in the study area interpreted as a sill, so it can be formed any time and existence of sand layer between andesite seems possible.
5. Based on previous researcher, the groundwater recharge is quite good and resistant to changing seasons in Indonesia.
6. We suggest maximum 40% of recharge supply can be extracted based on Regulation of The Minister of Energy and Mineral Resources the Republic of Indonesia to conserve ground water sustainability.

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