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Characteristics of Rock Layers as Aquifers in Tamalanrea Region

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Abstract

Groundwater can be used as a form of fulfilling needs, such as making wells for shallow groundwater (surface water) anddeep groundwater (aquifers). This study aims to determine the subsurface resistivity of the study area by calculating and modeling the results of geoelectrical measurements as well as information on the groundwater-bearing rock layers. Geoelectric measurements use the "Schlumberger" method then the data is processed by the "Res2DinV" program. Measurement points were in 3 places in the Tamanalrea area of Makassar City. The results found 6 subsurface layers, namely soil layers, tuff as shallow aquifers (freshwater), tuff as shallow aquifers (brackish), tuff as shallow aquifers (freshwater), hard volcanic breccias (massive), tuff as aquifers (freshwater) with prospects for exploited. The lithology is dominated by volcanic rocks consisting of water-saturated tuff rocks characterized by low resistivity values and volcanic breccia rocks have undergone weathering and massive conditions with high resistivity values.

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1. INTRODUCTION

Groundwater resources play a very important role as an alternative source of raw water to meet the needs of various needs and needs for clean water. Current occupancy rates tend to continue to increase from time to time in line with population growth and development in all regions.

Data collection/mapping needs to be done to meet raw water needs for the entire development in the Tamalanrea area, Makassar city, South Sulawesi. Distribution of subsurface water retaining layers (aquifers) in rocks which can provide an overview of subsurface water conditions, by measuring geoelectric resistivity, it is possible to estimate the distribution of rock formations (aquifers) containing groundwater [1] [2]. Groundwater can be used for various purposes, such as making wells for shallow groundwater (surface water) and deep groundwater (aquifers). Groundwater exploration wells can fail, this means that resources are used inefficiently because groundwater is not found at the required discharge or none at all. For this reason, before carrying out groundwater reconnaissance drilling, a survey or subsurface survey should be carried out in advance to predict the presence or absence of aquifers, the depth of the aquifers, and the locations of the most potential drilling points in the study area.

One of the geophysical methods that can be used to estimate the presence of deep groundwater aquifers is the resistivity geoelectric method. This method is one of the geophysical methods that can provide an overview of the composition and depth of rock layers, by measuring the electrical properties of the rock [3]. Furthermore, Loke [4] revealed that geoelectric surveys with resistivity mapping and sounding methods yielded information on changes in resistivity price variations, both in the lateral and vertical directions. The resistivity geoelectrical method, or better known as the resistivity method, is one of the geophysical methods commonly used to map subsurface resistivity [5]. One of the geophysical techniques that can be used to estimate the presence of deep aquifers is the resistivity geoelectric method. This method is a geophysical technique that can provide an overview of the composition and depth of rock formations by measuring the electrical properties of the rock, that geoelectrical surveys using resistivity and mapping methods sounding provide information about the inconsistent resistivity values both laterally and vertically. Geoelectrical resistivity or better known as resistivity is a geophysical technique commonly used for subsurface resistivity mapping [6].

This method is relevant to use in the presence of groundwater saturation. This is possible because layers of soil or rock filled with water conduct or conduct electricity very well. The conductive soil layer [7] tends to have a certain resistivity (low value). By showing--subsurface resistivity section, can estimate the water-saturated layers of soil and rock. This is very useful for predicting the location and depth of aquifers.

There are 3 (three) points then the objectives to be achieved through subsurface survey research using the geoelectrical resistivity method are (1) Determine the subsurface resistivity of the study area by calculating and modeling the results of geoelectrical measurements at each research location, (2) Providing information groundwater drilling points and drilling depths based on the results of Geoelectrical Resistivity Measurement Method with the "Schlumberger" measurement method which will be processed in the form of a one-dimensional cross-section based on the program using the "Res2Dinv" software, and (3) Determination of drilling recommendation points (exploitable) in groundwater-bearing rock layers.

2. METHODS

Implementation Geoelectric measurements in this area are carried out starting with survey initial as a step to determine the location of geoelectrical measurements based on topography/morphology, geology, and vegetation conditions. Collect digitized data on location maps and conditions of settlements, roads and other related access to smooth surveys and data collection processes in the field (geoelectric resistivity measurements) as well as other supporting data.

The equipment used during measurement and data collection in the field is a resistivity meter unit Geores Single Chanel, Global Positioning System Map (GPS Map) Garmin 76 CSX, Brunton Compass, Geological Hammer, and Digital Photo Camera. Geoelectric measurements use the Schlumberger method of electrode arrangement and extend the AB/2 cable up to 400 meters. This method for the MN potential electrode is placed at a certain distance, while the AB current electrode is always moved according to the chosen distance (according to the measurement table). The placement of the MN potential electrode path and the AB current electrode take precedence with the condition that the MN/2 distance is 1/5 of the AB/2 distance. Since the current electrode strain is constantly changing from measurement to measurement, the apparent resistivity value is based on the equation [8]:

$$\rho a = K \ \ V/I \text{ dan } K = \pi / 4a\ (L2 - a2)$$

where ρa = apparent resistivity (□m); V = potential difference (Volts); I = difference in current used (Amperes); a= MN stretch (m); L = AB stretch distance (m); K = geometric coefficient.

Transmitting and receiving equipment used for geoelectric measurements in this area is Resistivitymeter type Naniura NRD 22 S (Figure 1).

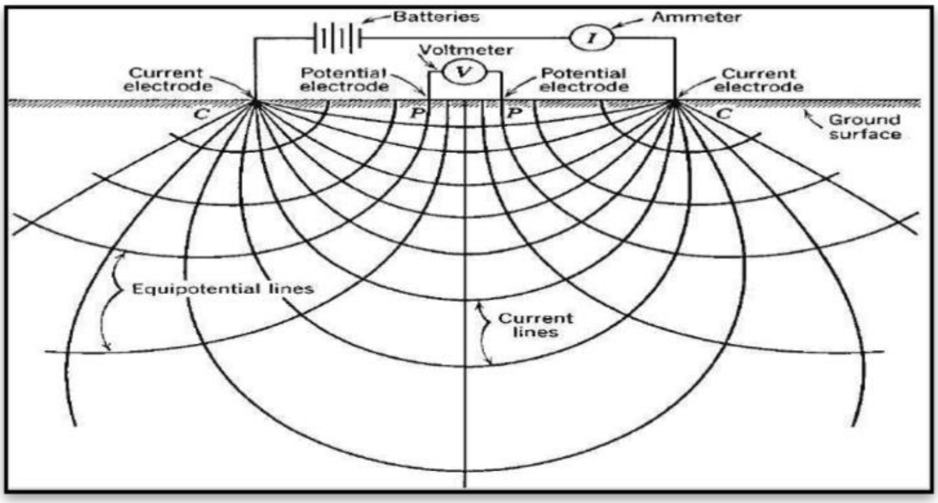


Figure 1. Representation of the electrode arrangement of the Schlumberger method for measuring geoelectricresistivity [9]

Data processing based on the results of field measurements includes calculating resistivity values, and modeling subsurface cross-sections of measurement paths for each location in the area survey. Consecutively – also processed as follows:

a. The data obtained from the measurements are available in the form of current values (I) and potential differences (V) at each measurement point.

a. Apparent resistivity is calculated from the measurement configuration factor and compared with the measured potential difference (V) and current (I).

b. The calculated apparent resistivity value is plotted in the form of a measurement graph (log-log) for each measurement point and carried out smoothing to get the apparent resistivity value at each measurement point location.

c. Apparent resistivity values are mapped to apparent depth (half the cable run length, AB/2) and then contoured to find apparent resistivity versus apparent depth for each measurement path (Figure 2).

d. The apparent resistivity section above is used to interpolate the ideal apparent resistivity data, assuming that the subsurface is connected between measurement points.

e. The results of the interpolation are used as input data for computer modeling of the subsurface resistivity layer.

f. Subsurface resistivity modeling was carried out using the inverse of the difference method, so that cross sections of the resistivity stratification model of subsurface soil/rock formations were obtained for each track.

g. This section is interpreted to predict the water saturation status of each layer to provide an overview of subsurface groundwater conditions along the measurement path.

3. RESULTS AND DISCUSSION

The geology of the study area includes sheet geology of Ujung Pandang, Benteng and Sinjai, Sulawesi [11], composed of pyroclastic rocks of the Tersier Miocene of Camba Formation (Tmcv), which regionally consist of volcanic breccias, conglomerate lava and fine-grained tuff to interbedded lapilli, marine sedimentary rocks in the form of new tuffaceous sand, calcareous sandstone and claystone containing plant remains [12]. The lower part contains more volcanic breccia than lava which is composed of andesite and basalt tires; conglomerates also consist of andesite and basalt with a size of 3 - 50 cm; well layered tuff, consisting of lithic tuff, crystal tuff and vitric tuff. The upper part contains a trachitic ignimbrite and leucite tephrite; ignimbrite has a columnar joint structure, brownish gray and dark brown in color, leucite tephrite has a flow structure with a bread crusted surface, black in color. The Tersier Miocene Camba Vulcanic unit includes those mapped by van Leeuwen [13] as Sopo Volcano Rock, Pamusureng Volcano Rock and Baruan Lemo Volcano. The volcanic breccias exposed on Selayar Island may include this formation; the breccias are very compact, partially flaky; consisting of basal amphibole, basal pyroxene and andesite (0.5 - 30 cm), with a tufa base mass containing biotite and pyroxene [14].

This unit has a thickness of about 2,500 m and is volcanic facies of the developed Camba Formation in the area to the north of the Pangkajene Sheet and the Western Part of Watampone; the seams are mostly weakly folded, with a slope of less than 20o; unconformably superimposed on limestone of the Tersier Eocene Tonasa Formation (Temt) and older rocks.

Data recording activities using the geoelectric method were then carried out at 3 (three) points, namely points GL.01, GL.02, and GL.03, as a comparison to determine which points would be recommended to be exploited later. Recording was carried out to obtain the apparent resistivity value (ρ) of the soil/rock layer at the greatest depth of 150 m. The apparent resistivity value indicates the type of lithology and indicates the presence of a water-carrying layer beneath the surface [15]. The values obtained from the measurement results at points GL.01, GL.02, and GL.03, successively the apparent resistivity range (ρ) of the soil/rock layers is between 1.5 – 50.9 Ωm, 3.4 – 556.9 Ωm, and 4.5 – 2124.5 Ωm. It can be generally divided into 6 (six) layers as shown in Table 1.

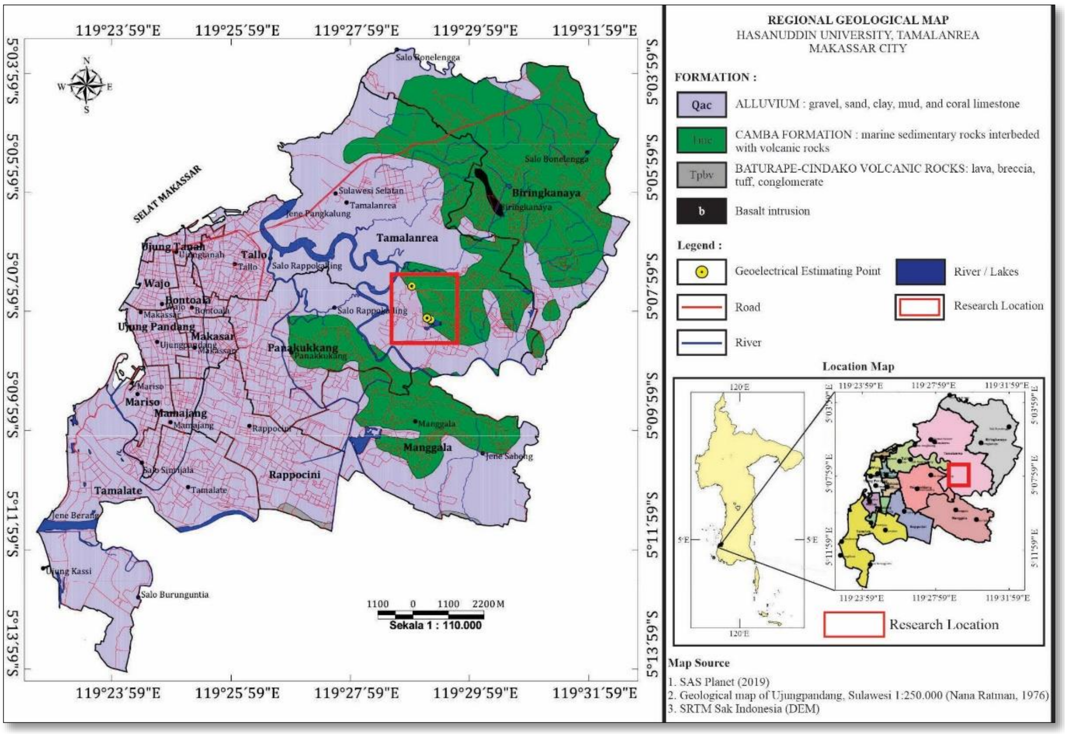


Figure 2. Map of observation point to the subsurface rock [10]

The range of measurement results Gl.01 (Table 1), the cross section of the inversion and vertical resistivity results of measurement points at this location can be seen in Figure 3. The apparent resistivity range (ρ) of the soil/rock layer is between 1.4 – 50.9 Ωm, generally divided into the first layer with a resistivity value between 17.2 – 19.4 Ωm, which is soil of volcanic weathered (surface layer), soft hardness, 5m thickness and 0-5m depth. The second layer has a resistivity value of 19.4-45.8 Ωm, which is a tuff layer estimated to be a potential shallow groundwater aquifer, with fresh water conditions but influenced by the season. This layer has sufficient freshwater discharge, 5-20 m deep and 15 m thick. The third layer with a resistivity value of 45.8-50.9 Ωm is a volcanic breccia.

The layer is a massive layer, the hardness of the layer is medium-hard, the depth is 20-30 meter, with a thickness of 10 meters. The fourth layer has a resistivity value of 5.3 – 48.2 Ωm, which is a tufa layer which is thought to be potential deep groundwater aquifer layer with fresh water conditions. The layer has a large enough water discharge with fresh water conditions so it can be recommended for exploitation, thickness up to 20 meters and depth between 30 - 50 meter. The fifth layer has a resistivity value of 1.4 –5.3 Ωm, which is interpreted as a tuff layer presumably a deep groundwater aquifer layer with brackish water conditions. The layer is considered not potential to be exploited, up to 45 meters thick and between 50 - 95 meter deep. The sixth layer has a resistivity value of 4.9 – 15.8 Ωm, interpreted as a tufa layer as a potential deep groundwater aquifer. between 95 - 150 meter. The groundwater layer as an aquifer can be utilized and exploited for use as subsurface groundwater (Table 2), the brackish water layer should not be exploited.

Table 1. Measurement result data

Guess Point	Layers	Interpretation Results			Lithology	Rock Condition
		Depth (m)	Thick(m)	Resistivity Value (Ωm)		
GL.01	1	0-5	5	17,2 – 19,4	Soil	Dry
	2	5-20	15	19,4 – 45,8	Tufa	Aquifer (Freshwater)
	3	20-30	10	45,8 – 50,9	Volcanic Breccia	Aquiclude
	4	30-50	20	5,3 – 48,2	Tufa	Aquifer (Freshwater)
	5	50-95	45	1,4 – 5,3	Tufa	Aquifer (Brackish Water)
	6	95-150	55	4,9 – 15,8	Tufa	Aquifer (Freshwater)
GL.02	1	0-5	5	13,4 – 15,7	Soil	Dry
	2	5-20	15	4,2 – 13,4	Tufa	Aquifer (Freshwater)
	3	20-30	10	3,4 – 4,3	Tufa	Aquifer (Brackish Water)
	4	30-55	25	4,3 – 179,8	Tufa	Aquifer (Freshwater
	5	55-110	45	158,4 – 556,9	Volcanic Breccia	Aquiclude
	6	110-150	40	4,5 – 158,4	Tufa	Aquifer (Freshwater)
GL.03	1	0-5	5	12,8 – 13,3	Soil	Dry
	2	5-20	15	4,5 – 12,8	Tufa	Aquifer (Freshwater)
	3	20-30	10	4,5 – 12,8	Tufa	Aquifer (Brackish Water)
	4	30-50	20	5,3 – 48,2	Tufa	Aquifer (Freshwater)
	5	50-125	75	139,5 – 2124,5	Volcanic Breccia	Aquiclude
	6	125-150	55	4,9 – 15,8	Tufa	Aquifer (Freshwater)

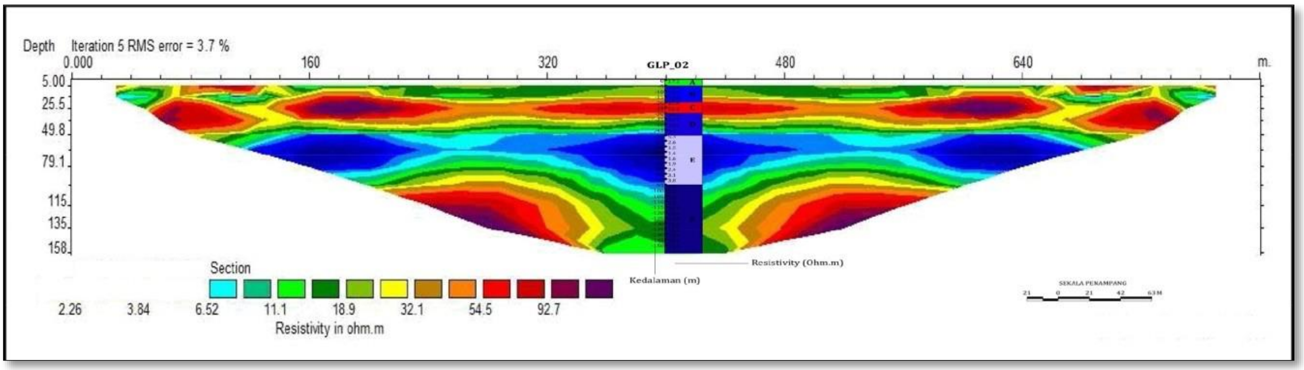
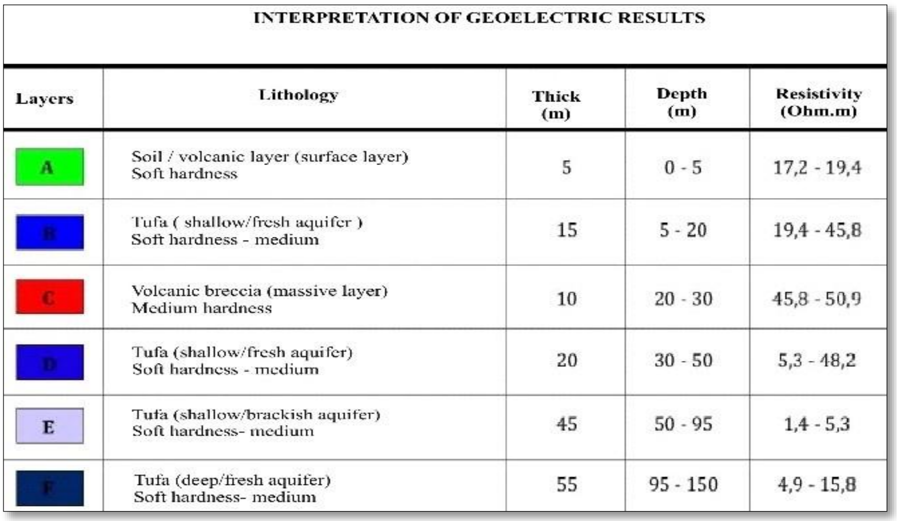


Figure 3. Geoelectrical inversion cross section of GL.01

Table 2. Drill point recommendations



INTERPRETATION OF GEOELECTRIC RESULTS

Layers	Lithology	Thick (m)	Depth (m)	Resistivity (Ohm.m)
A	Soil / volcanic layer (surface layer) Soft hardness	5	0 - 5	17,2 - 19,4
B	Tufa (shallow/fresh aquifer) Soft hardness - medium	15	5 - 20	19,4 - 45,8
C	Volcanic breccia (massive layer) Medium hardness	10	20 - 30	45,8 - 50,9
D	Tufa (shallow/fresh aquifer) Soft hardness - medium	20	30 - 50	5,3 - 48,2
E	Tufa (shallow/brackish aquifer) Soft hardness- medium	45	50 - 95	1,4 - 5,3
F	Tufa (deep/fresh aquifer) Soft hardness- medium	55	95 - 150	4,9 - 15,8

The range of measurement results Gl.02, the apparent resistivity (ρ) of the soil/rock layer is between 3.4 –556.9 Ωm (Table1). The cross section of the inversion and vertical resistivity results of measurement points at this location can be seen in Figure 4. From the results of field data processing, the pseudo-resistivity range of the soil / rock layer is between 3.4 - 556.9 Ωm and in general it is divided into 6 (six) parts, namely the first layer with resistivity values between 13.4 - 15.7 Ωm, which is soil / volcanic weathering (surface layer), soft hardness, thickness up to 5 meters and depth between 0 - 5 m.

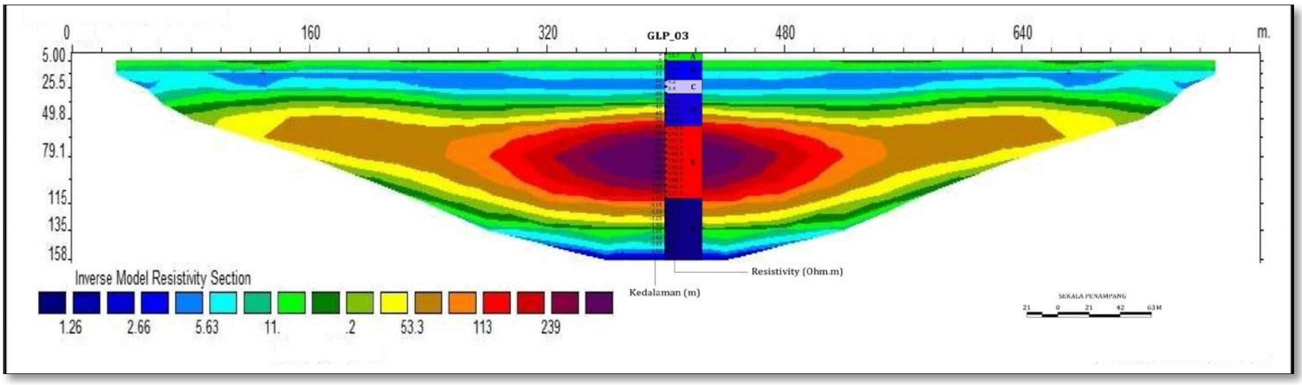
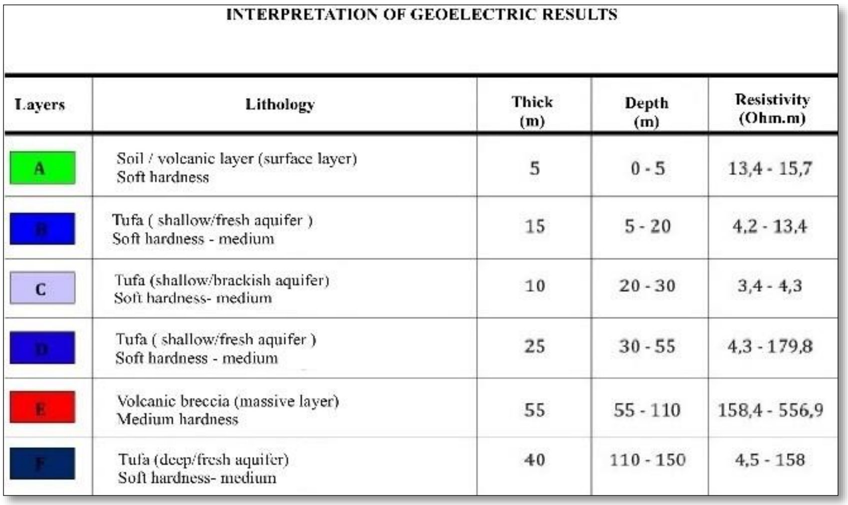


Figure 4. Geoelectrical inversion cross section of GL.02

The second layer has a resistivity value of 4.2 – 13.4 Ωm, which is interpreted as a tuff layer suspected of being a shallow groundwater aquifer layer with potential fresh water conditions but influenced by the season. The layer has sufficient water discharge with fresh water conditions, thickness of up to 15 meters and a depth of between 5 - 20 m. The third layer has a resistivity value of 3.4 – 4.3 Ωm, which is interpreted as a layer tuff are thought to be shallow groundwater aquifer layers with brackish water conditions. The layer is not recommended for exploitation, up to 10 meters thick and between 20 - 30 m deep. The fourth layer resistivity value of 4.3 – 179.8 Ωm, which is a tuff layer suspected to be a shallow groundwater aquifer layer that has potential with freshwater conditions but is influenced by the season. The layer has sufficient water discharge with freshwater conditions so. Thickness up to 25 meters (depth between 30 - 55 m). The fifth layer resistivity value of 158.4 - 556.9 Ωm is a volcanic breccia layer, the layer is a massive layer, medium - hard layer hardness, thickness up to 55 meters and depth between 55 - 110 m. The sixth layer has a resistivity value of 4.5 – 158.4 Ωm, interpreted tufa layer as a potential deep groundwater aquifer with fresh water conditions. The layer has a fairly large water discharge with fresh water conditions so it can utiliz and exploited, thickness up to 40 meters and depth between 110 - 150 m.

The groundwater layer as an aquifer can be utilized and exploited for use as subsurface groundwater (Table 3), the brackish water layer should not be exploited.

Table 3. Interpretation of resistivity values



INTERPRETATION OF GEOELECTRIC RESULTS

Layers	Lithology	Thick (m)	Depth (m)	Resistivity (Ohm.m)
A	Soil / volcanic layer (surface layer) Soft hardness	5	0 - 5	13,4 - 15,7
B	Tufa (shallow/fresh aquifer) Soft hardness - medium	15	5 - 20	4,2 - 13,4
C	Tufa (shallow/brackish aquifer) Soft hardness- medium	10	20 - 30	3,4 - 4,3
D	Tufa (shallow/fresh aquifer) Soft hardness - medium	25	30 - 55	4,3 - 179,8
E	Volcanic breccia (massive layer) Medium hardness	55	55 - 110	158,4 - 556,9
F	Tufa (deep/fresh aquifer) Soft hardness- medium	40	110 - 150	4,5 - 158

The range of measurement results Gl.03, the apparent resistivity (ρ) of the soil/rock layer is between 4.5 – 2124.5 Ωm (Table 4). The cross-section of the inversion and vertical resistivity of the measurement point at this location can be seen in (Figure 5). From the results of field data processing, the apparent resistivity range of the soil/ the rock layer is obtained between 4.5 - 2124.5 Ωm and is generally divided into 6 (six) parts, namely the first layer with resistivity values between 12.8 - 13.3 meter, which is volcanic soil / weathering (surface layer), soft hardness, thickness up to 5 meters and depth between 0 - 5 meter. The second layer resistivity value of 4.5 – 12.8 Ωm is a tuff layer suspected to be a shallow groundwater aquifer layer that has potential with freshwater conditions but is influenced by seasons. The layer has sufficient water discharge with freshwater conditions so, thickness up to 15 meters, depth between 5 - 20 meter.

The third layer resistivity value of 4.5 – 12.8 Ωm, which is a tuff layer suspected to be a shallow groundwater aquifer layer with brackish water conditions. The layer must be covered (grouting cement). Thickness up to 10 meters (depth between 20 - 30 m). The fourth layer resistivity value of 6.1 – 139.5 Ωm is a tuff layer suspected to be a shallow groundwater aquifer layer that has potential with freshwater conditions but is influenced by seasons.

The layer has sufficient water discharge with freshwater conditions so, thickness up to 20 meters and depth between 30 - 50 m. The fifth layer resistivity value of 139.5 - 2124.5 Ωm is a volcanic breccia layer, the layer is a massive layer, medium - hard layer hardness, thickness up to 70 meters and depth between 50 - 125 m. The sixth layer resistivity value of 4.8 – 143.4 Ωm is a tuff layer suspected to be a deep groundwater aquifer layer with potential freshwater conditions. The layer has a large enough water discharge with freshwater conditions, so that it can be recommended for exploitation, thickness up to 25 m and depth between 125 - 150 m.

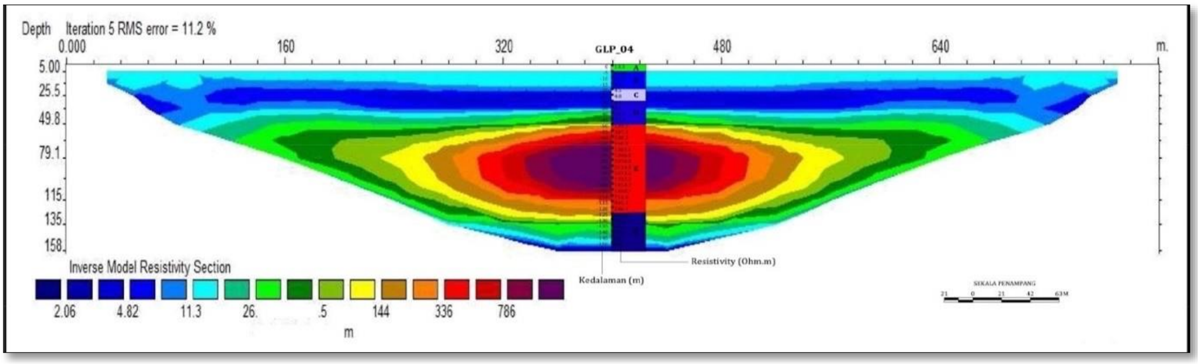
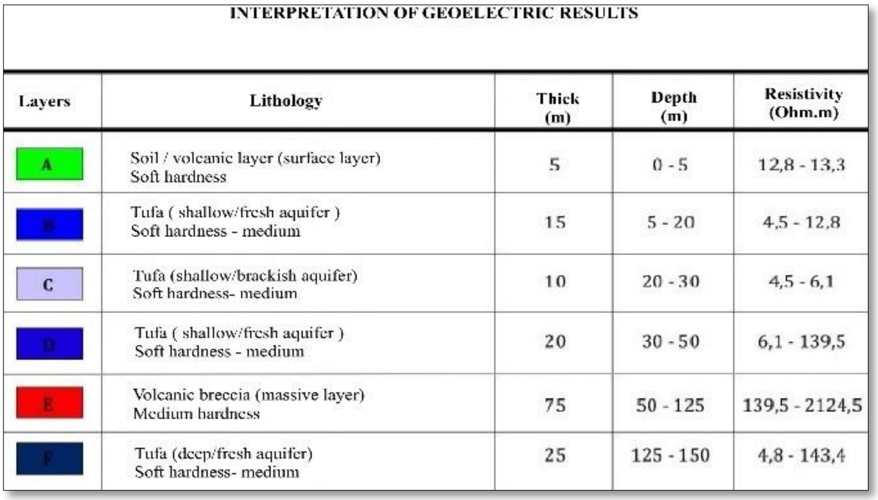


Figure 5. Geoelectrical inversion cross section of GL.03

Table 4. Interpretation of resistivity values



INTERPRETATION OF GEOELECTRIC RESULTS

Layers	Lithology	Thick (m)	Depth (m)	Resistivity (Ohm.m)
A	Soil / volcanic layer (surface layer) Soft hardness	5	0 - 5	12,8 - 13,3
B	Tufa (shallow/fresh aquifer) Soft hardness - medium	15	5 - 20	4,5 - 12,8
C	Tufa (shallow/brackish aquifer) Soft hardness- medium	10	20 - 30	4,5 - 6,1
D	Tufa (shallow/fresh aquifer) Soft hardness - medium	20	30 - 50	6,1 - 139,5
E	Volcanic breccia (massive layer) Medium hardness	75	50 - 125	139,5 - 2124,5
F	Tufa (deep/fresh aquifer) Soft hardness- medium	25	125 - 150	4,8 - 143,4

4. CONCLUSION

From the analysis that has been done, several conclusions can be drawn, including:

1. The results of the analysis of geoelectrical interpretation at 3 (three) investigation points can be made of 6 (six) subsurface layers, namely soil/volcanic weathering, tuff layers as shallow aquifers (freshwater), shallow aquifer tuff layers (brackish), shallow aquifer tuffs (freshwater), volcanic breccia layer as a hard layer (massive), tuff layers of deep aquifers that have prospects for exploitation (freshwater).
2. The lithological composition is generally volcanic rock in the form of water-saturated tuff, showing low resistivity values and weathered volcanic breccias in a compact (massive) state, with large resistivity values.
3. The recommended aquifer layer in the groundwater-carrying rock layer has the smallest resistivity value (aquifer) and the layer has the greatest thickness.

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