Hydrogeology study and determination of aquifer distribution using geoelectrical schlumberger method in subang regency

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Abstract. The amount of water demand will always increase, especially in Subang Regency. Efforts to control and monitor springs and groundwater are carried out to maintain the availability of springs and groundwater. Therefore, an analysis of geology - hydrogeology of springs and groundwater is needed. The purposes of this research are to determine the interpretation of geological data to investigate groundwater, know the location and distribution of aquifers based on the resistivity value of rock types, and to assess the potential of groundwater using the Darcy equation. This research was conducted in several steps, such as collection and analysis data. The processed data was the secondary geoelectrical data with the Schlumberger method. Calculation of groundwater storage was performed by using geoelectric and Darcy’s law approach. From the calculation result, it was obtained that the predicted groundwater storage was about 5380.375 m\textsuperscript{3}/day or 62.27 m\textsuperscript{3}/s.

1. Introduction
Water is very important for human survival. The amount of clean water demand from springs was increasing especially in Subang Regency. Efforts to control and monitor water sources and groundwater use become indispensable for maintaining the sustainability of the spring or the availability of groundwater. For this reason, an in-depth study of geological analysis - hydrogeological spring and groundwater resources that will be processed into clean water in sufficient quantities to support various business activities.

PT. Indonesian Seed Botany in Curugrendeng Village, Jalancangak District, Subang Regency requires a hydrogeological study to support the water demand in those area. This method by calculating the availability of water resources in the form of springs and groundwater exploration. To manage the spring or groundwater source, a study of control plans and sources of clean water sourced from groundwater will be processed into bottled clean water. A geoelectric estimation survey was carried out to determine several types of aquifers that were considered potential in the plan to make boreholes and aquifers that function as layers that emit springs.

The purpose of the hydrogeology study in Subang Regency is to determine the interpretation of geological data, determine the location and distribution of aquifers based on the resistivity value of rock types, and determine the potential presence of groundwater using the Darcy equation.
2. Methodology

Geoelectric measurements were carried out at the Tropical Fruit Seed Industry Start Up Plantation Office at Curungrendeng Village, Jalancangak District, Subang Regency (figure 1). Measurements in the field and analysis will be carried out for 7 days.

Figure 1. Measurement location in the field

The main equipment used to carry out field work and in the office are as follows:

a. Topography map, geological map, hydrogeological map, potential groundwater map with a scale of 1: 250,000 or smaller scale;

b. Geological compasses and hammers are mainly used for observation / measurement of rock outcrop positions;

c. A set of geological measuring devices of the SAS-3000 brand, Booster SAS-300 from Abem De Terameter, along with other equipment;

d. Writing equipment and computers and software for data analysis, report writing, and data depiction.

2.1. Basic principles of estimating geoelectrics

In principle, the geoelectric estimation is based on the physical properties of the water content of electric current, especially electrolyte solutions, compactness, hardness and grain size of rocks. This investigation is carried out by directing electric current into the ground (earth) through two electrodes current A and B. As a result of the different types of rock layers through which the current will cause a potential difference. This potential difference can be measured at the ground surface through 2 potential electrodes M and N, as shown in figure 2 of the electrode arrangement according to Schlumberger's rules [1].
Figure 2. The arrangement of the electrodes according to the Schlumberger rules

Value of pseudo type resistance at every time the measurement can be calculated using the Schlumberger configuration formula in the equation (1).

\[ \rho_a = K \frac{V}{I} \]

(1)

Which:
- \(\rho_a\) = apparent resistivity or apparent resistivity (Ωm)
- \(K\) = geometry factor which depends on the electrode arrangement / configuration where \(k\) (m) is the geometry factor which depends on the type of AB / 2 and MN / 2 distance configurations.
- \(V\) = measured potential difference (volts)
- \(I\) = current voltage (A)

The interpretation of the field curve obtained is done in two stages. The first step is curve matching by matching the field curves obtained with the standard curves that are available and theoretically calculated. At this stage, it is found that the resistivity value, thickness, and thickness of each rock layer. The second stage, with the help of computers that can process data quickly or computers that have high data access speeds and the Roland Type DXY-1100 plotter. Reinterpretation with this computer is done to improve accuracy in interpretation obtained to a minimum.

The computer program used in this interpretation is the Schlumberger Sounding Interpretation Program compiled by Koefoed, K., Felitz, and Mundry which has been modified by I Putu Danuraharja [2]. Groundwater density is greatly influenced by the interrelations of various supporters including lithology, geological structure, land use and rainfall. The research area is Curugrendeng Village, Jalancangak District, Subang Regency. Geographically the research area is located at coordinates 107°40'37.54" BT and 6°41'25.22" LS.

2.2. Geology
The lithology in this section consists of various Tertiary to Quaternary rock formations, in general, can be grouped as follows:
- Alluvium: a loose-sized, clay-to-scale material, local to bongkah, occupying floodplains in several major rivers.
• Young volcanic rocks: generally composed of tuffs, agglomerates, volcanic breccias and lava, with wide distribution and morphological features typical of volcanic cones.
• Old volcanic rocks: generally consisting of tuffs, volcanic breccias, and lava, generally coherent to very coherent, in the field it is observed as a hill area with several generation can reach more than 1000 m aml.
• Tertiary sedimentary rocks: consisting of limestone, sandstone, clay stone, marl, tufpasiran, are cohesive to very cohesive and form hills.

Based on the Bandung Sheet Geological Map, the study area contained sedimentary rocks namely Lava (Qyl).

2.3. Hydrogeology
Groundwater is separated into compressed groundwater and unconfined groundwater. Unstressed ground water is groundwater contained in unconfined aquifers which is bounded below by a waterproof layer and the upper part is not covered by a waterproof layer but by the pressure face of an atmospheric pressure (equal to air pressure). Meanwhile, compressed groundwater is groundwater contained in confined aquifers whose lower and upper parts are bounded by a waterproof layer. Based on the Bandung Sheet Hydrogeology Map, generally the study location has a small discharge with a deep groundwater level. The condition of the aquifer through the space between the grains between the soil through the cracking of the dissolving channel consisting of lava rock.

3. Result and Discussion
3.1. General situation of research location
Geoelectric method is a complex geophysical exploration method because it consists of various methods. The geoelectric method is used for exploration of mining goods, water supplies and geothermal. The geoelectric method is designed to provide information from rock formations that have electrical conductivity anomalies [3]. Geoelectric method is a method that is widely used and the results are quite good, namely to obtain a picture of the subsoil and the possibility of groundwater [4]. Groundwater exists in geological formations that can store and pass large amounts of water, known as aquifers [5]. Aquifers can also be interpreted as a water-bearing layer or permeable layer [6]. Measurements were made of 10 points (figure 3). The coordinates of each point can be seen through table 1.

![Figure 3 Measurement point](image-url)
Table 1. Data of measurement point

| No | Measurement point | Coordinate | Elevation |
|----|-------------------|------------|-----------|
| 1  | GL 1              | 6°41´42.3´S dan 107°40´33.6´E | 655       |
| 2  | GL 2              | 6°41´39.8´S dan 107°40´29.0´E | 663       |
| 3  | GL 3              | 6°41´36.2´S dan 107°40´31.1´E | 655       |
| 4  | GL 4              | 6°41´37.6´S dan 107°40´34.8´E | 658       |
| 5  | GL 5              | 6°41´37.8´S dan 107°40´32.5´E | 664       |
| 6  | GL 6              | 6°41´37.5´S dan 107°40´35.1´E | 640       |
| 7  | GL 7              | 6°41´35.4´S dan 107°40´43.6´E | 647       |
| 8  | GL 8              | 6°41´34.8´S dan 107°40´37.5´E | 639       |
| 9  | GL 9              | 6°41´34.2´S dan 107°40´29.5´E | 686       |
| 10 | GL 10             | 6°41´30.7´S dan 107°40´22.3´E | 626       |

From the results of interpretations of 10 (ten) points of geoelectric estimation after being correlated with local geological and hydrogeological data, in the geoelectric estimation area, the resistivity is between 2.31-12041.81 ohms. To get a clear picture of the state of the underground rock layer vertically, it can be made an image of the vertical cross section of each type of resistance from the point of geoelectric guess. Complete data are shown in table 2.

Table 2. Result of geoelectrical estimation

| Measurement point | Depth (m) | Resistivity value (Ωm) | Soil layer | Remark               |
|-------------------|-----------|------------------------|------------|----------------------|
| GL1               | 0-7.48    | 1448.57                | Igneous Rock |                     |
|                   | 7.48-8.48 | 193.99                 | Lime       |                     |
|                   | 8.48-24.29| 5012.81                | Igneous Rock|                     |
| GL 2              | 0-0.03    | 8.58                   | Clay       |                     |
|                   | 0.03-5    | 8522.58                | Igneous Rock|                     |
|                   | 5-40.12   | 120.83                 | Lime       |                     |
|                   | 40.12-65  | 5625.21                | Igneous Rock|                     |
| GL 3              | 0-0.01    | 2.31                   | Clay       |                     |
|                   | 0.01-2.6  | 4282.45                | Igneous Rock|                     |
|                   | 2-6.50    | 120.22                 | Lime       |                     |
|                   | 2.5-42.01 | 12041.81               | Solid Limestone|               |
|                   | 42.01-63  | 1082.92                | Igneous Rock|                     |
| GL 4              | 0-0.05    | 7.79                   | Clay       |                     |
|                   | 0.05-4.53 | 6984.98                | Igneous Rock|                     |
|                   | 4.53-23.23| 96.63                  | Lime       |                     |
|                   | 23.23-29  | 1070.72                | Igneous Rock|                     |
| GL 5              | 0-21.99   | 1790.90                | Igneous Rock|                     |
|                   | 21.99-37.11| 317.3                | Sand And Sandstone| Deep aquifer |
|                   | 37.11-64.81| 630.16                | Sand And Sandstone| Deep aquifer |
|                   | 64.81-93  | 11814.86               | Igneous Rock|                     |
| GL 6              | 0-0.03    | 19.51                  | Hard Flakes|                     |
|                   | 0.03-13.86| 2856.92                | Igneous Rock|                     |
|                   | 13.86-26.18| 195.78               | Lime       |                     |
|                   | 26.18-61.2| 2267.65                | Igneous Rock|                     |
|                   | 61.2-90   | 146.58                 | Lime       |                     |
| Measurement point | Depth (m) | Resistivity value (Ωm) | Soil layer | Remark |
|-------------------|-----------|------------------------|------------|--------|
| GL 7              | 0-7.46    | 1007.32                | Igneous Rock |        |
|                   | 7.46-15.16| 2762.67                | Igneous Rock |        |
|                   | 15.16-73.99| 417.71                | Sand And Sandstone | Deep aquifer |
|                   | 73.99-110| 19.75                  | Hard Flakes |        |
| GL 8              | 0-0.43    | 404.43                 | Limestone Shaft |        |
|                   | 0.43-2.47 | 8029.49                | Igneous Rock |        |
|                   | 2.47-29.46| 1043.64                | Igneous Rock |        |
|                   | 29.46-76.82| 811.47                | Sand And Sandstone | Deep aquifer |
|                   | 76.82-114| 95.59                  | Hard Flakes |        |
| GL 9              | 0-2.46    | 649.61                 | Lime       |        |
|                   | 2.46-14.49| 2576.1                 | Igneous Rock |        |
|                   | 14.49-74 | 753.12                 | Sand And Sandstone | Deep aquifer |
| GL 10             | 0-6.28    | 236.87                 | Lime       |        |
|                   | 6.28-22.65| 1226.42                | Igneous Rock |        |
|                   | 22.65-64.71| 61.29                | Hard Flakes |        |
|                   | 64.71-93 | 351.05                 | Sand And Sandstone | Deep aquifer |

Based on data analysis of geoelectric measurements, it is obtained that deep aquifers in the survey area are located at a depth of 15-93 m below the local land surface (BMT). The aquifer lithology is estimated to be rocks including sand and sandstone. Based on the Hydrogeological Map of Cirebon Sheet, the study location is a location with an aquifer through inter-soil granular space through a cracking of a dissolving channel consisting of lava rock. The thickness of the aquifer ranges from 15-60 m. The deep groundwater aquifer in the area of investigation is quite potential. In order to develop deep groundwater to meet the needs of plantation water, it is advisable to utilize deep ground water. For this purpose, prior to exploitation or groundwater production it is necessary to first drill exploratory wells which will later be increased to production wells.

Exploratory boreholes are recommended to be carried out at the geoelectric point of estimation GL 5 and GL 9. Aquifer at GL 5 lies at depths of 21.99-37.11 m and 37.11-64.81 m. For aquifers in GL 9 lies at a depth of 14.49 - possibly exceeding 74 m bmt. Thus the maximum depth of the well must reach 73 meters below the local ground level. The recommended well constructions are:

- Drilling is carried out at GL 5 and GL 9 because it has a higher elevation of the aquifer than other GL points, so it has more potential to find water faster
- Take groundwater from aquifers from a depth of 15 m to 73 meters. Placement of the filter is based on the results of the well long after completion of pilot hole drilling.

Cement (seal grouting) must be considered so that wells that are made really only take water from deep groundwater aquifers in accordance with their designation.

### 3.2. Groundwater potential

Groundwater movement can be determined by groundwater flow line pattern. A flow line (flownet) is a line along which water points will move from upstream to downstream through permeable soil media. By knowing the direction of groundwater movement, it can be seen the cross section of the aquifer from groundwater movement. Cross section of aquifer (W) is one of the parameters needed in measuring groundwater reserves using the Darcy equation. The data needed to make a flow line (flownet) with the help of surfer version 11 software is the coordinates of the research location and ground level elevation. 2-dimensional and 3-dimensional cross section are shown in figure 4 and figure 5.
After obtaining the direction of water flow, hydraulic gradient values can be found in the study area. Hydraulic gradient value is the result of the division between the difference in the depth of the aquifer face (δh) with the length of the aquifer path (δL). Table 3 is the elevation data of free aquifers and depressed aquifers.

### Table 3. Data of aquifer elevation

| Measurement point | Elevation (mdpl) | Upper boundary of aquifer (m bmt) | Elevation of aquifer (mdpl) |
|------------------|------------------|----------------------------------|---------------------------|
| GL 1             | 655              | -                                | -                         |
| GL 2             | 663              | -                                | -                         |
| GL 3             | 655              | -                                | -                         |
| GL 4             | 658              | -                                | -                         |
| GL 5             | 664              | 21.99                            | 642.01                    |
| GL 6             | 640              | -                                | -                         |
| GL 7             | 647              | 15.16                            | 631.84                    |
| GL 8             | 639              | 29.46                            | 609.54                    |
| GL 9             | 686              | 14.49                            | 671.51                    |
| GL 10            | 626              | 64.71                            | 561.29                    |
Groundwater potential in PT. Botany Seed can be calculated using the Darcy equation [7] shown in equation (2).

\[ Q = k i A \]  

Which:

\( Q \) = groundwater volume  
\( k \) = Hydraulic conductivity (m / day)  
\( i \) = \( (\partial h / \partial l) \); hydraulic tilt  
\( A \) = area (m\(^2\))

Based on geoelectric results, free groundwater (shallow groundwater) was not detected at the measurement location. Whereas the distressed aquifer or deep aquifer is known to be at a depth of 15 to 93 m below the local surface. The thickness of the deep aquifer ranges between 15-60 m. The width of the aquifer is limited by an impermeable layer which is 180 m apart with an average hydraulic conductivity sand type 2.5 m / day. The hydraulic slope of the study area is 0.11, so that the groundwater potential is 5380.375 m\(^3\) / day or 62.27 lt / sec. The amount of groundwater reserves in the study site can be stated to have a fairly large discharge of more than 5 liters/sec [8]. The distribution of aquifer results from the study area can be seen in figure 6.

![Aquifer distribution GL 1- GL 10](image)

**Figure 6.** Aquifer distribution GL 1- GL 10

### 4. Conclusion

Some conclusions obtained from geoelectric measurements. Measuring points that have aquifers are located at measurement points GL 5, GL 7, GL 8, GL 9, and GL 10. The detected aquifer is a type of deep aquifer. Drilling is done in the GL 5 and GL 9 points because it has a higher elevation of the
aquifer than the other GL points, so it has more potential to find water faster. Water potential in deep aquifer is 5380.375 m³ / day or 62.27 lt / sec.

5. References
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