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Identification of Aquifer Layer Using Geoelectric Method in Oil Palm Plantation Area of PT Unggul Widya Teknologi Lestari Pasangkayu Regency

M. Raam.[a,1)*] , M. Rusydi. [a,2], M. Rusli. [a,3]
[a]Geophysical Engineering Study Program, Faculty of Mathematics and Natural Sciences, Tadulako University
[1]E-Mail: muhammad.raamhidayat@gmail.com

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ABSTRACT

Introduction: Aquifer layers have been identified in the oil palm plantation area of PT Unggul Widya Teknologi Lestari Pasangkayu Regency. This study aims to determine the lithology of subsurface rocks and the depth of the aquifer layer as a source of clean water in the study area. **Method**: This study uses the geoelectric method of type resistance with Wenner configuration, with the number of electrodes 24 rods and a spacing of 10 meters. 2D cross-sectional model using *Res2Dinv software* program. **Results and Discussion**: Based on the value of the type resistance of the subsurface constituent rock lithology at the research site is interpreted to consist of three layers, namely clay with a specific resistance value < 29.15 Ωm, sand and sandy clay with a specific resistance value of 29.15 Ωm to 72.89 Ωm, and conglomerate with a specific resistance value > 72.89 Ωm. The aquifer layer is interpreted with a specific resistance value of 29.15 Ωm to 72.89 Ωm. The aquifer layer is detected to spread from the northeast to the southwest of the research site with a depth of ±25-39 m. **Conclusion**: In the oil palm plantation of PT Unggul Widya Teknologi Lestari, the subsurface layer consists of clay (1.98 Ωm - 29.15 Ωm), sand and passive clay (29.15 Ωm - 72.89 Ωm), and conglomerate (72.89 Ωm - 1120.5 Ωm). Thin aquifers, with a thickness of 5-10 m and depth of 25-39 m, are detected in the sand and sandy clay layers.

1. Introduction

PT Unggul Widya Teknologi Lestari (PT UWTL) is a company engaged in the oil palm plantation business which was founded in 1985. The oil palm plantation of PT Unggul Widya Teknologi Lestari is located in Motu Village and Balanti Village, Baras District, Pasangkayu Regency, West Sulawesi Province with an oil palm plantation area of 6,140 Hectares [1]. Oil palm is a plant that can produce oil, the product can be used as cooking oil, soap, and candles. Oil palm dregs are also used as animal feed and their shells as combustion material or briquettes

[2]. Oil palm will affect the hydrological cycle where oil palm can reduce up to 40% of the total water demand [3].

The fulfillment of clean water needs in the oil palm plantation area is daily supplied from the main factory which is ± 6 km away and distributed via a water tank car. The distribution of clean water using a tank car is not effective by taking into account the distance between the location of the main factory and the residential area of the oil palm plantation which is quite far. Therefore, to meet the need for a clean water supply in the oil palm plantation area of PT Unggul Widya Teknologi Lestari, other alternative water sources such as groundwater are needed. Information about aquifers in the oil palm plantation area is very important. The aquifer is a layer of soil that is able to hold and release water periodically [4]. Investigation of the aquifer layer can be known through geophysical methods, namely geoelectric-type resistance. The geoelectric method describes the subsurface aquifer layer from the value of the rock's specific resistance [5].

The need for clean water in the oil palm plantation area of PT Unggul Widya Teknologi Lestari is increasing day by day, therefore alternative water sources are needed. The potential of groundwater in this area is not yet known with certainty, due to the unavailability of data on the position of the aquifer layer. Research is needed to determine the potential of groundwater in the oil palm plantation area of PT Unggul Widya Teknologi Lestari. The aquifer layer is identified based on the specific resistance value obtained from geoelectric measurements. Specific resistance value data is also reinforced with water conductivity values and geological condition data to ensure the availability of groundwater in the aquifer layer.

Pasangkayu Regency is composed of several rock formations. According to Sukido, et al [6] the research area consists of several rock formations such as Aluvium (Qa) consisting of clay, sand, gravel, and pebbles. Pasangkayu Formation (TQp) consists of sandstone with claystone interspersed with conglomerate and limestone. The Lariang Formation (Tmpl) is composed of conglomerate with sandstone, claystone, and local tuff as shown in Figure 1.

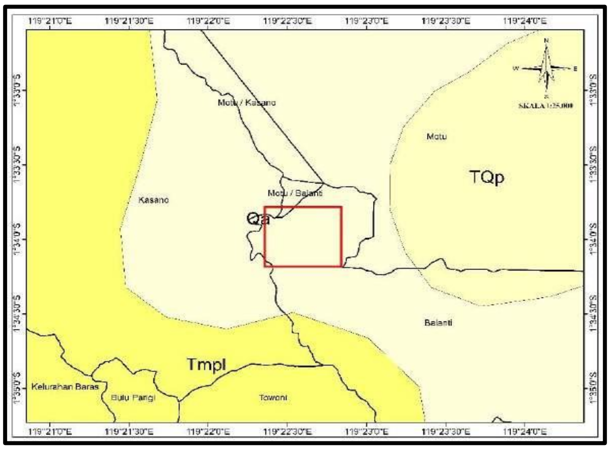

Fig 1. Geologic map of the study site and its surroundings [6]

In general, groundwater that can store large amounts of water reserves is located in saturated soil layers (*groundwater*) which will come out through springs or wells, while water in unsaturated soil layers (*soil water*) will be left behind and support vegetation on the surface [7]. Geological formations that are significant in ensuring the amount of groundwater used in daily life are known as aquifers. In some circumstances, aquifers are vertically separated by individual geological formations that allow water to flow in and out. Formations that act as a water barrier are called *Aquitards* which are less permeable than aqu*ifers* but still allow water to pass through. If the water barrier is nearly impermeable, and forms a formidable flow barrier between aquifers, it is known as an *Aquiclude*. Aquifers can be of two main types namely free aquifers or depressed aquifers. A free aquifer is an aquifer that has no *Aquitard* or *Aquiclude* [8].

The electrical properties of rocks refer to the ability of a rock to conduct electric current into it. The flow of electric current in rocks and minerals can be divided into three types, namely electronic conduction, electrolytic conduction, and dielectric conduction. Electronic conduction occurs when rocks or minerals have many free electrons that allow electric current to flow through them. Electrolytic conduction occurs in rocks or minerals that are porous and the pores are filled with an electrolyte solution that allows electric current to flow due to being carried by the ions of the electrolyte solution. While dielectric conduction occurs in rocks that are dielectric, namely rocks that have few or no electrons [9].

According to Telford et al. [9], based on their resistivity values, rocks and minerals on Earth can be grouped into three categories, namely:

a. Good conductor : 10^{-8} Ωm < ρ < 1 Ωm
b. Bad conductor : 1 Ωm << 10^{7} Ωm
c. Insulator ρ > 10 Ωm^{7}

Every rock has its characteristics, including its electrical properties. The nature of the rock is its specific resistance which describes the ability of the material to conduct electric current. The greater the resistance value of a rock, the more difficult it is for the rock to conduct electric current. This can be seen in Table 1.

Table 1. Earth Material Type Resistance Values [16]

No	Material	Specific Resistivity Value (Ωm)
1	Quartz	$500 – 8 \times 10^5$
2	Limestone	$500 – 10^4$
3	Sandstone	200 – 8000
4	Sand	1 – 1000
5	Clay	1 – 100
6	Dry Gravel	$600 – 10^4$
7	Clay	10 – 800
8	Conglomerate	$2 \times 10^3 – 10^4$
9	Sand and Gravel	100 – 1000
10	Granite	100 – 600

Table 2. Classification of Formation Factor Estimates for Sedimentary Rocks [14]

F	Formation	Aquifer/Aclude
≤ 1	Clay	Akuiklud
1 - 1,5	Peat, Sand, Clay or Silt	Akuiklud
2	Fine Silt-Sand	Slight to moderate aquifer
3	Medium Sand	Medium to productive aquifer
4	Coarse Sand	Productive aquifer
5	Gravel	Highly productive aquifer

The type resistance method is a geophysical method that describes the subsurface state of the nature of electric flow in the subsurface rocks of the earth consisting of potential field quantities, electromagnetic fields formed by the flow of electric current naturally (passive) or artificially active [11]. In the geoelectric method, electric current (I) is channeled into the ground through two current electrodes placed on the earth's surface. Furthermore, the potential difference (ΔV) that arises is measured using two potential electrodes according to its configuration. The results of current and potential difference measurements at each electrode are influenced by variations in the resistivity value of each layer below the measurement point. [12]. In the measurement of geoelectric methods with the Wenner configuration .

Automatic Array Scanning (AAS) is one of the measurement techniques in geoelectric methods. Data collection in the AAS method is carried out repeatedly and according to the depth of penetration. The AAS method is also known as the *Continous Vertical Electrical Sounding* (CVES) method used in hydrogeological applications. This method is often known as *Electrical Resistivity Tomography* (ERT). ERT is a geo-electrical technique using multiple electrodes to collect data about the condition of materials below the ground surface [13]. The AAS method is often used for geoelectric research with several electrode configurations including the Wenner configuration.

In the Wenner configuration, the electrodes are arranged in a line with symmetry with respect to the center point. This configuration offers good horizontal resolution, which means that the sensitivity to lateral changes is very high, but it is less effective in current penetration into depth [14]. This configuration consists of two electrodes for conducting current and two electrodes for measuring potential, which are placed at equal distances between them. The electrodes for potential measurement are placed inside, while the electrodes for current flow are placed outside, with a distance between electrodes of a. Measurements are made by moving all electrodes simultaneously to the outside with a fixed distance a, thus forming a triangular configuration with equal sides (C1P1=P1P2=P2C2) [8]. The electrode arrangement of the Wenner Configuration is shown in Figure 2.

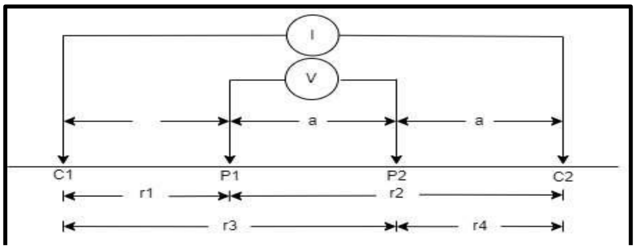

Fig 2. Electrode arrangement in the Wenner configuration [15].

Based on Figure 2, the K value for the Wenner configuration is

$$K = 2pa \quad (4)$$

2. Research Method

Geographically, the geoelectric measurement point is located between the coordinates 119°22'20" East - 119°22'40" East and 01°33'50" LS - 01°34'10" LS in the oil palm plantation area of PT Unggul Widya Teknologi Lestari. Administratively, this location is in Balanti Village, Baras District, Pasangkayu Regency, West Sulawesi. A map of the research location and its surroundings can be seen in Figure 3.

Fig 3. Map of the Research Site And Its Surroundings

The tools and materials used in this study are a set of geoelectric resistance-type tools, consisting of 4 rolls of cable, a resistivity meter, 2 batteries, a connector cable, 25 electrodes, and an electrode clamp. *Global Positioning System* (GPS), is used to determine the coordinates of the position of the measuring points and altitude. Roll a meter, to measure the length between electrode spaces and the length of the track and measure the *water table* in the well. Double face hammer, serves to pound the electrode so that it sticks into the ground. Laptop to process the measurement data. *Google Earth* satellite map 2022 scale 1:5,000. Geological Map of Pasangkayu Sheet scale 1:25,000. Stationery and data tables are used to record measurement data. *Conductivity meter TDC & EC meter (hold)*, to measure electrical conductivity. The measurement data is then processed with the following steps.

Calculating the apparent resistivity (ρa) of the measurement data using Equation (2.8), taking into account the geometry factor (K) obtained from the measurement results in accordance with Equation (2.10). Transferring calculation data in the form of datum values, n values, and apparent type resistance values (?$_a$) from *MS Excel Software* into *Notepad Software*. The data that has been entered into *Notepad Software* (.txt) is then converted into the *Res2Dinv Software* program. *The* results of the *Res2Dinv software* program are variations in the value of specific resistance, depth, and layer thickness of each measurement track, then analyzed and interpreted. Data interpretation is carried out on the 2D cross-section of the specific resistance by looking at the characteristics of the rock layers in the form of the specific resistance value of each rock. To produce a more accurate interpretation, supporting data related to the research location can be used in the form of groundwater level data, geological maps, tables of rock-specific resistance values, and documentation. For the interpretation of aquifer zone estimation using the formation factor value obtained from Equation (2) and its classification using the sedimentary rock formation factor table (Table 2).

3. Results and Discussion

Aquifer layer analysis is conducted based on the interpretation of a 2D cross-sectional model of specific resistance obtained in 5 geoelectric measurement tracks. In the process of interpreting the 2D cross-section of specific resistance, supporting data such as the geological condition of the research location, and DHL measurement data are needed. The research location is in the Aluvium Formation which consists of clay, sand, gravel, and pebbles. Formation factor estimation used classification for sedimentary rocks as in Table 2. Data from the calculation of the formation factor is then compared with the geological data of the research location so as to obtain an estimation of the subsurface lithological conditions of the research location.

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The value of the type resistance (?) obtained in the 2D cross-section of the type resistance is correlated with the value of the formation factor (F) obtained by the type of rock lithology and the type of aquifer of the study site can be grouped into:

a. Layer 1 which has a specific resistance <29.15 Ωm, with clay lithology and formation factor < 2, is depicted in yellow.
b. Layer 2, which has a specific resistance value between 29.15 to 72.89 Ωm, consists of sand and sandy clay lithologies, with formation factors ranging from 2 to 5, and is depicted in blue. It is thought that this layer is an aquifer.
c. Layer 3, which has a specific resistance value above 72.89 Ωm, consists of conglomerate lithology, with a formation factor >5, depicted in green.

Based on the formation factor value obtained, the description of the subsurface aquifer layer can be seen through the 2D cross-section of the type barrier as follows:

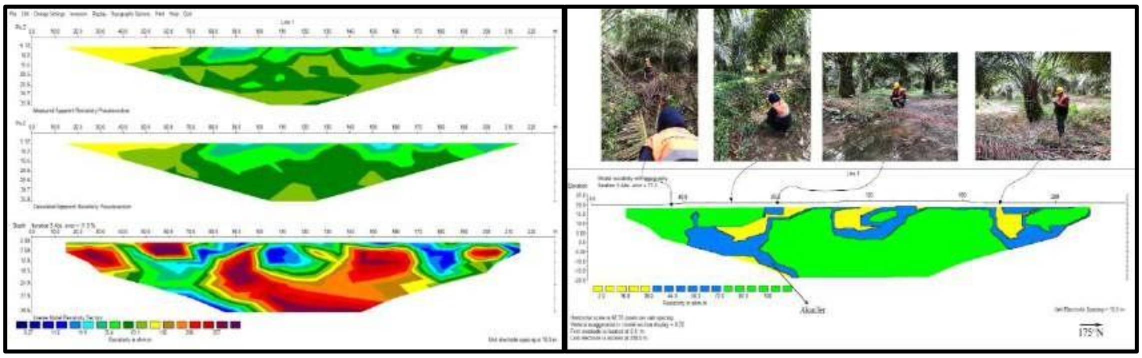

Fig 4. 2D Cross-section of Type Resistance with Formation Factor of Track 1

Based on the 2D cross-section on track 1 (Figure 4) there is layer 2 which is suspected to be an aquifer layer depicted in blue. This layer is detected at a depth of ± 20 m with a thickness of ± 5 m. A layer with the same specific resistance value and color as layer 2 is also detected on the surface to a depth of ±10 m but the layer cannot be categorized as an aquifer layer, the layer with the same specific resistance value and color as layer 2 is in a shallower position than the aquifer layer, so it is suspected to be layer 1 affected by seepage from standing water at electrodes 9-10 and electrodes 16- 19. The aquifer layer in this trajectory looks like small lenses with very little groundwater potential. At the top, this layer is bounded by layer 1 from electrodes 7-18, layer 3 from electrodes 1-7 and electrodes 19-21 and at the bottom it is bounded by layer 3 from electrodes 8-18 with a thickness of ±30 m.

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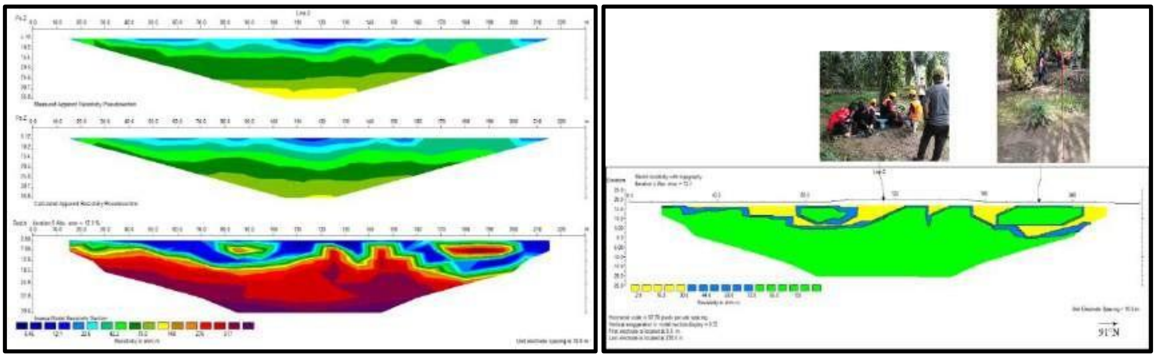
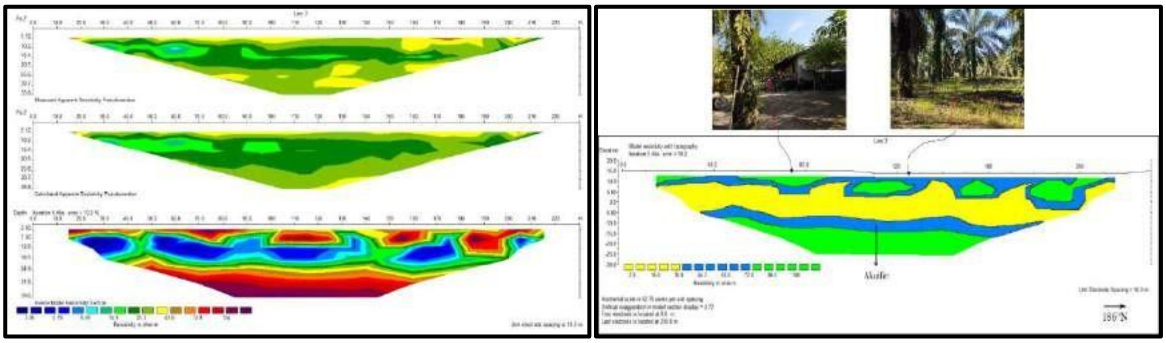


Fig 5. 2D Cross-section of Type Resistance with Formation Factor of Track 2



Based on the 2D cross-section of traverse 2 (Figure 5) there is layer 2 which is suspected to be an aquifer layer depicted in blue. This layer is detected at a depth of ±15 m with a thickness of ±2 m. A layer with the same specific resistance value and color as layer 2 is also detected on the surface to a depth of ±15 m, but the layer cannot be categorized as an aquifer layer, the layer with the same specific resistance value and color as layer 2 is in a shallower position than the aquifer layer, so it is suspected to be layer 1 which is exposed to seepage from standing water around the measurement location. The aquifer layer in this trajectory is very thin. The top of this layer is bounded by layer 1 along the track interspersed by layer 3 which looks like small lenses at electrodes 9-11 and electrodes 18-21.

Fig 6. 2D Cross-section of Type Resistance with Formation Factor of Track 3

Based on the 2D cross-section on track 3 (Figure 6) there is layer 2 which is suspected to be an aquifer layer depicted in blue. This layer is detected at a depth of ±25 m with a thickness of ±5 m and spreads along the track from north to south. This layer is bounded by layer 1 at the top with a thickness of ±10 m that spreads along the measurement track and at the bottom is bounded by layer 3 with a thickness of ±15 m that spreads along the measurement track. West of the measurement track there is a borehole located ±180 m away with a borehole depth of ±30 m, this is in accordance with the results of the interpretation of the depth of the aquifer layer. The surface layer with the same

value of specific resistance and color as the aquifer layer spreads along the track which is not continuous, this layer cannot be categorized as an aquifer layer, this layer is thought to be layer 1 which is exposed to seepage from standing water around the measurement track. In the western part of the measurement track, there is a drainage that is ±10 m from the measurement track and extends along the measurement track, it is suspected to be the source of seepage in layer 1. The upper layer is also interspersed by layer 3 which looks like small lenses successively at electrodes 7-9, electrodes 12-13, electrode 16, and electrodes 19-22.

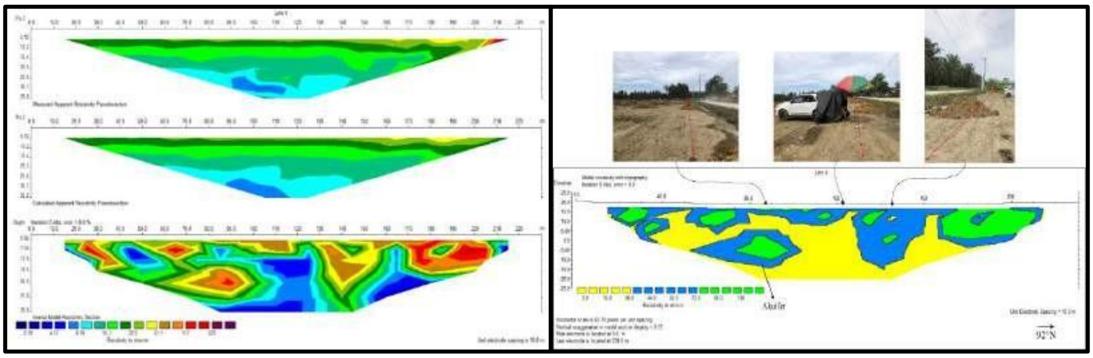


Fig 7. 2D Cross-section of Type Resistance with Formation Factor of Track 4

Based on the 2D cross-section on track 4 (Figure 7) there is layer 2 which is suspected to be an aquifer layer depicted in blue. This layer is detected at a depth of ±25 m with a thickness of ±5 m in the form of a small lens bounded by layer 1 at the top and bottom, layer 1 thickens towards the east of the measurement track with a thickness of ±30 m, this layer is also interspersed by layer 3 of electrodes 8-9. The surface layer with the same value of specific resistance and color as the aquifer layer spreads along the track which is not continuous, this layer cannot be categorized as an aquifer layer, this layer is thought to be layer 1 which is exposed to seepage from standing water around the measurement track. In the northern part of the measurement track, there is a drainage that is ±5 m from the measurement track and extends along the measurement track, it is suspected to be the source of seepage in layer 1. The upper layer is also interspersed by layer 3 which looks like small lenses successively at electrodes 3-5, electrodes 7-15, and electrodes 18-22.

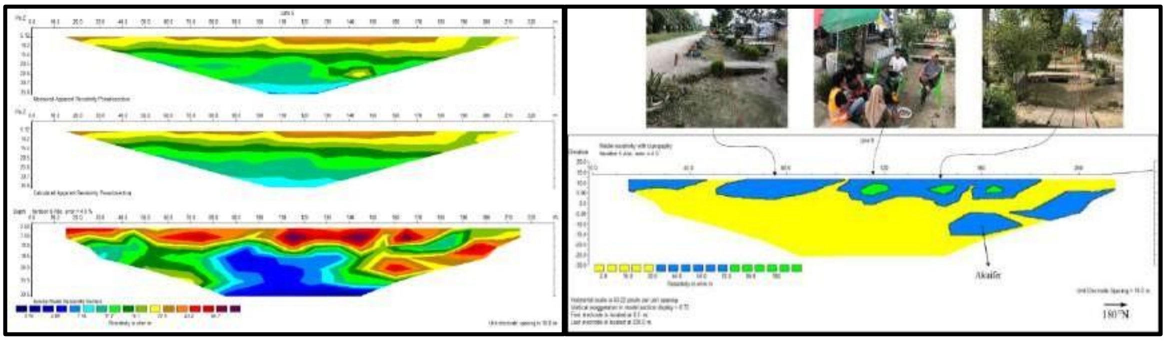


Fig 8. 2D Cross-section of Type Resistance with Formation Factor of Track 5

Based on the 2D cross-section on track 5 (Figure 8) there is layer 2 which is suspected to be an aquifer layer depicted in blue. This layer is detected at a depth of ±20 m with a thickness of ±10 m in the form of a small lens bounded by layer 1 at the top and bottom, layer 1 thickens towards the north of the measurement track with a thickness of ±30 m. This corresponds to the western part of the measurement track where there is a borehole located ±80 m away with a borehole depth of ±30 m. West of the measurement track there is a borehole located ±80 m away with a borehole depth of ±30 m, this is in accordance with the results of the interpretation of the depth of the aquifer layer. The layer with the same type of resistance value and color as the aquifer layer spreads almost along the track which is not continuous, the layer cannot be categorized as an aquifer layer, this layer is thought to be layer 1 which is exposed to seepage from standing water around the measurement track. The upper layer is also interspersed by layer 3 which looks like small lenses in electrodes 12-13, electrode 15, and electrodes 17-18 respectively.

By considering the overall interpretation result of the 2D cross-section with formation factor and correlated with the geological condition data of the research location, it is suspected that the aquifer layer obtained in the oil palm plantation area of PT Unggul Widya Teknologi Lestari is a type of free aquifer because, at the top and bottom, it is limited by *permeable* layer. The aquifer at the study site is located in an alluvial formation identified to spread from northeast to southwest, with thickness increasing from the northeast towards the southwest, at a depth of ±25 to 39 meters.

4. Conclusion

From the research conducted at the oil palm plantation of PT Unggul Widya Teknologi Lestari, Balanti Village, Baras Subdistrict, Pasangkayu Regency, it can be concluded that the subsurface constituent rock lithology at the research site based on the value of specific resistance is interpreted to consist of 3 layers, namely clay with a specific resistance value of 1.98 Ωm to 29.15 Ωm, sand and sandy loam with a specific resistance value of 29.15 Ωm to 72.89 Ωm, and conglomerate with a specific resistance value of 72.89 Ωm to 1120.5 Ωm. The aquifer layer is interpreted with a specific resistance value of 29.15 Ωm to 72.89 Ωm with rock lithology in the form of sand and sandy clay. The aquifer layer is detected to be very thin with a thickness of ±5-10 m spreading from the northeast to the southwest of the research site with a depth of ±25-39 m.

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