



## VES Geoelectrical Method for Identification of Aquifer Depth in Coastal Area of North Lombok Regency, Indonesia: Implications for the Sustainable Utilization of Water Resources

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### Abstract

Measurement of the resistivity value distribution of subsurface rocks has been carried out in Mumbul Sari Village, Bayan District, North Lombok, which is one of the drought-prone areas in NTB Province, Indonesia. This research was conducted to identify the presence of groundwater aquifer layers in the study area based on the distribution of resistivity values. Data collection was carried out at two measurement points, namely the MBLS-1 Point with a track length of 700 m and the MBLS-2 Point with a length of 750 m. Data processing was carried out using IP2WIN Software to obtain a one-dimensional subsurface cross-sectional model, then interpreted using a resistivity log to make it easier to draw information on the subsurface point of measurement. Based on the distribution of resistivity values, it is known that the geological layers in the study area consist of pumice tuff, silty silt, sandy silt, and lava. The inversion results from the IP2WIN software show that the depth of the aquifer zone at Point MBLS-1 is 15.6 – 70.2 m with a resistivity value of 90.3  $\Omega$ m and a thickness of 54.5 m, while at Point MBLS-2 it is located at a depth of 21.9 – 86.1 m with a resistivity value of 112  $\Omega$ m and a thickness 64.3m. The aquifer zone at both measurement points is interpreted as a sandy silt layer. Groundwater drilling is recommended at the MBLS-1 point to a depth of 70 m and at the MBLS-2 point to a depth of 86 m. The geological structure that forms the boundary of the aquifer zone is a layer of compact and hard lava, so for groundwater utilization in the study area, it is recommended to use drilled wells to a depth of 70 – 86 m which is the lower limit of the aquifer layer.

**Keywords:** aquifer, geological layers, groundwater, resistivity, vertical electrical sounding (VES)

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## INTRODUCTION

Water is a very important, strategic, and limited natural resource according to time and place. The use of water to meet the basic needs of many people's lives will increase along with the rate of population growth and the conversion of land functions into settlements. Therefore, effective and environmentally sound processing and preservation are needed in an effort to maintain its balance,

both in quality and quantity. Most of the water on earth is in the oceans, which is 96.5%, fresh water in the form of ice, glaciers and eternal snow is 1.74%, and only about 1.69% of the remainder is groundwater with an accumulated volume of 23,400,000 km<sup>3</sup> km<sup>3</sup> (Christopher & Gregory, 2020). The percentage and amount of water in each water source can move with changes in time which are influenced by the hydrological cycle. The hydrological cycle provides opportunities to increase or decrease the amount of water available on land so that it can affect the needs of living things on land.

Groundwater is all the water that is found in the subsurface layers of the soil, fills the pore space of the rock, and is below the groundwater table. Groundwater is a component of natural resources that can overcome the problem of lack of clean water in the lives of everyday living things. Groundwater is stored in a water-saturated geological formation that has the ability to store and pass water in sufficient and economical quantities, which is called an aquifer layer (Brindha & Elango, 2012). The quantity of water on land is dominated by subsurface water, which is 98% hidden in rock pores and the remaining 2% is seen as water in rivers, lakes, and reservoirs (Direktorat Jenderal Sumber Daya Air Kementerian PUPR, 2020). The availability of water suitable for consumption by humans is only 1% and the remaining 99% is in the form of seawater which is not suitable for consumption. The portion that is suitable for consumption is 1%, only 1% is on the surface of the earth in the form of lake water as much as 0.86%, river water as much as 0.02%, and other surface water as much as 0,02% (Brands et al., 2016). The potential of the groundwater basin on Lombok Island is 3.490 km<sup>2</sup> or 36.83% of the total area of groundwater basin in West Nusa Tenggara province (9.475 km<sup>2</sup>) (Menteri Pekerjaan Umum, 2010).

Geological and hydrogeological conditions are important parameters that greatly affect groundwater potential, so that the distribution of aquifer layers varies greatly in one area. This happened in the Bayan District, North Lombok Regency (Takahashi et al., 2000). Most areas are still experiencing difficulties utilizing groundwater as a source of water suitable for consumption. Mumbul Sari Village is one of the drought-prone areas in Bayan District, North Lombok Regency. West Nusa Tenggara province spatial plan data for 2010 noted that there were 735 heads of households and 2,246 people affected by drought in Mumbul Sari Village (Pemprov NTB, 2010). The initial survey that has been conducted illustrates that the residents of Mumbul Sari Village rely on water from springs to meet their daily needs. During the dry season, the volume of available water decreases significantly, causing most of the population to pay for water (Nielsen et al., 2012). Utilization of groundwater as a source of water supply can be chosen because it has several advantages, namely generally good water quality, relatively low investment costs and its utilization can be carried out where it is needed (in situ) (Direktorat Jenderal Sumber Daya Air Kementerian PUPR, 2020).

Based on the condition of water availability in Mumbul Sari Village, a scientific study is needed as an effort that can be carried out to determine the potential availability of groundwater, one of which is by conducting a geophysical survey. One of the most effective solutions to meet the need for a consumable water source other than surface water is groundwater (Theon et al. 2021). Identification of the presence of groundwater aquifers through a geophysical approach needs to be carried out to obtain a clear picture of the subsurface as an effort to explore consumable water resources (Masseroni et al., 2020).

Determination of groundwater aquifers through geophysical studies can be done using the geoelectric method (Siregar & Kurniawan, 2018). Information on rock resistivity values obtained from geoelectrical measurements is able to provide an estimate of the thickness and depth of the aquifer layer which can be used as a basis for planning for drilling wells (Hamilton, 2005). Vertical Electrical Sounding (VES) is one of the electrode configurations in the geoelectric method which is quite effective in groundwater exploration (Prabowo et al., 2022). The VES Geoelectrical method is able to effectively represent one-dimensional subsurface images based on resistivity values, so that the depth of each layer vertically can be known (Telford, Geldart, and Sheriff 1990). Good vertical resolution accuracy is an advantage of the VES geoelectric method compared to other electrical methods, making it suitable for groundwater exploration (Syifaurohman et al., 2018). A study on the presence of groundwater conducted by Muzaki et al (2021) found that the penetration depth that can be obtained from the VES geoelectric method reaches 110.9 m (Muzakki, Lestari, and Fajar 2021). This research was conducted to obtain an overview of the 1D cross-section model of the groundwater

aquifer zone in Mumbul Sari Village, Bayan District, North Lombok based on the interpretation of subsurface rock resistivity data.

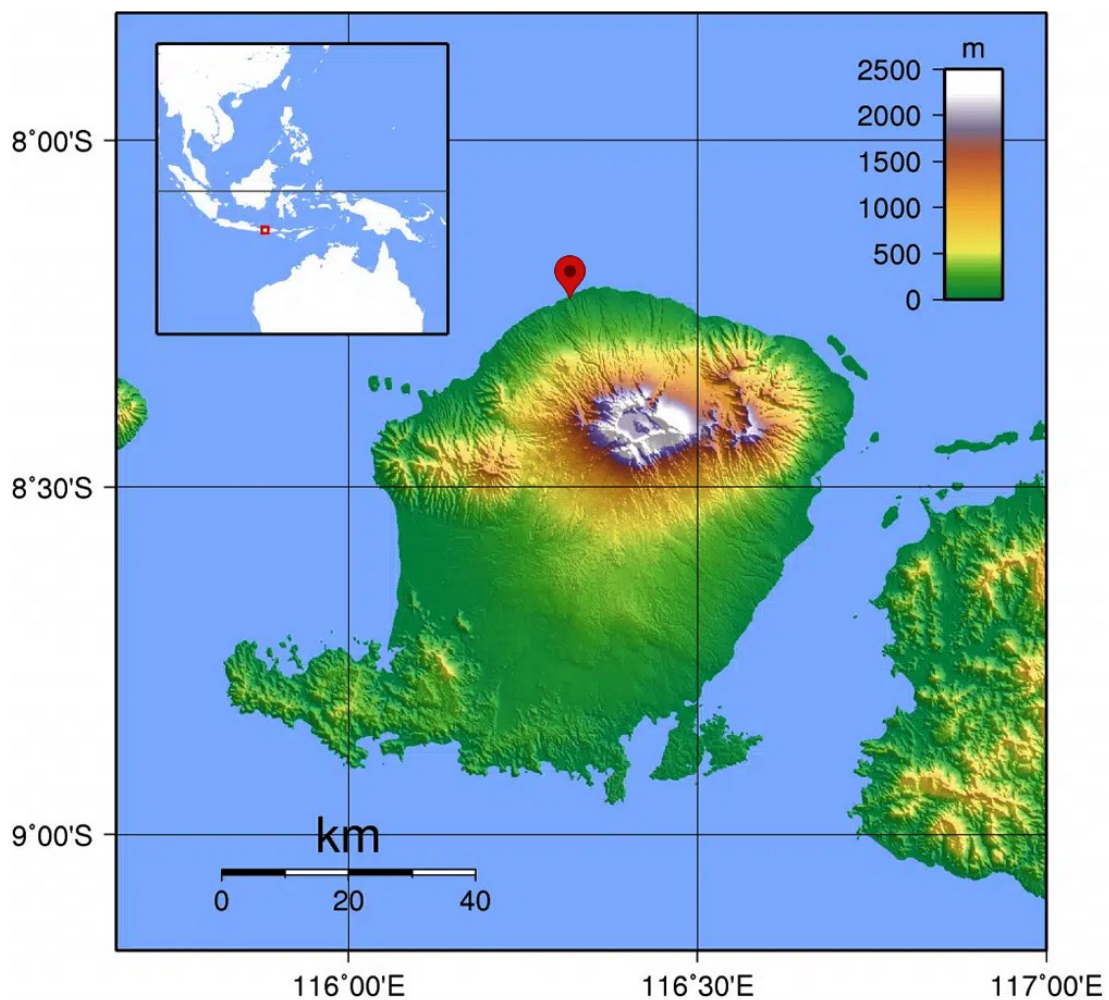
In this study, a magnetic method was used to determine the subsurface structure of the fault. This method was chosen because in addition to utilizing the magnetic properties of rocks without damaging the subsurface structure of the study area, also because it has a fairly high measurement accuracy, instrumentation and operation in the field are relatively simple, easy and fast when compared to other geophysical methods and are environmentally friendly (W.M. Telford, 1991). This method is very suitable for preliminary surveys with a fairly wide area coverage.

## METHOD

The methodology describes in detail the steps taken in this research. The explanation of these steps starts from the preparation stage, field activities to field data analysis and then ends with the results in accordance with the research objectives.

### Research Location and Time

This research was conducted in Mumbul Sari Village, Bayan District, North Lombok Regency, West Nusa Tenggara Province. The research location is shown in **Figure 1**. This research was carried out from 07 November 2022 to 11 November 2022.



**Figure 1.** Research Site Map

Geographically, Mumbul Sari Village is located at  $8^{\circ}13'35.0''S$   $116^{\circ}19'22.9''E$ . The Mumbul Sari area is an area covering a fairly large forest area on the slopes of Mount Rinjani, some of which are managed as community forests. Based on a 1:250,000 scale geological map, the formations that make

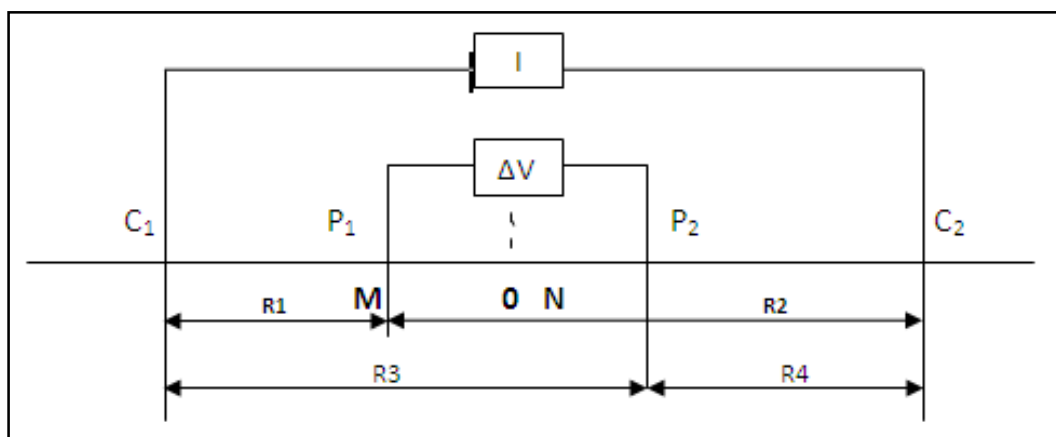
up the Mumbul Sari area are the Lekopiko Formation (Qvl) with rock lithology consisting of pumice tuff, breccia, lava and lava (Wafid et al., 2014).

### Research Equipment

The instrument used in the resistivity geoelectric method research in Mumbul Sari Village, Bayan District, North Lombok is a unit of OJS Electrical Resistivity Meter V.RM.02.19 with an accuracy of potential difference readings up to  $1 \times 10^{-1}$  mV. The output current that can be injected by this tool is 2 A with an impedance of 10 M $\Omega$ . In this study also used supporting equipment in the form of a Global Positioning System (GPS) type MAP 60CSx to determine the position of the measurement point. The software used in processing this geoelectric data is Ms. Software. Excel 2010 and IP2Win.

### Data Acquisition

Geoelectrical measurements in this study used the Schlumberger Configuration which consists of 4 electrodes, 2 current electrodes (C1 and C2) and 2 potential electrodes (P1 and P2) as shown in Figure 2.



**Figure 2.** The arrangement of the electrodes in the schlumberger configuration

Where the description of **Figure 2**;

- A and B : Current electrode
- M and N : Potential electrode
- C1 and C2 : The current measured at the current electrode AB
- P1 and P2 : Potential measured at the potential electrode MN
- R1 : Electrode spacing MN
- R2 : Electrode spacing BN
- R3 : Electrode spacing AM
- R4 : Electrode spacing AN

Before carrying out geoelectric data acquisition, first determine the measurement trajectory. In this study, the measurement of rock resistivity was carried out in 2 tracks, namely MBLS-1 with a measuring track length of 700 meters and MBLS-2 with a track length of 750 meters. The spacing of the electrodes used is 10 meters. The most important thing that must be done before data acquisition is the calibration of geoelectric devices which aim to accuracy field data and facilitate data processing. The process of acquiring VES Geoelectrical Resistivity data in Mumbul Sari Village, Bayan District, North Lombok is shown in **Figure 3**.



**Figure 3.** The process of acquiring VES Geoelectrical Resistivity data in Mumbul Sari Village, Bayan District, North Lombok.

### Data processing

The data generated at the data acquisition stage are changes in potential difference ( $\Delta V$ ), electric current ( $I$ ), current electrode positions ( $C1$  and  $C2$ ), electrode positions and potential ( $P1$  and  $P2$ ). The data processing is carried out through several stages, namely determining the apparent resistivity value of the measurement data based on **Equation 1** using MS. Exel 2010.

$$\rho_a = k \frac{V}{I} \quad (1)$$

Then the inversion process is carried out using the IP2WIN software. The next step is to make a 1D cross section to find out the distribution of resistivity values. The final stage is the results of the 1D cross-section inversion are interpreted using resistivity logs to simplify the description of the subsurface lithology (N. Kumar et al., 2015).

### Data Interpretation

Based on the research objectives, the data interpretation stage carried out is to determine the location of the aquifer and geological layers which contain the parameters of the thickness and depth of the rock layers. Interpretation of measurement results is carried out in 2 (two) ways, namely curve matching which aims to obtain the number of layers below the surface along with the resistivity value and thickness of each layer. The curve matching technique is to match the apparent resistivity curve measured in the field with the theoretically calculated apparent resistivity curve. The second way of interpretation is by using the VES data processing software, in this report the IP2WIN software is used. The value of the layer that becomes an aquifer generally has a relatively low resistivity value. Based on the results obtained, the geological strata, aquifer zones and recommendations for the location and depth of groundwater drilling in the study area can be described.

## RESULTS AND DISCUSSION

The geoelectrical data obtained from field measurements in this study is the apparent resistivity value and then processed using IP2WIN software to obtain the actual resistivity value. This resistivity value reflects the resistivity value of the subsurface rock layers at the point of measurement. Once the actual resistivity is known, the rock interpretation is carried out according to the resistivity value of the reference rock.

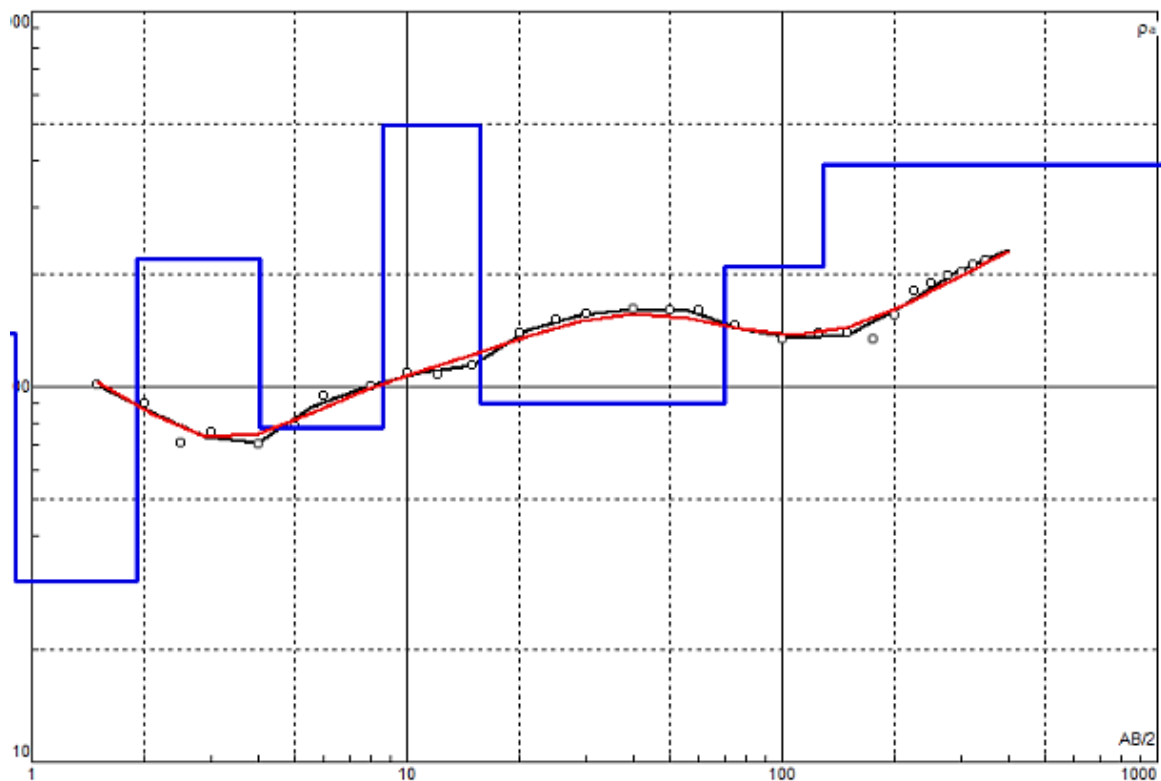
The results of geoelectrical data processing are in the form of 1D cross-sections that depict variations in resistivity values vertically. A description of the state of the rock layers vertically is obtained from the resistivity vertical section of the geoelectric measurement at the measurement

point. Vertical cross-sections of rock layers are often used to facilitate interpretation of the thickness and depth of the aquifer at the measurement point

### Results of 1D Cross-section of MBL-1 Point

The measurement of the MBL-1 track was carried out with a measuring stretch of 700 meters, so that a fairly deep rock interpretation was obtained. The penetration depth obtained from the results of data processing for the MBL-1 survey point reaches 129 meters below the earth's surface (Figure 4).

The results of the distribution of the actual resistivity values, depth and layer thickness in Figure 4 and Table 1 are displayed in the form of rock resistivity logs to facilitate interpretation. Based on Table 2 it can be seen that there is a layer that has the potential to act as a water-carrying layer (aquifer), namely the fifth layer with sandy silt lithology. This layer is located at a depth of 15.6 – 70.2 m with a resistivity value of 90.3  $\Omega\text{m}$ . Groundwater drilling at this point is recommended to a depth of 70 meters and it is not recommended to dig deeper because it is a compact and hard lava layer. Surface water at this point cannot be utilized, so it is not recommended to do manual digging for well construction.



**Figure 4.** Results of 1D Cross-section of MBL-1 point data processing using IP2WIN software. Apparent resistivity curve vs electrode spacing.

**Table 1.** The results of resistivity ( $\rho$ ), thickness ( $h$ ) and depth ( $d$ ) values of rock layers at 1D Cross-section of MBL-1 measurement points.

No	$\rho$	$h$	$d$	Alt
1	139	0.9	0.9	-0.9
2	30.2	1.01	1.91	-1.91
3	219	2.15	4.06	-4.06
4	77.7	4.56	8.62	-8.62
5	499	7.02	15.6	-15.64
6	90.3	54.5	70.2	-70.17
7	209	58.5	129	-128.6
8	390			

**Source :** Data of this study

Based on the Engineering Geological Map (Wafid et al., 2014), the lava in this area has a flow structure, is compact, hard, and has a vesicular structure, namely a hollow structure with regular directions as a result of the release of gas when the magma cools (Prastowo et al., 2019). The existence of this vesicular structure allows the lava layer to also store water, but the low permeability causes this layer to not be able to drain water properly to other areas so it has no potential as an aquifer layer (Sadjab et al., 2020; Triani et al., 2021). Lava layers with higher resistivity values are interpreted as solid/fresh lava layers, while those with lower resistivity values are interpreted as weathered lava layers.

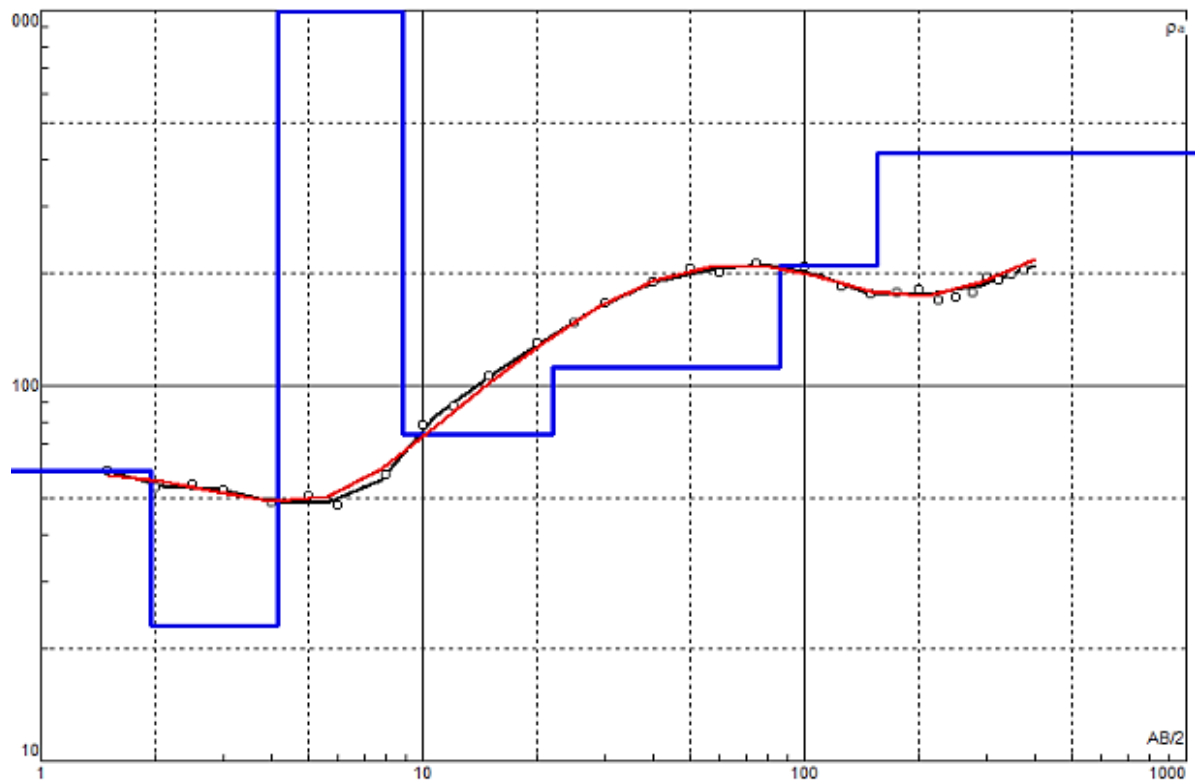
**Table 2.** The Resistivity Logs and Rock Layer Interpretation of MBL-1 Measurement Points

Resistivity Logs	Interpretation
	<p>The measurement results are interpreted into six layers as follows:</p> <p><b>Topsoil:</b> the yellow layer is a layer of overburden with a resistivity of 30.2 – 139 <math>\Omega\text{m}</math> which is composed of lithology in the form of pumice tuff, sandy silt, and is located at a depth of 0 – 1.91 m.</p> <p><b>Lava:</b> the brown layer is a layer of vesicular, compact and hard structure located at a depth of 1.91 – 4.06 m with a resistivity value of 219 <math>\Omega\text{m}</math>. This layer is also exposed at the bottom of the river.</p> <p><b>Clay Silt:</b> the yellow layer is the result of weathering of local rocks located at a depth of 4.06 – 8.62 m with a resistivity value of 77.7 <math>\Omega\text{m}</math>.</p> <p><b>Lava:</b> layers of gray color at a depth of 8.62 – 15.6 m with a resistivity value of 499 <math>\Omega\text{m}</math>.</p> <p><b>Sandy Silt:</b> a layer of blue color at a depth of 15.6 – 70.2 m with a resistivity value of 90.3 <math>\Omega\text{m}</math>.</p> <p><b>Lava:</b> gray layer located at a depth of 70.2 – 129 m with a resistivity value of 209 - 390 <math>\Omega\text{m}</math>.</p>

**Source :** Data of this study

### Results of 1D Cross-section of MBL-2 Point

The distribution of resistivity, depth and thickness values at the cross section of the MBL-2 point shows the same subsurface rock lithology as the MBL-1 point. The penetration depth of the MBL-2 point is deeper than the MBL-1 point because the track length is longer, which is 750 meters. The longer the measurement path in the Schlumberger configuration, the deeper the depth information of the measured rock layers. The interpretation of **Figure 5** and **Table 3** is presented in the form of a log of rock resistivity in **Table 4**.



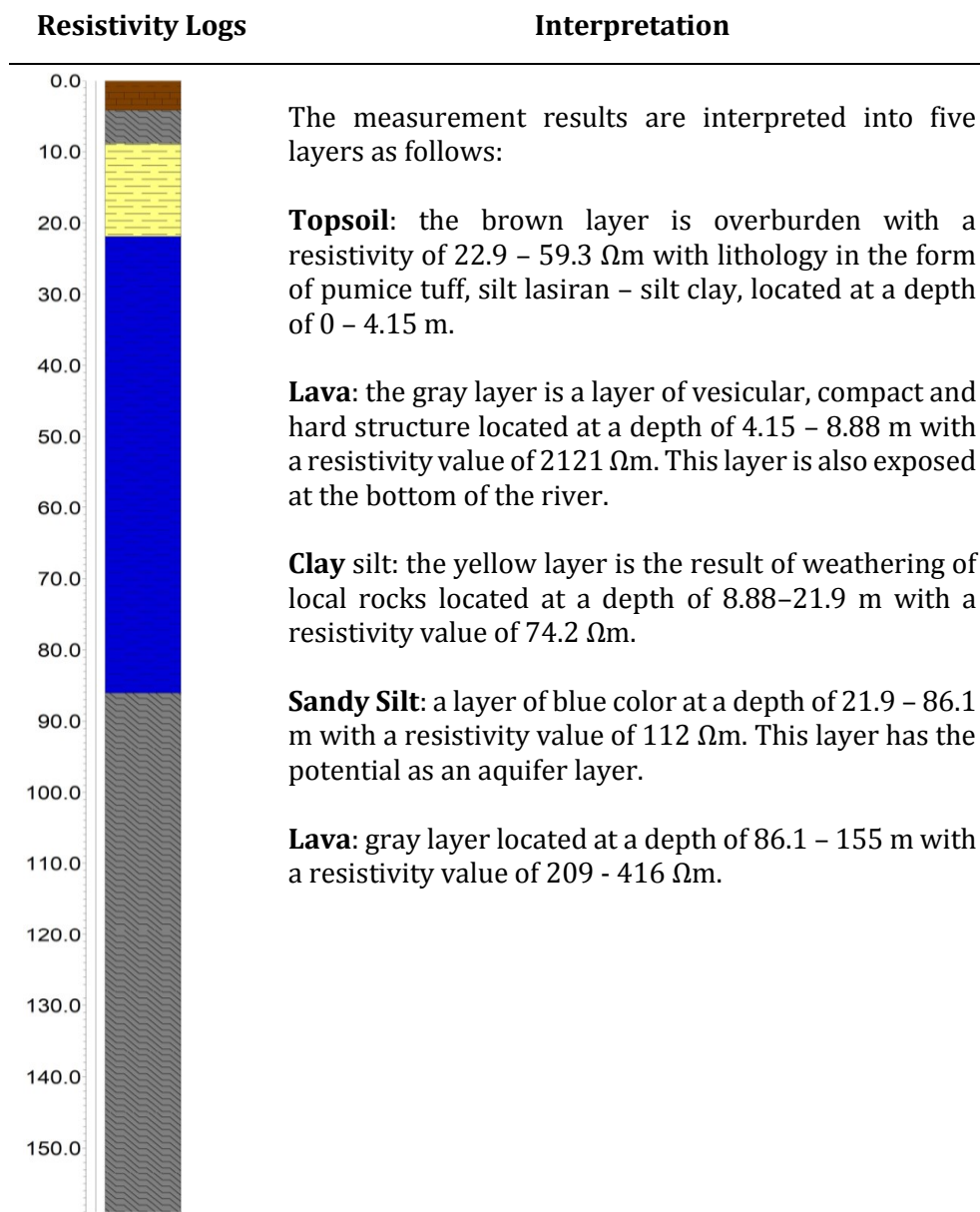
**Figure 5.** Results of 1D Cross-section of MBLs-2 point data processing using IP2WIN software. Apparent resistivity curve vs electrode spacing.

**Table 3.** The results of resistivity ( $\rho$ ), thickness ( $h$ ) and depth ( $d$ ) values of rock layers at 1D Cross-section of MBLs-2 measurement points.

No	$\rho$	$h$	$d$	Alt
1	59.3	1.94	1.94	-1.94
2	22.9	2.21	4.15	-4.15
3	2121	4.73	8.88	-8.88
4	74.2	13	21.9	-21.88
5	112	64.3	86.1	-86.15
6	209	68.8	155	-155
7	416			

**Source :** Data of this study

Based on the results of curve matching and resistivity logs at this measurement point (**Figure 5**), it is known that the layer that has the potential to act as an aquifer layer is in the Silt Pasiran layer which is located at a depth of 21.9 – 86.1 m below the local surface with a resistivity value of 90.3  $\Omega$ m and has a layer thickness of 51.3 m. Groundwater drilling at the MBLs-2 point is recommended to reach a depth of 86 m. This is based on having to pay attention to the thickness of the groundwater catchment area. Surface water at this point cannot be utilized, so it is not recommended to do manual digging for well construction (FAO, 2016; Masseroni et al., 2020).

**Table 4.** The Resistivity Logs and Rock Layer Interpretation of MBL5-2 Measurement Points

**Source :** Data of this study

The pattern of subsurface layering at both measurement points shows the same lithology even though there is a significant difference in the height of the measurement points, namely 43 m with a downward slope towards the MBL5-2 point. Based on this, if excavation is to be carried out between two measurement points, drilling can be carried out between 70 – 86 m below the local surface.

Groundwater exploitation must pay attention to the lithology of the layer and the thickness of the aquifer. Groundwater that is utilized on a large scale should be under an impermeable layer. At this research location, the aquifer layer is located in the form of a confined aquifer layer because it is located between two layers of lava (Aizebeokhai & Oyeyemi, 2015; R. Kumar & Yadav, 2015; Stopforth & Adali, 2019). Lava layers in this area are interpreted as impermeable layers because of the flow structure, compact and hard. The layer below the lava layer is a layer of clay silt. This clay silt layer can also be referred to as an aquifer layer but has low water continuity. Some residents dig and or drill wells up to this layer. Based on information from local residents, excavations carried out to the depth of this layer will experience a decrease in water discharge during the dry season.

## CONCLUSION

Based on the results of processing and interpretation of resistivity geoelectric measurement data in this study, it can be concluded that the depth of the aquifer zone at MBLS-1 Point is 15.6 – 70.2 m with a resistivity value of 90.3  $\Omega$ m, while at MBLS-2 Point it is located at a depth of 21.9 – 86.1 m with a resistivity value of resistivity 112  $\Omega$ m. Groundwater drilling is recommended at the MBLS-1 point to a depth of 70 m and at the MBLS-2 point to a depth of 86 m. The geological structure that forms the boundary of the aquifer zone is a layer of compact and hard lava, so it is not recommended to drill wells beyond the recommended limits. The groundwater utilization in the study area, it is recommended to use drilled wells to a depth of 70 – 86 m which is the lower limit of the aquifer layer. This is of course with consideration of sustainability and resilience of water discharge for use on a large scale.

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## CONFLICTS OF INTEREST

The authors declare no conflict of interest concerning the publication of this article. The authors also confirm that the data and the article are free of plagiarism.

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