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Fresh Water Exploration in Housing Estate with Schlumberger Electrodes Geoelectric Methods

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Abstrak: Geoelectricity is one of geophysical methods performed by injecting electric current into the earths. This research objected to map aquifers using geoelectric with Schlumberger electrode configuration consisting of 4 sounding points. The results are then processed with IP2WIN software which yields a real resistivity map as a function of depth. The correlation of sounding points produces three-dimensional real resistivity maps. The results of this study located at a housing estate, Mataram, West Nusa Tenggara, consists of 4 sounding points show that the aquifer is have huge amount of fresh water The aquifer layer in this area is a free aquifer. At point PA1 the depth of the aquifer starts from a depth of 81.4 – 125 meters; PA2 point at a depth of 80 – 124 meters; PA3 point at a depth of 91.8 – 118 meters; and Point PA4 at a depth of 47.4 – 113 meters.

Keywords: Water Exploration; Schlumberger; Geoelectric

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INTRODUCTION

One of housing estate in Mataram City, West Nusa Tenggara Province is Griya Pesona Alam, need fresh water supply from underground water. The availability of clean water, especially fresh water, is not yet available in this place. Drilling without proper planning will be in vain if the results are not as expected, for example the air is brackish or not found at all. Whereas the existence of fresh water is needed by tourism organizers in this area. To avoid this risk, groundwater exploration is carried out using geoelectric, the most popular geophysics method in finding water aquiver.

Groundwater is water that is below the ground surface in aquifer rocks. The main characteristics distinguishing groundwater from surface are its very slow movement and very long residence time. This duration can reach tens to hundreds of years. Groundwater can be divided into two types, namely free ground water and compressed groundwater. Free groundwater is groundwater from an aquifer that is only partially filled with water, and is located on watertight bottom, and has a free surface. Compressed groundwater is groundwater from an aquifer that is completely saturated with water, with the top and bottom bounded by watertight layer (Efendy, 2011).

Geophysical method is a method used to study the interior of the earth by using physical instruments on the surface or below the earth's surface. The geoelectric method is one of the geophysical methods that studies the physical properties below the earth's surface using an electric current passed through the earth, so that subsurface geological information is obtained through its electrical properties. There are several kinds of rules/configurations for estimating the subsurface layer using geoelectric, including:

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Wenner, Schlumberger, dipole-dipole and so on. The measurement procedure for each configuration depends on the variation of resistivity with depth, namely in the vertical direction (sounding) or horizontal direction (mapping). The geoelectric method is usually also used for initial surveys before further exploration is carried out.

Groundwater exploration using the geoelectric method has been carried out by many previous researchers as a reliable and precise method. Hasibuan, et al, (2013), conducted a study of seawater intrusion using the Wenner-Schlumber configuration electrical resistivity method. Asfiannisa, et al., 2015, estimated seawater intrusion in preparation for deep well drilling using the 2d geoelectric method using the Wenner electrode configuration. Irham et al, (2006), mapping the distribution of salty groundwater in deep aquifers in the Lower Semarang area. Husni and Roh, (2012), investigated groundwater subsidence and prediction of seawater intrusion in South Tangerang City (Ratnakumari et al., 2012). Perform 2D mapping of the aquifer at the bottom of the Chandrabhaga river, Nagpur District, Maharashtar, India. (Sadjab, et al., 2012). Mapping groundwater aquifers with geoelectricity in Prambanan District, Sleman Regency, Yogyakarta Province. Sedana et al, (2015), mapping groundwater aquifers using the geoelectric method in Malendeng Village. Meanwhile, Andriayani et al, (2010), used the geoelectric imaging method with a dipole-dipole configuration for tracing the underground river system in the Karst area of Pacitan, East Java.

METHOD

The use of geoelectric was first carried out by Conrad Schlumberger in 1912. Geoelectric is one of the geophysical methods to determine changes in the resistivity of rock layers beneath the soil surface by flowing DC electric current ('Direct Current') with high voltage into the ground. This electric current injected using a 'current electrode' which is plugged into the ground at a certain distance. The longer the distance between the current electrodes, the more current will flow through the deeper rock layers. The flow of electric current will cause an electric voltage in the ground. The electric voltage occurs at the ground surface is measured using a multimeter that is connected through a voltage electrode that is shorter than the current electrode distance. When the position of the current electrode distance is changed to be greater, the electric voltage that occurs at the potential electrode also changes according to the information on the type of rock that is injected with an electric current at a greater depth (Anonymous, 2010).

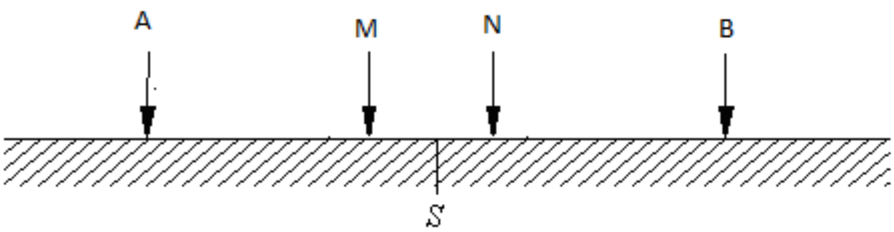


Figure 1. Schlumberger electrodes configuration

Generally, the geoelectric method that is most likely used is the one that uses 4 electrodes located in a straight line and symmetrical to the midpoint, namely 2 current electrodes (AB) on the outside and 2 voltage electrodes (MN) on the inside. The depth of the rock layer that can be penetrated by electric current is equal to half of the distance between the current electrodes (eg current electrode A and current electrode B) with the value of AB / 2 (if pure DC electric current is used). It can be estimated that the effect of the injection of electric current is in the form of a hemispherical shape with radius AB/2. The measurement procedure for each configuration depends on the variation of resistivity with depth, i.e in the vertical (sounding) or lateral (mapping) direction .

By combining of the distance AB/2, distance MN/2, the amount of electric currents flow and the voltage yields, it will get an apparent resistivity value ('Apparent Resistivity'). It is called apparent resistivity because the calculated resistivity is a combination of many layers of rock beneath the surface through which electric currents pass. If a set of apparent resistivity measurements from the shortest distance AB to the longest is depicted on a double logarithm graph with distance AB/2 as the X-axis and apparent resistivity as the Y-axis, a geoelectrical data curve will be obtained. From the curve data, it can be calculated and estimated the properties of the rock layers below the surface using the auxiliary curve as a reference to find the resistivity and depth of the research target.

The Schlumberger electrodes configuration as shown in figure 1, ideally the MN distance is made as small as possible, so that the theoretical MN distance does not change. However, due to the limited sensitivity of the measuring instrument, when the AB distance is relatively large, the MN distance should be changed. The change in MN distance should not be greater than 1/5 of the AB distance. The advantage of this Schlumberger configuration is the ability to detect the presence of non-homogeneity of rock layers on the surface, by comparing the apparent resistivity values when the MN/2 electrode distance changes. In order for the voltage reading on the MN electrode to be reliable, when the distance AB is relatively large, the MN electrode distance should also be enlarged (Bisri, 1991).

To find the apparent resistivity (ρ) we can use the equation:

$$\rho = K\frac{V}{I} \quad (1)$$

where V is the voltage value, I is the current value that is read on the resistivity-meter and K is the geometric factor for the Schlumberger electrode configuration. The value of K can be determined by the equation:

$$K = \frac{\pi(AB/2)^2}{2(MN/2)} \quad (2)$$

The resistivity method with the Schlumberger configuration is carried out by conditioning the space between the potential electrodes to be fixed while the spacing between the current electrodes changes gradually (Sherif, 2002).

An aquifer is a layer of rock below the earth surface that contains water and can be permeated by water because of its porosity. An aquifer is a geological formation or group of formations that contains water and is significantly capable of draining water through its natural state. Another terminology used is groundwater reservoir or water-carrying layer. Todd (1980) states that the aquifer comes from Latin, namely *aqui* from aqua which means water and *ferre* which means to carry, so the aquifer is a water-carrying layer. Groundwater is water that moves in the soil contained in the space between soil grains that seeps into the soil and combines to form a layer of soil called an aquifer. Layers that are easily passed by groundwater are called permeable layers, such as layers found in sand or gravel, while layers that are difficult to pass by groundwater are called impermeable layers, such as layers of clay and silt stone.

Geoelectric data acquisition in this study was carried out on 4^{th}-6^{th} of Juli 2019, with the suspected aquifer position being in Sayang-Sayang Village, Cakranegara District, Mataram City, West Nusa Tenggara. The instruments needed for the data acquisition include a resistivity-meter, cable rollers, roller meters, electrode rods, HT communication devices and positioning devices in the form of GPS.

The methodology used in this research is to acquire geoelectrical data (primary data collection) with Schlumberger electrodes, in the field to obtain current and potential difference data which will be used to determine the resistivity value. Based on the range of the resistivity, it can be seen that there are lithological variations, the thickness of the resistivity range or the presence or absence of aquifers. Data collection was carried out at 4 measurement points at the measurement location.

RESULT AND DISCUSSION

Based on the results of data acquisition in the field using the Schlumberger configuration, which is then processed using IP2WIN and Rockwork 15 software, information obtained is the real resistivity value, depth and thickness of the subsurface layer. The location and position of the sounding point for geoelectrical data acquisition is shown in Figure 2.

Figure 2. Location of data acquisition at Griya Pesona Alam 2

Table 1 shows the sounding point data consist of point's name, coordinates and elevation. Coordinates of sounding points are in UTM and elevations are meters above mean sea level.

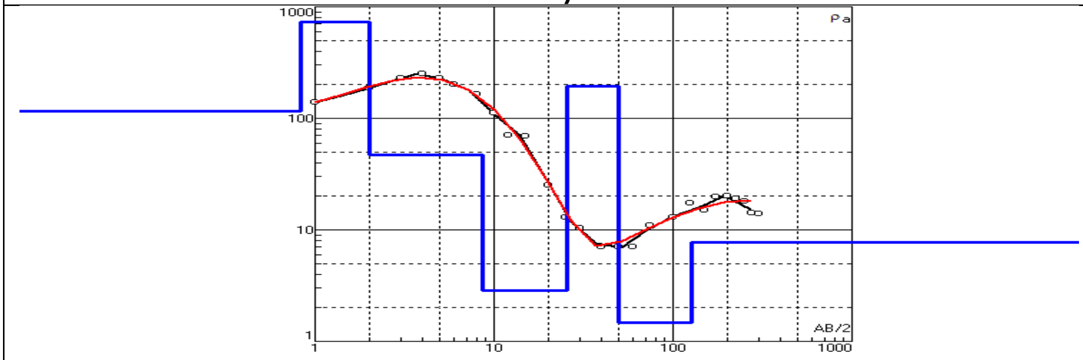
Table 1. Location of data acquisition

Sounding Points	Coordinates (UTM)	Elevations (m)
Point 1	0405594; 9053398	59
Point 2	0405578; 9053188	52
Point 3	0405378; 9053400	55
Point 4	0405782; 9053207	61

Geoelectrical measurement data obtained from field measurements are apparent resistivity. The data is then processed using IP2Win software to obtain true resistivity. This resistivity value reflects the resistivity of the subsurface rock layers at the position below the measurement point. After knowing the actual resistivity, the interpretation of the rock is carried out according to the value of the resistivity of the rock according to Telford (2011).

The depiction of the state of the rock layers vertically is obtained from the vertical cross-section of the respective resistivity of the geoelectrical measurements at the measurement point. The vertical cross-section of rock layers is often referred to as a bore-log or fence diagram. Bore-log can measure aquifer thickness and aquifer depth at the point of measurement. The interpretation results for each point of estimation are shown in each measurements. The interpretation of rock layers at point 1 of the Griya Pesona Alam 2 housing estate can be seen in Figure 3. below:

Resistivitay Curve



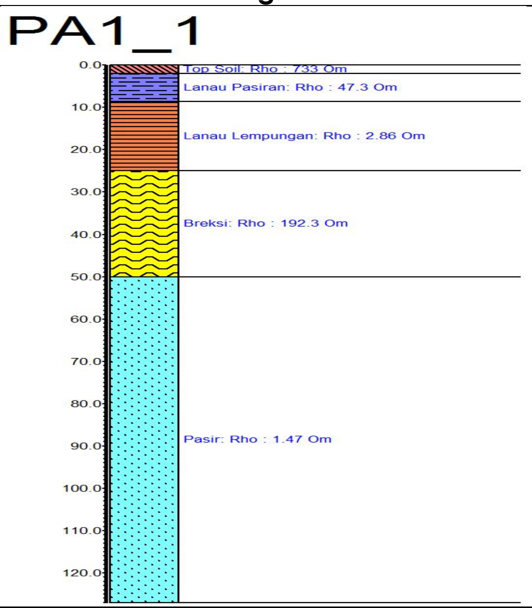
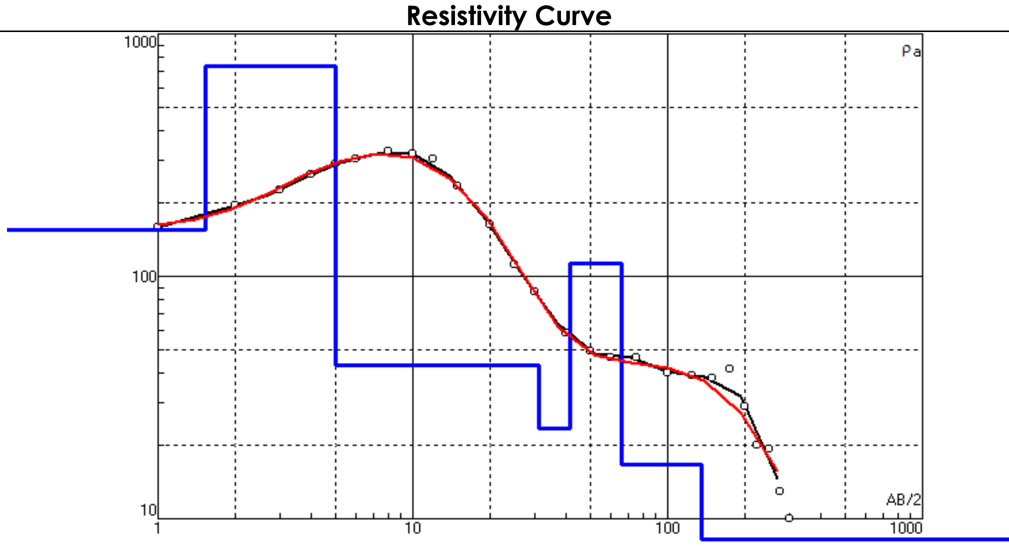
Bore-log Model	Lithology Interpetation
	Topsoil: Overburden with a resistivity of 733 Ohm.m consisting of sandy silt at a depth of 0 – 2 m. Sandy Silt: Depth 2 – 8.6 m with a resistivity value of 47.3 Ohm.m Clay silt : Depth 8.6 - 25 m with a resistivity value of 2.86 Ohm.m Breccia: Depth 25 - 50 m with resistivity value 192.3 Ohm.m Sand : Depth 50 - 127 m with resistivity value 1.47 Ohm.m It is estimated that there is groundwater in the sand layer that has the potential as an aquifer with a free aquifer type at a depth of 50 - 127 meters.

Figure 3. Bore-log and it's litoloogy interpretation of point PA 1

The interpretation of rock layers at point 2 of the Griya Pesona Alam 2 housing estate can be seen in Figure 4. below:

Resistivity Curve



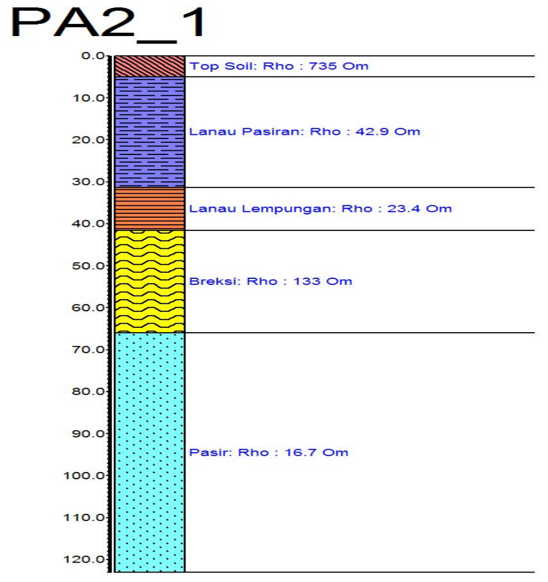
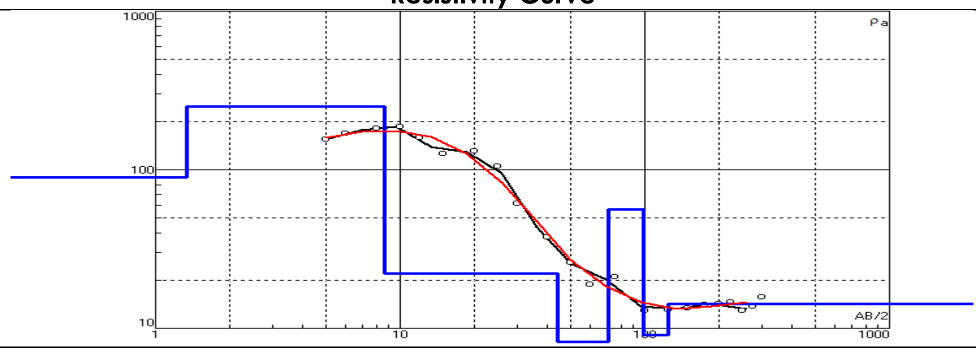
Bore-log Model	Lithology Interpetation
	Topsoil: Overburden with a resistivity of 735 Ohm.m consisting of sandy silt at a depth of 0 – 4.98 m. Sandy Silt: Depth 4.98 – 31.3 m with a resistivity value of 42.9 Ohm.m Clay silt : Depth 31.3 – 41.6 m with a resistivity value of 23.4 Ohm.m Breccia: Depth 41.6 - 66 m with resistivity value of 133 Ohm.m Sand : Depth 66 - 123 m with resistivity value 16.7 Ohm.m It is estimated that there is groundwater in the sand layer which has the potential as an aquifer with a free aquifer type at a depth of 66 - 123 meters.

Figure 4. Bore-log and it's litoloogy interpretation of point PA 2

The interpretation of rock layers at point 3 of the Griya Pesona Alam 2 housing estate can be seen in Figure 5 as follows:

Resistivity Curve



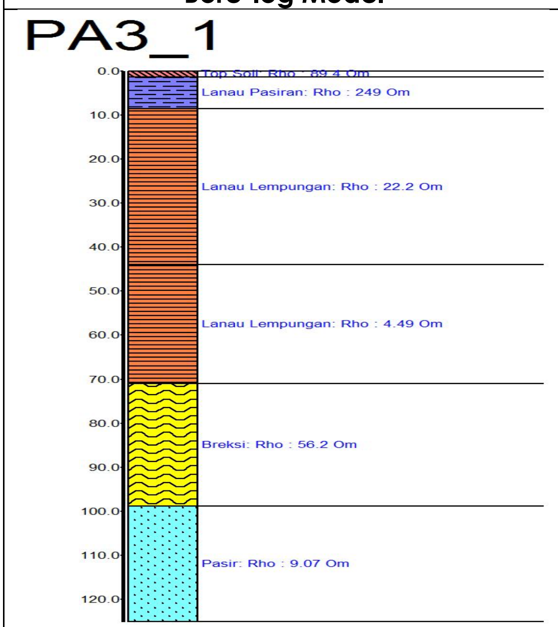
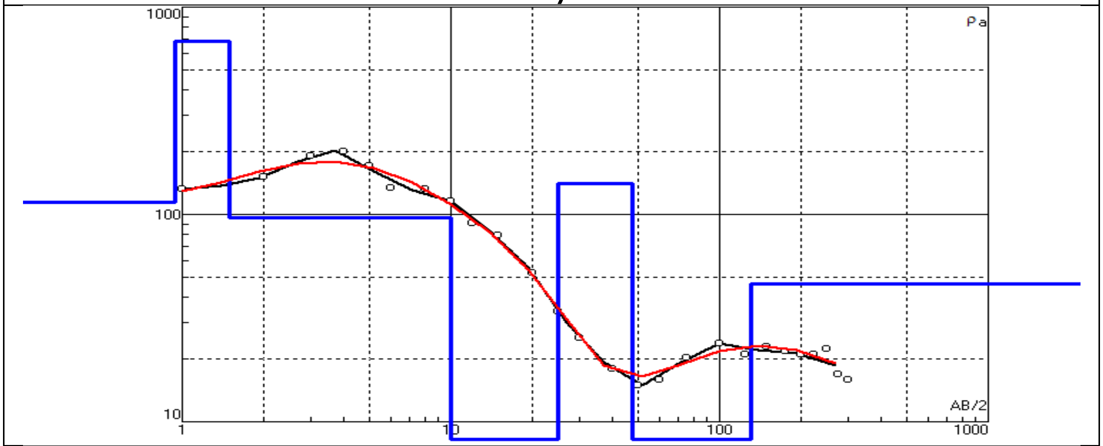
Bore-log Model	Lithology Interpetation
	Topsoil: Overburden with a resistivity of 89.4 Ohm.m consisting of sandy silt at a depth of 0 – 1.34 m. Sandy Silt: Depth 1.34 – 8.62 m with a resistivity value of 249 Ohm.m Clay silt : Depth 8.62 - 44 m with a resistivity value of 22.2 Ohm.m Clay silt: Depth 44 – 71 m with a resistivity value of 56.2 Ohm.m Breccia: Depth 71 – 98.8 m with resistivity value 56.2 Ohm.m Sand : Depth 98.8 - 125 m with resistivity value 9.07 Ohm.m It is estimated that there is groundwater in the sand layer that has the potential as an aquifer with a free aquifer type at a depth of 98.8 - 125 meters.

Figure 5. Bore-log and it's litoloogy interpretation of point PA 3

The interpretation of rock layers at point 4 of the Griya Pesona Alam 2 housing estate can be seen in Figure 6. as follows:

Resistivity Curve



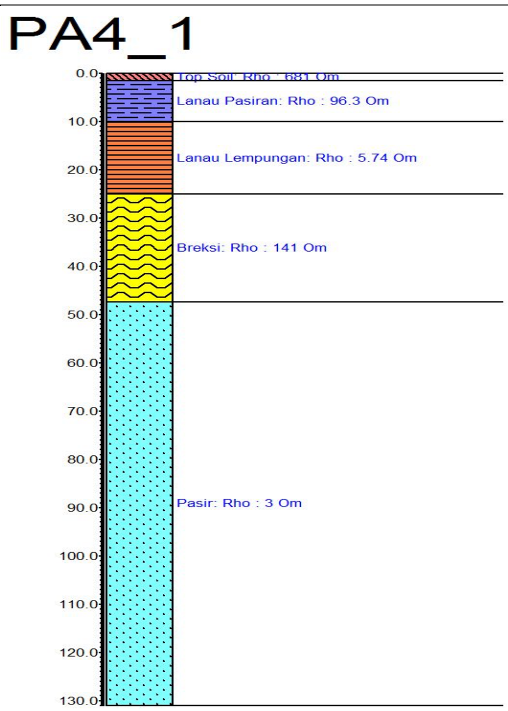
Bore-log Model	**Lithology Interpetation**
	Topsoil: Overburden with a resistivity of 681 Ohm.m consists of sandy silt at a depth of 0 – 1 5 m. Sandy Silt: Depth 1.5 - 10 m with resistivity value 96.3 Ohm.m Clay silt : Depth 10 – 25.1 m with a resistivity value of 5.74 Ohm.m Breccia: Depth 25.1 – 47.7 m with a resistivity value of 141 Ohm.m Sand : Depth 47.7 – 131 m with resistivity value 3 Ohm.m It is estimated that there is groundwater in the sand layer which has the potential as an aquifer with a free aquifer type at a depth of 47.7 – 131 meters.

Figure 6. Bore-log and it's litoloogy interpretation of point PA 4

After the bore-log is made, the bore-log correlation of the geoelectric estimation points is made to determine the potential layers as aquifers in the measurement area. From the results of 2-dimensional and 3-dimensional bore-log correlations (Figure 7 and Figure 8) it is known that the Griya Pesona Alam 2 area has a fairly large aquifer potential up to a depth of more than 100 meters. From the correlation results, we can determine the minimum depth taken, which is about 60 meters with the consideration that this aquifer is relatively unaffected by surface changes, both in terms of quality and quantity.

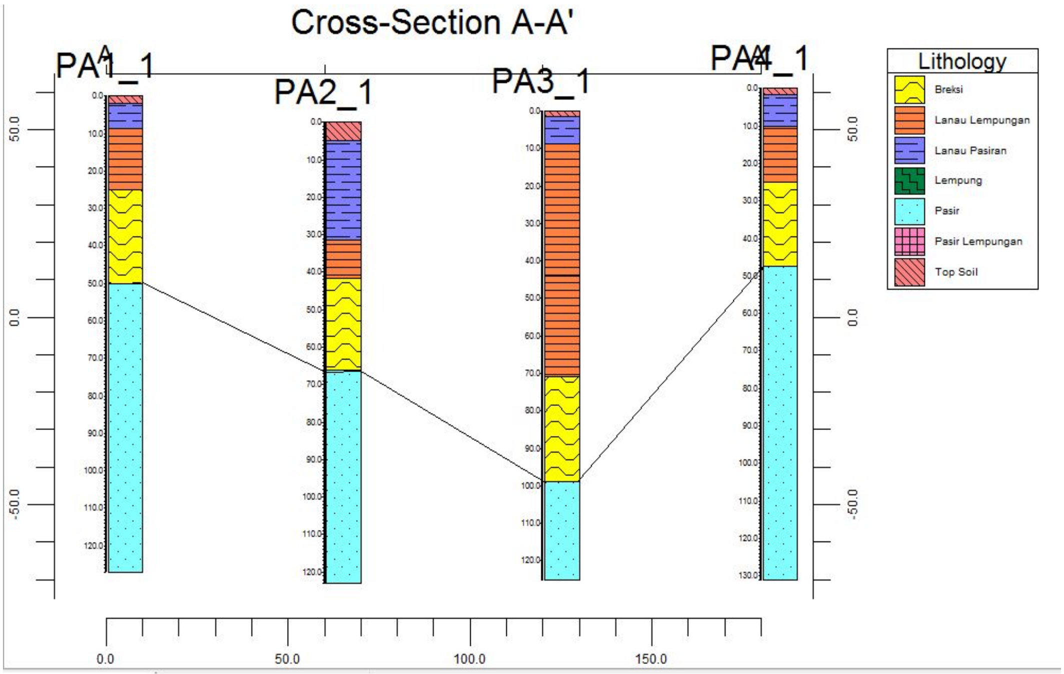


Figure 7. Two dimensional bore-log correlation

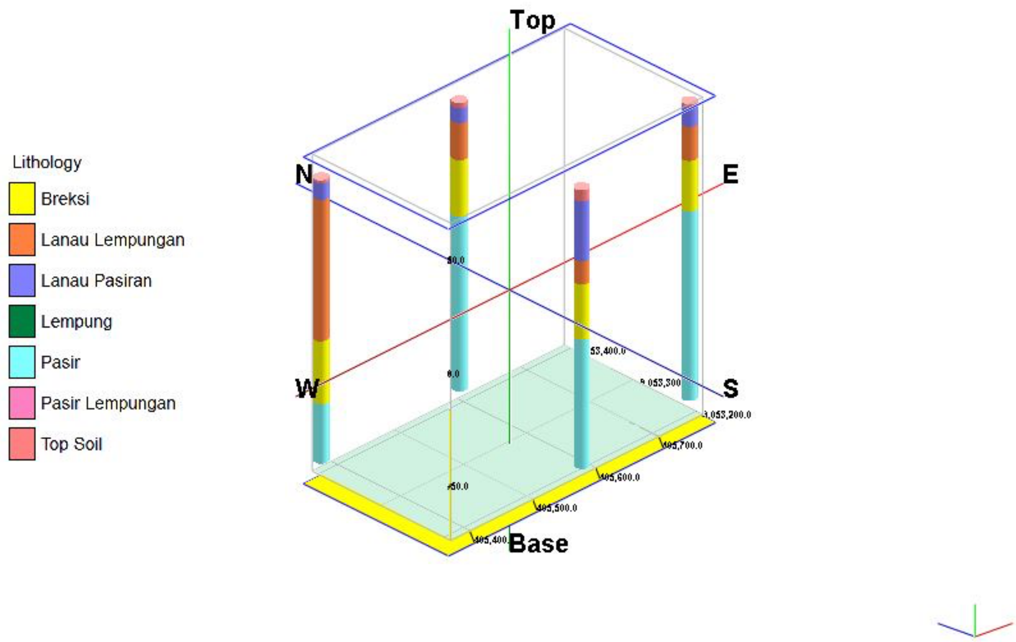


Figure 8. Three dimensional bore-log correlation

The 3-dimensional bore-log cross-sectional model from each point of estimation is used to made a three-dimensional distribution cross-section of the resistivity by using Rockwork 15 software. This step is carried out to determine the overall aquifer flow pattern under the surface based on the distribution of true resistivity obtained from the IP2Win software processing (Figure 9).

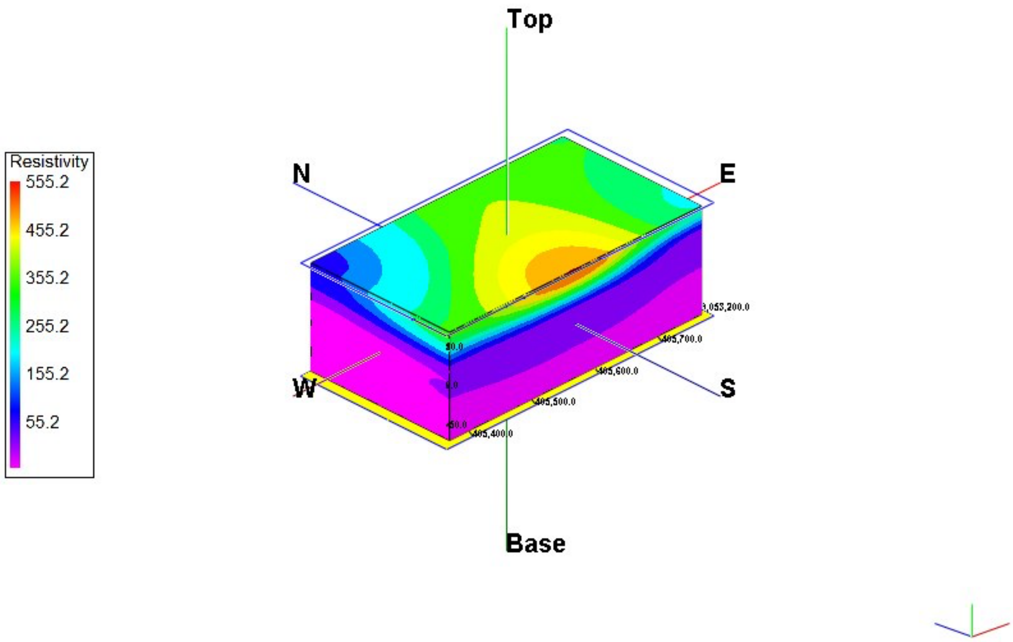


Figure 9. Three-dimensional true resistivity map

From Figure 9, it can be seen that the depth of aquifer is about 50 meters. High resistivity values are found at points PA2 and low resistivity values are spread at points PA1, PA3, and PA4. It is known that the groundwater level at point PA4 is relatively deeper than the groundwater level at points PA2 and PA3, while the groundwater level at point PA1 is the shallowest point. Based on these two facts, it shows that the area around PA2, PA4 are the recharge area and the area around the PA1 point is the discharge area.

From the data above, it can be concluded that there is a difference in the height of the water table on the north side compared to the water table on the south side. This difference in depths indicates that there is a potential for underground fluid flows from the North side to the South side of aquiver. The existence of fluid flow in this aquifer can ensure the continuity of water supply in housing so that normal water consumption can be met with adequate aquifer supply.

CONCLUSION

The results of the geoelectric survey by measuring the geoelectrical estimation points at 4 points in Griya Pesona Alam 2 Housing, Sayang-Sayang Village, Cakranegara City District, it can be concluded that geoelectric measurements at four points found aquifers with high productivity. The aquifer layer in this area is a free aquifer. At point PA1 the depth of the aquifer starts from a depth of 81.4 – 125 meters; PA2 point at a depth of 80 – 124 meters; PA3 point at a depth of 91.8 – 118 meters; and Point PA4 at a depth of 47.4 – 113 meters.

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